# *Airports Commission*

## 1. Strategic Fit: GDP/GVA Impacts

June 2015

pwc

# *Revisions to the report*

This report provides an update on our original report published in November 2014. It incorporates additional analysis which we have been instructed to undertake by the Airports Commission, following its national consultation, to provide further information needed to support the its consideration of its shortlisted options.

In particular, this document contains the following additional analyses or changes, which have been undertaken on the instruction of the AC:

- **Sensitivity tests.** We have performed additional tests to understand the sensitivity of the results of our analysis to a variety of assumptions:
    - **Passenger spending:** We have tested assumptions regarding the split between inbound and outbound passenger flows and passenger expenditure per visit. The results of this analysis are contained in Sections 6.8.3, 7.8.3, and 8.8.3 for the LGW 2R, LHR NWR and LHW ENR schemes, respectively.
    - **Passenger mix:** We have tested the impact of profiling the additional passengers under the LGW 2R scheme only, such that they share the same characteristics as those currently using London Heathrow, in Section 6.8.4.
    - **TEE business passengers:** Previously, we modelled the impact of changes in producer and consumer surplus for all passengers (passengers travelling for both business and leisure purposes). We test the impact of this assumption by modelling the impact of changes in producer and consumer surplus relating only to business passengers. This allows us to isolate the direct economic impact on the supply side of the economy. The results of this analysis are contained in Sections 6.8.5, 7.8.4, and 8.8.4 for the LGW 2R, LHR NWR and LHW ENR schemes, respectively.
    - **Labour markets:** We tested the impact of both fixing, and restricting, the flexibility of labour supply. This allows us to isolate the impact of the labour supply assumptions applied throughout this report, and demonstrate the sensitivity of the modelling results to changes in this assumption.The results of this analysis are contained in Sections 6.8.6, 7.8.5, and 8.8.5 for the LGW 2R, LHR NWR and LHW ENR schemes, respectively.
    - **Imperfect competition:** We previously assumed imperfectly competitive markets, whereby an output expansion brought about by reduced costs gives rise to an additional welfare benefit over and above what would be seen in a perfectly competitive framework. In this way, the S-CGE model allows us to depart from the conventional assumption in scheme appraisal of perfect competition. We re-run the model to test the model results under similar assumptions to those used in conventional welfare analysis. The results of this analysis are contained in Sections 6.8.7, 7.8.6, and 8.8.6 for the LGW 2R, LHR NWR and LHW ENR schemes, respectively.
    - **Carbon-capped scenarios**: In our primary analysis, we based the scenarios on the assumption of a "carbon-traded", rather than a "carbon-capped" emissions policy. Under both policies, limits are set on the amount of carbon that can be emitted and then sold or allocated to firms. Under the "carbon-traded" scenario, firms can trade their allocations. Given the uncertainty of future carbon emissions policy, it is appropriate to test the sensitivity of the results to changes in the carbon assumption. The results of this analysis are contained in Sections 6.8.8, 7.8.7, and 8.8.7 for the LGW 2R, LHR NWR and LHW ENR schemes, respectively.
    - **WebTAG-based productivity:** The AC instructed us to model the outputs from its Wider Economic Impacts welfare analysis as inputs to the S-CGE analysis. This is in order to understand how using this approach how the impacts might play out and interact with one

another in a general equilibrium setting. The results of this analysis are contained in Sections 6.8.9, 7.8.8, and 8.8.8 for the LGW 2R, LHR NWR and LHW ENR schemes, respectively.

- **Revised Transport Economic Efficiency inputs.** Transport Economic Efficiency (TEE) effects represent the possible gains to consumers in the form of price reductions associated with capacity enhancement. These have been incorporated into our modelling on the instructions of the AC. The AC has advised that some of the inputs they initially provided in respect of the LGW 2R scheme have changed. We have therefore updated our analysis to reflect the revised inputs from the AC. Revised graphs and tables are presented in Chapter 6.

- **Revised inputs for all channels.** The AC has advised that the inputs they initially provided in respect of the LGW 2R scheme for all channels excluding construction have changed for two scenarios. We have therefore updated our analysis to reflect the revised inputs from the AC. Revised graphs and tables are presented in Chapter 6.

- **Transport costs.** In Section 3.3.3.5, we have described the two types of transport costs considered in the literature: transport costs of goods/outputs, and transport costs of factors of production. We discuss their relevance to the S-CGE analysis in this report, as many S-CGE analyses take explicit account of transport costs and model the impacts of transport interventions as a reduction in transport costs. In Appendix C, we have also clarified the way in which we have controlled for correlation between different types of transport costs.

- **Multiplier commentary.** We have provided further discussion on each channel's 'multiplier' impact – which provide a useful approach for evaluating the scale of the impacts that the S-CGE model generates – emerging from the modelling. This is explored in Appendix E.

- **FDI commentary.** For the purposes of our November 2014 report, we made the assumption that the construction cost of the three airports schemes was funded "wholly by the domestic private sector". This assumption was discussed and agreed with the AC and its external advisors at that time. However, it is also possible to assume in the S-CGE model that the airport schemes are fully or partly funded by foreign investors. In Boxes 4, 10 and 16, we discuss how the results might have varied if we had made an assumption regarding partial or full foreign investment.

- **Choice of closure rules.** In order to be able to obtain a solution for a CGE model, the number of equations that need to be solved must equal the number of endogenous variables. Therefore, some key variables occurring endogenously in the model must be constrained. This process is more commonly referred to as macroeconomic closure. There are a number of options available for closure rules and the closure rule chosen can have significant implications for the behaviour of the model. In Appendix B, Section 2.10, we outline the closure rule choices available and explain our rationale for the choices of closure rule in the analysis. These are: the current account closure rule; the government closure rule; the labour market closure rule; and the investment-savings closure rule.

- **Definition of GDP.** We have amended the definition of GDP in Table 8, to clarify that it is based on a chain volume measure, following response to the AC's consultation.

- **Report Title:** This has changed from "2. Economy: Wider Impacts Assessment" to "12. Strategic Fit: GDP/GVA Impacts"

The table below sets out a list of figures and tables which have been revised relative to our November 2014 report, or added to the report.

| **Figure/Table** | **Chapter** | **Notes** |
|---|---|---|
| Figure 6 | Chapter 6 | Revised version of Figure 6 in November 2014 document, reflecting updated inputs from AC. |

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|---|---|---|
| Tables 10-11 | Chapter 6 | Revised versions of Tables 10-11 in November 2014 document, reflecting updated inputs from AC. |
| Tables 14-18 | Chapter 6 | Revised versions of Tables 14-18 in November 2014 document, reflecting updated inputs from AC. |
| Figure 13 | Chapter 6 | Revised version of Table 13 in November 2014 document, reflecting updated inputs from AC. |
| Figure 29 | Chapter 6 | Revised version of Figure 29 in November 2014 document, reflecting updated inputs from AC. |
| Tables 21-22 | Chapter 6 | Revised versions of Tables 21-22 in November 2014 document, reflecting updated inputs from AC. |
| Tables 28-29 | Chapter 6 | New tables, reflecting additional sensitivity tests. |
| Figures 38-48 | Chapter 6 | New figures, reflecting additional sensitivity tests. |
| Table 30 | Chapter 6 | New table, reflecting additional sensitivity tests. |
| Figures 49-52 | Chapter 6 | New figures, reflecting additional sensitivity tests. |
| Table 31 | Chapter 6 | New table, reflecting additional sensitivity tests. |
| Figures 53-54 | Chapter 6 | New figures, reflecting additional sensitivity tests. |
| Table 32 | Chapter 6 | New table, reflecting additional sensitivity tests. |
| Figure 55 | Chapter 6 | New figure, reflecting additional sensitivity tests. |
| Tables 33-34 | Chapter 6 | New tables, reflecting additional sensitivity tests. |
| Table 35 | Chapter 6 | New table, reflecting additional sensitivity tests. |
| Figure 56 | Chapter 6 | New figure, reflecting additional sensitivity tests. |
| Tables 36-39 | Chapter 6 | New tables, reflecting additional sensitivity tests. |
| Figure 57 | Chapter 6 | New figure, reflecting additional sensitivity tests. |
| Tables 58-59 | Chapter 7 | New tables, reflecting additional sensitivity tests. |
| Figures 90-100 | Chapter 7 | New figures, reflecting additional sensitivity tests. |
| Table 60 | Chapter 7 | New table, reflecting additional sensitivity tests. |
| Figures 101-103 | Chapter 7 | New figures, reflecting additional sensitivity tests. |
| Table 61 | Chapter 7 | New table, reflecting additional sensitivity tests. |
| Figure 104 | Chapter 7 | New figure, reflecting additional sensitivity tests. |
| Table 62 | Chapter 7 | New table, reflecting additional sensitivity tests. |
| Figures 105-106 | Chapter 7 | New figures, reflecting additional sensitivity tests. |
| Tables 63-65 | Chapter 7 | New tables, reflecting additional sensitivity tests. |

| | | |
|---|---|---|
| Figure 107 | Chapter 7 | New figure, reflecting additional sensitivity tests. |
| Table 66-69 | Chapter 7 | New tables, reflecting additional sensitivity tests. |
| Figure 108 | Chapter 7 | New figure, reflecting additional sensitivity tests. |
| Tables 88-89 | Chapter 8 | New tables, reflecting additional sensitivity tests. |
| Figure 141-151 | Chapter 8 | New figures, reflecting additional sensitivity tests. |
| Table 90 | Chapter 8 | New table, reflecting additional sensitivity tests. |
| Figures 152-154 | Chapter 8 | New figures, reflecting additional sensitivity tests. |
| Table 91 | Chapter 8 | New table, reflecting additional sensitivity tests. |
| Figure 155 | Chapter 8 | New figure, reflecting additional sensitivity tests. |
| Table 92 | Chapter 8 | New table, reflecting additional sensitivity tests. |
| Figures 156-157 | Chapter 8 | New figures, reflecting additional sensitivity tests. |
| Tables 93-95 | Chapter 8 | New tables, reflecting additional sensitivity tests. |
| Figure 158 | Chapter 8 | New figure, reflecting additional sensitivity tests. |
| Table 96-99 | Chapter 8 | New tables, reflecting additional sensitivity tests. |
| Figure 159 | Chapter 8 | New figure, reflecting additional sensitivity tests. |
| Table 109 | Appendix E | New table, supporting multiplier commentary. |

# Contents

# *Introduction*

## *Report commissioning*

This report has been prepared by PricewaterhouseCoopers LLP (PwC), for the Airports Commission (AC). The purpose of the report is to present PwC's findings based on our research into the wider[1] economic impacts of aviation capacity expansion on GDP/GVA in the UK economy.

Whilst the AC commissioned and financed the work, and commented on our draft reports, the final report represents the independent analysis of PwC. The analysis has been independently peer reviewed by the AC's expert panel of academics, as well as Professor Sourafel Girma and Professor Peter Forsyth who we retained in order to help us to carry out the work. We also consulted extensively with Professor Adam Blake throughout the modelling and review processes. This version of the report reflects these comments in so far as we have been able to implement them within the constraints of available data, the time and budget given to us by the AC to complete this work, and the practical applications of the techniques we have applied.

[1]The term "wider" is used to denote that the scope of the economic impacts evaluated in this study extends beyond those associated with the direct users of any expanded airport to those which are forecast to arise indirectly as a result of expanded airport capacity and hence aviation activity.

# 1 Introduction

## 1.1 Scope

We analyse the wider GDP/GVA impacts of the following three schemes in this report:

1. Gatwick Airport Second Runway (LGW 2R).

2. Heathrow Airport Extended Northern Runway (LHR ENR).

3. Heathrow Airport Northwest Runway (LHR NWR).

PwC have been commissioned to analyse the wider economic impacts of these different proposed schemes for airport expansion. In particular we have forecast the impact of the three schemes on variables such as GDP, investment, trade and jobs.

The AC have conducted or commissioned separate studies on other impacts, such as direct user benefits, local economic impacts, environmental impacts and safety. This report is therefore intended to be one input into a broader assessment, and its findings should be considered alongside the other studies that have been undertaken.

## 1.2 Our approach

The Department for Transport (DfT) have published guidance on best practice in assessing the economic impact of transport infrastructure investment – this is known as WebTAG (Web based Transport Appraisal Guidance). Other appraisal guidance is also available in the form of the HM Treasury Green Book and the reports of expert working panels such as the SACTRA (1999) report[2], as well as a substantial body of academic evidence. The AC have also conducted their own consultation and analysis on the scope of wider economic effects and the associated evidence base. In conducting our assessment of wider economic effects we have sought to draw on this previous work and guidance and use it to inform both our methodological approach and our interpretation of its findings. It is also important to note that the DfT launched a consultation in October 2013 to explore whether, and if so how, their existing approach to appraising transport infrastructure projects should be improved. Professor Tony Venables, Professor Henry Overman and Dr John Laird were commissioned to review the relevant literature in this regard. Their findings were published in October 2014 alongside a number of recommendations[3]. These included the need for appraisal techniques to be more project-specific, and to take account of land use change where appropriate.

The main analytical tool used in this report is a Computable General Equilibrium (CGE) model of the UK economy.[4] We consider that this is the best approach in order to meet the different recommendations that have emerged from the guidance and previous studies described above. CGE models are often used to assess the impact of different government or institutional policies, or to investigate the effects of different economic scenarios. CGE models allow us to forecast the impact of the introduction of new airport capacity on key economic metrics such as GDP, employment, household consumption, exports, imports, investment, tax receipts etc. Our CGE model covers three geographical regions of the UK economy separately: London & South East, the Rest of England and the Rest of the UK. Each of the regions interacts with the others, and the model can also capture the overall effects on the UK economy. As we have added a regional dimension to the model, we refer to the model as a "Spatial" CGE (S-CGE) model.

Our S-CGE model estimates the economic impact of the introduction of new airport capacity by comparing the outcome for the economy in the presence of the new capacity with the outcome absent that additional capacity. The equations in the S-CGE model are calibrated based on historic actual UK economic data, and a baseline scenario for the economy (absent any new airport capacity) has been created. In order to use the S-CGE model

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[2] The Standing Advisory Committee on Trunk Road Appraisal. Their report is Transport and the Economy. The Stationary Office, London, 1999.

[3] Transport investment and economic performance: Implications for project appraisal, Venables, A., Laird, J. and Overman, H., October 2014. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/386126/TIEP_Report.pdf

[4] More detail on the model is provided in the next Section and in Chapter 3 and Appendix B of this report.

to estimate the impact of an airport expansion scheme, we change key variables in the model which are associated with increased airport capacity. Most of the data supporting the changes in these variables based on the characteristics of the three airport expansion schemes, have been supplied to us either by the AC, based on their own internal analytical workstreams, or by the consultancy firm LeighFisher, who have been tasked by the AC with verifying construction and operating costs.

The AC's work on the implications of the proposed airport schemes for aviation travel includes three key impacts with likely macroeconomic consequences which we have reflected in our modelling:

- The removal of a runway capacity bottleneck in the South East will allow **more passenger flights to and from a wider range of destinations**. In our model we reflect this in two ways:
  - in **Effect 1**, we model how these additional journeys are likely to change passenger expenditure patterns; and
  - in **Effect 2** we model the potential implications of the implied boost to trade-derived productivity associated with the improved connectivity that UK firms will have with overseas firms and markets.
- The greater numbers of flights and destinations, together with the provision of more spare capacity which should improve operational reliability, will result in **a reduction in effective journey times for air passengers**. In our model we reflect this:
  - in **Effect 3**, where we model the effects of the potential boost to productivity associated with the AC's estimates of frequency benefits for business passengers.
- The removal of the runway capacity bottleneck is expected by the AC to result in **lower cost of travel** as airlines are less able to charge premium prices for congested peak services. In our model we reflect this:
  - in **Effect 4**, where we model the potential implications for changes in expenditure and other key economic variables as a result of the gains to air passenger consumers (offset by some losses for airline shareholders).

Since the purpose of this work is primarily to understand the long-term impact of the schemes as a result of the improved aviation linkages, our principal focus is on the operational effects described above. However, there are also impacts associated with the construction of the schemes. In our model we assume that the construction is funded £1 for £1 by diversion of resources from elsewhere in the economy (mainly private consumption, but some private investment and public investment for surface transport)[5]. In principle, since the economy is assumed to be near to full employment in the baseline scenario, and hence resources must be "diverted" towards construction of new airport capacity from other activities, the overall impact of constructing the airport could be to increase GDP, reduce it, or have little or no effect. It is therefore instructive to use the S-CGE model to understand how construction of the schemes may, in itself, impact on the economy. In particular therefore, we investigate the impact of incremental capital associated with the airport schemes and the incremental cost of providing the surface access.

The fact that construction impacts are characterised by diverting resources from one part of the economy to another (as described in the last paragraph) is an example of a general principle in our modelling: we do not provide a "free lunch", with many of the impacts we describe being counteracted by effects that work in the opposite direction. Other examples include recognition in the model that:

- Some of the extra flights enabled by the schemes will actually have the potential to diminish GDP by, for example, allowing British residents more and cheaper opportunities to spend abroad rather than at home;

[5] This means, for example, that the funds used to build the airport must ultimately be repaid, and households and firms in the model recognise this and make their consumption, production and investment decisions in light of that information. The model therefore has what economists might call "Ricardian" properties, following the 17th century economist Ricardo who emphasised similar points in the context of governments' long-term tax and expenditure policies.

- Whilst the lower economic rents extracted by airlines as a result of the schemes (modelled by the AC) are likely to boost consumer spending power, simultaneously the profitability of the airline sector is reduced and airline shareholders (who are assumed to be UK households in the S-CGE model) are made worse off; and

- To the extent that enhanced airports capacity boosts demand and activity, there is a danger that this could result in inflationary pressures and/or benefit London & South East at the expense of other parts of the UK. Both of these factors are captured in our analysis.

Our modelling explicitly considers whether the offsetting effects described above will occur, and if so their extent, and provides insight into the "net" impacts of the various effects. The results that we obtain – including that there will likely be a significant positive GDP impact that is spread across the UK (see Part II) – result from:

- The relative "multiplier" effects of the new pattern of expenditure and investment;
- Productivity boosts associated with better connectivity and time savings; and
- The knock-on implications for different regions of the UK as the economy moves to a new equilibrium reflecting the changed pattern of economic activity.

Crucially, our modelling allows the following impacts to be modelled which are not usually reflected in conventional appraisal methodologies:

- Secondary economic impacts – not just direct user impacts, but also the knock-on implications for prices, productivity, employment, the capital stock and so forth;

- Dynamic impacts – the S-CGE model simulates the linkages in the economy over time, so that the full ramifications of direct and secondary impacts can be obtained. We take into account potential crowding-out and diffusion effects (such as changes in prices which offset an initial impact) explicitly;

- Regional impacts – using a S-CGE model allows us to model the dynamic impacts at a sub-national level, taking into account agglomeration effects and allowing us to evaluate likely impacts on different regions; and

- The impacts of imperfect competition– the S-CGE model allows us to depart from the conventional assumption in scheme appraisal of perfect competition, and to capture the real world implications of how most markets in the economy are characterised by effective but imperfect competition.

It should be noted that each of the effects described above will have both supply-side and demand-side features. For instance, if under Effect 1 passenger spending increases, then this will benefit businesses in sectors which fulfil the demand of visitors to the UK (e.g. hotels, restaurants etc.) on the demand-side, which in turn will feed through to demand in other sectors of the economy as businesses in the sectors that fulfil demand of visitors to the UK demand more inputs in order to carry out their activities. But there will also be a supply-side effect as the sectors increase investment and more individuals work (and work for longer) in order to meet this additional demand. The more predictable and longer-term this increase in demand is, the greater the incentive there will be for businesses to invest and individuals to enter the labour force, rather than for increased demand to result in increased prices. Similarly, if productivity increases, as per Effect 2, then there will be a supply-side effect associated with increased business investment and greater employment, but also a demand-side effect as households gain from cheaper and/or better quality goods. With Effects 3 and 4, we adjust productivity in the model in a manner that replicates the supply-side impact of business passengers being able to travel with lower effective journey times and the demand-side impact of passengers being assumed to fly more cheaply.

Changes in air freight activities are not used as inputs to the S-CGE analysis. We do, however, report the impacts on the air freight sector associated with the various effects described above in Part II of this report. This impact is estimated through the strong links between the air freight sector and the other sectors within the economy.

## 1.3 Understanding the results

The overall economic impact results presented in this report may be regarded by the reader as being "large", in the sense that the predicted monetary boost to GDP may seem large relative to the cash investment in the airport schemes themselves. There are two main reasons why we might expect such schemes to have a "large" impact on the UK economy. Firstly, the AC's estimates of the scale of the impacts of the schemes in terms of increased passenger numbers, reduced air fares and journey time savings are large. Secondly, the air travel impacts can be expected to have a direct effect on economic activity in one of the largest cities in the world, with significant spillover effects to the rest of the UK economy as well. Our research has shown that air travel and connectivity is an important "enabler" of economic activity across the wider UK economy, so it is reasonable to expect that significantly improved air connectivity will have important spillover effects in the form of increased trade, business growth, productivity improvements, and job creation etc. in other sectors of the UK economy.

For such spillover effects to occur, however, our model assumes that there will be increased investment and operating expenditure in sectors of the economy other than aviation. Whilst the forecast expansion of these sectors is linked to, or enabled by, the original investment in airport capacity, the overall final forecast impact on GDP also depends on firms in other sectors investing and incurring operating costs to capitalise on the opportunities created by better UK air links to the rest of the world. In this sense the forecast monetary increase in GDP is associated with a cash increase in investment which is far larger than simply that in the airport schemes themselves.

Furthermore, our modelling recognises that such spillover effects will likely be diffused by associated wage increases, rises in capital costs and increases in imports, so that their full benefit is not realised in UK GDP. For each of the effects we have modelled we show the extent of this diffusion in the form of a "multiplier". This multiplier compares the scale of the cash value of the model inputs (for example, spending in the UK economy associated with increased air passengers) with the model estimates in terms of additional GDP. In the majority of examples considered in this analysis these multipliers are less than 1 – for example £1 of additional demand in the UK economy driven by increased passenger spending yields less than £1 of additional UK GDP. The S-CGE approach captures a wider range of impacts than would normally be captured using other techniques as well as their interactions and feedback to non-aviation users. Because of the associated diffusion effects, the magnitudes of some of the individual effects are smaller than those observed in many of the airport impact studies that look at gross effects only.

This approach and finding is consistent with the wide-ranging academic and institutional literature on dynamic impact multipliers. There are only a limited amount of transport infrastructure modelling exercises against which our modelling can be benchmarked (see the literature review in Chapter 3 of this report). Our modelling suggests a similar range of effects to these other examples and is also consistent with our separate econometric analysis of the relationship between airline seat capacity and GDP conducted for the AC as part of their December 2012 interim report.

It should be noted that the S-CGE modelling approach primarily focuses on GDP/GVA type impacts rather than welfare impacts in a typical transport appraisal. It should be considered a complementary approach to those used elsewhere in the AC's analysis and should not be assumed additional to other impacts that the AC have calculated.

## 1.4 Report outline

This report is divided into three Parts:

- Part I – Our methodology: Part I describes the methodology that we have used to assess the wider economic impacts of the three schemes described above;
- Part II – Results: Part II presents the results of the analysis for each of the three schemes; and
- Part III – Appendices: Part III contains appendices which cover some of the technical issues that have been considered as part of our work.

Below, we describe each part in further detail.

### 1.4.1 Part I – Our methodology

Part I sets out our methodology for modelling the wider economic impact of an increase in airport capacity. It is divided into three chapters:

2) **Defining wider economic impacts:** In this chapter we cover what is meant by wider economic impacts in the context of this analysis, and how they are typically captured in transport appraisal. We also introduce the literature on some of the key theoretical issues to which we refer in the report. Finally, we introduce different approaches that can be used to model wider economic impacts, and discuss the relative advantages and disadvantages of using S-CGE modelling compared with alternative methods.

3) **An overview of the modelling approach:** We begin this chapter by providing more detail on CGE models, and the relationships within an economy which they capture. This is followed by a brief literature review covering the use of CGE modelling within transport appraisal, and relevant precedents for estimating the wider economic impact of an airport. Using the literature as a basis we then outline the key features of the S-CGE model used in this analysis, followed by a description of the data used in the model.

4) **Modelling methodology:** In the final chapter of Part I, we explain in detail the modelling methodology used to capture the wider economic impacts of an increase in airport capacity in London & South East. Here we describe the three schemes which we have modelled, and the five different passenger scenarios which have been applied to each scheme. Following this we outline the four effects which we model, the mechanism through which each is assumed to impact on overall GDP, and finally how each effect is captured within the CGE framework.

### 1.4.2 Part II – Results

Part II sets out the impact of each proposed scheme on key economic variables, such as the level of GDP and employment. This part is divided into two types of chapter:

5) **Interpreting results:** In this chapter, we briefly outline how the reader should interpret the results in the following chapters. This primarily focusses on some common assumptions used to drive the model, and the interpretation of some of the key charts which appear regularly in the results section. We conclude this chapter by discussing potential areas of uncertainty within the model inputs which drive the overall results, and therefore what considerations should be taken into account when interpreting the findings.

6, 7, 8) **Results for each scheme:** In the final three chapters of Part II, we separately present the inputs and economic impacts of the three proposed schemes. Chapter 6 presents the results for the LGW 2R scheme, Chapter 7 for the LHR ENR scheme and Chapter 8 for the LHR NWR scheme. Each of these chapters follows a similar format, focussing on the overall forecast GDP impact of the change in airport capacity under each passenger scenario, and setting out what drives this forecast impact. In addition to the GDP impact, we also present the forecast impacts on job creation, house prices, concentration of firms and welfare. Finally, we also present the results of some sensitivity tests of the robustness of the findings. A number of additional sensitivity test have been added since the original version of this report was published, as a result of responses to the AC's consultation.

### 1.4.3 Part III – Appendices

Part III supports our analysis with four Appendices which provide further information on a selection of key areas. The four appendices are:

A) **Economic geography and multiple equilibria:** This appendix sets out in more detail the literature and theory behind the economic geography and multiple equilibria concepts which are introduced in Part I.

B) **Model structure:** Here we set out in greater detail the key components and assumptions within the S-CGE model, which are also introduced in Part I.

**C)** **Econometric estimation of the link between passenger flows and trade:** This appendix provides more information on the intention, approach and results of the econometric analysis which we performed in order to estimate a relationship between seat capacity and trade.

**D)** **Transmission mechanisms:** This appendix contains four diagrams showing the transmission mechanisms through which the changes in passenger spending, productivity, frequency benefits, transport economic efficiency (TEE) and construction inputs are assumed to impact on the level of GDP.

**E)** **Multiplier analysis:** This appendix compares the multiplier estimates arising from this study with those in the wider literature. This appendix has been added since the original publication of this report.

# *Part I –Methodology*

# 2 Defining wider economic impacts

## 2.1 Section overview

The purpose of this chapter is to provide background on, and context to, the explanations of our approach to the analysis and our results which follow. In turn, we summarise:

- How schemes such as those currently being considered by the AC might be analysed using more conventional approaches to transport infrastructure appraisal;
- Some of the key concepts (i.e. imperfect competition, agglomeration and tax) that frequently arise when assessing the wider economic effects of such schemes;
- An aspect of the "New Economic Geography" (i.e. multiple equilibria) which is particularly relevant to our analysis but which is often less comprehensively addressed in the conventional approach to transport infrastructure appraisal;
- How the AC has previously adapted the conventional approach to assessing wider economic impacts and some of the literature which is particularly pertinent to the aviation sector;
- Some of the key principles that we consider should be applied when deciding on the overall approach to analysing the wider economic impacts of the schemes;
- The main approaches to modelling that could be applied and why we selected the approach that we did, i.e. Spatial Computable General Equilibrium (S-CGE) modelling; and
- Some important points to note about how to interpret our results, given how our approach differs to the conventional approach to transport infrastructure appraisal.

## 2.2 Conventional approach to appraisal

Transport projects being considered by government are generally appraised from the perspective of welfare analysis using the Department for Transport's WebTAG (Web-based Transport Analysis Guidance). This approach focusses on the direct user benefits of the project (such as the value of time savings made by leisure and business passengers) and compares these benefits with the costs of the project. WebTAG (in modules A3, A4.1 and A4.2) also provide guidance on a range of other factors such as environmental effects, safety and social and distributional impacts, but our analysis does not consider these and we exclude them from the rest of this discussion.

Under WebTAG module A2.1, wider impacts (previously called wider economic impacts) are or may be added to the direct transport impacts. Note that conceptually these may be positive or negative. Wider impacts (WIs) currently included in WebTAG guidance include:

- Agglomeration benefits that are expected to be brought about by the project (i.e. businesses being made more productive as a result of effectively being located more closely to each other);
- The impact of imperfect competition (i.e. since in imperfectly competitive markets, the marginal benefits of increasing output (measured by price) are above marginal costs, this means that an increase in output (and reduction in price) brought about by lower transport costs will have an additional benefit over and above that experienced in perfectly competitive markets); and
- Exchequer effects (e.g. the impact on tax returns of increased economic growth).

Vickerman (2007)[6] conducts an extensive review of transport appraisal evidence. From his review and more recent developments we can infer the following about conventional transport appraisal techniques:

- For small to medium sized schemes the effort needed to estimate the wider impacts may be regarded as out of proportion to the likely size of the impacts. This is a pragmatic rather than principled argument for omitting them;

- Direct user benefits can be regarded as constituting a relatively large proportion of the impact of a project, and WIs are generally unlikely to be anything like as large as them; and

- There are some transport infrastructure projects where WIs could be particularly important. Examples range from large projects such as High Speed 2 and the Lower Thames Crossing through to smaller projects such as a road to a hitherto poorly connected town. The key criterion is likely to be whether the project has the potential to induce significant change in behaviour or activity.

Turning now to costs, in conventional CBA the construction and operating/maintenance costs of schemes are usually assumed to be real resource costs. This reflects the HM Treasury Green Book assumptions of full employment and competitive markets. The lynchpin of this approach is that the wage is taken to equalise the marginal opportunity cost of labour with the value of its marginal product. The wider impacts are not usually deployed on the cost side because construction costs are tacitly assumed to displace equivalent resources elsewhere in the economy and therefore to have no net macroeconomic effect.

Finally, we note that the DfT is considering whether, and if so how, its existing approach to appraising transport infrastructure projects should be updated. It launched a consultation on the subject in October 2013 and commissioned a number of academics (Professor Tony Venables, Professor Henry Overman and Dr James Laird) to explore the economic theory and literature on the relevant issues. Their findings were published in October 2014 alongside a number of recommendations[7]. These included the need for appraisal techniques to be more project-specific, and to take account of land use change where appropriate.

## 2.3 Key concepts

In this section we summarise the main WIs that are codified in the DfT's guidance on transport appraisal best practice. WebTAG has a module dedicated to the assessment of wider economic benefits (WebTAG Unit A2.1):[8]

- Agglomeration;
- Output changes in imperfectly competitive markets; and
- Tax revenues arising from labour market impacts.

### *Agglomeration*

According to TAG Unit A2.1, agglomeration *"refers to the concentration of economic activity over an area"*. Agglomeration impacts arise because firms derive productivity benefits from being close to one another and from being located in large labour markets. If transport investment brings firms closer together and closer to their workforce this may generate an increase in labour productivity over and above that which would be expected from the direct user benefits

### *Output change in imperfectly competitive markets*

The second wider impact set out in WebTAG relates to output increases in imperfectly competitive markets as a result of cost reductions from transport improvements. In particular, transport investment can reduce firms' costs, for example by reducing the costs (be it in cash terms or through time savings) of delivering goods to markets. This allows firms to increase output in a profitable manner. By definition, in imperfectly competitive

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[6] Vickerman, R. (2007). Recent evolution of research into the wider economic benefits of transport infrastructure investments (No. 2007/9). OECD Publishing.

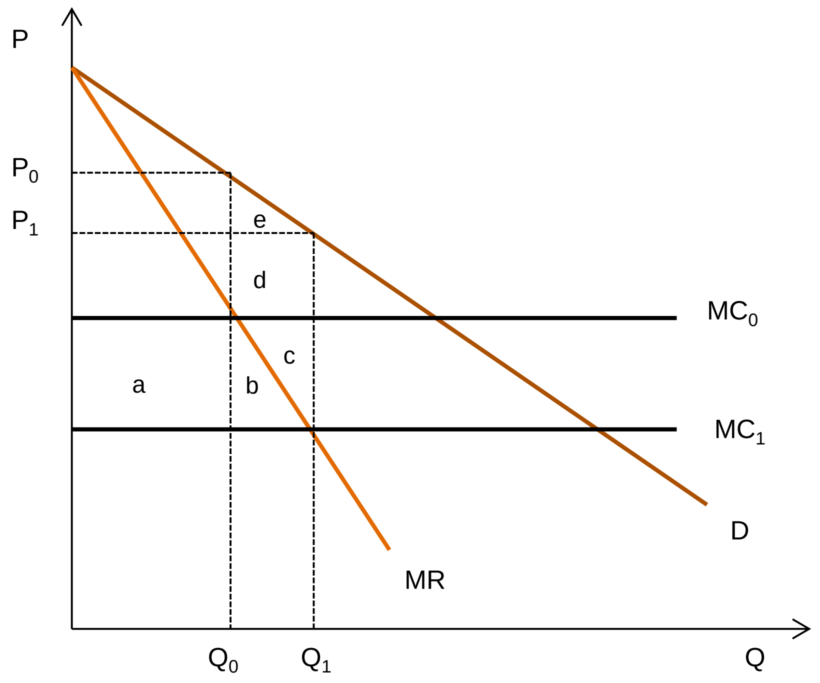
[7] Transport investment and economic performance: Implications for project appraisal, Venables, A., Laird, J. and Overman, H., October 2014. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/386126/TIEP_Report.pdf

[8] WebTAG Unit A2.1 "Wider Impacts", Department for Transport, January 2014. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/339551/webtag-tag-unit-a2-1-wider-impacts.pdf

markets prices are higher than marginal costs. Thus, an output expansion brought about by reduced costs gives rise to an additional welfare benefit over and above what would be seen in a perfectly competitive framework.

This is illustrated in Figure 1 below, which depicts an imperfectly competitive market. Marginal costs are assumed to be constant, and initially at $MC_0$. The resulting profit-maximising price is $P_0$ and output is $Q_0$. Suppose that as a result of a transport intervention, marginal cost falls to $MC_1$, giving a new equilibrium with a lower price $P_1$ and higher output $Q_1$. Areas $a$ and $b$ in the diagram represent a welfare gain to society since the existing and new output which comprise $Q_1$ can now be produced at lower cost. Direct cost savings similar to these associated with the production process becoming more efficient would be present in a model of perfect competition and are captured in conventional transport appraisal. However, where the market is imperfectly competitive, there are further effects. In particular, since price is above marginal cost, the area $c + d + e$ accrues as a welfare gain (in particular, the consumer benefits by $e$ and the producer gains $c + d$).

*Figure 1: Output change in imperfectly competitive markets*




*Source: WebTAG*

### *Tax revenues arising from labour market impacts*

TAG Unit A2.1 emphasises that changes in transport provision and costs can affect decisions in the labour market. It goes on to identify two types of labour market impacts:

- **Labour supply.** Transport costs are likely to affect individuals' labour supply decisions. In deciding whether to participate in the labour market at all, and in deciding which particular role they take, transport and commuting costs are likely to be an important part of individuals' thinking; and

- **Productivity**. Changes in transport costs can also affect firms' and workers' decisions concerning where to locate and work. This can have implications for overall productivity, since agents may be more productive in some locations than in others.

Much of the economic benefits will be taken into account in conventional transport appraisal since they accrue to consumers making the decisions. However, the taxation changes to the exchequer will not be counted. The exchequer impacts of these changes are included in WebTAG-compliant transport appraisal as the third wider impact.

## 2.4 New economic geography

Our analysis in this report seeks to estimate the regional, as well as the national, economic impact of an expansion in airport capacity. A key question we want to consider is whether building airport capacity in London & South East will have wider economic impacts which are highly concentrated in this region, or whether the wider economic benefits could be distributed throughout the UK, with supply chains being strengthened across the country to take advantage of the potential gains from airport expansion. In economic theory, the extent of such dispersion is determined by the nature of competition between firms and the propensity for agglomeration.

Much of the theory relating to imperfect competition and agglomeration effects in a general equilibrium framework is referred to as the "New Economic Geography" (NEG). One aspect of the theory underpinning the NEG, advanced by Krugman (1991)[9], predicts the possibility of "multiple equilibria" in the spatial distribution of activity. The concept of multiple equilibria implies that agglomeration benefits can "lock themselves in" and effectively lead to one region growing faster than another.

While the existence of multiple equilibria may be regarded as a relatively abstract concept, they are important in determining the spatial distribution and permanency of wider economic effects. The multiple equilibria framework can be understood by considering an example of what might happen if an increase in airport capacity brings about an outward shift in demand for the services provided by airlines:

- On the one hand, airlines that are currently in the market might set their prices relatively low in order to mitigate the potential that other airlines will infer from the increased demand that there is an attractive opportunity for market entry. If this pricing strategy prevails, then the airline market will develop in a particular way (e.g. on a trajectory consistent with relatively high growth but low margins) and trigger a wide range of secondary economic effects which will affect customers of, and suppliers to, the sector in London & the South East and beyond - as well as people who work for companies in these sectors and reside in different regions of the country; and

- On the other hand, airlines that are currently in the market might consider the likelihood of market entry to be relatively low, in which case they might set prices at a relatively high level, in which case the airline market will develop in a different way (e.g. on a trajectory consistent with lower growth but higher margins). This would trigger a likely different range of secondary economic effects for customers, of and suppliers to the sector in London & the South East and beyond - as well as people who work for companies in these sectors and reside in different regions of the country.

It is therefore possible that the same policy intervention (i.e. an expansion of capacity) could result in a number of different equilibria which would have different outcomes (e.g. in terms of regional and national levels of GDP). Moreover it can be impossible to predict in advance which equilibrium will prevail (i.e. whether airlines that are currently in the market will price high or low in response to an increase in demand), hence the need to consider each of these potential equilibria.

Understanding the potential for these effects to occur is critical in transport infrastructure appraisal – an approach that just examined the effects of the investment on London & South East, would overlook potential impacts on the Rest of the UK (e.g. as businesses in these areas expand or contract and people move to or from the areas). To capture these types of effects, the flows of trade and worker movements between London & South East and the Rest of the UK need to be included in the methodological framework. For instance, if London & South East were to gain from the transport infrastructure investment through imperfect competition effects, then the Rest of the UK might benefit in the longer-term through increased trade with London & South East, since London & South East would require more resources in its production process which the Rest of the UK could supply.

[9] Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy*, 99, 483-99.

The above example only covers the effects of imperfect competition and this concept is well documented by Krugman (1991)[10], Fujita *et al*[11]. (2001) and Combes *et al*. (2008)[12]. In other models, multiple equilibria can be determined by knowledge spillovers, whereby firms are able to enhance their performance by learning from other firms with which they are co-located (for example through demonstration effects, or labour turnover). Knowledge spillovers were identified by authors as far back as Marshall (1920)[13] and Hoover (1948)[14]. The labour market turnover point has since been discussed by Gabe and Abel (2010)[15] who point out that firms may seek to relocate to obtain benefits from being in close proximity to a new labour market pool of skilled workers. Possibilities for firms to obtain knowledge spillovers and subsequent gains from labour market pooling could be enhanced by transport infrastructure investment.

Examples of the existence of multiple equilibria are growing in the economic literature and the examples described above suggest its importance as a concept in determining the outcomes of transport infrastructure investment.

## *2.5 The Airports Commission's approach*

In their 2013 interim report[16] the AC have considered the role of wider economic effects and in doing so have broadened the scope of the discussion set out in the WebTAG framework. In their report they present a broader range of impacts in the context of aviation. These impacts are set out in Figure 2 below.

This diagram sets out some of the key impacts associated with increased air connectivity. What is different about the AC's thinking is their willingness to consider economic flows (tourism, trade and FDI) in addition to the underlying concepts of imperfect competition, agglomeration and tax revenues included in WebTAG. The AC separately commissioned a literature review of these economic flows which was published alongside their 2013 interim report. In order to avoid repetition, we refer the interested reader to this review document for a more detailed discussion of these flows and the associated evidence.

[10] Krugman, P. R. (1991). *Geography and trade*. MIT press.

[11] Fujita, M., & Krugman, P. (1995). When is the economy monocentric?: von Thünen and Chamberlin unified. *Regional Science and Urban Economics*, *25*(4), 505-528

[12] Combes, P.P., Duranton, G., & Gobillon, L. (2008). Spatial wage disparities: Sorting matters!. Journal of Urban Economics, 63(2), 723-742.

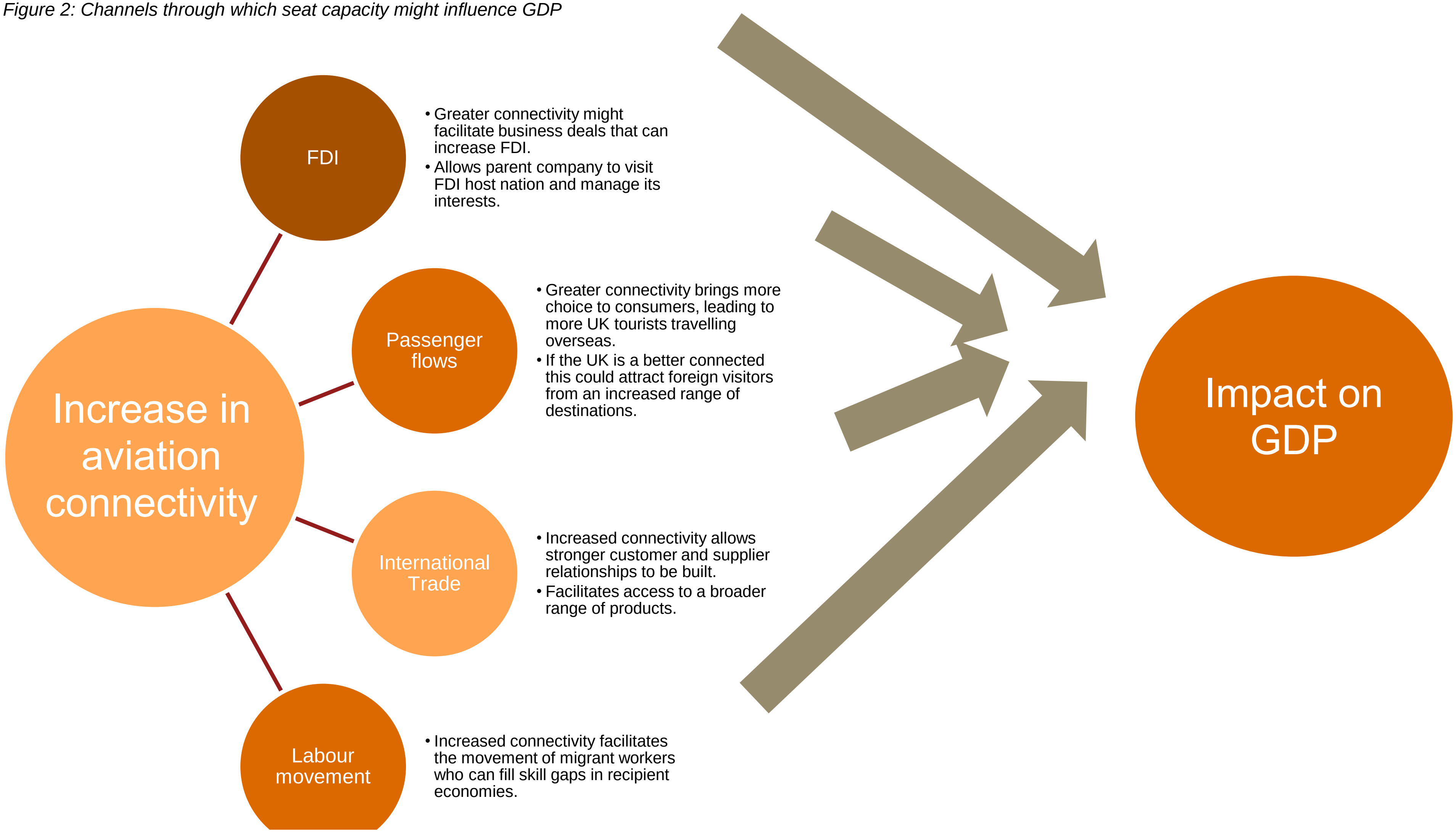
[13] Marshall, A. (1920). Principles of Economics; An Introductory Volume. Macmillan and Co. London, U.K.

[14] Hoover, E. M., (1948)The Location of Economic Activity. New York: McGraw Hill

[15] Abel, J. and Gabe, T (2011) "Human Capital and Economic Activity in Urban America," Regional Studies, Taylor & Francis Journals, vol. 45(8), pages 1079-1090.

[16] Airport Commission (2013). Airports Commissions Interim Report. London, UK

*Figure 2: Channels through which seat capacity might influence GDP*




*Source: PwC analysis*

## 2.6 Literature on the role of businesses and productivity gains

In addition to the concepts set out by WebTAG, the NEG and the AC, there is a further important trigger of wider economic benefits associated in particular with the business benefits that can be drawn from greater connectivity.

In the case of the aviation sector a link is often made between improved transport connectivity and increased GDP. This relationship is driven by businesses' use of aviation and the benefits they derive from it. In this section we discuss the underlying rationale and associated evidence behind this relationship.

We would expect an increase in aviation capacity to raise the level of connectivity of the UK economy. Hong, Chu and Wang (2011)[17] outline three separate elements of how improved transport sector connectivity boosts productivity through its impact on business:

- **Travel times fall and businesses gain access to a wider marketplace.** This improves productivity in a number of ways. Firstly, falling travel time reduce business costs. Secondly, by raising the potential volume of sales, transport links give businesses a greater ability to exploit economies of scale. Incentives to invest in projects with high fixed costs (such as R&D) are also increased as the costs of doing so can be spread over a wider sales base. Finally, an exposure to global competitive forces provides incentives to reduce costs, improve quality or differentiate product or service offerings, ultimately resulting in higher levels of innovation;

- **Businesses can improve the efficiency of existing production and supplier relationships**. Transport links allows businesses to be managed more effectively by making it easier for managers and executives to oversee non-local operations. Transport links can also help to build future business relationships by providing the opportunity for businesses to network with potential clients and collaborators, which can eventually boost the scale of existing operations; and

- **Businesses can undertake cross border investment more easily**. Investing is also made easier by transport for a number of reasons. The time taken to transfer the intellectual capital involved in such investments can be reduced. Better transport links may also increase the available returns from some projects (by allowing access to a greater marketplace, for instance). Lastly, better infrastructure attracts foreign direct investment and companies moving operations to take advantage of improved transport links. More local competition helps to drive down costs, whilst outside technology and business practices help companies to improve existing products and hone management techniques.

Against this backdrop, business usage of air transport can be thought of as particularly important for these linkages in a global setting. Flying is often the only way for firms' employees and owners to travel long distances. Whilst video conferencing and similar technologies offer an alternative to travel, independent studies have shown that the scope for such alternatives to replace face-to-face meetings is limited. The Committee for Climate Change report into the feasibility of aviation emission targets found that a modal shift to videoconferencing alone may only reduce aviation passenger numbers by 1% by 2050 under their "likely" scenario.[18] This is consistent with academic studies which have suggested that videoconferencing could actually be complementary to air travel, rather than acting as a substitute (see Wang and Law (2007)[19] and Choo and Mokhtarian (2007)[20]).

Business air usage may have additional benefits for firms in certain sectors in the economy. Keller and Hovhannisyan (2012) [21] found that business travel improves innovation between firms in high-tech industries, as technology is "*best explained and demonstrated in person*". Their study found a statistically significant link between business air travel and patenting activity (a proxy for innovation). Specifically, a 10% increase in business travel leads to a 0.2% increase in patenting.

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[17] Hong, J., Chu, Z., & Wang, Q. (2011). Transport infrastructure and regional economic growth: evidence from China. *Transportation, 38*(5), 737-752. A similar framework can also be found in: Button, K., & Reggiani, A. (Eds.) (2011*). Transportation and Economic Development Challenges*. Edward Elgar Publishing.

[18] In the 'optimistic' and 'speculative' scenarios this impact on aviation volumes rises to 7% and 16% respectively. Source: Committee on Climate Change (2009). 'Meeting the UK aviation target – options for reducing emissions to *2050*. London, UK:2050', Committee on Climate Change, December 2009.

[19] Wang, D., & Law, F. Y. T. (2007). Impacts of Information and Communication Technologies (ICT) on time use and travel behaviour: a structural equations analysis. *Transportation, 34*(4), 513-527.

[20] Choo, S., & Mokhtarian, P.L. (2007). 'Telecommunications and travel demand and supply: Aggregated structural equation models for the US. *Transportation Research Part A: Policy*', *41*(1), 4-18.

[21]Hovhannisyan, N., & Keller, W. (2011). International Business Travel: An Engine of Innovation? Working Paper No.17100. *National Bureau of Economic Research*.

A summary of these studies is given in Table 1 below.

*Table 1: Studies showing a positive productivity gain from increase in transport infrastructure*

| **Source** | **Scope of report** | **Mechanism for productivity gain** | **Other key findings** |
|---|---|---|---|
| Hong, Chu and Wang (2011) | Examines the linkage between transport infrastructure and regional economic growth in China using a sample of 31 Chinese provinces from 1998 to 2007. | Transport infrastructure reduces travel time, with consumers and businesses gaining directly from the time and cost saving. Businesses can also realise additional gains through lowering minimum inventory levels and gaining access to longer-distance domestic and export markets. | The results provide *"strong evidence that transport infrastructure plays an important role in economic growth".* |
| Button and Reggiani (2011) | Provides a theoretical and empirical overview of transport's role in economic development. | Transport infrastructure reduces costs to production inputs. It can also attract private capital investment which has further productivity effects. | The authors summarise their findings as providing a *"relatively strong theoretical and empirical support for the positive economic benefits from transport infrastructure investment".* |
| Keller and Hovhannisyan (2010) | Assesses the role that international business travel plays for innovation. Quantifies the impact by analysing the impact of US business travel on 36 countries' patenting activity in the period 1993-2003. | The paper argues that developed economies such as the US hold significant levels of technical knowledge. Business travel helps to improve the transfer of this technology knowledge between international firms in high-tech industries, as technology is "*best explained and demonstrated in person*". | Their study found a statistically significant link between business air travel and patenting activity. Specifically, a 10% increase in business travel leads to a 0.2% increase in patenting. |

*Sources: See footnote*[22]

In the context of a new airport scheme, companies will be better connected to international markets. Furthermore, an expanded airport will make more international routes viable, boosting connectivity and facilitating increased overseas trade. Higher business air usage can also improve the efficiency of existing production and supplier relationships and facilitate cross-border investment, leading to more productive business outcomes.

The section above has discussed the theory underlying the links between transport infrastructure and aviation connectivity and GDP. However, there are only a limited amount of studies that seek to quantify this relationship in a direct way.

It is typical for these studies to find a strong correlation between connectivity and economic growth. Most find some form of linkage, but not all are able to pass tests associated with Granger causality[23]. The key papers we have reviewed are discussed as follows.

[22] Sources: Hong, J., Chu, Z., & Wang, Q. (2011). Transport infrastructure and regional economic growth: evidence from China. *Transportation, 38*(5), 737-752..

Button, K., & Reggiani, A. (Eds.) (2011). Transportation and Economic Development Challenges. Edward Elgar Publishing.

Hovhannisyan, N., & Keller, W. (2011). International Business Travel: An Engine of Innovation? Working Paper No.17100. National Bureau of Economic Research.

[23] Granger causality is a statistical test that assesses the suitability of one variable e.g. air connectivity in predicting another variable e.g. GDP. If historical patterns in air connectivity provide a strong enough statistical link with GDP outcomes, then air connectivity is said to "Granger cause" GDP. The effects can flow both ways e.g. GDP can Granger cause air connectivity as well. The Granger technique seeks to unravel the direction of this causal effect.

The most recent study we have been able to obtain is by Mukkala and Tervo (2012)[24] who find, using Granger causality tests, a relationship between air traffic and economic growth among different European regions. Their analysis is undertaken at the European level with separate treatment for 86 regions and 13 countries, between 1991 and 2010. Special treatment is given to regional economic differences (i.e. central hubs and more remote airports) and their central finding is that there is a stronger Granger causal relationship between air traffic and regional growth in peripheral regions than in core regions.

Poort *et al*. (2000)[25] conduct a European level study and again uses the Granger approach to test for a statistical link between aviation growth and GDP growth. They find that a 10% increase in aviation growth is associated with a 1.7% increase in GDP growth for a panel of European countries. Green (2007)[26] finds that there is a causal relationship between the number of passengers and economic growth but the direction of causality cannot be determined from his analysis. Green does, however, suggest that the number of passengers can be a useful predictor of GDP growth.

A study by Ishutkina, and Hansman (2009)[27] finds a strong positive correlation between air transport passengers and GDP of around 0.99 for the UK and two-way causality i.e. an increase in passenger numbers leads to an increase in GDP and vice versa.

There is no conclusive study that tests for Granger causality between seat capacity and GDP for the UK economy, so the AC asked PwC to test for this relationship. This work was published alongside the AC's Interim Report in December 2013[28]. Our results showed that, in the short run, a 10% change in the growth rate of seat capacity is associated with approximately a 1% change in the growth rate of real GDP. Using the Granger approach, our model was tested to determine whether an expansion in seat capacity leads to an increase in GDP or vice versa. Our results show that this result runs both ways. This effect is found to be significant at the 5% confidence level. However, it is possible to identify a separate statistical link between an increase in seat capacity causing an increase in GDP - techniques such as GMMIV (Instrumental Variable-Generalised Method of Moments), SGMM (System Generalised Method of Moments) and IVPPML (Instrumental Variable Pseudo Poisson Maximum Likelihood) estimators, by virtue of using instrumental variable (IV) approach, allow us to deal with potential reverse causality problems

## 2.7 Key principles that should be considered when analysing wider economic effects

The discussion above has highlighted some important concepts that need to be taken into account when analysing transport infrastructure impacts, e.g. spatial dimensions, the role of imperfect competition and agglomeration, the role of FDI, tourism, international trade and labour movements, and the relationship between air connectivity and productivity. In as far as possible, these concepts need to be included in any appraisal of an expansion in air transport infrastructure.

In this section we turn to the different modelling tools that could be used to capture these effects in a coherent analytical framework. To guide our choice of analytical framework we first present a set of key principles that have been drawn from government guidance on infrastructure investment appraisal. Guidance includes HM Treasury's Green and Magenta Books and its Five Part Business Case, and the DfT's WebTAG. All provide detailed guidelines and methodological suggestions[29].

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[24] Mukkala, K., & Tervo, H. (2012). Regional airports and regional growth in Europe: which way does the causality run?. In *ERSA Conference papers12, p.642, European Regional Science Association.*

[25] Poort, J.P., Sadiraj, K., & van Woerkens, C.M. (2000). Hub, of spokestad? Regionaal economische effecten van luchthavens Breukelen: NYFER.

[26] Green, R. K. (2007). Airports and economic development. *Real Estate Economics*, *35*(1), 91-112.

[27] Ishutkina, M. and Hansman, J. (2009). Analysis of the interaction between air transportation and economic activity: a worldwide perspective, Cambridge (MA) : MIT International Centre for Air Transportation (ICAT).

[28] Airports Commission: Interim Report, Appendix 3: Technical Appendix, December 2013, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/266670/airports-commission-interim-report-appendix-3.pdf

[29] Department for Transport, (2011) The Transport Business Case,. London: Department for Transport., Available at: <http://www.dft.gov.uk/publications/transport-business-case/>

HM Treasury (HMT) (2014). *Public Sector business cases using the Five, Business Case Model: Guidance*. London: HM Treasury. Available at <http://www.hm-treasury.gov.uk/data_greenbook_business.htm>

HM Treasury (HMT) (2014). The, 2007, HM Treasury Green Book: appraisal (Appraisal and evaluation in central government. London: HM Treasury. Available at <http://www.hm-treasury.gov.uk/data_greenbook_index.htm>

Based on our understanding of this guidance, our own experience of large-scale impact assessment and of best practice in the review of airport scheme appraisals we conducted for the AC[30], our view is that a robust assessment of wider economic impacts should follow some key principles:

- **A focus on value added as well as economic welfare**. This may require some benefits to be monetised e.g. the potential gains from increased flight frequency. Other non-monetary impacts such as changes in pollution or noise levels could also be monetised and included in a welfare assessment. However, welfare effects that are non-economic are outside the scope of this particular study, but are considered separately by the AC;

- **Consider the impacts over the project lifetime:** the recommendations of the AC will potentially affect the UK's economic landscape for at least the next 60 years but, although such time horizons are difficult to forecast, the full benefits of additional airport capacity may not immediately offset costs, so longer-term analysis is needed;

- **Focus on the net impacts of the options (rather than the gross impacts):** this means that the options need to be compared not only against each other but also against a baseline scenario (a counterfactual) which describes what would be likely to happen without additional airport capacity;

- **Have general equilibrium properties:** the analysis should consider the range of economic processes that would be triggered by the provision of additional airport capacity not just within the aviation sector but in other sectors (manufacturing, services) and institutions (households, government) as well;

- **Consider the macro-micro linkages:** large-scale infrastructure projects do not operate in economic isolation as they impact on wages and prices in the economy and these impacts can alter the viability of other projects (including airport schemes). These feedback loops to the wider economy need to be incorporated to avoid the Lucas critique;[31]

- **Link economic modelling with transport usage modelling**: the relationship between a new airport scheme and surface access will have a critical bearing on its success, but surface access schemes have their own costs and impacts[32] which need to be linked directly to the economic modelling process that determines the overall impact on GDP. Note, however, that we have not assessed the impact of surface access schemes because we understand these are being addressed elsewhere in the AC's analysis; and
- **Adjust for bias and risks:** there is a demonstrated, systematic tendency for project appraisers to be unduly optimistic about the benefits, timings and costs of their schemes which means that the assessment of each scheme needs to mitigate these factors by making use of appropriate methodologies such as sensitivity analysis.

## *2.8 Choosing the right model*

There is a large literature on the economic and social effects of transport infrastructure investments (recent examples include SACTRA 1999; Graham 2007; Venables 2007; Vickerman 2007; Lakshmanan 2010) [33] which we discussed in our previous report. A wide range of different methods have been used. The most common are listed by Tavasszy *et al.* (2011).[34]

1. Micro surveys with firms;
2. Estimation of quasi production functions;
3. Partial equilibrium potential models;
4. Macroeconometric and regional economic models;

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[30] "Econometric analysis to develop evidence on the links between aviation and the economy: A report by PwC for the Airports Commission", December 2013

[31] The Lucas critique named after Robert Lucas's work on macroeconomic policymaking, argues that it is naive to try to predict the effects of a change in economic policy entirely on the basis of relationships observed in historical data, especially highly aggregated historical data. Economic models should combine both theory and data as the relationships being modelled may not be present in historical data, so limiting its predictive power.

[32] We have not looked at the impacts of surface access schemes beyond their construction impacts. These impacts are being examined separately by the AC.

[33] PwC (PricewaterhouseCoopers) (2013). Econometric analysis to develop evidence on international business impacts. PwC report for the Airports Commission and Department of Transport, December.

[34] Tavasszy, L.A., Thissen, M.J.P.M., & Oosterhaven, J. (2011). Challenges in the application of spatial computable general equilibrium models for transport appraisal. *Research in Transportation Economics*, *31*(1), 12-18.

5. Land Use / Transportation Interaction (LUTI) models;
6. Multiplier models;
7. Input Output (IO) models; and
8. CGE models.

On this list, methods 1, 2 and 3 have limited or no capacity to capture wider economic effects as they are not designed to fully capture sectoral interactions. This means that they would overlook the wide range of costs and benefits that businesses and households would derive from airport expansion. Macroeconometric models (4) are also not considered for this project because they do not deal effectively with the Lucas critique described in the previous section. The more commonly used approaches are methods 5 – 8. We discuss each of these in more detail below:

- **LUTI models** seek to capture the interaction between land use and travel demand. Travel is derived from the need of households and businesses to interact with their environment. They are spatially based models and examine the travel-related decisions that individuals make. These travel decisions tend to be endogenously determined;

- **Multiplier models** are computed in static form from Supply Use or input-output tables. They tend to measure linear partial equilibrium relationships which are assumed to be fixed and do not change in the short- or long-term. If simple multipliers were to be applied to the airport expansion schemes large amounts of information about how the economy might react would not be factored into the appraisal;

- **Input-Output models** are an effective way to measure the linear relationships between different sectors of the economy (e.g. if sector X expands, how will sector Y be affected?). If the economic reactions are likely to be substantial, however, as might be the case with significant additional airport capacity, these linear relationships might no longer hold; and

- **CGE models** build on the foundations of multiplier analysis and IO models. They are multi-sector models that capture the non-linear relationships between different sectors of the economy, households and the government. They can be used to map the behavioural response of the economy to changes in airport capacity.

An advantage of LUTI models is that they make it possible to assess the impacts of transportation projects on business markets and locations, and on household locations, at a detailed spatial level. However, these models tend to be better suited to analysis of more localised issues rather than the UK level and international dimensions associated with air travel. Also, LUTI models' treatment of some of the key features associated with wider economic effects can be limited.[35] For this reason we do not consider the application of a LUTI approach to be appropriate.

Of the remaining techniques, multiplier and IO models have been used widely in the analysis of airport expansion. CGE models are technically superior to these approaches, but their application is still in its infancy. We are aware of it having been done once before: in Sydney. A comparison of these techniques is provided in Table 2 below.

[35] The SACTRA report (1999) notes that *"there are key features of the CGE approach that do not appear in current LUTI models. These include imperfect competition, location decisions of firms, economies of scale and agglomeration effects. In essence, these are both the main reasons to worry that CBA might inadequately represent total economic benefits as opposed to transport benefits"*.

*Table 2: Features of different types of economic model*

| | **Multiplier analysis** | **Input-output analysis** | **CGE modelling** |
|---|---|---|---|
| **Are the data available?** | Supply Use Tables (SUT) allow multiplier analysis, input-output and CGE modelling to be carried out. Unlike econometric approaches, these methods are not reliant on a long time series of historical data. The Office of National Statistics publishes Supply Use Tables annually.<br><br>CGE models in the past have not been widely applied to evaluation in the field of transport economics. This is because of the lack of regional SUT data, which prevents the estimation of regional benefits which are crucial to evaluating large transport projects.<br><br>As a part of our analysis, we have estimated the regional data required to apply CGE modelling techniques. Our approach in estimating regional data is consistent with the leading academic literature in the area. It is also consistent with the approach used by international organisations such as the IMF and the World Bank to estimate national data where national income statistics are poorly reported. Robinson *et al.* (2001)[36] and RAEM (2006)[37] also use a similar approach to estimate regional tables. Finally, we have worked previously for HMRC to produce similar regional data to estimate the regional impact of fiscal changes implemented by regional governments. | | |
| **Who else uses this type of model?** | Still widely used in various forms, although the analysis tends to be very specific to a particular situation and therefore not flexible. Multipliers would need to be estimated that are specific to airport interventions. | Largely superseded by CGE models, so used less and less. Mostly restricted to academics. | Used widely by the IMF and World Bank. HM Treasury/HMRC has its own model that is used for tax policy modelling but does not include key aspects such as the passenger-related industry which are critical for modelling aviation sector issues. |
| **Is it a suitable tool for assessing the impacts of increased airport capacity?** | Not practical as a scenario analysis tool as it cannot easily capture the feedback from the scenario to the economy. For example, if a new airport was built, how would this affect the behaviour of businesses that use the airport?<br><br>Multiplier models do not consider supply/demand interactions nor can they consider interactions between different sectors of the economy. The multiplier approach has no capacity to consider important concepts such as imperfect competition or multiple equilibria and therefore cannot capture agglomeration benefits in a theoretically consistent manner. | Input-output models generally do not include price functions, and therefore would not be able to answer questions about the effects of airport expansion on prices and wages. This lack of detail on changes in prices limits the usefulness of IO modelling.<br><br>There have been instances of IO models being built with imperfect competition, but these applications are less useful as they do not capture price adjustments, which are a major part of any modelling of imperfect competition. | Designed specifically for scenario analysis. Captures both feedback loops and relative price changes to provide a more comprehensive assessment for analysing airport expansion. The model approach is also based on economic theory relating to firm expansion. This allows it to capture the catalytic effects of airport expansion. |

*Source: PwC analysis*

Based on the inherent limitations of the multiplier and the IO approaches, our preferred approach is the CGE method. CGE models can take various forms: the simplest approach would be to construct a static CGE model for the UK as a whole and ignore effects such as imperfect competition. But this would not have substantial benefits over the IO or multiplier approaches.

CGE models can be extended to incorporate multiple regions – hence the term “Spatial –CGE” (S-CGE). They can also be extended to capture imperfect competition and agglomeration effects, and hence deal with more technical concepts such as multiple equilibria. CGE models can also consider interactions between changes in the level of trade, tourism and FDI and the wider economy, as well as the interactions between regions and sectors.

[36] Ivanova, O., Heyndrickx, C., Spitaels, K., Tavasszy, L., Manshanden, W., Snelder, M., & Koops, O. (2007). RAEM: version 3.0. Transport Mobility Leuven, Leuven.

[37] Robinson, S, Cattaneo, A, and El-Said, M. (2001), Updating and Estimating a Social Accounting Matrix Using Cross Enthropy Methods. Economic System Research 13.1

Our S-CGE model structure is described in the next chapter. The next chapter and Appendix B also describe how the model has been extended to deal with the issues raised in this chapter.

## 2.9 Interpreting our results

Our approach has focussed on the analysis of scheme options on a range of economic variables, but most notably GDP. We therefore refer to it as an assessment of economic impact rather than an assessment of economic benefits.

We have carried out our work in a way that makes use of the welfare analysis that has been performed by the AC, most notably its estimates of:

- The value of improved effective journey times experienced by business users as result of being able to fly to more locations and to do so more efficiently;
- The benefits that will be derived by all passenger types as a result of increased airport capacity e.g. lower air fares. This is known technically as the "consumer surplus";[38] and
- If fares fall following an increase in capacity, airlines will make less profit per ticket sold, but can expect to sell more tickets. This change is accounted for in welfare economics through a change in the "producer surplus". [39]

There are, however, a number of other differences between our approach and the approach which is more conventionally applied (i.e. in addition to our focus on variables such as GDP rather than welfare):

- We have included the impact on GDP of increases in consumer surplus (a key component of TEE) that are experienced by individuals (i.e. not just those which accrue to businesses) because we assume that in the long-run such benefits will be equivalent to an "income effect" (i.e. consumers are made better off as a result of facing lower prices). We have also included the impact of the corresponding reduction in producer surplus, as the increase in capacity is assumed to make it more difficult for airlines to generate scarcity rents;
- We include the impact on the economy of constructing the airport but we do so through a piece of sensitivity analysis. A HM Treasury Green Book style appraisal would assume that construction costs would have been spent elsewhere in the economy and therefore would exclude them from the analysis (because construction costs are assumed to be displaced from other, fully productive activities). Whilst we also assume that such displacement takes effect, our analysis captures the real and widespread impacts on the economy of such displacement (e.g. the positive impact of investment being funded through a reduction in consumption and therefore the economy being rebalanced toward more productive activities); and
- Our model is general equilibrium (rather than partial equilibrium) in nature. This is crucial in that our modelling allows the following impacts to be modelled which are not usually reflected in conventional appraisal methodologies: (i) secondary economic impacts - not just direct user impacts, but also the knock-on implications for productivity etc.; (ii) dynamic impacts - the CGE model simulates all the linkages in the economy over time so that the full ramifications of direct and secondary impacts can be obtained. We take into account potential crowding out and diffusion effects explicitly; (iii) regional impacts - using a S-CGE model allows us to model the dynamic impacts at a sub-national level, taking into account agglomeration effects and allowing us to evaluate likely impacts on different regions; and (iv) the reality of how most, if not all, markets in the economy are characterised by imperfect, rather than perfect, competition.

While it is difficult to make a clear and explicit comparison of our results with the results that might be obtained from a more conventional welfare analysis, we recognise that our estimates of economic impact are

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[38] In this context the consumer surplus is the difference between the total amount that consumers are willing and able to pay for a flight (as determined by their demand curve) and the total amount that they actually pay (i.e. the price charged by airlines). Given the AC's assumption that air fares will fall following the introduction of increased airport capacity, the gap between willingness to pay and the market price falls and consumers will experience a welfare improvement.

[39] In this context, producer surplus can be defined as the difference between the price at which airlines are willing and able to charge for flights and the price they actually receive.

higher than one might expect if the schemes were viewed through the lens of conventional appraisal techniques (e.g. if one were to compare the PV of the GDP impact of a scheme with the PV of the user benefits calculated).

We nonetheless consider our approach to be appropriate. We think the “wedge” between the results from our approach and that which might be expected from conventional welfare analysis is likely to be driven, in large part, by: the different focus of our analysis (e.g. GDP rather than welfare); the economic assumptions in our analysis (e.g. imperfect rather than perfect competition); and the general equilibrium and dynamic nature of our analysis, which enables the impact of the scheme on the wider economy over time to be captured in a realistic way. We think this is important when modelling major transport schemes, since typically the aim of such schemes is to enable more journeys to be undertaken in order to facilitate other economic activity, the impact of which is likely to be felt beyond the immediate user benefits. We think that the WIs of the schemes should anyway be expected to be considerable given how they are designed to alleviate a situation of congestion rationing for critical infrastructure that enables a wide range of other economic activities in one of the world’s major cities and one of the world’s largest national economies.

# 3 An overview of our modelling approach

## 3.1 Section overview

This chapter sets out our application of the CGE approach in more detail, through:

- A summary of CGE modelling concepts;
- A literature review of CGE models and their application to the appraisal of transport infrastructure; and
- An overview of the S-CGE model used in this report.

## 3.2 What are CGE models?

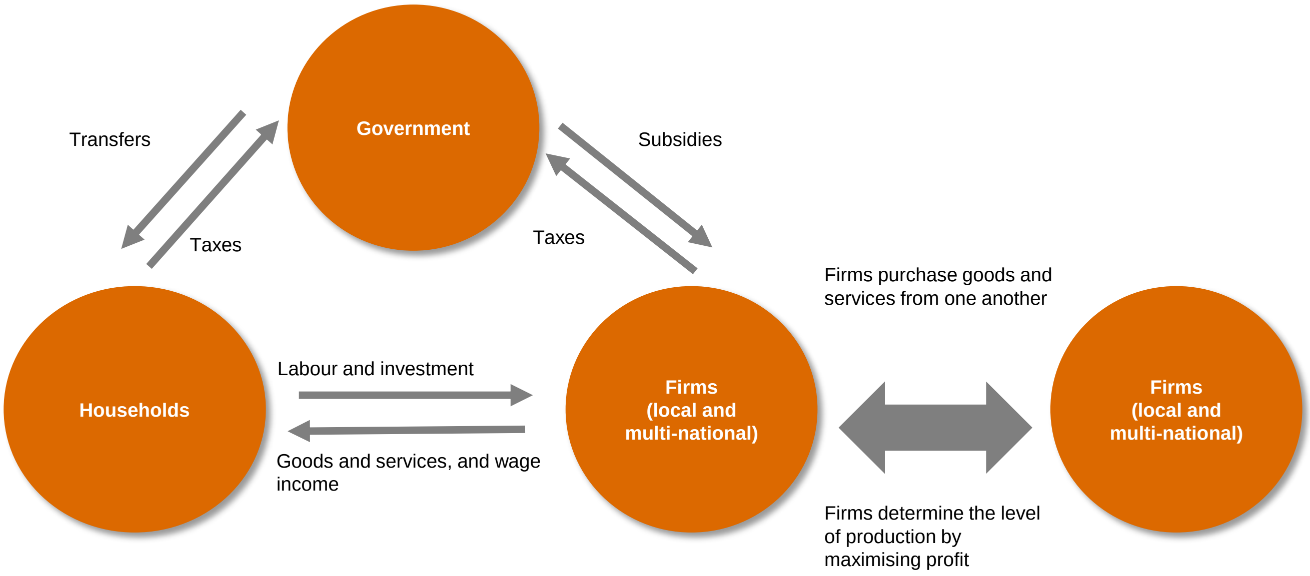
CGE models have become a standard tool for certain types of empirical economic analysis. They are used widely by international institutions such as the World Bank, IMF, OECD and European Commission as well as the UK government. Their primary domestic use is to assess the "impacts" of different government or institutional policies (e.g. changes in tax policy, government spending and the economic effects of $CO_2$ emissions) or to investigate the effects of different economic scenarios (e.g. a change in real exchange rates, or the level of consumer demand).

A CGE model was used by PwC as an input into the AC's interim report[40] examining the wider economic impact of aviation capacity in the UK. Aviation capacity expansion, in addition to the *direct* impact on passengers, airports and airlines, is also likely to have a wider indirect impact on GDP which was estimated using CGE techniques. The change in seat capacity was input as a change in airline sector output, of 5% by 2030 and 8% by 2050 to examine the effect on GDP. Our CGE analysis indicated that a 1% increase in aviation sector output is associated with a 0.1% increase in GDP when capacity is unconstrained and a 0.06% increase in GDP when capacity is constrained. When capacity is constrained, the GDP effect is smaller but still present as the economy will adjust and find other ways of delivering capacity, so some GDP benefit is still realised. Examples of this might include using larger aircraft, reconfiguring cabins or changing marketing strategies to increase load factors. However, the full economic gain from the increase in seat capacity is not fully realised with capacity constraints.

A CGE model combines economic data and a complex system of equations in order to capture the interactions of the three main institutions in an economy – households, businesses and the government. Each institution is defined and interlinked through labour market or capital market flows, household consumption, intermediate product demand, taxes or government transfers. Figure 3: Relationships captured in a CGE model provides a basic representation of these interactions.

[40] Airports Commission: Interim Report (December 2013) (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/266670/airports-commission-interim-report-appendix-3.pdf)

*Figure 3: Relationships captured in a CGE model*




*Source: PwC analysis*

The economic systems that CGE models proxy are complex. The multiple households and businesses that are defined in each model engage in repeated local microeconomic interactions that in turn give rise to macroeconomic relationships affecting variables such as employment, investment and GDP growth. These macro relationships also feed back into the determination of local micro interactions. Because of this relationship, CGE models are often referred to as micro-macro models (Sue-Wing and Balistreri, 2012).[41]

CGE models are used to analyse the implications of different scenarios. The equations in our CGE model have been calibrated to UK economic data and a baseline view of the economy has been created. A particular new scenario is then imposed on this baseline scenario and the CGE model measures the difference between the new scenario and the baseline scenario to produce key changes in economic metrics such as GDP, employment, household consumption, exports, imports, investment, tax receipts etc. More detailed results at the industry and household level can also be generated.

#### 3.2.1.1 How does a "regional" model differ from a national model?

The particular CGE model we have used for this analysis extends our existing UK-level CGE model from a single region to a multi-region model of the UK. Because we have expanded the regional dimension, we refer to the model as a "Spatial"-CGE model or S-CGE model. This S-CGE model divides the UK economy into three geographical regions: London & South East, the Rest of England, and the Rest of the UK.

The regions in the S-CGE model are based on groupings of ONS NUTS1[42] regions. The composition of our S-CGE regions is as follows:

- **London & South East** comprises Greater London and South East England;
- **Rest of England** comprises North East England, North West England, Yorkshire and the Humber, East Midlands, West midlands, the East of England and South West England; and
- **Rest of the UK** comprises Scotland, Wales and Northern Ireland.

Each of the regions in the model interacts with the others. For instance, if wages rise in the London & South East region, the model will take into account that workers from the Rest of England or Rest of the UK regions might migrate to the London & South East region in order to achieve higher earnings.

[41] Sue-Wing, I., & Balistreri, E.J. (2012). Computable General Equilibrium Models for Economic Policy Evaluation and Impact Analysis. *Working Paper, Department of Earth and Environment, University of Boston*.

[42] More information on NUTS1 regional definitions and key statistics can be found on the ONS website at: http://www.ons.gov.uk/ons/regional-statistics/index.html

The S-CGE model specification captures the full effect of movements in economic activity. For instance, if the London & South East economy expands and attracts workers from other UK regions then this could have a negative GDP effect on the regions they leave, as it reduces the pool of labour in that region available to work in other sectors. The model would therefore capture the net effect on the UK as a whole.

A full set of trade linkages also exists, so if a business in the construction sector in London & South East expands, it may then in turn demand more production inputs (cement, plant and machinery etc.). These production inputs could be sourced from within the London & South East, imported from another region of the UK, or imported from overseas.

#### *3.2.1.2 Key issues relevant to spatial-CGE model specification*

In this section, we summarise some of the key issues relevant to specifying an S-CGE model. This section is informed by Partridge and Rickman (2010)[43] who prioritise four issues that should be taken into consideration when constructing spatial CGE models:

- **A spatial-CGE model should be specified on the basis of regional economic theory instead of borrowing specifications from other national or international CGE models.** The interactions between regions are different from the interactions between nations. For example, the role of government stimulus in increasing the regional quality of life and inter-regional migration are not captured in national models, but can be explicitly portrayed in a regional model. For instance, an S-CGE model can assume a central UK government providing services to the whole country, or a devolved government system providing services to a defined region with region-specific public finances. In our modelling, consistent with the UK government structure, we include both central and local government elements;

- **S-CGE models should account for a region's influence on national trade patterns.** National and international models assume that international trade terms and patterns are not influenced by activity in a sub-region (the "small country" assumption)[44]. However, at the country-level, large regions can influence trade terms and patterns between regions and this must be captured when specifying an S-CGE model. In our modelling, each of the three regions has its own set of inter-regional trade flows, and businesses in each region can buy goods and services from each other;

- **S-CGE models should contain a time element**. By including a time element, the dynamic impact of economic scenarios can be assessed. Partridge and Rickman note that, until recently, regional models largely ignored the time element, or mimicked the dynamic behaviour of national models. They recommend that the parameterisation of an S-CGE model must be consistent with the dynamic behaviour of the regional economy. Dynamic-regional models using national parameters may produce adjustment periods inconsistent with empirical evidence on regional dynamic adjustment. However, external data is not usually available to calibrate the model based on a benchmark time period, or the external data is usually out-of-date. More complex approaches such as Bayesian estimation approaches (Adkins *et al.*, 2003)[45] or using calibration based on several years of data (Kehoe *et al.*, 1995)[46] have been implemented but the use of such approaches is not widespread. Furthermore, the limitations of the UK data prevent this approach. In our S-CGE model we use sensitivity analyses around the dynamic parameters of interest, and then make comparisons with other empirical evidence. Partridge and Rickman note that this is a common approach; and

- **S-CGE models should differ from national and international models by accounting for migration.** Partridge and Rickman note from their survey that national and international models often make simplifying assumptions of perfectly mobile labour markets and full employment, thereby underestimating any regional income (wage) changes, or they assume immobile labour markets, overestimating regional income (wages) changes. The human capital approach to migration assumes that

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[43] Partridge, M.D., & Rickman, D.S. (2010). Computable general equilibrium (CGE) modelling for regional economic development analysis. *Regional Studies, 44*(10), 1311-1328.

[44] Harris, R. (1983). Applied general equilibrium analysis of small open economies with scale economies and imperfect competition. *Working Papers* 534, Queen's University, Department of Economics.

[45] Adkins, L.C., Rickman, D.S., & Hameed, A. (2003). Bayesian estimation of regional production for CGE modeling. *Journal of Regional Science, 43*(4), 641-661.

[46] Kehoe, T.J., Polo, C., & Sancho, F. (1995). An evaluation of the performance of an applied general equilibrium model of the Spanish economy. *Economic Theory, 6*(1), 115-141.

individuals are influenced in their migration choice by the income they expect to receive at different locations (Sjaastad 1962)[47]. Since Sjaastad's paper there has been a greater focus on the spatial characteristics that determine migration flows.

On this basis, in our S-CGE model we capture migration flows between London & South East, the Rest of England and the Rest of the UK using a dynamic labour market function that simulates free movement of labour limited by "adjustment costs" to account for training when workers move between sectors. This is discussed in more detail in Appendix B.

## 3.3 Literature review

The section below summarises the relevant literature which was used to inform and justify our modelling approach and analysis. Given the scope of the analysis, and the breadth of research which has been undertaken in this area using similar methodologies, this should not be seen as an exhaustive list of literature in this field. However, the literature summarised below is the most relevant to the modelling and analysis set out in this report.

The review below is structured into the following three sections:

1. Use of CGE modelling in transport infrastructure projects;
2. Examples of CGE modelling in the context of airport infrastructure investment; and
3. Additional modelling and analysis.

The first two of these demonstrate some of the differences between CGE modelling and alternative techniques, and the precedents for using a CGE approach in the context of transport and airport infrastructure projects. The final section outlines some of the specific modelling challenges which we face in this context and some of the existing literature on how best to meet these.

### 3.3.1 Use of CGE modelling in transport infrastructure projects

Traditionally, large-scale public infrastructure investment appraisals are conducted using Cost-Benefit Analysis (CBA), as recommended for the UK by the HM Treasury Green Book[48]. However, applying solely this approach can be limiting, particularly in understanding the macroeconomic impact of an investment and the nature of any distributive effects. As a result, a number of recent studies have applied CGE modelling to complement and expand on the results of a CBA evaluation. We discuss some key examples below.

In the context of the evaluation of airport infrastructure investment in Sydney, Forsyth (2013)[49] considered some of the benefits and limitations of using CGE modelling as a means of impact assessment, relative to CBA. He considered there to be a number of differences between the approaches:

- Primarily, a CGE model is different from standard CBA in that it allows the estimation of general equilibrium effects, relative to the partial effects estimated within CBA. This allows for the impact of an intervention on all agents and relationships within the model to be captured.
- In addition, a CGE model is typically better suited to identifying the macroeconomic effects of a project, relative to a standard CBA approach. This ensures that CGE modelling is typically a more relevant approach when the objective is to find the overall impact of a scheme or investment on economic output or unemployment. While CGE modelling does not provide an unambiguous answer in these areas, it does provide a framework for calculating sensitivities. [50]
- On the other hand, CGE analysis can be constrained by the formal model it uses, and often this model will be at a reasonably high level of aggregation. Alternatively, CBA can capture a broader range of effects that cannot all necessarily be captured within a CGE model. This highlights the importance of specifying the CGE model structure appropriately to capture the most relevant areas for evaluation, while recognising that this can provide less flexibility than is possible with CBA. Forsyth also highlights that sub models can be created to explore an area more explicitly (e. g. an aviation sub-sector can be included within a transport sector).

[47] Sjaastad, L. A. (1962). The costs and returns of human migration. The journal of political economy, 80-93.

[48] HM Treasury (HMT) (2014). *The Green Book*. London: HM Treasury.

[49] Forsyth, P. (2013). Air capacity for Sydney. International Transport Forum Discussion Paper.

[50] Forsyth, P. (2013). Air capacity for Sydney. International Transport Forum Discussion Paper.

- A CGE model is more adept at modelling the distributional effects of an intervention than CBA, although it may be less easy to incorporate location-specific factors (Forsyth uses the example of noise) into such a model.

As a result of the differing benefits of each approach, Forsyth recommends that both CBA and CGE approaches be used, especially in the evaluation of a major investment. He further reinforces that the two approaches are complementary, and therefore that the best understanding is likely to arise from looking at the two together, rather than as separate exercises.

#### *3.3.1.1 The RAEM model*

There are a number of examples of CGE modelling being used to evaluate the effect of specific infrastructure projects. A number of these use the RAEM model, an S-CGE model developed for the Netherlands by Transport and Mobility Leuven, a Dutch research organisation focusing on the economic impact of transport infrastructure. This model has been extensively reviewed and cited by the academic community and can be viewed as a best-in-class example of an S-CGE model.

The RAEM model was developed by dividing the Dutch national input-output framework into 40 interacting regional matrices. The regional goods markets within the model are linked through the estimation of inter-regional transport costs. It is a dynamic model in the sense that it assesses changes in economic variables over time, and is broken down into 14 sectors, as in the 1993 Dutch SBI classification[51]. Markets operate under conditions of monopolistic competition, consumers are assumed to have utility functions which include a love of variety, and the labour market is based on the search-and-matching theory set out in Pissarides' (2000)[52] (for more detail on the model structure and assumptions, see van Oort, Thissen & van Wissen (2005)[53]. The approach for developing the S-CGE model we used in this study, and the principles on which it is based, are strongly influenced by the RAEM model.

The RAEM model has been applied in a number of different studies and academic papers[54]. One such example is the study by Thissen, Limtanakool, & Hilbers (2011)[55] into the impact of a congestion charging scheme on agglomeration effects. This paper uses a two-stage approach to evaluate the impact of additional infrastructure investment and changes in road pricing.

The first of these stages involves the calculation of the "partial direct effect". This uses only the demand curve to determine the partial direct effect of additional transport infrastructure investment. This is calculated through a shift in the supply curve, which maps the relationship between the number of trips taken and the willingness to pay for each journey. The second stage uses the S-CGE model to calculate additional indirect effects, which are not captured within partial equilibrium modelling.

#### *3.3.1.2 UNITE project*

The objective of the UNITE project, as defined in Nash (2003)[56] was to support policy makers in setting charges for the use of transport infrastructure by the provision of appropriate methodologies and empirical evidence. The analysis of the impact of transport infrastructure use and cost was undertaken using both partial and general equilibrium analysis. The general equilibrium element of this consisted of analysing what the overall impact on the economy would be of differing approaches to transport pricing. The analysis was completed using separate models of both Belgium and Switzerland. This analysis concluded that marginal social cost pricing generally improves welfare, while average cost pricing has a negative welfare effect. The project acknowledges that estimating marginal costs is difficult and the most practical way of estimating marginal costs is through a combination of case studies and social accounts data.

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[51] http://www.cbs.nl/en-GB/menu/methoden/begrippen/default.htm?ConceptID=646

[52] Pissarides, C.A. (2000). The Economics of Search. *Manuscript. London School of Economics, London*.

[53] van Oort, F., Thissen, M., & van Wissen, L. (2005). A survey of spatial economic planning models in the Netherlands. Theory, application and evaluation. Rotterdam: NAi-Uitgevers.

[54] See, for example, van Oort, Thissen & van Wissen (2005) and Knaap, T., & Oosterhaven, J. (2011). Measuring the welfare effects of infrastructure: A simple spatial equilibrium evaluation of Dutch railway proposals. *Research in Transportation Economics, 31(1)*, 19-28.

[55] Thissen, M., Limtanakool, N., & Hilbers, H. (2011). Road pricing and agglomeration economies: a new methodology to estimate indirect effects applied to the Netherlands. *The Annals of Regional Science, 47*(3), 543-567.

[56] Nash, C. (2003). Final report for publication. *UNITE Project (1999-AM. 11157).*

Comparison of the partial and general equilibrium approaches, outlined by Nash (2003)[57], found similar conclusions to those in Forsyth (2013)[58] above. Specifically, it was noted that a general equilibrium approach provided greater understanding of the link between financing transport investment and the rest of the economy, for example by capturing the increased taxation revenue required if financed through public funds. In addition, it was found that general equilibrium modelling was better able to track the impact of a policy change on the utility of different individuals. As a result, general equilibrium modelling was seen as better suited, especially in handling macro aspects such as employment. It was however also noted that the partial equilibrium modelling provided a greater degree of modelling detail into the specific impact on the transport sector.

## 3.3.2 Examples of economic impact modelling in the context of airport infrastructure investment

There have been a wide range of studies attempting to evaluate the total economic impact of current, historical or future aviation capacity. The implied multiplier[59] estimates from a number of these studies are summarised in Table 3 below, taken from Ernst & Young's 2012 analysis of potential airport sites in Sydney[60]. This demonstrates the range of findings which can be generated, based on different methodological approaches and the airport context.

*Table 3: Summary of previous studies investigating the total economic impact of an airport – implied multipliers*

| Region | Minimum estimate | Maximum estimate | Weighted average |
|---|---|---|---|
| **North America** | 1.7 (Florida, RSW) | 6.2 (Sacramento, SMF) | 3.5 |
| **Europe** | 3.0 (Brussels, BRU) | 4.5 (Budapest, BUD) | 3.6 |
| **Asia & Middle East** | 2.5 (New Delhi , DEL) | 3.5 (Dubai, BXB) | 3.1 |
| **Australia** | 1.7 (Brisbane, BNE) | 2.1 (Sydney, SYD) | 2.0 |

*Source: Ernst & Young (2012)*

However, these studies are typically based on partial equilibrium analysis using input-output modelling, and the range of literature evaluating the wider economic benefit of aviation infrastructure investment through CGE modelling is much narrower. Recent examples of CGE modelling in the context of the aviation industry can only be found in Australian studies, two examples of which are outlined here.

### 3.3.2.1 Sydney Aviation Capacity Study

The largest and most comprehensive example of the use of CGE modelling as a tool for aviation infrastructure investment evaluation was based on the MMRF general equilibrium model, developed by Monash University's Centre of Policy Studies. This was in the context of the 2012 study into the economic impact of potential airport sites in Sydney, and the CGE model was used to determine the economic and employment impacts of each site. The full results and model structure can be seen in the full report (Ernst & Young, 2012)[61].

The MMRF is a dynamic model, split between 58 industries, 63 products, 8 states/ territories and 56 sub-state regions. It was run based on 5 key inputs relating to the different elements of each airport investment:

1. Airport & supporting infrastructure construction & renewal;
2. Airport and aviation operations;
3. Freight impacts;

[57] Ibid.

[58] Forsyth, P. (2013). Air capacity for Sydney. International Transport Forum Discussion Paper.

[59] This multiplier is the ratio of the indirect effects on the economy (i.e. increase in demand on the supply chain), to the value (wages and profits) generated directly by the airport.

[60] See Ernst & Young (2012) for full list of references.

Ernst & Young (2012). *Economic and social analysis of potential airport sites: Sydney Aviation Capacity Study*. Report for the Australian Government Department of Infrastructure and Transport.

[61] Ibid.

4. Passenger flow impacts; and
5. Landside business development.

In addition to these inputs, a number of restricting assumptions on areas such as profit factors, domestic shares and passenger flow spending were also imposed upon the model. A more complete list of assumptions, and the model structure, can be found in Appendix H of Ernst & Young (2012)[62].

As outlined above, the outputs of the modelling were used to demonstrate the state-wide and national economic and employment impacts of the proposed airport developments. Table 4 below summarises some of the key economic indicators arising from this study. This demonstrates that by 2060 the additional impact on the Australian economy could be in excess of $20bn per year, or more than 1% of GDP. The modelling also revealed important distributional effects, with approximately 80% of the additional national output being generated in New South Wales, where economic activity was estimated to increase by up to 3.2% by 2060. The analysis also demonstrated that that the majority of the national GDP increase was a result of increased private consumption, although substantial increases in investment and improvements in the trade balance also had a significant impact.

*Table 4: Key economic impacts of a new airport in Sydney*

| Airport option | Badgery's Creek | Richmond | Wilton |
|---|---|---|---|
| **Additional passengers (2060)** | 54 million | 5 million | 44.2 million |
| **Additional regional FTEs (2060)** | 60,584 | 7,808 | 40,707 |
| **Additional real GDP (2060)** | $23.9bn | $1.0bn | $20.0bn |
| **Increase in real GDP (2060)** | 1.2% | 0.05% | 1.0% |

*Source: Adapted from Ernst & Young (2012)*

In addition to this report, Deloitte Access Economics (2013)[63] performed similar analysis, specifically looking at one of the three options considered, using their in-house Regional General Equilibrium Model (RGEM). The findings of this analysis are presented in Table 5 below. This similarly found that additional regional gross product could exceed $16bn per year by 2050, and were able to demonstrate that approximately two-thirds of this benefit would relate to the Western Sydney region, with the remainder in the rest of Sydney.

[62] Ibid.

[63] Deloitte Access Economics (2013). Connecting Australia: The economic and social contribution of Australia's airports. Prepared for Australian Airports Association.

*Table 5: Key economic impacts of a new airport in Western Sydney*

| Growth scenario | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| **Additional Passengers (2050)** | 27 million | 33.1 million | 33.1 million |
| **Additional regional FTEs (2050)** | 35,216 | 44,766 | 46,285 |
| **Additional Gross Regional Product (2050)** | $11.6bn | $14.7bn | $15.2bn |

*Source: Adapted from Deloitte Access Economics (2013)*

#### *3.3.2.2 Airport Subsidies*

Although not directly investigating the impact of additional airport infrastructure investment, Forsyth (2007)[64] investigates the economic impact of regional airport subsidies. In particular, this study examines the link between additional passenger flow expenditure resulting from the subsidy, adjusted through a range of distributive and labour market assumptions, and the total product and welfare impact. This demonstrates how CGE models can be used to capture the general impact of an increase in passenger flows, which is an important element of any increase in airport capacity.

The analysis was completed using a multi-regional model of the Australian economy, developed by the Sustainable Tourism Cooperative Research Centre at the Centre for Tourism Economics and Policy Research. The model comprises two regions, New South Wales and Rest of Australia, and consists of roughly 50 industrial sectors. The model has also been amended to include a number of detailed passenger expenditure-related industries, in order to allow for more specific analysis of changes in expenditure in this area. As with the Ernst & Young (2012)[65] analysis, this model is a variant of the MMRF model, developed and implemented by the Monash University Centre of Policy Studies.

The findings from the modelling identified the potential positive welfare impact for a region of offering airport subsidies to attract passengers, through the positive GDP impact of the expenditure associated with these additional passengers. The paper also highlighted how this is largely a distributive effect, with surrounding regions likely to see a fall in overall welfare, with the net national impact uncertain.

### *3.3.3 Additional modelling and analysis*

In addition to the general literature on the application of S-CGE modelling to transport infrastructure and airport investment, we also consider precedents relating to two specific elements of the analysis: capturing agglomeration economies in an S-CGE model and incorporating econometrically-estimated impacts of infrastructure investment on GDP. A summary of some of the literature surrounding these topics is outlined below.

#### *3.3.3.1 Agglomeration economies & clustering*

As discussed in Chapter 2, the positive effects of clustering economic activity are known as agglomeration economies. These arise where there is an efficiency gain for all firms within a market, resulting from their close proximity to each other. The majority of the literature on the topic (see, for example, DfT (2006)[66] and Cohen & Paul (2008)[67]), summarises these benefits into three distinct categories:

- **Knowledge spillovers** – firms interact with, and learn from, other firms within the market. This facilitates efficient sharing of knowledge within the market;
- **Access to labour –** the industry cluster attracts skilled labour to an area, thus increasing the quality of a firm's workforce and reducing their search costs; and

[64] Forsyth, P. (2007). The impacts of emerging aviation trends on airport infrastructure. *Journal of Air Transport Management*, 13(1), 45-52.

[65] Ernst & Young (2012). *Economic and social analysis of potential airport sites: Sydney Aviation Capacity Study*. Report for the Australian Government Department of Infrastructure and Transport.

[66] Department for Transport (DfT) (2006). *Agglomerations in the UK and the role of transport policy*. London: Department for Transport and Eddington Study.

[67] Cohen, J.P., & Paul, C.J.M. (2009). *Agglomeration, productivity and regional growth: production theory approaches* (pp. 101-117). Cheltenham: Edward Elgar Publishing.

- **Input effects –** the presence of the industry cluster attracts suppliers to locate nearby. This gives firms access to a greater range of specialized inputs, whilst also reducing transport costs.

A study by Rosenthal and Strange (2004)[68] reviewed the range of literature which has attempted to quantify these benefits and found that doubling the size of a city typically leads to an increase in productivity of 3-8%. This range, however, does not fully capture the breadth of estimates, or of specific drivers which may alter the magnitude of this relationship.

#### *3.3.3.2 Estimating the magnitude of agglomeration economies*

Graham (2007)[69] outlines an approach and empirical estimates for the magnitude of agglomeration economies by sector. As described above, the paper identifies that within a particular industry firms can benefit from labour market pooling, sharing of intermediate inputs and knowledge sharing. This generates agglomeration economies, which act as positive externalities to a given firm's activities. This is particularly relevant to transport infrastructure project appraisal, as a transport improvement shifts the commuting cost curve downwards and the number of workers available to a firm increases. The positive productivity impact of this shift is captured through the elasticities of productivity with respect to some measure of agglomeration.

To estimate these elasticities, data must be gathered on production characteristics of firms across a range of sectors. Geographical Information System (GIS) software is then used to identify the location of each firm, while a framework of small spatial units to measure agglomeration is overlaid on top. Finally, firm data and measures of agglomeration are used within a production function framework to estimate the effect of agglomeration on firm productivity. This firm data consists of a range of variables, including data on capital stocks and number of employees, wages and total costs of each firm. The link between agglomeration and productivity is estimated using a Cobb-Douglas production function which includes a primary production function. The results of this analysis give estimated elasticities of productivity with respect to agglomeration, by sector. The findings demonstrate a wide variation in elasticities across industries, ranging from manufacturing, where a 1% increase in agglomeration, proxied by an accessibility-based "effective density" measure at the ward level in the UK, leads to a 7.7% increase in productivity, to transport storage and communication, where a 1% increase in agglomeration leads to a 22.3% increase in productivity.

A key limitation of this empirical approach is that it does not identify the magnitude of the productivity effects from each type of agglomeration economy (i.e. knowledge spillover, access to labour and input effects). This could limit the degree to which investment can be targeted to remove specific constraints on productivity. For example, while some investment may assist the labour market through reducing commuting times, others may improve business productivity or reduce transportation costs. It is likely that the benefits of each of these will differ by setting and sector.

#### *3.3.3.3 Using RAEM to capture agglomeration*

The RAEM model captures these agglomeration economies through three channels

- Monopolistic competition framework, whereby the degree of competition determines the agglomeration strength;
- Change in transport costs which makes regions with better connectivity more productive; and
- Change in labour market search costs, which changes the costs associated with looking for employment or, for a firm, the costs of filling a vacancy.

The first channel is through monopolistic competition. The monopolistic competition framework assumes that a number of varieties of goods are produced in each sector and all these varieties are imperfect substitutes. A firm may choose to use inputs from any region in its production process. The more varieties of imports a firm is able to choose between, the more it can increase productivity by having a more optimal production process, with lower unit cost of production.

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[68] Rosenthal, S.S., & Strange, W.C. (2004). Evidence on the nature and sources of agglomeration economies. *Handbook of regional and urban economics, 4*, 2119-2171.

[69] Graham, D.J. (2007). Agglomeration, productivity and transport investment. *Journal of transport economics and policy (JTEP), 41*(3), 317-343.

The second channel is through transportation costs which act as the link between regional goods markets, therefore affecting the range of varieties within a market which a given firm can access. Therefore, if products become more expensive, access to variety decreases, and so productivity decreases. In addition to general changes in productivity, agglomeration effects can have important distributive consequences. These could take the form of cheaper transport costs to one region because of economies of scale for transporters, which would make the products in that region more competitive in other regional markets. As a result, local firms in every other region will face more competition. Activity would then be expected to relocate to the region with the reduced transport costs, potentially leading to lower productivity in all other regions due to scale effects. In this instance, the relative price of imports to these regions would decrease, enhancing the negative output effect. The size of this effect will depend on the size of the regions and the openness of the regions to inter-regional trade.

Finally, agglomeration economies are further captured within a CGE model through the labour market. Under this framework, the labour market is based on the equilibrium search model outlined in Pissarides (2000)[70]. This model assumes that, in the long-run, equilibrium labour supply is such that utility is equal for workers among regions. In the medium-term, migration is limited between regions and so there can be regional utility differences. In the short-run, each individual job match is given by the probability of a job search being successful in a given region and period, based on the local vacancy and unemployment rate. For example, in the case of an increase in road prices, the rise in the cost of transport decreases the matching efficiency between regions and therefore may lower overall productivity. However, the direction of impact on welfare of a change in travel costs is not certain. A fall in transport costs may not increase welfare if it results in workers looking for jobs in a wider range of areas, thereby resulting in agglomeration diseconomies of scale. Similarly, lower transport costs may simply lead to an increase in commuting distance with no discernible impact on national productivity or wages.

The magnitude of indirect effects can be measured through the "total benefits multiplier", which calculates the ratio of total to direct benefits. Evidence from Thissen *et al.* (2011)[71] suggests that the indirect inter-region welfare effects are significant, at approximately 30% of the direct welfare effects.

#### *3.3.3.4 Using econometric methods within CGE modelling and for infrastructure evaluation*

The final element of the approach which we discuss is the application of econometrically-estimated relationships, which are determined outside of the S-CGE model. In the case of an increase in aviation capacity, one element of the GDP impact will be through the productivity effect of the resulting increased openness and connectivity. This relationship between connectivity and productivity is exogenous to the model, and therefore needs to be input as an additional exogenous change.

There are many examples of when econometric techniques have been used to calibrate exogenous changes to a general equilibrium model. For example, Hassine *et al.* (2010)[72] use econometric analysis to incorporate technical change in agriculture, trade openness and poverty into a CGE model to estimate the impact of alternative trade liberalisation scenarios on poverty and equity. The estimated productivity effects induced from higher levels of trade are combined with a general equilibrium analysis of trade liberalisation to evaluate the income and prices changes. Eboli *et al.* (2010)[73] use econometric analysis to estimate the productivity impact of climate change, which is then used as an exogenous change in a CGE model to measure the impact of climate change on economic growth.

#### *3.3.3.5 Representing transport costs in S-CGE analyses*

Many S-CGE analyses take explicit account of transport costs and model the impacts of transport interventions as a reduction in transport costs. Two types of transport costs have been considered in the literature:

[70] Pissarides, C.A. (2000). The Economics of Search. *Manuscript. London School of Economics, London*.

[71] Thissen, M., Limtanakool, N., & Hilbers, H. (2011). Road pricing and agglomeration economies: a new methodology to estimate indirect effects applied to the Netherlands. *The Annals of Regional Science, 47*(3), 543-567.

[72] Hassine, N.B., Robichaud, V., & Decaluwé, B. (2010). Agricultural trade liberalization, productivity gain and poverty alleviation: A general equilibrium analysis. *Cahiers de recherche Working Paper*, (10-22).

[73] Eboli, F., Parrado, R., & Roson, R. (2010). Climate-change feedback on economic growth: explorations with a dynamic general equilibrium model. *Environment and Development Economics, 15*(05), 515-533.

1. **Transport costs of goods/outputs.** Authors such as Brőker *et al.* (2010)[74] and Tavasszy et al. (2011)[75] explicitly model costs of transporting goods/outputs from one region/country to another. In these models, the further a good has to travel, the higher the price becomes reflecting the underlying costs of transportation. Consequently, transport costs are key determinants of the volumes of trade between regions/countries.
2. **Transport costs of factors of production.** Pilegaard and Fosgerau (2008)[76], Hirte and Tscharaktschiew (2013)[77] and others model the costs that individuals may incur in travelling (these costs could include the direct costs of travel, the opportunity costs of time spent travelling and so forth) and the cost savings as a result of transport interventions.

We consider each of these transport cost types in turn.

**Transport costs of outputs**

In some S-CGE applications, it is appropriate to explicitly consider transport costs of goods and the role that these costs have in determining prices and the volume of trade between regions/countries. In this context, transport costs could include the pecuniary costs of moving the goods, deterioration of products whilst shipping and so forth. Such an approach has been pursued by authors such as Brőker *et al.* (2010) and Tavasszy *et al.* (2011)[78]. In these models, the effects of transport investment are captured as reductions in transport costs, which in turn reduce the price of goods which are traded between regions/countries. This approach has the advantage of relating the volume of trade to its underlying costs.

However, for the purposes of this study, the approach described above is not appropriate. There are two reasons for this:

1. The emphasis of this work is on understanding the wider impacts of improved aviation linkages – particularly the productivity effects of enhancing aviation connectivity by permitting the adoption of technologies from abroad and exploiting scale economies for example – rather than the direct benefits to users in terms of lower transport costs (see Chapter 4). Using a direct approach in which only transport costs of the movement of goods were taken into account would mean that the full productivity effects may not be captured in the S-CGE model. This is because some of the productivity effects which we are seeking to capture will take place as a result of passenger movements (for example managers 'learning' as a result of new technologies) rather than movements of goods.
2. And on a practical level, in order to employ such an approach, estimates of changes in transport costs as a result of the different scheme options (under different scenarios) would be required. However, the AC modelling framework does not provide estimates of changes in costs as a result of the options under consideration. Instead, as noted in Chapter 4, the relationship between trade and passenger numbers is used to capture the relationship between the expansion of aviation connectivity and trade.

**Transport costs of factors of production**

As noted above, many models capture the costs that individuals may incur in travelling. As noted in Chapter 4, the S-CGE framework captures these costs by means of frequency benefits. The frequency benefits of business travellers (but not leisure travellers) are modelled as productivity improvements in the S-CGE analysis.

### *3.3.3.6 Our S-CGE modelling approach – key features*

The model built for this project is a single-country dynamic model for the UK, based on 2010 data. As outlined above, the UK is split into three regions: London & South East, the Rest of England and the Rest of the UK. Each region interacts with the others through the movement of goods and services, capital and labour. Each region is further broken down into 23 industries and 23 product markets, and differentiates capital provisions

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[74] Brocker, J., Korzhenevych, A., & Schurmann, C. (2009). Assessing spatial equity and efficiency impacts of transport infrastructure projects.

[75] Tavasszy, L.A.(2011). Challenges in the application of spatial computable general equilibrium models for transport appraisal. *Research in Transportation Economics*.

[76] Fosgerau, M. & Pilegaard, N. (2008). Cost Benefit Analysis of a Transport Improvement in the Case of Search Unemployment.

[77] Hirte, G. & Tscharaktschiew, S. (2013). Income tax deduction of commuting expenses in an urban CGE study: The case of German cities. *Transport Policy, Volume 28*, 11-27.

[78] In the model of Brőker *et al.* (2010) for example, the price of a good in region $i$ which is produced in region $j$ is $t_{ij}p_j$. $t_{ij} \geq 1$ is a multiplier capturing transport costs (and potentially border costs such as trade tariffs) from $j$ to $i$ i.e. $t_{ij} - 1$ represents transport costs as a percentage of the price in region $j$ (see also Hummels, D. (2007). Transportation Costs and International Trade in the Second Era of Globalization. *Journal of Economic Perspectives, 21(3),* 131-154.).

between debt and equity. The model also allows for the introduction of frictions which affect the freedom with which capital, labour and traded goods and services move between different regions or overseas.

The S-CGE model uses a mixture of regional accounts data published by the Office for National Statistics (ONS), the Scottish Government, business survey data from the FAME database[79], and HMRC's sector tax and international trade data to capture the complex transactions in the economy. These data provide a snapshot of the three regional economies in a single year, which is used as a starting point for comparing policy simulations against a baseline scenario. The number of industries, product markets and household types are constrained by the availability and consistency of data across the three regions. The model is programmed using GAMS software (General Algebraic Model Software)[80] with the MPSGE (Mathematical Programming Software for General Equilibrium) interface[81]. The number of equations and amount of data used are also constrained by the ability of this software to solve such a model. GAMS/MPSGE is a standard programming tool for CGE models.

## 3.4 Data used in the model

### 3.4.1 National accounts and survey data used in the model

CGE models are often based on a form of National Accounts (NA) data known as Supply Use Tables (SUTs). SUTs provide data on sector-level output, consumption, business costs and taxation. They are "balanced" in the sense that income equals expenditure, which is an essential property for CGE models. Other forms of data that can be used to build CGE models are input output (IO) tables or Social Accounting Matrices (SAMs). IO tables and SAMs are built on the same structural principles as SUTs and contain much of the same data. The key differences are that IO tables tend to be net taxes in an economy (providing a better picture of the economic linkages that exist between consumers and businesses), but they contain less information about industry structure and supply. SAMs contain the core data from either a SUT or IO table, but have less of a fixed structure. Some SAMs add more detailed labour market or household consumption data and often include more detail on trade balances between households and governments and the rest of the world.

The UK government publishes both SUTs and IO tables for the UK. SUTs are updated annually (with an 18 month lag, the most recent being for 2012), while IO tables are updated approximately every 5 years (2010 being the most recent year). The Scottish government publishes a partial SUT (it does not provide as detailed sector information on industry supply) for the year 2010. An IO table exists for Wales for the year 2007 published by the Welsh Economy Research Unit (WERU) at Cardiff University. There is no separate IO or SUT data for England and Northern Ireland.

Our analysis builds on work completed by PwC for HMRC, where a 4-region SUT dataset, covering England, Wales, Northern Ireland and Scotland for the year 2010, was developed. Following discussions with the AC, we have updated this dataset by splitting England into two regions: London & South East and the Rest of England. The other three regions in the model developed for HMRC, Scotland, Wales and Northern Ireland, are combined in this update into one region, the Rest of the UK. Given the presence of the increased airport capacity in the London & South East region under all schemes, this split allows for the disaggregation of the national impact into relevant regional impacts. This split was completed using a similar approach to the 4-region table, based on data from the National Accounts (NA) and a range of other Office for National Statistics (ONS) publications, such as the Annual Business Survey.

A further adjustment to this model was made by expanding the list of sectors from 20 to 23. This was done by splitting out the Transportation & Storage Sector into four smaller sectors:

- Air passenger transport;
- Other passenger transport (all excluding air transport);
- Air freight; and
- Other freight (all excluding air freight).

This was done in order to allow for more specific changes to the aviation sector, and therefore to increase the accuracy of our estimates of the impact of increased airport capacity. This split was done primarily using data

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[79] The FAME database is a commercially available database containing information on UK company accounts. http://www.bvdinfo.com/en-gb/products/company-information/national/fame?gclid=CMCSyoPvsL0CFTTItAodjxwA_g

[80] More information on the GAMS software package can be found at: http://www.gams.com

[81] More information on the MPSGE software interface can be found at http://www.MPSGE.org

from the Annual Business Survey published by the Office for National Statistics, which gives the sub-sectoral breakdown across a number of areas, including number of employees, GVA and intermediate consumption.

In summary, our S-CGE model uses National Accounts (NA) data published by the Office for National Statistics (ONS), HMRC, academics and business survey data from the FAME database.[82] Data is taken from a single year (2010) and provides a snapshot of the economy in that year. Details of the key data sources used in this project are provided in Table 6.

[82] Fame contains comprehensive information on companies in the UK and Ireland. It is used for the purposes of deriving debt equity ratios according to ONS SIC codes for the purposes of the S-CGE model.

*Table 6: Key data sources used in the SCGE model*

| Data | Time | Source |
|---|---|---|
| UK SUTs | 2010 | Office for National Statistics[83] |
| Scotland SUTs | 2007 | The Scottish Government[84] |
| Wales Input Output table | 2007 | Cardiff Business School[85] |
| Scotland export data | 2010 | Global Connections Survey 2010, The Scottish Government[86] |
| Scotland GDP breakdown | 2010 | Scottish National Accounts Project (SNAP), The Scottish Government[87] |
| Scotland household expenditure data | | Scottish National Accounts Project (SNAP), The Scottish Government[8] |
| Earnings data by UK Region | 2010 | Annual Survey of Hours and Earnings, Office for National Statistics[88] |
| Gross operating surplus by sector and UK Region | 2010 | Office for National Statistics[89] |
| Compensation of employees by sector and UK Region | 2010 | Office for National Statistics |
| UK Self-employment income by sector and UK Region | 2010 | Office for National Statistics |
| UK Production tax by sector and UK Region | 2010 | Office for National Statistics |
| Inter-regional trade data by sector and UK Region | 2010 | PwC calculations |
| Regional household income and consumption by UK region | 2010 | Office for National Statistics[90] |
| Household tax data by UK region | 2010 | Office for National Statistics[91] |
| International trade data EU and non-EU | 2010 | HMRC |
| Levels of debt and equity finance by sector | 2010 | FAME database[92] |

[83] http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-256175

[84] http://www.scotland.gov.uk/Topics/Statistics/Browse/Economy/Input-Output/IOAllFiles2007

[85] http://business.cardiff.ac.uk/sites/default/files/IO_2007_Final_30_6.pdf

[86] http://www.scotland.gov.uk/Topics/Statistics/Browse/Economy/Exports/GCSData

[87] http://www.scotland.gov.uk/Topics/Statistics/Browse/Economy/SNAP/expstats/aggregates/SNAP2012Q2

[88] http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-238620

[89] Provided directly by ONS.

[90] http://www.ons.gov.uk/ons/rel/household-income/the-effects-of-taxes-and-benefits-on-household-income/50-years-of-the-effects-of-taxes-and-benefits-analysis/sty-taxes-and-benefits-on-household-income.html

[91] http://www.ons.gov.uk/ons/rel/household-income/the-effects-of-taxes-and-benefits-on-household-income/50-years-of-the-effects-of-taxes-and-benefits-analysis/sty-taxes-and-benefits-on-household-income.html

[92] http://www.bvdinfo.com/en-gb/products/company-information/national/fame?gclid=CMCSyoPvsL0CFTTItAodjxwA_g

*Source: PwC analysis*

Following the collection of data from the different sources listed above, the data were organised to fit into the SUT framework. Further details on the structure of the SUT data used in the model are included in Appendix B. As referenced above, it is critical that income equals expenditure in an SUT. The NA as a whole reflect this balancing principle. However, survey material drawn from a range of sources will inevitably demonstrate some inconsistency in terms of the SUTs and NAs balancing. The standard approach taken in such circumstances is to balance the matrices using a computer algorithm that preserves the core structure of the data but makes iterative adjustments to preserve the income-expenditure relationship. There is a range of algorithms that can be used to undertake these adjustments and they are used as standard practice by European and international governments to balance SUTs.[93] The ONS have previously used the RAS (Row and column Sums) approach to balance the UK SUTs and this is the approach used in our modelling.[94]

In the model, the baseline GDP and employment numbers are based on the 2010 IO table. The model then projects this baseline over a 60 year horizon. In 2010 London & South East constituted 38.7% of UK GDP and 30.2% of UK employment while the Rest of England constituted 47.1% and 55.0% respectively and the Rest of the UK constituted 14.1% and 14.8% respectively.

Services constitute the largest sector in the model, accounting for 36.0% of GDP and 30.5% of employment in 2010. Retail and wholesale trade is the second largest sector by GDP, accounting for 17.0% of GDP and 15.9% of employment, whereas the public sector contributes 26.5% of employment but only 15.0% of GDP.

The baseline real GDP growth rate, of 2.75% per annum based on HM Treasury's long-term economic forecasts, is applied uniformly across sectors. Over a period of 60 years, from 2010 to 2070, GDP increases from £971bn to £4,900 bn. Total employment, over the same time period, increases from 31m to 48m (in line with long-run ONS population growth estimates of 0.8% per annum).

[93] Eurostat (2007). Manual of Supply, Use and Input-Output Tables. (2007), Eurostat Methodologies and Working Papers Series ISSN 1977-0375. Available at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-RA-07-013/EN/KS-RA-07-013-EN.PDF

[94] Akers, R., & Clifton-Fearnside, A. (2008). Blue Book 2008-Balanced Estimates of Gross Domestic Product using a Supply and Use Approach. *ONS website*. Available at: <file:///C:/Users/901792/Downloads/BlueBook2008SUT_tcm77-144039.pdf>

*Table 7: Regional employment by sector, thousands*

| | London & South East | | Rest of England | | Rest of the UK | |
|---|---|---|---|---|---|---|
| | **2010** | **2070** | **2010** | **2070** | **2010** | **2070** |
| **Agriculture and mining** | 56 | 73 | 293 | 350 | 198 | 164 |
| **Industries** | 421 | 603 | 1,896 | 2,715 | 397 | 568 |
| **Utilities** | 42 | 60 | 121 | 173 | 78 | 112 |
| **Construction** | 382 | 547 | 810 | 1,160 | 250 | 358 |
| **Retail and wholesale** | 1,393 | 1,994 | 2,861 | 4,096 | 716 | 1,025 |
| **Passenger transport excl. air** | 123 | 176 | 201 | 288 | 38 | 54 |
| **Accommodation** | 703 | 1,007 | 1,136 | 1,627 | 319 | 457 |
| **Services** | 3,791 | 5,428 | 4,489 | 6,427 | 1,240 | 1,775 |
| **Health, education and public admin.** | 2,241 | 3,209 | 4,811 | 6,888 | 1,225 | 1,754 |
| **Air transport** | 288 | 412 | 572 | 819 | 157 | 225 |
| **Freight excl. air** | 3 | 4 | 6 | 9 | 1 | 1 |
| **Total** | **9,443** | **13,520** | **17,196** | **24,621** | **4,620** | **6,615** |

*Source: ONS, PwC analysis*

*Table 8: Regional GVA by sector, £ millions*

| | London & South East | | Rest of England | | Rest of the UK | |
|---|---|---|---|---|---|---|
| | **2010** | **2070** | **2010** | **2070** | **2010** | **2070** |
| **Agriculture and mining** | 2,586 | 13,169 | 7,558 | 38,487 | 5,438 | 27,692 |
| **Industries** | 26,465 | 134,766 | 92,780 | 472,459 | 23,901 | 121,710 |
| **Utilities** | 8,030 | 40,891 | 18,210 | 92,730 | 5,887 | 29,978 |
| **Construction** | 26,348 | 134,171 | 44,670 | 227,471 | 12,591 | 64,117 |
| **Retail and wholesale** | 51,013 | 259,771 | 85,658 | 436,192 | 20,761 | 105,720 |
| **Passenger transport excl. air** | 4,853 | 24,711 | 6,874 | 35,004 | 1,635.13 | 8,326 |
| **Accommodation** | 14,132 | 71,964 | 19,810 | 100,877 | 5,873 | 29,907 |
| **Services** | 271,728 | 1,383,707 | 239,095 | 1,217,532 | 58,721 | 299,022 |
| **Health, education and public admin.** | 80,447 | 409,656 | 145,827 | 742,588 | 46,761 | 238,119 |
| **Air transport** | 2,151 | 10,951 | 3,046 | 15,512 | 725 | 3,690 |
| **Freight excl. air** | 14,932 | 76,036 | 21,151 | 107,705 | 5,031 | 25,620 |
| **Total** | **502,684** | **2,559,793** | **684,679** | **3,486,558** | **187,324** | **953,901** |

*Source: ONS, PwC analysis*

Having identified the structure of the core S-CGE model, this framework must be applied in the specific context of an increase in airport capacity. The following chapter identifies the key inputs into the model and how these are captured within the S-CGE framework.

# 4 Modelling methodology

In this chapter, we explain in detail the modelling methodology used to capture the wider economic impacts of an increase in airport capacity in London & South East. We present the main mechanisms or "effects" through which the schemes may impact on the economy. We outline the manner in which each effect is assumed to impact on overall GDP, and how each effect is captured and incorporated into the S-CGE framework.

Airport expansion is likely to affect the economy through a number of different mechanisms. As noted in Chapter 1, the AC has identified three likely impacts of airport expansion which could have macroeconomic consequences, and which we therefore need to reflect in our modelling – more passenger flights to and from a wider range of destinations; a reduction in effective journey times (frequency benefits) for air passengers; and lower air fares. We model the implications of these three impacts through four mechanisms which we refer to as "effects". Each is incorporated into the S-CGE framework separately. The four effects we consider are as follows:

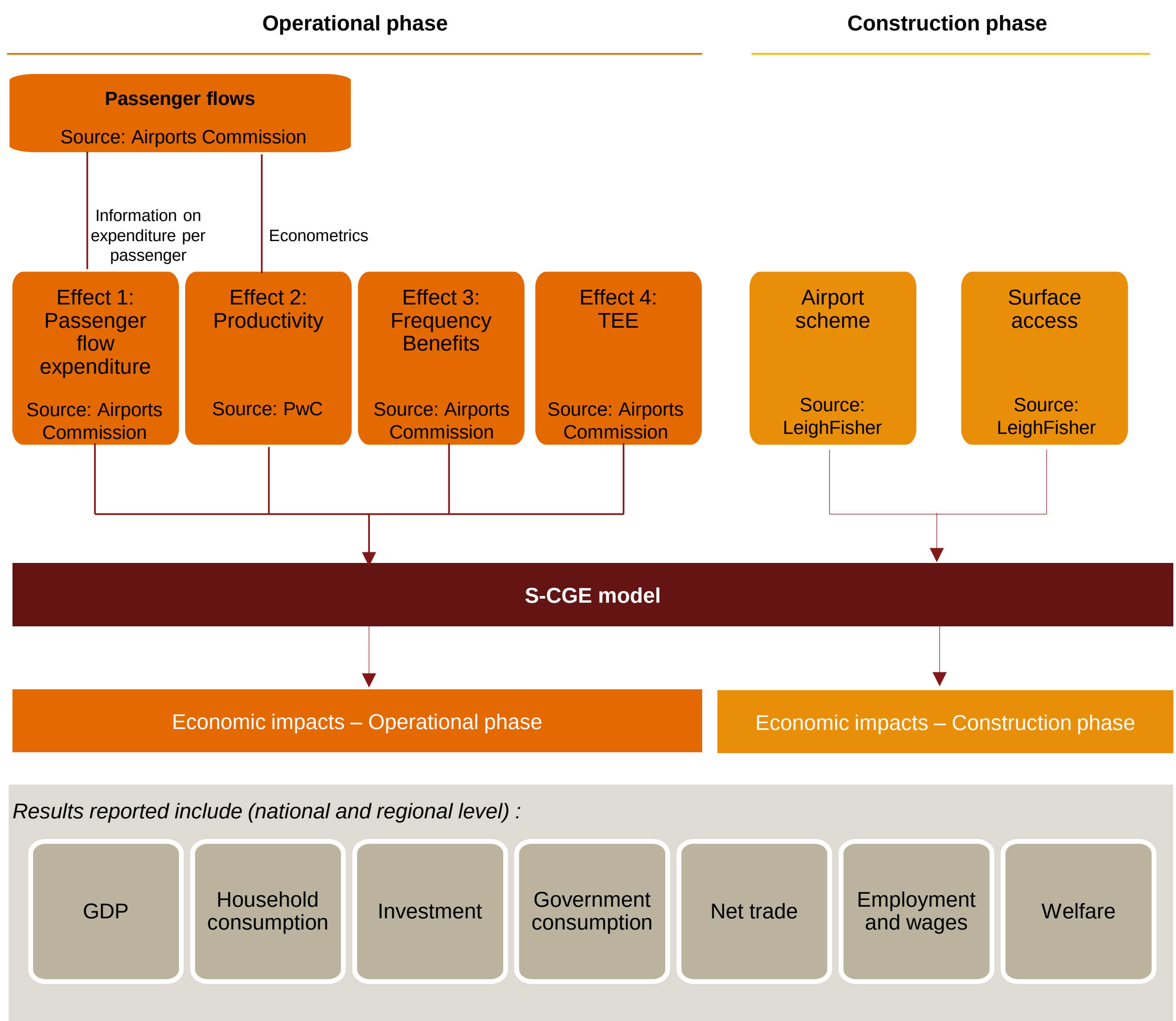
- **Effect 1: changes in passenger flows** – Changes in passenger flows will result in changes in the pattern and level of spending in the UK and overseas.
- **Effect 2: productivity effects (captured through increased international trade)** – The increase in connectivity associated with more passenger flights will provide a productivity benefit to businesses.
- **Effect 3: frequency benefits to airport users** – An increase in flight frequency also means that business travellers benefit from greater choice and a reduction in effective travel time and time spent while transferring at the airport.
- **Effect 4: transport economic efficiency effects (TEE)** – The relaxation of the capacity constraint in the UK aviation sector may reduce prices and make aviation affordable to more customers, but may also reduce the margins that airlines are able to charge. The net effect on the economy is captured through this effect.

Since the purpose of this work is primarily to understand the long-term impact of the schemes as a result of the expected improvement in aviation linkages and outcomes, our principal focus is on these four effects associated with the operation of the expanded capacity. However, there may also be impacts associated with the construction of the schemes. In principle, since resources of the economy must be "diverted" towards construction of the airport schemes from other activities, the overall impact of constructing the airport could be to increase GDP, reduce it or have little or no effect. It is therefore instructive to use the S-CGE model to understand how construction of the schemes may, in itself, impact on the economy. In particular, we investigate the impact of: the projected incremental capital expenditure associated with the airport schemes and the incremental cost of providing the surface access.

## 4.1 Summary of modelling approach

Figure 4 below summarises the modelling approach and, in particular, how the various inputs underlying the effects are fed into the S-CGE framework. The changes in passenger flow inputs are fed into the S-CGE model directly (see below for further detail), but they also inform the productivity impacts and therefore also enter the S-CGE model indirectly. Frequency and TEE benefits are input into the S-CGE framework directly. Construction effects are incorporated directly into the S-CGE model. The S-CGE framework then allows us to understand how the effects are transmitted through the economy and the possible implications for variables of interest such as GDP, economic welfare, jobs and wages.

*Figure 4: Modelling approach*




*Source: PwC analysis*

It should be emphasised that the effects described above are not sequential – the order in which the effects are modelled has no impact on the results, and each of the four effects could operate separately or in any combination with the other three. We have simply labelled them as effects 1 to 4 for ease of exposition.

The remainder of this section provides a brief overview of each of the effects in turn. We then consider each of these in detail.

### *4.1.1 Changes in passenger flows*

We input estimates of the forecast increase in passenger numbers associated with each scheme to the S-CGE model. The passenger number estimates are obtained from the DfT aviation model and have been provided to us by the AC.

The S-CGE model links an increase in passenger numbers – whether they are leisure, businesses or other visitors – to a change in passenger spending, through the ONS Tourism Satellite Accounts (TSAs). Additional demand elasticities are sourced through a literature review; the details of which are given in Appendix B. We can therefore input the projected change in passenger numbers directly into the S-CGE model and the model itself generates associated changes in the macroeconomic outcome. Note that the elasticities are assumed to be constant over time.

We consider five different scenarios for passenger flows, provided to us by the AC, which are set out in Section 4.3 which also explains the precise way in which we have incorporated forecast changes in passenger flows into the S-CGE framework.

### *4.1.2 Productivity effects*

We input estimates of the projected productivity benefits from each of the shortlisted options directly into the S-CGE model.

The increases in projected business passenger journeys supplied by the AC imply that UK-based businesses should become more efficient. Improved aviation linkages can improve firms' productivity in a number of ways. For example, better aviation linkages may enable firms to access larger markets, allowing them to exploit scale economies. Less tangibly, but equally importantly, by being able to access foreign markets more readily, aviation linkages could allow firms to "learn" from customers and competitors in other countries, helping them to exploit technologies and adopt more efficient "ways of working" (these effects form the basis of the so-called "endogenous growth" literature which has revolutionised the way economists think about how economies grow). We refer to this outcome of expanded airport capacity as a "productivity effect".

The S-CGE model is capable of modelling these effects explicitly, but the size of the effect input into the model needs to be calibrated, based on the change in productivity that has historically occurred in response to a change in aviation capacity. Due to the lack of representative airport capacity expansion projects in the recent past, we estimated this relationship through the econometric analysis of the relationship between international trade (imports and exports) on the one hand and changes in passenger numbers on the other. Section 4.4 sets this out in greater detail and explains the precise way in which we have incorporated changes in passenger flows into the S-CGE framework.

### *4.1.3 Frequency benefits*

We input estimates of frequency benefits that are expected to result from the shortlisted options into the S-CGE model as an increase in business productivity. Increased frequency means that:

- passengers are able to choose from an increased range of flight times so that flights can be taken at times which may be more efficient and/or convenient;
- effective travel time is reduced by shortening the amount of time that passengers may have to wait prior to or after taking a flight; and
- using an airport as a transfer hub is a more viable and attractive option for transfer passengers, which can help support an even larger number of flights and destinations, and in turn enhance passenger choice.

Data on the frequency benefits that are expected to accrue to business passengers are derived from the DfT aviation model and have been provided to us by the AC. These benefits vary with the pattern of passenger flows, so we consider five alternative scenarios which correspond with the passenger flow scenarios (and which are set out in detail below).

Section 4.5 explains the precise way in which we have incorporated frequency benefits into the S-CGE framework.

### *4.1.4 Transport economic efficiency*

We input the TEE effects from the airport capacity to the S-CGE model. The TEE effects relate to welfare changes – particularly the changes to consumer (i.e. passenger) surplus and producer (i.e. airline) surplus. The DfT modelling suggests that as capacity constraints are relaxed air fares or the cost of travel fall, thereby increasing consumer surplus. However, the majority of this will in effect be a transfer of surplus from the producer who can no longer charge passengers scarcity rent.

Data on the TEE is derived from the DfT aviation model and has been provided to us by the AC. As with frequency benefits, the TEE benefits vary with forecast passenger flows, so we investigate five alternative scenarios which correspond with the AC's passenger flow scenarios (see below).

Section 4.6 explains the precise way in which we have incorporated TEE effects into the S-CGE framework.

### *4.1.5 Construction costs*

We input construction cost estimates for the airport facilities and surface access enhancements into the S-CGE model. The costs of the airport schemes themselves are based on capital cost estimates (including long-term replacement costs) which were provided to us by the consultancy firm LeighFisher. Surface Access cost capital cost estimates (which also include long-term replacement costs) have been provided by consultancy firm LeighFisher. Operating expenditure has not been included in the model.

We have only modelled the effects of **constructing** new surface access and not the surface access-specific efficiency or agglomeration benefits that could be attributed to them. We understand that this is considered elsewhere in the AC's assessment.

Section 4.7 explains the precise way in which we have incorporated construction cost effects into the S-CGE framework.

## *4.2 Schemes and scenarios*

As described previously, we model three separate schemes:

- Gatwick Airport Second Runway (LGW 2R).
- Heathrow Airport Extended Northern Runway (LHR ENR).
- Heathrow Airport Northwest Runway (LHR NWR).

Five passenger forecast scenarios were considered. These were provided to us by the AC and are referred to extensively in the rest of this report. They are:

- **Assessment of Need[95]:** Worldwide GDP growth continues on current trend and existing airline operational models prevail;
- **Global Growth:** Strong global growth in passenger demand, continued market liberalisation and a variety of successful operating models;
- **Relative Decline of Europe:** Continuing decline of European airlines' market share and growth of Middle Eastern hubs, continued market liberalisation and competition driving consolidation;
- **Low Cost is King:** Strong global growth, continued market liberalisation and the low cost model expands to new markets, including long haul; and
- **Global Fragmentation:** Stagnating global passenger demand, countries/markets are protectionist, leading to fragmentation.

These scenarios differ in terms of the overall passenger numbers forecast at each airport and for each scheme. The data for each scenario have been generated using the DfT aviation model.

The scenarios above are based on the assumption of a "carbon-traded", rather than a "carbon-capped" emissions policy. Under the carbon-traded scenario, firms can then trade their allocations: firms emitting less than their allocated limits can sell the remainder of their allocations to firms that are likely to emit more than their allocated limits. We have been instructed by the AC to consider the estimates based on the carbon-traded policy option assumption, and all the data provided by the AC are consistent with this assumption. Within each results chapter we have considered the impact of a carbon-capped scenario as a sensitivity test.

Below, we set out our modelling approach to estimating the economic impact of each airport scheme. In particular, we describe how the various inputs are incorporated into the S-CGE model and, where appropriate, any assumptions made. This chapter draws heavily on the previous chapter on Model Structure and is intended to facilitate understanding of the Results chapters which follow. The remainder of this chapter explains the modelling approach in more detail, considering each of the inputs and their corresponding effects in turn.

## *4.3 Changes in passenger flows*

We were provided with forecast passenger flow data from the AC's Demand Forecast Model, produced using a version of the DfT's aviation forecasting model up to 2050. For more information on the model and approach,

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[95] This was the scenario used by the DfT to assess the need to expand aviation capacity.

please refer to the AC Demand forecast report from consultation[96], and the technical appendix 3 to the Interim Report[97]. Passenger flows affect the results of the S-CGE analysis by determining:

- The size of the aviation sector;
- Changes in productivity; and
- The level and nature of inbound and outbound passenger (leisure, business and other) spending.

The forecast passenger data with which we were provided can be split according to the different schemes and different scenarios (described above) and also across the following geographies:

- UK (i.e. domestic flights);
- Africa;
- Central & South America;
- East Asia;
- Europe;
- Middle East;
- North America; and
- Oceania.

The passenger flow data projections can also be disaggregated into the following flow types:

- Leisure;
- Business; and
- Other (mainly international transfer passengers).

### *4.3.1 Incorporating passenger flows into the S-CGE framework*

As described in Chapter 3, the S-CGE model has been built with a passenger flow sector which captures passenger flows (business, leisure and other) and associated expenditure. This allows us to feed directly into the S-CGE framework the increased demand from inbound passenger flows and reduced demand brought about by outbound passenger flows, using the relevant data provided to us for the different schemes and scenarios. The S-CGE model converts the changes in passenger numbers into changes in passenger expenditure based on the Tourism Satellite Account dataset from the ONS. In particular, the following steps are undertaken within the S-CGE model to convert passenger flows to expenditures:

- Changes in passenger flows are converted to changes in passenger expenditures using elasticities derived from S-CGE research (see Appendix B for sources and sensitivity tests which are undertaken to understand the impacts of the choice of elasticities); and

- Changes in expenditures are then allocated across regions and sectors using historical proportions based on Tourism Satellite Accounts.

It is important to note how different passenger flow types are reflected in the S-CGE model. As described above, the three flow types in the inputs provided by the AC are leisure, business and other flows. For the purposes of the passenger flow effects, separate elasticities are used for passengers travelling for business, leisure and visiting friends and relatives. For the purpose of this analysis we have assumed on the advice of the AC that the balance of inbound and outbound passengers and their associated spending patterns remain constant in the event of airport expansion. Any difference from this assumption in reality would have an impact on the magnitude of the impact on GDP.

We are then able to observe how the changes feed through the economy based on the structure of the S-CGE model and understand the multiplier effects of the inbound and outbound passenger expenditure. These mechanisms are described in detail in the results chapters.

The GDP impacts of transfer passenger spending are not explicitly modelled in the S-CGE framework, since they are likely to be relatively small in the context of the UK economy. However, we understand that, to the extent that transfer passengers enable more flights, the impacts will be reflected in the domestic leisure and

[96] See: Airports Commission (2014). *Airport level passenger forecasts*. https://www.gov.uk/government/publications/airports-commission-airport-level-passenger-forecasts-2011-to-2050

[97] See: Department for Transport (DfT) (2014). *Appendix 3: Technical Appendix to the Airports Commissions Interim Report*. London: Department for Transport.

business passenger flow inputs provided by the AC, and in frequency benefits and TEE effects (see below). As such, the enabling effects of transfer passengers should be captured in our results.

Finally, it should be stressed that the passenger flow effect only captures business and leisure passenger *expenditure* or *demand* impacts (which will in turn have multiplier impacts throughout the economy). Any benefits from improved productivity as a result of business trips are not captured through this effect, but rather through the productivity effect to which we now turn.

## 4.4 Productivity effects

As discussed above, the operation of each airport scheme can stimulate an external positive supply-side effect to the economy. Each airport scheme will lead to improved transport connectivity which in turn provides a benefit to those businesses that use air transport. The drivers of these benefits are so called productivity effects. The mechanism through which this effect impacts on the economy is outlined in Appendix D.

In this section we describe how these benefits are incorporated in the model. This section builds upon the discussion in the earlier chapters, which describe the theory behind the productivity effects of transport, the econometric analysis that we have undertaken to inform the size of the effect to be incorporated into the S-CGE model, and the concept of multiple equilibria which occur in the S-CGE framework in reaction to the productivity impacts. No additional data inputs are presented in this section because, as explained below, the productivity effects are driven by passenger flows (discussed above).

### 4.4.1 Econometric analysis

We used econometric analysis to estimate the link between international trade and passenger numbers. This relationship is used in the S-CGE framework to proxy productivity effects.

In summary, to conduct our econometric analysis we used a gravity model based on a panel of 112 countries (UK trading partners) over the period 2001-2011. We use a Pseudo-Poisson Maximum Likelihood (PPML) estimation technique to estimate the model. The PPML approach has several advantages, and is the standard technique used to estimate a gravity model. The key results are that a 10% increase in passenger numbers is associated with a:

- 2.4%-2.9% increase in exports of goods;
- 5.8%-6.1% increase in imports of services; and
- 2.5%-3.0% increase in exports of services.

We have not been able to establish a significant econometric relationship between passenger numbers and UK goods imports.

These results have been used to determine the appropriate size of the effect input into the S-CGE model (as explained in section 4.4.2 below).

We note that there are alternative approaches that could have been used to estimate the productivity benefits. For example, improved connectivity also has an impact on FDI. FDI can bring in new products to the UK market and also strengthen supply chains into and out of the UK. However, FDI may also reflect other factors (e.g. changes in the ownership of assets), which are not directly linked to airport connectivity. This makes trade a more robust channel for modelling the productivity impact of airport capacity expansion. In addition, using trade **and** FDI would risk double-count in the S-CGE model, since the S-CGE model anyway recognises the relationship between FDI and international trade (i.e. even though we only input the trade effect into the S-CGE framework directly, internal mechanisms within the model mean that we are also capturing the FDI effect).

In addition, given that changes in connectivity have a geographical element, the most direct effect on macroeconomic outcomes will also be on geographic specific outcomes such as trade. Modelling trade therefore gives us a suitable way of linking connectivity and the economy (by contrast GDP, for example, does not have any dimension that would enable us to identify a correlation with different degrees of improved connectivity to different parts of the world).

When interpreting the results it should be remembered that this effect captures the gains from increased openness through productivity. This should be distinguished from the direct impact on GDP from an increase in the net trade balance.

### 4.4.2 Incorporating productivity into the S-CGE framework

The econometric results are used to estimate an appropriate input to the S-CGE framework, which is intended to proxy the effects of productivity. In particular, we go through the following steps in order to incorporate the change into the model:

1. Use the econometric relationship between growth in passenger numbers and trade to derive the implied trade impact from the forecast passenger flow numbers provided by the AC for the relevant scheme and/or scenario; and
2. Input productivity changes in the S-CGE framework so that the productivity input delivers the increases in trade implied by the first effect.

Put another way, we use the S-CGE framework to understand the magnitude of the productivity input required to deliver the increase in trade implied by the AC's passenger growth figures, given the econometric relationships between passenger numbers and trade. We then input that productivity change to the S-CGE model, which allows us to understand the economic impacts in respect of other important economic variables such as GDP and employment.

It should be noted that the S-CGE model itself accounts for the relationship between trade and aviation activities internally (albeit only partially). Therefore, it is important that the effects are not counted twice. To avoid such double counting, any impacts that are driven by the model's internal mechanism relating to trade and aviation have been removed from the final impacts.

## 4.5 Frequency benefits

In this section, we describe the forecast frequency benefits of increased aviation capacity across the scenarios and schemes. It should be emphasised that we only consider the forecast frequency benefits to businesses in our work, since frequency benefits to leisure passengers may not have a direct impact on GDP. Greater frequency of services provides benefits to businesses in a number of ways. In particular, greater frequency:

- Means that passengers are able to choose from an increased range of flight times so that flights can be taken at times which may be more efficient and/or convenient;

- Effective travel time is reduced by shortening the amount of time that passengers may have to wait prior to or after taking a flight; and

- Makes using an airport as a transfer hub a more viable and attractive option, which can help support an even larger number of flights and destinations, in turn further enhancing passenger choice.

The mechanism through which this effect impacts on the economy is outlined in Appendix D.

### 4.5.1 Incorporating frequency benefits into the S-CGE framework

Frequency benefits are incorporated into the S-CGE model as positive effects on total factor productivity. In particular, whole-economy total factor productivity is increased to the point at which the value of the increase is equal to the forecast frequency benefits provided to us by the AC.

The increased productivity among firms accruing from frequency benefits is potentially also measured as a part of the TEE effect, below. However, these inputs are sourced from the same DfT modelling suite and we were advised by the AC that the framework is internally consistent and the impact of these potential sources of double-counting is not significant, and that frequency benefits should be treated as a separate effect.

Also, we would emphasise that the risk of double-counting between the frequency benefit effect and the productivity benefit effect above is small. In particular, the econometric estimation period used to inform the productivity effect did not include any step-changes in frequency benefits. Therefore, frequency benefits are unlikely to have been captured in the coefficients estimated as part of the econometric analysis, meaning that frequency benefits are not included in the productivity effect described above.

## 4.6 Transport economic efficiency

The DfT use the term TEE to describe the benefits that may arise if the relaxation of the capacity constraint in the UK aviation sector were to reduce fares (implying a reduction in the margins that airlines are able to charge). Scheme promoters have emphasised the benefits of enhanced airline competition and lower fares in their submissions to the AC[98]. DfT's WebTAG (TAG Unit A2.1[99]) guidance describes TEE benefits and how these may be estimated, and the reader is referred to that source for further information. The AC requested us to incorporate TEE effects generated by the AC's aviation deamdn forecasting model in the S-CGE model.

In this section, we describe how we have incorporated TEE effects in the S-CGE model and discuss the issue that airport charges may ultimately have to increase to cover the costs of constructing the scheme which could feed through to increased fares, which in turn could offset the TEE benefits.

### *4.6.1 Incorporating TEE effects into the S-CGE framework*

The TEE inputs provided to us by the AC are made up of two distinct effects: the change in consumer surplus[100] and the change in producer surplus[101] resulting from the possible reduction in the costs of travel (assumed to be fare premium in this case). Both are generated from the AC's demand forecasts. These consumer and producer surplus effects are very different and it is appropriate that they are incorporated into the S-CGE model in different ways. In particular, whilst it would be possible to incorporate the net change in welfare (i.e. the increase in consumer surplus plus the reduction in producer surplus) as a single input in the S-CGE framework, doing so would ignore the potential downstream linkages associated with *shifting* surplus from producers to consumers. It should be noted that due to efficiency benefits (e.g. new passengers, or passengers moving to move convenient airports), the net effect of the two effects is positive. Below, we discuss how the increase in consumer surplus and the reduction in producer surplus change are incorporated in the S-CGE model.

#### *4.6.1.1 Consumer surplus*

In the WebTAG framework consumers receive a gain from capacity expansion by means of increased consumer surplus as travel costs are assumed to fall. In order for this to have a meaningful impact on economic activity, we assume that consumers "use" the benefit, in the sense that they spend and/or save it. It is appropriate to make this assumption since the reduction in price associated with the expansion of capacity in the TEE framework can be thought of as an increase in real income to consumers. Put another way, as costs fall the "purchasing power" of consumers' income rises. By monetising the consumer surplus impact, we are able to capture this effective increase in real income in the S-CGE framework. Falling travel costs, as a result of enhanced capacity, is an important assumption used by the AC to derive the TEE benefits.

In order to incorporate the consumer surplus impact into the S-CGE framework, we model the TEE benefits in the CGE framework as a positive effect on whole-economy Total Factor Productivity (TFP). In particular, we stimulate productivity in the economy by an amount proportional to the increase in consumer surplus. The productivity effect ultimately benefits consumers (the owners of firms in the model), who then decide how to "use" this surplus (their choices being determined endogenously within the model based on historic information about such choices). The model then describes the various multiplier effects as this spending proliferates through the economy, the results of which are considered in the results chapter.

It would have been possible to use an alternative approach to model this effect, for example by incorporating a lump-sum transfer to consumers.

We recognise that incorporating the change in consumer surplus by implementing a productivity effect may not be the most intuitive approach. However, following discussion with our academic advisors we consider that this is the appropriate approach. This approach has also been reviewed by external experts in S-CGE modelling.

The specific rationale behind changing productivity as a proxy for an increase in consumer surplus is as follows. In a partial equilibrium framework the increase in consumer surplus following a removal of airport capacity constraints, and a subsequent reduction in cost, is effectively a transfer from the airlines, who were able to charge scarcity rents, to consumers. Consumers can spend this money how they wish – either back in the airline sector, or in other sectors of the economy. They may also choose to save it. The knock on effects of this captured in a general equilibrium framework would imply a subsequent increase in consumer demand. The positive effects on demand would lead to an expansion in output and subsequent increase in investment and reduction

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[98] See for example the submission of Heathrow Airport Limited, available at: http://your.heathrow.com/wp-content/uploads/2014/05/TBF-Volume-2-72dpi-jm.pdf.

[99] Available at: https://www.gov.uk/government/publications/webtag-tag-unit-a5-2-aviation-appraisal

[100] The consumer surplus is the difference between a consumer's willingness to pay for a good or service and the actual price paid. It is a measure of consumer welfare. At the market level, this is effectively summed across all consumers. Consumers in this context are passengers.

[101] The producer surplus is the difference between the price received by a producer for a unit of output and the marginal costs incurred in producing that unit of output. It is an economic measure of profit. At the market level, this is effectively summed across all producers. Producers in this context are airlines.

in unemployment. The changes in investment and reductions in unemployment would lead to an increase in productivity. There are three different ways in which this effect could be picked up in a CGE model:

- Simply providing a lump sum transfer to consumers in the form of a cash boost in a CGE model is not straightforward. If a lump sum transfer is made then the products and services that initially consumers spend their money on must be specified. But this would be artificial and overly prescriptive – the consumer should have the choice;

- The partial equilibrium framework also implies an income effect for households. So an alternative would be to model a boost to household incomes, with households then choosing how this additional income would be spent. This approach would also be unsuitable as if incomes are increased in a CGE model this must be matched through an increase in either capital or labour income. This would imply an immediate boost to tax receipts, which would be a secondary effect, and we would also have to make an assumption about the channel through which incomes increased. Again, such an assumption is felt to be artificial and overly prescriptive;

- A further option, and the one that we chose, is to raise total factor productivity by an equal percentage amount across all sectors of the economy. This lowers prices and entices consumers to spend more, as if they had received a boost through increased consumer surplus. Spending patterns are determined by the households' income elasticity of demand and the relative price reductions implied by the TFP adjustment. This stimulates a positive income effect for households and a rise in aggregate demand. Firms will raise prices in response to an increase in demand, and seek to achieve higher mark-ups. Mark-ups will increase according to a firm's perception of the households' income elasticity of demand – the more inelastic this perceived income elasticity of demand, the greater the increase in mark-ups. Households will allocate their increased spending power across a range of goods and services as determined endogenously within the model. Sectors which experience a smaller (larger) corresponding increase in demand will lower (raise) any subsequent levels of investment or employment that have increased following the TFP effect. The economy reaches a new equilibrium with increased consumer spending and saving, a higher level of demand and higher levels of employment, investment and productivity. The net price effects for sectors where demand has risen will be higher than in the baseline and where demand has been slower to materialise (i.e. for products that are deemed less essential) prices will be lower. Effectively the same outcome has been achieved as described in the paragraph that describes the rationale for changing productivity above. On this basis, this is our preferred approach.

#### 4.6.1.2 Producer surplus

In order to ensure that the model can accommodate the change in producer surplus, the model baseline is adjusted to accommodate an appropriate increase in gross operating surplus in the "do minimum" scenario. The full rationale for increased profits amongst airlines – and therefore for the baseline adjustment – is provided in TAG Unit A5.2 of WebTAG. In essence, in the absence of capacity expansion, aviation slots are likely to become an increasingly scarce resource. This could generate "economic scarcity rents" or "excess profits" among airlines and others in the aviation supply chain. Whilst in practice some of these rents may be competed away or in fact airlines become more efficient as a result of more competition, this is very difficult to predict with accuracy. Therefore, WebTAG assumes (and the AC's TEE figures reflect this) that these rents are not competed away or reversed by any efficiencies and resulting high profits for airlines, and it is necessary for us to adjust the S-CGE model baseline scenario to accommodate these effects.

The decrease in producer surplus, as estimated by the AC demand forecast, is then input as a change in capital productivity (i.e. returns to capital or gross operating surplus) in the airline sector.

As with all of the inputs described above, this has multiplier impacts throughout the economy (considered in the results chapter). By modelling the consumer surplus and producer surplus effects differently, we account for the possibility of different multipliers being associated with the two effects. The different ways in which the two effects impact on the economy are shown in Appendix D.

### 4.6.2 TEE and airport charges

As described above, TEE benefits are derived from the reduction in fares that may be possible as a result of capacity expansion, as suggested by the WebTAG framework and included in the forecast data provided to us by the AC. A potential issue is that when the schemes become operational it is likely that the airports will increase charges in order to fund the capital expenditure associated with expansion. Any increase in airport charges could be passed through to passengers in the form of fare rises, which could offset the effects described by the TEE theory above and suppress demand.

The impacts of higher airport charges have been considered in the AC's airline competition and cost and commercial work, but are not explicitly included in its modelling of TEE. This issue is partially addressed by the requirement of the S-CGE framework for internal consistency. The model recognises that the airport capital expenditure must eventually be repaid, and that these costs will ultimately flow back to consumers in the form of higher prices for the output of the aviation sector (effectively, ticket prices). In effect, the model proxies the fare increases that follow from higher airport charges, which in turn flow from the capital expenditure on the schemes.

Although the internal consistency of the S-CGE model requires that consumers ultimately pay for the airport expansion by means of higher prices of aviation-sector output, the effect is very much a proxy. The relatively limited nature of the work undertaken so far to understand the possible impacts of aeronautical charges on fares and demand, and the lack of explicit modelling to take account of the possible impact of aero charges to generate TEE inputs, is an important limitation of the analysis. We seek to reflect this uncertainty in the next chapter.

### *4.6.3 Inputs*

The AC have provided us with estimates of the welfare impacts described above, specifically the forecast changes in consumer and producer surplus resulting from the expanded capacity associated with the three schemes across the five different passenger flow scenarios. It should be emphasised that the estimated changes in consumer and producer surplus are relative to the level of consumer and producer surplus that would be expected in the absence of capacity expansion (rather than being compared to today's levels of producer and consumer surpluses).

The estimates used as inputs to the S-CGE model corresponding to each scheme are described in the relevant chapters below.

Finally, an important point relates to the possibility of double-counting between TEE and productivity. Part of the increase in consumer surplus described above accrues to firms consuming the output of the aviation sector. Part of the reason that firms may demand aviation is that travel may provide a mechanism through which they can increase their productivity (for example by "learning" from customers, suppliers or competitors). This appetite to increase productivity through aviation linkages could be reflected in firms' demand curves for aviation. In turn, this would imply that this effect is captured as part of the change in consumer surplus change in the TEE calculation (as well as the productivity effect considered above).

We consider that the risk of any significant double-count is low. The principal reason is similar to that described for the frequency benefits. In particular, the econometric estimation period used to inform the productivity effect does not include periods in which capacity was significantly constrained. This means that the econometric coefficients should not capture this effect.

Moreover, even if the econometric relationships did capture this effect, the risk of double-counting remains small because:

- Only around one third of the benefits of the price falls accrue to businesses (as opposed to leisure passengers) across the schemes and scenarios;
- The productivity effect captures only the benefits associated with **new** aviation activity. However, the majority of the TEE benefits are simply transfers from airlines for lower fares on existing air travel (i.e. are associated with **existing** aviation activity); and
- Only the productivity effects that increase firms' own internal productivity will be represented in their demand curves. However, much of the benefits of increased productivity from improved aviation linkages will be enjoyed not by the firms using the aviation sector directly, but by other firms which benefit from the positive externalities. For example, if Firm A is able to exploit improved aviation linkages to copy a more efficient production practice from abroad, other firms in the domestic economy may benefit in turn by copying that production practice from firm A (i.e. without actually using aviation themselves).

# 4.7 Construction costs

## 4.7.1 Airport construction costs

This sub-section examines the approach we took to the modelling of the wider economic impact of the construction costs of the airport schemes themselves. This is followed by a sub-section which deals with the costs of surface access enhancements. Construction costs have been estimated by LeighFisher on the basis of passenger flows. However, since the variation in construction costs only varies to a negligible extent across the passenger scenarios, we have assumed the construction costs to be constant across the scenarios for the purposes of the Wider Impacts Assessment.

### 4.7.1.1 Financing

In a general equilibrium framework, the finance for any new construction project involved in the shortlisted options must come from somewhere else in either the domestic or a foreign economy. In order to make the analysis as simple and transparent as possible, we have assumed, following discussions with the AC, that the airport schemes, which include both the infrastructure required for core airport operations as well as the facilities (such as shops and booking offices), are financed by the domestic private sector.

Given the size of the schemes, an important consideration with regard to private investment is the extent of any "crowding-out" of investment from other schemes, whereby investment could simply be drawn in from other projects. We assume that there is no excess capital in the UK economy and therefore that, in order to secure investment, the airport schemes must offer a higher return on investment than could be earned elsewhere. As described in Chapter 3, the model equations are specified on the basis of Input Output tables for 2010 published by the ONS which contain information on how the economy allocates funds between investment and consumption. The model suggests that the schemes will be funded primarily through "new" investment (which is enabled by reduced consumption), with a small reduction in investment from other projects in the UK.

An alternative to the assumption that the schemes would be funded from domestic sources is that they would be funded through Foreign Direct Investment (FDI). Using such an assumption would likely increase the modelled net impact of the schemes on GDP, since similar positive forces would be placed on output but there would be less of a reduction in domestic consumption and in investment in other schemes in order to fund the airport schemes. However, we adopted what we consider to be a prudent assumption of domestic funding because funds available for airport capacity expansion, even in global capital markets, are likely to be limited. Furthermore, since investors may wish to diversify risk across a large number of countries, investment from abroad in the airport schemes might come at the expense of other UK projects.

### 4.7.1.2 Airport scheme construction costs

On behalf of the AC, LeighFisher, a consultancy firm, estimated the required annual capital expenditure for each of the shortlisted options between the start of construction, which differs between schemes, and 2050. The estimates used for this analysis are consistent with those from consultation.

The capital expenditure required for the airport schemes refers to the expenditure on core airport infrastructure and facilities and does not include external surface access (see below). Costs have been calculated in two stages: the capex that would be required under the baseline scenario regardless of whether airport capacity is expanded, and the incremental capital expenditure that would be necessary to build the scheme. For the purpose of the Wider Impacts Assessment, we have only used the incremental expenditure in order to estimate the impact of airport expansion (i.e. we have not included capex that is expected to be required regardless of expansion).

The airport scheme construction costs include expenses relating to terminal buildings, plant, tunnels and bridges, transit systems, runways, taxis and aprons, equipment, land, airfield ancillary, car parks, third party land users, environment and community, and incremental maintenance and renewal costs. The capital expenditure includes long-term replacement costs of airport facilities (but not operating expenditure). The total incremental construction costs of each of the schemes are described in the relevant results chapters below.

## 4.7.2 Surface-access construction costs

This sub-section outlines the projected capital expenditure that would be required for each of the schemes' associated surface access requirements, which have also been forecast by LeighFisher. These figures act as a direct input to our model. Surface access comprises road schemes and rail schemes.

We have agreed with the AC that for our modelling purposes we should assume that surface access schemes are government funded. The AC are undertaking a separate analysis to decide what level of public funding, if any, may be required or appropriate. This treatment of surface access funding is therefore simply an assumption, and should not be interpreted as an indication of the AC's desired approach. For simplicity, surface access costs for each scheme are assumed not vary with the passenger flow scenario considered (although clearly in reality the costs may depend on airport passenger flows). Surface access costs corresponding to each scheme are described in the relevant results chapters below.

### *4.7.3 Incorporating construction costs into the S-CGE framework*

#### *4.7.3.1 Airport construction costs*

The S-CGE model allows us to "exogenously" (that is to say, from "outside" of the model) change expenditure on construction for a given sector. We model the core scheme construction as an increase in investment demand in the air transport sector. This increase in investment demand raises the return on capital so that funds flow to the aviation sector in order to finance construction of the scheme. As noted above, we have assumed that the airport facilities themselves are funded by the domestic private sector. This means that funds flow to the aviation sector for scheme construction from the following sources:

- Domestic consumption, as consumers recognise the increased returns available and are enticed to increase savings; and
- Domestic investment in other projects, as investors observe relatively high returns in the aviation sector and switch investment from projects in other parts of the economy (this is a "crowding-out" effect).

This investment then flows into other sectors of the economy (especially the construction sector) as increased demand for those sectors' outputs. Expansion in these sectors in turn has various "multiplier" impacts throughout the economy (for example as intermediate inputs are sourced for construction activities). These effects are, however, counteracted by reduced consumption and the multiplier effects of lower consumption, as well as reduced investment in other parts of the economy (these effects are discussed in detail in the results chapter). This transmission mechanism is shown in more detail in Appendix D.

Following the construction of the scheme, investment demand from the aviation sector recedes to a steady-state level (which is slightly higher than before the construction of the scheme in order to fund ongoing maintenance requirements at the enhanced facilities). Similarly, the increased returns on capital attributable to the construction phase diminish, and funds flow back to consumption and other investment projects.

#### *4.7.3.2 Surface access construction costs*

Surface access construction is incorporated into the S-CGE framework in a slightly different way to airport construction costs themselves because of our simplifying assumption (discussed above) that surface access schemes are government funded.

The S-CGE model allows us to exogenously input government investment demand. On account of the "closure rule" required in the model which states that any government deficit must remain a constant proportion of GDP, the investment must be funded by reductions elsewhere in government expenditure. The government investment flows into the construction and other sectors, which in turn make further purchases, generating multiplier effects throughout the economy. These positive effects will be offset by the reduction in other government expenditure and the foregone multiplier impacts associated with that expenditure. As with the airport construction, the impact of surface access construction recedes following the completion of the construction scheme. In the long run, government consumption will be transferred to a small extent towards ongoing maintenance activities for surface access to the airport.

# Part II – Results

# 5 Interpreting the results

Part II presents the results of our S-CGE analysis. It is made up of the following chapters:

- Chapter 5 (this chapter) explains how the results should be interpreted and provides some important commentary regarding the degree of certainty associated with inputs used in the modelling;
- Chapter 6 presents the results and explains the economic mechanisms underlying them for the LGW 2R scheme;
- Chapter 7 presents the results and explains the economic mechanisms underlying them for the LHR NWR scheme; and
- Chapter 8 presents the results and explains the economic mechanisms underlying them for the LHR ENR scheme.

Chapters 6, 7 and 8 are intended to be read independently of one another. This does mean that anyone who reads more than one of the chapters will notice a degree of repetition in the structure of the exposition and the narrative relating to the economic mechanisms at play. In particular, for the two LHR schemes, the inputs and therefore the results are similar, and this is reflected in the similar narratives in Chapters 7 and 8. Schemes are considered in alphabetical order.

## 5.1 Interpreting the results

As described in detail below, in order to present the results, each scheme is compared to a "Do Minimum" baseline scenario for UK GDP growth. In this baseline, UK airport capacity does not increase. In the baseline, the economy grows at a steady-state growth rate of 2.75% per annum. This in is line with HM Treasury's (HMT's) trend growth rate assumption for GDP. Our understanding is that HMT's assumptions about the long-term growth rate for the UK economy include judgments about long-term infrastructure capacity – albeit with no specific assumptions about airport capacity[102].

We have not sought to model the Bank of England's "reaction function" i.e. we do not explicitly model any central bank response in the form of changes in monetary policy as a result of any changes in economic variables (such as GDP and inflation) due to airport expansion. In the future there may be other external economic factors that may amplify or depress these results which would also form part of any judgement that the Bank would exercise when considering whether to adjust interest rates. In any case, the inflationary implications in our results are relatively muted, and do not suggest that the Bank would need to respond.

In principle, it would be possible to devise separate macroeconomic baseline scenarios reflecting the possible different states of the economy associated with the different passenger scenarios. We have not pursued this since doing so would involve significantly more complexity and could introduce an additional source of uncertainty in assessing impacts, and would anyway be unlikely to have any significant influence on the results which are concerned with changes from the baseline scenario rather than the baseline itself.

Some of the effects give rise to multiple equilibria in the S-CGE model (an upper and a lower case). This phenomenon is described in Chapter 2 and Appendix B. The higher of these scenarios assumes that the increase in landing slots will stimulate additional competition, driving efficiency within the sector. The lower scenario instead assumes that the increase in capacity instead leads to an increase in monopoly power for incumbents, and subsequently lower efficiency. Economic theory and the current competition within the market suggest that the former of these is the more likely scenario. Unless clearly stated otherwise, all of the results presented in chapters 6, 7 and 8 relate to the equilibrium in which GDP is at its highest level. The results from the lower of the two equilibria generated by the model are not substantially different to the higher results in terms of GDP effects and both equilibria are shown in our discussion to show the sensitivity of our results.

The results from the S-CGE model should be interpreted as follows. The model projects forward a baseline scenario (illustrated in Panel A of Figure 5 below as an index) for the level of GDP. In the baseline scenario –

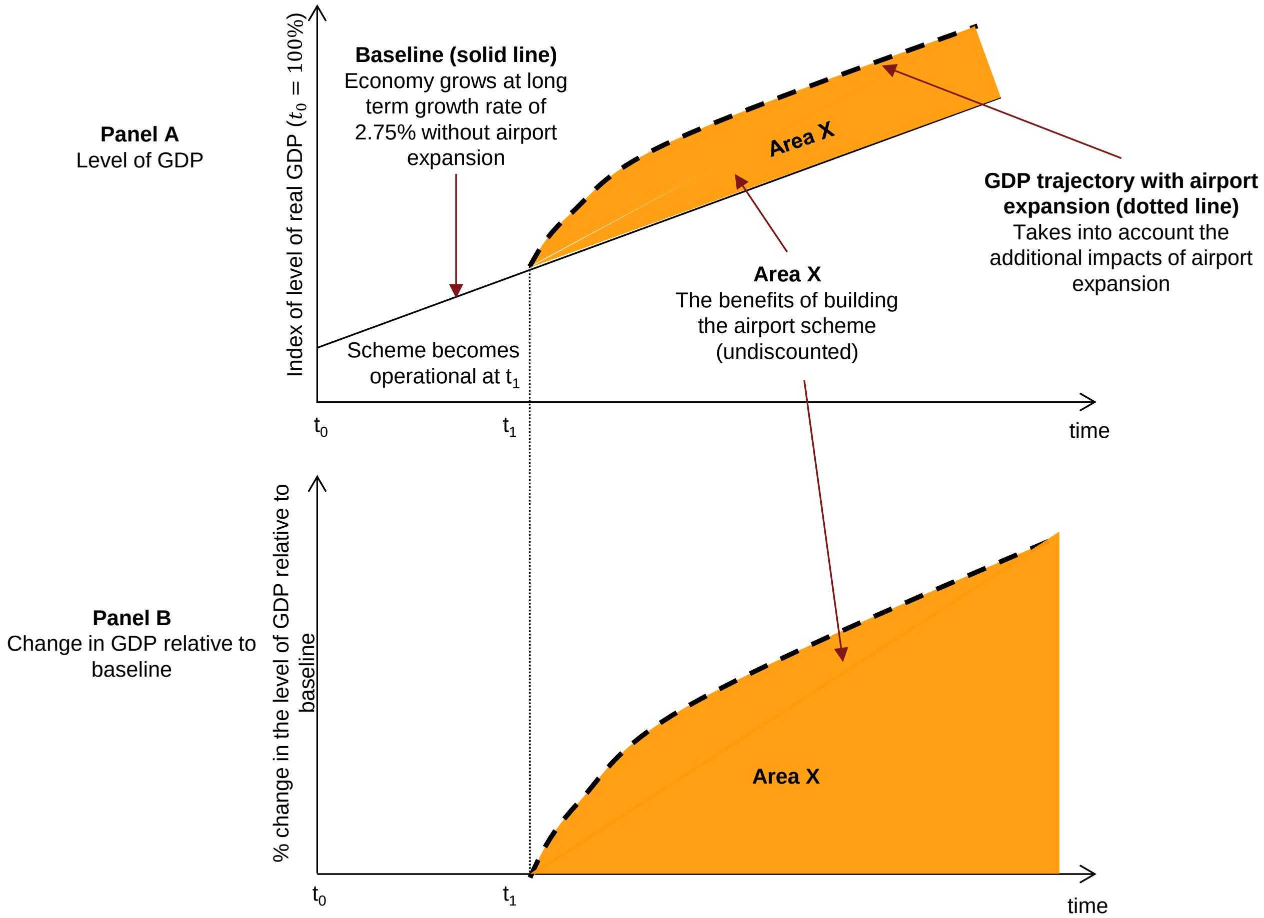
[102] We have used HM Treasury's long-term forecasts for GDP growth, rather than those of the Office of Budget Responsibility. The OBR's forecasts are based on a period which includes the recent financial crisis, whereas the HM Treasury forecasts do not take this effect into account. Given the very long-term nature of the analysis, the HM Treasury forecasts – which abstract from the effects of the recent financial crisis – are likely to be more pertinent. It should be noted that the results discussed in the next three chapters are largely unaffected by this result.

that is to say, in the absence of the scheme – GDP is assumed to grow at a constant rate. The scheme is assumed to open at time $t_1$. In the example in Figure 5, the positive economic effects of the airport scheme means that the economy moves to a new, higher GDP trajectory, represented by the dotted line. Area X – the area between the two trajectories – represents the value of the scheme over the appraisal period (without discounting).

In order to present the results clearly and to isolate the specific effects of the airport schemes, all results in the chapters which follow this one are presented **relative to the baseline scenario**. This is illustrated in Panel B of Figure 5. Panel B represents, in percentage terms, the change in GDP relative to the baseline scenario (so that area X in Panel A is equal to the area between the graph and the x-axis in Panel B). The results presented in the following chapters are for the change in the **level of real GDP** relative to the baseline scenario in any year or period: they do not represent changes in the growth rate of GDP.

The S-CGE model reports results at three-yearly intervals (six-yearly intervals where there are multiple equilibria). For intermediate years, we have calculated the results by linear interpolation. In addition, the S-CGE model only reports results for the 48 year period from 2019 to 2066. For the purposes of calculating Present Values (PVs) over a longer appraisal period, we have extrapolated the figures for the final years, assuming a constant percentage growth rate. At this point in the future the economy has reached a new equilibrium growth path, so this extrapolation can be made with a high degree of confidence.

*Figure 5: Interpreting the results*




*Source: PwC analysis*

In chapters 6, 7 and 8 we present figures for the forecast monetary boost to GDP (expressed as a PV in £s) for each of the three proposed airport schemes for each of the five different passenger flow scenarios. Given that we also report the size of the investment for each of the schemes as a PV in £s, it might be thought that the ratio of the additional forecast GDP to the size of the associated investment can be regarded as indicative of the scale of the benefits associated with each scheme relative to the costs.

**In fact, we have deliberately not calculated such ratios as we think that they are potentially highly misleading. Great care would need to be taken in their interpretation, and they should certainly not be compared with ratios derived in other types of transport infrastructure**

**appraisal in order to make inferences about the scale of the impacts we have calculated**. Instead, these results should be considered net of the capital cost, which is repaid by consumers over the appraisal period. We explain the appropriate interpretation of our results, and offer some observations on comparisons with other types of appraisal, in the paragraphs which follow.

Comparing the PV of additional GDP with the PV of scheme investment is valid in the sense that, if our forecasts of the GDP impacts are correct then, compared with the baseline scenario, our monetary estimates of additional GDP are directly associated with the additional cash spend on runway capacity. For any of the three proposed schemes under any of the five passenger flow scenarios we begin with the baseline scenario and no additional airport investment (beyond “Do Minimum” expenditure). We then introduce the additional airport investment associated with a particular scheme, and for any particular passenger flow scenario calculate forecast additional GDP. So the estimated additional GDP is directly associated with the additional airport investment.

However, it would be wrong to regard the additional GDP as resulting directly from the investment in an airport in the same way that, for example, additional output of widgets would result from investment in a widget factory. A key reason why GDP is expected to increase when airport capacity expands is that this new capacity is expected to improve the connectivity of the UK with other countries, to the benefit of a wide range of UK businesses, in the form of larger market opportunities and boosted efficiency.

Demand for transport is what economists term a “derived” demand – travel is not (normally) seen as an end in itself, but as a means to an end. Our research has suggested that there is a strong link between increases in the UK’s connectivity by air to other countries and increases in UK GDP and trade. So improving air connectivity acts as an “enabler” for sectors other than aviation to expand. This is the reason that the extent of GDP growth may appear large relative to the initial investment – compared with our widget example where the effect of investment was limited to increased production of widgets, here we consider the implications for the whole UK economy, in the context that air travel is an important determinant of market opportunity and efficiency.

Furthermore, in order for GDP to expand as much as predicted by our S-CGE model, businesses outside of the aviation sector must take advantage of the new opportunities open to them as a result of improved air connectivity by making their own investments and incurring operating costs associated with extra output. The overall forecast additional GDP figure is underpinned by significant investment that is additional to the initial airports investment, which is made across a wide range of businesses in the UK economy, incentivised by the new opportunities associated with improved air connectivity.

For this reason a calculation which expressed the additional GDP we have estimated as a multiple of only the additional airport investment would be highly misleading if compared with, for example, the ratio of the PV of revenue to the PV of investment in standard discounted cash flow appraisal, or the ratio of the PV of benefits to the PV of investment in transport cost benefit analysis. In our analysis we have calculated wider economic impacts as a result of the type of modelling we have performed, but importantly this modelling also implies wider investments made than the scheme investments themselves. The total GDP impact would not be achieved by investment in airport capacity alone without this “follow-on” investment (e.g. expanding capacity within the tourism sector to cater for the additional demand). If a comparison with ratios from other types of appraisal were to be attempted, this additional investment would need to be included in order for the comparison to be like-for-like.

Finally, it is instructive to consider what drives the overall scale of the projected GDP impact we have derived. There are three links between investment in an airport scheme and the GDP impact we have forecast:

1. The scale of the direct impact on aviation outcomes associated with new capacity needs to be forecast, in terms of the forecast effects on passenger journeys, via the cost of travel;
2. The aviation impacts in link (1) need to be input as effects into our S-CGE model. In some cases this is straightforward, in others we rely on proxy effects or econometric estimation; and
3. Once the effects in link (2) have been inputted, the S-CGE model generates implied GDP and other economic changes through its model structure and parameters.

PwC are responsible for links (2) and (3) and the AC for link (1).

With regard to link (2), this report describes in detail how we have reflected the aviation impacts from link (1) in the four effects used to generate results in our S-CGE model. The translation of impacts into effects does involve judgement. For example, in the case of Effect 2, the productivity benefit associated with better connectivity, we needed to derive an econometric relationship between air passenger flows and UK trade with other countries, and we used this to determine how to include the AC's passenger flow impact as an effect in our model, both in terms of the variables to be changed in the S-CGE model, and the scale of that change. In the case of Effect 4, TEE, we chose to model the implications of increased consumer surplus as a productivity change rather than, for example, a lump sum increase in household income.

Given the need for judgement, and the scope to have implemented the four effects differently or with an altered scale, the ultimate GDP impacts derived from the modelling are clearly influenced by the judgements we made in link (2). We set these judgements out clearly in this report. However, we have no reason to believe that our judgements or our choice of effect implementation have had a material impact in either direction on the final results.

With regard to link (3), clearly our S-CGE model can provide only a representation of the UK economy based on a series of relationships and assumptions. We have incorporated best practice in the design of our model, and the parameters within in it have been set based on actual historic figures or best practice assumptions. Nevertheless, judgement has been exercised, and different modelling choices would yield different results.

However, we have no reason to believe that the S-CGE modelling itself in step (3) has resulted in any exaggeration in the overall GDP impact calculated. Indeed, an important benefit of using a CGE approach is that it imposes consideration of important diffusion effects – for example, as activity increases (perhaps because of an increase in air passenger expenditure) there is competition amongst firms for resources to enable increased output, which forces prices and wages up, with generally offsetting implications for activity. Because of this, in the majority of cases in our modelling the impact of including an effect in our S-CGE model is for a multiplier of less than 1 – in other words, if we input £1 as an additional effect, it results in a less than £1 increase in additional GDP, due to diffusion effects.

Given that we have no reason to think that our assumptions and modelling in steps (2) and (3) are likely to have introduced any unwarranted increase in modelled GDP impacts, this implies that the scale of the GDP effects forecast are largely driven by the AC's forecasts of significantly increased aviation activity in step (1), combined with the positive relationship we have found between air connectivity and economic growth. The precise nature of this GDP impact will then be determined by the economic linkages established within the model.

In summary, projected wider economic impacts are forecast to be significant because the airport schemes are expected to have significant impacts on the numbers of passenger journeys, on air fares and on journey times. Given the scale of these, the effects that air transport has as an "enabler" of activity in other sectors of the economy, and the siting of the new capacity next to one of the world's largest cities and with its connections to the wider UK economy, it is reasonable that a CGE model approach will predict significant additional GDP impacts.

Finally, our main assessment is of the wider economic impacts associated with the operation of the enhanced airport capacity, although for completeness we do also consider the economic impact of construction. This emphasises that the GDP impacts we model are not associated simply with demand-side effects of expenditure on airport scheme construction. Furthermore, where we do model the implications of the construction phase of a scheme, we assume that the funding of the additional airport capital expenditure must be diverted from other parts of the economy – we assume an economy at near full employment, and do not assume that the additional airport capital expenditure represents a net addition to the UK economy's resources (e.g. we do not assume it is funded by increased foreign direct investment in the UK).

## *5.2 Key effects and model features*

The AC work on the implications of the proposed airport schemes for aviation travel include three key impacts with likely macroeconomic consequences which we have reflected in our modelling:

- The removal of a runway capacity bottleneck in the South East will allow **more passenger flights to and from a wider range of destinations**. In our model we reflect this in two ways:
  - in **Effect 1**, we model how these additional journeys are likely to change passenger expenditure patterns; and

- in **Effect 2** we model the potential implications of the implied boost to productivity associated with the improved connectivity that UK firms will have with overseas firms and markets.

- The greater numbers of flights and destinations, together with the provision of more spare capacity which should improve operational reliability, will result in **a reduction in effective journey times for air passengers**. In our model we reflect this:

  - in **Effect 3**, where we model the effects of the potential boost to productivity associated with the AC's estimates of frequency benefits for business passengers.

- The removal of the runway capacity bottleneck is expected by the AC to result in **lower air fares** as airlines are less able to charge premium prices for congested peak services. In our model we reflect this:

  - in **Effect 4**, where we model the potential implications for changes in expenditure and other key economic variables as a result of the gains to air passenger consumers (offset by some losses for airline shareholders).

Since the purpose of this work is primarily to understand the long-term impact of the schemes as a result of the improved aviation linkages, our principal focus is on the operational effects described above. However, there are also impacts associated with the construction of the schemes. In our model we assume that the construction is funded £1 for £1 by diversion of resources from elsewhere in the economy (mainly private consumption, but some private investment and public investment for surface transport)[103]. In principle, since the economy is assumed to be near to full employment in the baseline scenario, and hence resources must be "diverted" towards construction of new airport capacity from other activities, the overall impact of constructing the airport could be to increase GDP, reduce it, or have little or no effect. It is therefore instructive to use the S-CGE model to understand how construction of the schemes may, in itself, impact on the economy. In particular therefore, we investigate the impact of incremental capital associated with the airport schemes and the incremental cost of providing the surface access.

The fact that construction impacts are characterised by diverting resources from one part of the economy to another (as described in the last paragraph) is an example of a general principle in our modelling: we do not provide a "free lunch", with many of the impacts we describe being counteracted by effects that work in the opposite direction. Other examples include recognition in the model that:

- Some of the extra flights enabled by the schemes will actually have the potential to diminish GDP by, for example, allowing British residents more and cheaper opportunities to spend abroad rather than at home;

- Whilst the lower economic rents extracted by airlines as a result of the schemes (predicted by the AC demand forecasting model) are likely to boost consumer spending power, simultaneously the profitability of the airline sector is reduced and airline shareholders (who are assumed to be UK households in the S-CGE model) are made worse off; and

- To the extent that enhanced airports capacity boosts demand and activity, there is a danger that this could result in inflationary pressures and/or benefit London & South East at the expense of other parts of the UK. Both of these factors are captured in our analysis.

Our modelling explicitly considers whether the offsetting effects described above will occur, and if so their extent, and provides insight into the "net" impacts of the various effects. The results that we obtain – including that there will likely be a significant positive GDP impact that is spread across the UK (see Part II) – result from:

- The relative "multiplier" effects of the new pattern of expenditure and investment;

- Productivity boosts associated with better connectivity and time savings; and

[103] This means, for example, that the funds used to build the airport must ultimately be repaid, and households and firms in the model recognise this and make their consumption, production and investment decisions in light of that information. The model therefore has what economists might call "Ricardian" properties, following the 17th century economist Ricardo who emphasised similar points in the context of governments' long-term tax and expenditure policies.

- The knock-on implications for different regions of the UK as the economy moves to a new equilibrium reflecting the changed pattern of economic activity.

Crucially, our modelling allows the following impacts to be modelled which are not usually reflected in conventional appraisal methodologies:

- Secondary economic impacts – not just direct user impacts, but also the knock-on implications for prices, productivity, employment, the capital stock and so forth;

- Dynamic impacts – the S-CGE model simulates the linkages in the economy over time, so that the full ramifications of direct and secondary impacts can be obtained. We take into account potential crowding-out and diffusion effects (such as changes in prices which offset an initial impact) explicitly;

- Regional impacts – using a S-CGE model allows us to model the dynamic impacts at a sub-national level, taking into account agglomeration effects and allowing us to evaluate likely impacts on different regions; and

- The impacts of imperfect competition– the S-CGE model allows us to depart from the conventional assumption in scheme appraisal of perfect competition, and to capture the real world implications of how most markets in the economy are characterised by effective but imperfect competition.

It should be noted that each of the effects described above will have both supply-side and demand-side features. For instance, if under Effect 1 passenger spending increases, then this will benefit businesses in sectors which fulfil the demand of visitors to the UK (e.g. hotels, restaurants etc.) on the demand-side, which in turn will feed through to demand in other sectors of the economy as businesses in the sectors that fulfil demand of visitors to the UK demand more inputs in order to carry out their activities. But there will also be a supply-side effect as the sectors increase investment and more individuals work (and work for longer) in order to meet this additional demand. The more predictable and longer-term this increase in demand is, the greater the incentive there will be for businesses to invest and individuals to enter the labour force, rather than for increased demand to result in increased prices. Similarly, if productivity increases, as per Effect 2, then there will be a supply-side effect associated with increased business investment and greater employment, but also a demand-side effect as households gain from cheaper and/or better quality goods. With Effects 3 and 4, we adjust productivity in the model in a manner that replicates the supply-side impact of business passengers being able to travel with lower effective journey times and the demand-side impact of passengers being assumed to fly more cheaply.

## *5.3 Levels of certainty in model inputs*

It is important to understand the possible sources of uncertainty associated with the model findings. There are two fundamental categories of uncertainty in the outputs of the S-CGE model:

1. **Model input uncertainty.** This is uncertainty associated with the inputs to the model, for example in relation to passenger flows and frequency benefits; and
2. **Within-model uncertainty.** This is uncertainty from assumptions made in the construction of the model itself and associated with the parameters which determine the model’s behaviour. For example, there are different estimates in the academic literature for the “intertemporal elasticity of substitution” (which describes how willing consumers are to forego current consumption in exchange for increased consumption in the future) and adopting different assumptions could lead to different results from the S-CGE framework.

The second source of uncertainty is investigated in detail in chapters 6, 7 and 8. The first source of uncertainty is also important and there are different levels of certainty associated with the various input effects described above.

Some key considerations with regard to the uncertainty of model inputs are as follows:

1. **Measurability: Can the input be readily observed and measured?** The ability to measure a variable with confidence – even if only ex-post – is important in determining the certainty associated with an input. For example, if the variable being used as an input can be easily measured, historic experience can be used to guide forecasts for the future and ex-post data can be used to assess whether the predicted impacts have been realised;

2. **Modelling approach: What is the level of certainty surrounding the modelling approach used to generate the inputs?** The more robust the modelling approach used to generate the inputs, the great confidence can be attached to the resulting outputs emerging from the framework; and

3. **Model incorporation: Can the inputs be incorporated into the model directly and with relatively few assumptions?** As described in Chapter 4, some of the effects can be readily and directly incorporated into the S-CGE framework. Others, on the other hand, have to be integrated into the model by making certain assumptions, which reduces confidence in their use as inputs to the framework. Table 9 below summarises the uncertainty associated with the various inputs.

*Table 9: Levels of certainty in model inputs*

| | Measurability | Modelling approach | Model incorporation |
|---|---|---|---|
| **Passenger flows** | Passenger flow data are derived from the AC demand forecasts. Passenger flows are easily measured and current and historic levels of passenger flows can be used to test forecasts. | Although there are significant challenges associated with forecasting passenger flows and there are different passenger scenarios, the AC has substantial capability in the area and we understand that their forecasts have been discussed in some detail with the Scheme Promoters. | Passenger flows can be incorporated directly into the S-CGE framework, which has been designed specifically with international movements in mind, and with minimal assumptions. For the purposes of the S-CGE modelling, it is necessary to convert passenger flows into expenditures using information derived from Tourism (including business flows) Satellite Accounts. This adds a further layer of uncertainty. |
| **Productivity** | Productivity is a readily observable and measurable economic variable (for example the value of output produced by a given unit of labour). | In our modelling approach the impact of greater connectivity is captured by an econometric relationship between passenger numbers and trade (described in Chapter 4 and Appendix C) with productivity being "shocked" to deliver trade at the level suggested by this relationship. Although these econometric results and the way in which they are incorporated into the model appear robust and have been validated through peer review, this introduces a source of modelling uncertainty. | Incorporating productivity effects into the S-CGE framework is a simple process which involves changing a single parameter in the model, representing total factor productivity (the coefficient on the production function, see Appendix B). |
| **Frequency benefits** | In contrast to passenger flows and productivity (and construction expenditure, considered below), frequency benefits are conceptual and are not directly observable. | The modelling approach also introduces uncertainty since benefits must be estimated by making assumptions about the nature of passenger demand, albeit on the basis of empirical research, and changes in passenger numbers. | The process of incorporating frequency benefits into the S-CGE model requires that we assume that frequency benefits to firms manifest themselves as increased productivity. Whilst this assumption seems reasonable, it does introduce an additional layer of uncertainty. |
| **Transport economic efficiency (TEE)** | Like frequency benefits, TEE effects are not directly observable. | The modelling approach introduces uncertainty since the impacts on consumer and producer surplus must be estimated by making assumptions about the nature of demand and supply, and the effects on fares of new capacity. As discussed in Chapter 4, the impacts of higher airport charges have been considered in the AC airline competition and cost and commercial work, but are not explicitly fed into the TEE inputs provided by the AC for the purposes of this work. In reality increased airport charges, which could then be passed on to consumers in the form of higher fares, could offset part or all of the TEE effect. | The steps required to incorporate the TEE impacts into the S-CGE framework necessitate a number of assumptions. In particular, we must (i) adjust the baseline GVA of the aviation sector in order to ensure that the sector can accommodate the implied reduction in producer surplus, and (ii) assume that the increase in consumer surplus is regarded by consumers as an increase in real income so that it is "spent". We then incorporate TEE effects through a change in TFP which, whilst not the obvious approach intuitively, provides the best way of modelling without imposing artificial or overly prescriptive assumptions about consumer behavior. |
| **Construction** | Construction costs are clearly measurable, and historic information can be used to generate forecasts for construction costs (which can be supplemented with adjustments for risk, optimism bias and other factors). | Although there is a degree of uncertainty around the construction cost figures, a considerable amount of work has been done to prepare them. | As described in Chapter 4, the process for incorporating construction costs into the S-CGE framework is very direct as the model has been designed to account for effects of this kind. It is, however, worth noting that our approach generates results which are different to a standard Green Book approach. |

*Source: PwC analysis*

# 5.4 Output elasticities & multiplier analysis

## 5.4.1 Output elasticities

In the most general terms an output elasticity measures the response of GDP with respect to a change in inputs. Output elasticities are widely applied in terms of calculating transport infrastructure impacts. In this section we explore the scope and relevance of these applications to our analysis of the wider economic impacts of airport expansion.

There are two critical elements that must be considered when deriving output elasticities:

1. **Defining the change in inputs**: the scope of what is embodied as an input in terms of generating a GDP response.
2. **Defining the change in outputs:** the standard output is GDP, but how is this GDP impact calculated? In many instances the GDP impact is calculated on a partial equilibrium basis as opposed to a general equilibrium basis i.e. it does not account for market interactions outside of the transport sector.

In the transport infrastructure context output elasticities are usually measured through regression techniques. The regressions tend to take a standard Cobb-Douglas form (Melo *et al.* 2013)[104]:

$$lnY_{i,t} = \beta_L lnL_{i,t} + \beta_K lnK_{i,t} + \sum_Z \beta_Z lnZ_{i,t} + \beta_T lnT_{i,t}$$

Where:

$Y_{i,t}$ is output in region $i$ at time $t$;

$L_{i,t}$ and $K_{i,t}$ represent labour and capital inputs;

$Z_{i,t}$ represents a Hicks neutral shift factor picking up broader factors relating to the economic environment such as agglomeration or educational attainment; and

$T_{i,t}$ is investment in transport infrastructure. The regression coefficient, $\beta_T$, represents the output elasticity.

We do not provide a detailed discussion of this extensive evidence base (although a more thorough exposition is given in Annex E). We do however, recognise its importance in determining the economic linkages between transport infrastructure and GDP and much of the work has been summarised already. Melo *et al.* (2013) have conducted meta-analysis[105] based on 563 elasticity estimates and were able to consider different types of transport infrastructure as well as geographic variation. They report an output elasticity of 0.027 for aviation i.e. a 1% increase in aviation infrastructure capital leads to a 0.027% increase in GDP. This is based on a sub-sample of 26 studies all undertaken prior to 2008. Other similar studies and estimates exist, one of the more sophisticated studies has been conducted by Calderón *et al.* (2015)[106] which finds that the long-run elasticity of output with respect to the synthetic infrastructure index ranges between 0.07 and 0.10.

These estimates are a useful guide as to the potential impacts of transport infrastructure investments - Calderón *et al.* seek to take account of private sector contributions Melo et al. are more focused on government investment.  Given that each of the airport schemes considered in this study are funded using private sector capital (albeit supported by government funded surface access schemes).

In the regression form defined above these estimates are conducted within a 'partial equilibrium' framework which explores relationships between variables assuming everything else remains constant (this is referred to as the *ceteris paribus* assumption in economic theory). This means that the change in inputs or outputs in these regressions do not fully account for all of the wider economic effects of airport expansion. For instance, our modelling will show that there are substantial knock-on effects into other sectors of the economy e.g. tourism, manufacturing etc. Take the tourism sector for example, the knock on effect could occur through growth in

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[104] Patricia C. Melo, Daniel J. Graham, Ruben Brage-Ardao, "The productivity of transport infrastructure investment: A meta-analysis of empirical evidence", *Regional Science and Urban Economics*, Volume 43, Issue 5, September 2013, Pages 695-706

[105] Meta-analysis comprises statistical methods for contrasting and combining results from different studies in the hope of identifying patterns among study results, sources of disagreement among those results, or other interesting relationships that may become known in the context of multiple studies.

[106] Calderón, César, Enrique Moral-Benito, and Luis Servén (2015) "Is infrastructure capital productive? A dynamic heterogeneous approach." *Journal of Applied Econometrics* 30.2: 177-198.

hotel capacity resulting from higher tourism demand associated with greater aviation capacity and the subsequent contribution of that hotel capacity to GDP. Output elasticities estimated using the *ceteris paribus* assumption, do not account for these knock-on effects.

It could be possible elements of this hotel expansion capacity could be picked up in the $Z_{i,t}$ parameter presented in the regression specification above. But this would be a very ad hoc and rather inaccurate way of estimating an output elasticity. It would be better to account for the labour costs and associated capital investment associated with the hotel expansion to be added to the input side of the regression in the corresponding $L_{i,t}$ and $K_{i,t}$ parameters. However, after exploring the most recent academic literature in this area we have found no evidence of this linkage being applied.

Therefore, because of the omission of these knock-on effects and the partial equilibrium nature of the elasticities it means that much of this corresponding academic literature is therefore not comparable with the estimates produced in this report.

### *5.4.2 Multiplier analysis*

Finally, a useful approach for evaluating the results from the modelling is to evaluate the scale of the multiplier effect that the S-CGE model generates. Multipliers can take various forms (e.g. ratio of change in gross value added attributed to the airport scheme to total construction costs, ratio of change in employment to change in passenger numbers etc.).

Multipliers are the ratio of the present value (PV) of the inputs in the model, to the PVs of the outputs, and they capture the degree to which the input has been fully passed through to a positive GDP impact. They also reflect second-round impacts of the inputs, through the supply chain and employee expenditure. After releasing the initial version of this report, the Airports Commission requested that we provide greater detail on the size of the multipliers coming out of the analysis. This greater detail is provided in Appendix E.

Another way of looking at output elasticities is through the lens of the fiscal multiplier – a basic definition of a fiscal multiplier is provided by Spilembergo *et al.* (2009)[107] as a change in GDP brought about by a change in government expenditure. They note that as a rule of thumb the government spending impact multiplier, based on an extensive literature review, in large countries is between 1 and 1.5. In 2010, the Office for Budget Responsibility applied a fiscal multiplier of 1 for the impact of capital spending.[108] They note that slightly larger multipliers might be expected from investment spending. It should be noted that all of the multipliers generated by the S-CGE model are lower than 1, these are shown separately in the results chapters, while the multipliers literature is reviewed in more detail in Annex E. Our multipliers also do not correspond directly to government capital expenditure – we have pointed out above that the schemes will be financed privately – nonetheless, fiscal multipliers can still make a useful point of comparison as they are often estimated using models that have structural general equilibrium features, unlike the partial equilibrium approaches of the output elasticity technique described above.

[107] Spilimbergo, Mr Antonio, Mr Martin Schindler, and Mr Steven A. Symansky.*Fiscal multipliers*. No. 2009-2011. International Monetary Fund, 2009.

[108] Office for Budget Responsibility (2010) Budget Forecast http://budgetresponsibility.org.uk/wordpress/docs/junebudget_annexc.pdf

# 6 Gatwick Airport Second Runway results

This chapter presents the results of our analysis of the LGW 2R scheme and describes the underlying transmission mechanisms through which the various effects described in previous chapters are forecast to impact on the economy. The chapter proceeds as follows:

- Section 6.1 provides a summary of the results;
- Section 6.2 presents the total GDP impacts;
- Section 6.3 sets out the Present Values of the GDP impacts;
- Section 6.4 explains the drivers of the GDP impacts;
- Section 6.5 sets out the impacts by region;
- Section 6.6 presents the construction impacts;
- Section 6.7 provides the results for other economic impacts; and
- Section 6.8 describes a number of sensitivities.

## 6.1 Summary of results

This section provides an overview of some of the key results emerging from the S-CGE framework for the LGW 2R scheme and describes, at a high-level, the underlying economic mechanisms that drive the results. Depending on the passenger flow scenario, by 2050, the level of GDP is forecast to be around 0.2% to 0.6% higher than in the baseline scenario (as discussed in Chapter 5, the economy is assumed to grow at 2.75% in per annum in the baseline scenario, which is consistent with HM Treasury's long-term growth assumptions). This is a result of changing net inbound passenger flows[109], increased net trade, and higher consumption and investment. In the Assessment of Need scenario, the scheme is forecast to create approximately 50,000 new jobs in 2050 (of which, approximately 45% are at the airport itself). Each of the regions of the UK considered in this analysis (London & South East, the Rest of England and the Rest of the UK) are expected to experience increases in GDP as a result of the scheme, the extent of the gain depending on the passenger flow scenario considered.

### 6.1.1 Phases of impacts

The forecast impacts of the LGW 2R scheme are experienced in two broadly defined phases:

1. The **construction phase**, during which the economic impacts are principally associated with the building activities of the scheme; and
2. The **operational phase**, during which the construction impacts fade but other economic impacts – notably passenger flow, productivity, frequency benefits and TEE (Transport Economic Efficiency) effects – are felt.

For the LGW 2R scheme, the construction and operational phases overlap to a significant extent. The construction phase of the LGW 2R scheme is assumed to be relatively prolonged, lasting from 2016 to the mid-2040s, and consists of three separate sub-periods of heightened activity (the first of which peaks in 2022, the

[109] i.e more of the additional passenger journeys associated with the scheme originate outside the UK than within the UK.

second in 2037 and the third in 2045). More specifically, Gatwick Airport Limited has proposed a phased construction of the scheme's terminal infrastructure in line with demand. While the AC has assumed a runway opening date of 2025, the terminal infrastructure would be delivered in a number of instalments. Different demand scenarios produce different construction profiles. Under low demand scenarios, the final construction phase may not occur prior to 2050.

In order to provide a summary of the overall progression of the LGW 2R scheme over time and its forecast wider economic impacts, we consider the impacts in the construction as well as the operational phase of the scheme. In later sections of this chapter, the main emphasis is on the forecast impacts of the scheme excluding construction, since we are primarily interested in the long-term effects of the enhanced aviation linkages created (although we reintroduce construction impacts towards the end of the chapter for completeness).

### *6.1.2 Construction phase effects*

The first forecast impact of the scheme occurs as a direct result of the construction activities. Clearly the construction impacts do not, in themselves, provide reasons for undertaking the scheme. However, the S-CGE model suggests that diverting[110] available resources of the economy towards constructing the airport may have significant economic impacts in its own right.

We assume that the scheme itself is funded wholly by the domestic private sector (although surface access improvements are assumed to be funded by government for the purposes of this report, see below). Therefore, whilst the construction sector expands, this will be offset by reductions in activity elsewhere in the economy. Higher investment returns than those in other parts of the UK economy would be needed in order to attract investment to the scheme which: (i) would encourage households to increase their saving (at the expense of consumption) and (ii) would draw in funds that would otherwise be invested in other projects (although past experience, on which the model is based, suggests that the impact on investment in other projects should be modest).

Airport investment boosts the overall demand for construction. There is a positive multiplier effect that is associated with this expansion[111]. However, there will also be a reduction in both consumption and other forms of investment as the investment funding has to be found from elsewhere in the economy, offsetting the previous effects, as described above. This generates an offsetting negative multiplier effect. In addition to this, in the long-term, borrowers would also have to pay back this money in the future which also generates a negative multiplier.

The overall or "net" effect of shifting the economy towards construction depends on the strengths of the two opposing effects described in the preceding paragraph. The model, and the evidence on which the multipliers are based, suggests that the net impact is to increase GDP, since the positive effects of expanding the construction sector outweigh the negative effects of contractions elsewhere. Our modelling suggests that re-orientating the economy towards building the LGW 2R airport scheme might increase GDP by around 0.1% in 2022 (the first and largest of the three construction phases).

The construction multiplier implied by the ONS UK Supply Use Tables, which are the basis for the S-CGE model, is higher than those for other sectors – this is because the import content of construction is relatively low, and construction has strong inter-linkages with some high value added sectors. The forecast construction impacts of LGW 2R are effectively the same across the different passenger flow scenarios, since the assumptions for construction costs and phasing are invariant with respect to these scenarios.

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[110] We use the phrase 'diverting' to emphasise that resources for construction of the scheme must come from elsewhere in the economy in the S-CGE framework.

[111] It should be noted that not all of the investment taking place comes from the construction sector. Other sectors will invest too. This is because the economy assumes 'perfect foresight' and rational expectations. This means that agents will make an expectation of the future benefits of the new airport. The S-CGE model tends to front load this investment in the results (as it would be rational for agents to take action to capitalise on the gains associated with the expanded runway as early as possible). However, in reality agents may not operate with perfect foresight and rational expectations so we might expect this effect to be more muted and spread out over a longer period of time.

The PV of the GDP impact is forecast to be £3.4bn over the 60 year appraisal period (the figure for construction is very similar across the scenarios), compared to costs of £11.1bn[112]. This implies that for every £1 of expenditure on the LGW 2R scheme, GDP is forecast to increase by around £0.30 on a present value (PV) basis.

### *6.1.3 Operational phase effects*

The operational phase for LGW 2R is scheduled to commence immediately after completion of the first construction phase in 2025, and it is in this phase that the long-term economic impacts associated with passenger flows, productivity, frequency benefits and TEE are first felt.

At the outset of the operational phase, there is a small forecast reduction in GDP of up to 0.4% (depending on the scenario), relative to the baseline scenario. This occurs because households in the model are assumed to be "rational" (make decisions that maximise their welfare) and "forward-looking" (consider their future wellbeing as well as current). In particular, households foresee that the airport expansion will have a positive effect on whole economy GDP once the scheme becomes fully functional. They therefore anticipate increased returns in the future. In order to capitalise on higher returns across the economy, households reduce their consumption in the short-term in order to increase savings, which results in a temporary and modest contraction in output.

It is difficult to be sure whether this effect will materialise in reality and it is possible that the effect will be less pronounced than that implied by the model. However, the assumption of "forward looking" households has been thoroughly investigated within the academic literature and has sound theoretical underpinnings, and in any case is relatively small and transitory.

We now turn to the operational phase effects (passenger flows, productivity, frequency benefits and TEE), and consider the mechanisms through which they may have an impact on GDP, and set out the high-level forecasts implied by the model.

*Passenger flow effects*

One of the most palpable effects expected once the scheme becomes operational is an increase in UK passenger expenditure outside of the UK and foreign passenger expenditure in the UK. Increased passengers flow expenditures have **direct demand-side effects** that have an impact on GDP – they result in changes in spending by visitors to and from the UK that "flow through" the economy[113]. UK passenger expenditure outside of the UK and foreign passenger expenditure in the UK have opposing impacts on GDP:

- UK passenger expenditure outside of the UK represents foregone consumption in the UK. UK passenger expenditure outside of the UK therefore represents a "leakage" from the UK economy, which reduces UK GDP. The S-CGE model suggests that domestic GDP is relatively sensitive to outbound passenger expenditure – the "**UK passenger expenditure outside of the UK multiplier**" is relatively large. This is because the consumption foregone in the UK – for example, a household appliance which is not bought in the UK as the UK resident instead spends the money on meals and accommodation abroad – has strong supply chain linkages into the domestic economy; and

- Foreign passenger expenditure in the UK increases GDP since it increases UK aggregate demand. However, the S-CGE model suggests that domestic GDP is less sensitive to inbound expenditure – the **"foreign passenger expenditure in the UK multiplier"** is relatively small. This is because the inbound expenditure – spending, for example, on accommodation and restaurants in the UK – has weaker linkages into the wider UK economy.

These expenditures also have important "diffusion" effects which dampen the impacts described in the bullet points above. For example, the foreign passenger expenditure in the UK increases prices in the UK, for instance,

[112] As set out elsewhere in this report, this assumes a 60 year appraisal period with a discount rate of 3.5% for the first 30 years and 3.0% for the remaining 30 years.

[113] We refer to the passenger flow effects as "demand-side" impacts from international movements of visitors, since they are not associated directly with changes in the productivity of firms (except to the extent that changes in demand may increase or reduce scale economies, generate incentives to invest or otherwise endogenously affect productivity).

for accommodation and other goods and services used by visitors and domestic residents, which reins in the overall level of demand.

While the inbound passenger expenditure multiplier is relatively small, inbound passenger spending still provides a boost to the UK economy. It is an important source of foreign exchange and is equivalent to an exported good or service in this sense. This effect occurs on the demand-side of the economy: inbound passengers spend money on a range of goods and services in the UK economy (e.g. hotels, restaurants, retail sector etc.) Increased flows of "exports" can have important supply-side effects. The sectors of the economy associated with inbound passengers will expand as a result of the increase in spending and these sectors will need to hire more workers and invest more to support any expansion. Sectors which service inbound passenger demands are important for the UK economy as they provide a range of low-skilled and school leaver jobs and can facilitate working on a part-time basis. These types of jobs are often taken up by the long-term unemployed. If sectors which service inbound passenger demand expand, this can also have positive upstream effects for those sectors that supply goods and services to this sector (e.g. the manufacturing or agriculture sectors). Overall the model suggests a small, but permanent increase in productivity resulting from the supply-side expansion associated with inbound passenger demand.

During the first 15 years of operations the AC forecasts that passenger flows associated with the LGW 2R scheme will increase (15.5m additional passengers are forecast to use the UK system by 2050 in the Assessment of Need scenario). The increase in foreign passenger expenditure in the UK (£3.0bn per annum compared to the baseline scenario in 2040 in the Assessment of Need scenario) is forecast to be somewhat larger than the increase in UK expenditure outside of the UK (which is forecast to increase by around £2.1bn per annum on a comparable basis). A full description of the underlying reasons is provided later in this chapter.

Although the foreign passenger expenditure in the UK is estimated to be somewhat larger than the UK expenditure outside of the UK for the LGW 2R scheme in 2040, the difference is relatively modest. Since the model suggests that the UK passenger expenditure outside of the UK multiplier is greater than the foreign passenger expenditure in the UK multiplier, the net impact of the passenger flow effect is to reduce GDP by a small amount in 2040 (the reduction in GDP is approximately 0.03% in the Assessment of Need scenario). Subsequently, inbound flows increase by more than outbound flows (by 2064 inbound expenditure is forecast to be £6.6bn and outbound expenditure is forecast to be £4.5bn). This means that, by 2064, the net impact on GDP of passenger flows is forecast to be positive (in the Assessment of Need scenario).

The PV of the passenger flow impact for LGW 2R is forecast to be a decrease of between £2.3bn and £42.8bn over the 60 year appraisal period, depending on the scenario (the PV is negative across the scenarios because, as noted above, the net effect becomes positive towards the end of the appraisal period). The absolute magnitude of the PV is highest in the Low Cost is King scenario (i.e. it is most negative in this passenger flow scenario), and lowest in the Assessment of Need scenario (i.e. it is least negative in this passenger flow scenario). These results are driven by the number and type (e.g. inbound or outbound, short-haul or long-haul etc.) of passenger.

*Productivity effects*

Improved aviation linkages can improve firms' productivity in a number of ways. For example, better aviation linkages may enable firms to access larger markets, allowing them to exploit scale economies. Less tangibly, but also importantly, by being able to access foreign markets more readily, aviation linkages could allow firms to "learn" from customers and competitors in other countries, helping them to exploit technologies and adopt more efficient "ways of working" (these effects form the basis of the so-called "endogenous growth" literature which has revolutionised the way economists think about how economies grow). Similarly, by facilitating international trade, aviation linkages can allow firms to increase their productivity by importing more efficient equipment and technology from abroad.

An increase in productivity has a direct positive impact on GDP: firms can produce more output for a given amount of resources used as inputs. At the "microeconomic" level (i.e. at the level of individual firms) higher productivity means that it becomes profitable for firms to produce output that was previously unprofitable, so that firms increase the amount they produce. This productivity improvement may be experienced across the economy, and not just by firms in the immediate vicinity of the airport.

In a "partial equilibrium" framework, the effects would end here. In the S-CGE model, however, a number of indirect impacts also come in to play. On the supply-side, firms pass on their increased efficiency to consumers and other producers in the form of lower prices. In addition, increased productivity places upward pressure on wages since workers become more efficient (and hence more valuable to firms), which in turn attracts people into work and reduces unemployment. Both of these effects place further upward pressure on real GDP. On the demand-side, the higher output produced by firms increases demand for intermediate inputs, which also increases GDP.

As with the passenger flow effect, there are also diffusion impacts – effects which limit the net impact on GDP due to use of scarce resources. The increases in GDP result in higher aggregate demand which places upward pressure on prices. This dampens the size of aggregate demand increases and it is this increase in prices that ultimately keeps the economy "in check" and prevents economic activity from spiralling ever-upwards.

Turning to the results, our model forecasts that the productivity effect associated with the LGW 2R scheme may develop relatively slowly, since the effects are cumulative and it takes time for them to permeate the economy. Ultimately, however, the productivity effect is forecast to be the largest of all of the effects considered in our analysis for the LGW 2R scheme. In 2035, the productivity effect is forecast to add between 0.0% and 0.4% to the level of UK GDP, increasing to around 0.1% to 0.4% by 2050 (depending on the scenario). The model suggests that for every additional £1 incorporated into the model as increased productivity, GDP increases by £0.80 in 2050, in the Assessment of Need scenario. The primary reason for the "multiplier" being less than one is that the diffusion impacts of price increases suppress demand and GDP.

The PV of the productivity impact is forecast to be between £17.9bn and £90.3bn over the 60 year appraisal period (depending on the scenario). The PV is highest in the Low Cost is King scenario, and lowest in the Global Fragmentation scenario, reflecting the differing magnitude of passenger flows between the two scenarios (which drives the size of the productivity impact, see Chapter 4).

*Frequency benefits*

Greater frequency of services can increase firms' productivity, for example by enabling travel at more efficient and/or convenient times, thus reducing the effective travel time. We only consider frequency benefits accruing to businesses – frequency benefits to leisure travellers have been excluded from our analysis since it is unclear whether they will impact directly on GDP. Frequency benefits are an additional, albeit relatively modest, source of economic gains associated with the LGW 2R scheme[114].

Since frequency benefits increase business productivity, the transmission of the effect through the economy is very similar to that described above for the productivity effect. In particular, there is a direct impact as firms are able to increase the amount they produce for a given level of inputs, but there are also indirect effects as the economy responds dynamically (for example as wages increase, as described above). As with the productivity effect described above, diffusion effects ultimately mean that prices rise and keep the economy in check.

The results of the S-CGE model suggest that the frequency benefit effect to businesses associated with the LGW 2R scheme may add between 0.0% and 0.1% to the level of UK GDP by 2050, depending on the scenario. The model suggests that for every additional £1 incorporated into the model as frequency benefits, GDP increases by £1.20 in 2050, in the Assessment of Need scenario.

The PV of the frequency benefits impact is forecast to be between £2.7 and £10.0bn over the 60 year appraisal period (depending on the scenario). The PV is highest in the Global Growth scenario, and lowest in the Global Fragmentation scenario, reflecting the differing magnitude of passenger flows between the two scenarios.

*Transport Economic Efficiency effects*

TEE is the final effect examined in the analysis. Input data provided by the AC assumes that the relaxation of the capacity constraint in the UK aviation sector means that airlines are able to extract less "economic rent"

[114] The econometric estimation period used to inform the productivity effect did not include any step-changes in frequency benefits. Therefore, frequency benefits were not captured in the coefficients estimated as part of the econometric analysis. This point is considered in more detail in Chapter 4.

associated with the scarcity of available airline capacity, implying that fares fall, benefiting consumers but with an offsetting effect on airline shareholders. The net impact on real GDP is captured in the TEE effect.

Consumers benefit from the assumed fall in prices (the benefits to consumers of a fall in prices are captured by means of a change in "consumer surplus"). For modelling purposes, we interpret the reduction in price as an increase in households' real incomes or "purchasing power"[115]. This results in increased demand for air travel, and potentially other goods and services in the economy as households' savings from lower fares can be spent elsewhere (this is called the "income effect" of a price change). This increased demand places direct upward pressure on GDP: consumers are willing to pay more for goods and services, meaning that firms are able to produce output profitably that was previously unprofitable, so that output expands. In turn, this has multiplier impacts through the supply chain as firms increase their demand for inputs. As GDP and aggregate demand increase, upward pressure is placed on prices – this, again, is the diffusion effect. This dampens the ultimate impact of the effect of the real increase in consumer incomes.[116]

Conversely, airlines are able to extract less economic rent as a result of the reduction in capacity constraints and experience a reduction in profitability as a result of the price fall (a reduction in "producer surplus"). Airlines pay lower dividends to households – the ultimate owners of firms in the model – which places additional downward pressure on GDP. As with the consumer gain, diffusion effects (diffusion tends to *decrease* prices in this case) dampen the ultimate impact on GDP.

The overall impact of the TEE effect depends on:

1. The relative sizes of the gains to consumers and losses to producers; and

2. The relative strength of the multiplier linkages of the gains to consumers and losses to producers.

The sizes of the forecast gains to consumers and losses to airlines have been provided for use in our modelling by the AC. In the Assessment of Need scenario in 2050 the gains to consumers are £8.4bn, compared to the losses to producers of £8.0bn. The S-CGE model suggests that in the same year and scenario, for every £1 of consumer gain, the increase in GDP is £0.60, whilst for every £1 of airline loss, the fall in GDP is £0.30. The reason that the GDP loss associated with a £1 reduction in producer surplus is larger (in absolute terms) than the GDP gain associated with a £1 increase in consumer surplus is as follows. The reduced producer surplus results in lower returns to airline shareholders. In the S-CGE model these shareholders are households. However, the households most affected by the reduction in airline profits are amongst the most affluent in the economy, and their consumption does not reduce at the same rate as the boost to consumption associated with the increased consumer surplus since these wealthier households have a higher propensity to save (consumer surplus accrues to a broader set of households, being those who use airlines). For both the consumer gain and the airline loss, the final impact on GDP is less than the original input, reflecting the diffusion effects described above.

On the basis of this information, the results of our analysis suggest that the TEE effect might increase GDP by between 0.0% and 0.3% in 2050, depending on the scenario. The PV of the TEE impact is forecast to be between £15.3bn and £55.9bn over the 60 year appraisal period (depending on the scenario). The PV is highest in the Global Growth scenario, and lowest in the Global Fragmentation scenario, reflecting the differing magnitude of passenger flows between the two scenarios.

### *6.1.4 Overall impact*

The level of GDP in 2050 is forecast to be around 0.2% to 0.6% higher than it would have been in the absence of the LGW 2R scheme, depending on the scenario. When all of the effects are taken together, the PV of the GDP impacts of the LGW 2R scheme is forecast to be between £29.4bn and £99.8bn, excluding construction impacts (depending on the scenario). This rises to £32.8bn to £103.2 when construction impacts are included. The ratio of the PV of the GDP impacts to the PV of the inputs to the S-CGE (i.e. the total PV of the net passenger

[115] For technical reasons, the price impact on consumers is modelled as a change in productivity. See Chapter 4 for details of this.

[116] There could be a risk of an overlap when considering only business passengers, between these benefits and the productivity effects outlined above, as the potential increase in trade could be a reason for business travellers demanding air transport. However, this issue does not occur within our analysis as the econometric relationship between connectivity and trade has not been estimated over a period where there was a step-change in seat capacity, and therefore it does not capture the reverse impact of changes in capacity on demand (please see Section 4 in Appendix C for a full exposition of this).

expenditure, productivity, frequency benefits, and TEE inputs) for the LGW 2R scheme is 0.75. This ratio provides an indication of the magnitude of the GDP impact implied by the model, relative to the magnitude of the inputs to the model. The fact that this ratio is less than one is largely as a result of the diffusion effects of price rises described above. This illustrates the point made in the introduction that the CGE framework does not allow a "free lunch", and many of the impacts we describe are offset by effects working in the opposite direction. The projected increase in GDP by 2050 is underpinned by increased:

- Net inbound and outbound passenger spending (outbound passenger spending is forecast to be 0.1% to 0.2% higher than it otherwise would be and inbound spending is forecast to be 0.1% to 0.4% higher);
- Net trade (net trade is forecast to be 0.0% to 0.2% higher than it otherwise would be)[117] while the trade deficit increases the additional flows of imports and exports have facilitated a substantial productivity gain; and
- Consumption (which is forecast to be between 0.1% lower to 0.3% higher).

Among the sectors of the economy, the air passenger and transport industry is forecast to experience the largest percentage growth, being a forecast 21.0% higher in 2050 compared to the baseline scenario (in the Assessment of Need scenario). The sector is forecast to grow by more than the increase in passenger numbers in proportional terms, owing to the projected shift towards more high-value and long-haul services. Due to their strong international linkages, the manufacturing and agriculture sectors are also expected to be important beneficiaries: by 2050 manufacturing is forecast to expand by 1.5% relative to the baseline scenario, with agriculture expanding by 0.9% over the same period (in the Assessment of Need scenario). The construction sector is also forecast to benefit, with output increasing by 9.5% in 2020 compared to the baseline as a result of the largest phase of airport construction, and by 1.6% in 2050, principally as a result of ongoing maintenance activities at the airport (in the Assessment of Need scenario).

The model suggests that the LGW 2R scheme could create approximately 50,000 new jobs by 2050 (both at the airport itself and indirectly in the wider economy), many of which would be in the aviation and manufacturing sectors. The number of firms in the economy is expected to increase by 0.1% in the long run (an analysis by sector is provided in Section 6.4.2).

The LGW 2R scheme would also be expected to have important regional impacts. The model suggests that the benefits would be somewhat concentrated in London & South East, which is forecast to gain by between £11.0bn and £65.1bn in PV terms (excluding construction). Over time, prices in London & South East would be expected to rise relative to other regions as a result of the increased activity. With projected increases in GDP of £3.3bn to £36.7bn and £7.6bn to £28.5bn in PV terms respectively by 2050 the Rest of England and the Rest of the UK also stand to benefit by a significant amount from the schemes. The reason is that productivity impacts are experienced nationally (for example, even firms which do not use the aviation linkages directly may still benefit, since they may be able to "learn" from firms which do seek to increase their productivity by exploiting the improved aviation linkages), and the frequency and TEE benefits would be expected to accrue to all airport users, a large proportion of whom reside outside of London & South East. Further detail on the regional effects is provided below.

The estimated impact of the LGW 2R scheme is in line with the findings from previous studies. For example, analysis of potential airport sites in Sydney found that a new airport carrying up to 54 million passengers in 2060 could increase the level of real GDP in Australia by 1-1.2%[118]. Given the greater increase in passenger flows enabled by the new airport in Sydney, relative to the LGW 2R scheme, one would expect it to have a greater impact on GDP. In addition, the smaller size of the Australian economy, relative to the UK, would ensure that additional passenger flows have a relatively larger impact.

[117] It should be emphasised that this represents the *net* change in trade (excluding tourism/passenger flow impacts). This is underpinned by significant increases in both imports and exports, which have an offsetting effect.

[118] Ernst & Young (2012). *Economic and social analysis of potential airport sites: Sydney Aviation Capacity Study*. Report for the Australian Government Department of Infrastructure and Transport.

Whilst some of the impacts are less certain than others (see Chapter 5) and the figures are different under alternative scenarios, this illustrates the extent of forecast GDP benefits associated with the LGW 2R scheme.

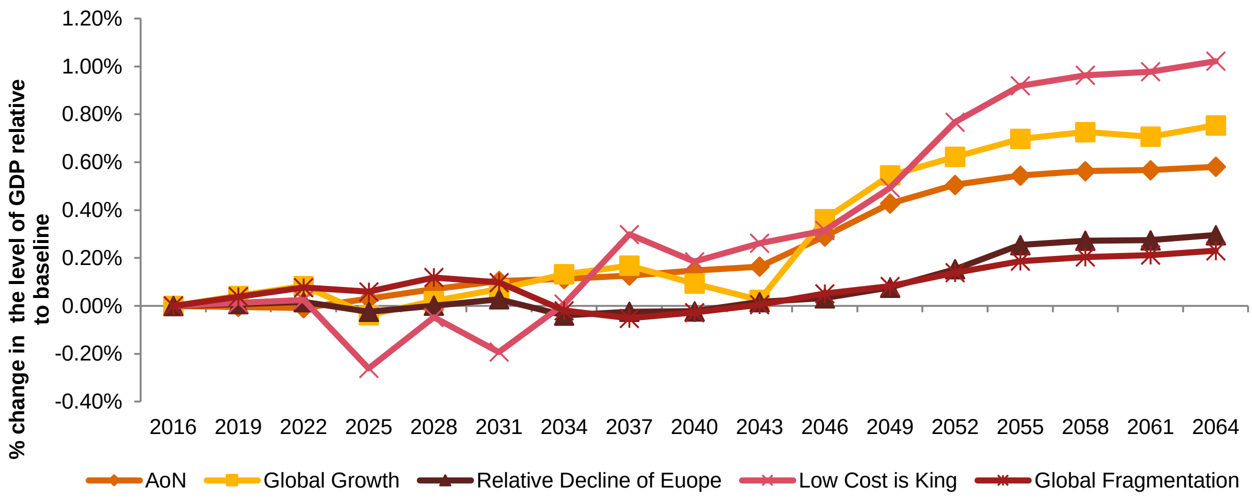
## 6.2 Total GDP impacts

This section examines the forecast GDP impacts of the LGW 2R scheme by scenario at a national level. In this analysis we look only at the effects produced during the operational phase of the expanded airport, since we are primarily interested in the effects of improved aviation linkages rather than construction impacts.

This updated version of the report reflects revised inputs for the some of the effects, provided to us by the Airports Commission. These updates relate only to the TEE inputs for the Global Growth scenario, and for all inputs for the Relative Decline of Europe and Low Cost is King scenarios. All charts and tables have been updated accordingly. Figure 6 below summarises the overall forecast impact on real GDP of the operations of the LGW 2R scheme. In all scenarios, the operational phase impacts would be expected to increase relatively gradually, reflecting the underlying assumptions embodied in the passenger flow figures supplied to us by the AC. The overall effect of passenger spending itself is negative in GDP terms, but the increase in runway capacity is expected to increase connectivity and bring with it new business travellers. The increase in business travel would be associated with increased international trade, FDI and inflows of skilled migrant labour. UK businesses can also communicate with international clients more effectively allowing them to build up stronger business relationships (Chapter 2 provides the associated evidence and a more detailed discussion on this topic). By the mid-2040s, the Gatwick scheme is forecast to produce an increase in real net UK GDP of between 0.03% and 0.55%, and the figure could be close to 1.0% by 2064. The modelling suggests that any increase in real GDP represents and upward shift in the level of GDP, rather than a permanent effect on the growth rate. The dip in the Global Growth scenario in the mid-2040s is driven by the profile of the TEE inputs for this scenario. The TEE effect is discussed in more detail later in the results.

During the operational phases, the drivers of projected GDP effects are: passenger flows; productivity; frequency benefits; and TEE. Of the four effects, the passenger flow impacts have the most substantial short-term impact, as they directly change the level of domestic demand. In the long-term, however, the productivity and TEE impacts outlined in Chapter 4 are most important, accounting for a large part of the real GDP impacts forecast across the schemes. A detailed description of these effects is provided below.

*Figure 6: LGW 2R Impacts on the level of real GDP, by scenario*




*Source: PwC analysis*

## 6.3 Present value of GDP impacts

Table 10 below displays the PVs of the forecast total real GDP impact for each of the scenarios. All PVs are calculated on the basis of a 60 year appraisal period (from 2019 to 2078) using a 3.5% discount rate for the first 30 years and a 3.0% rate for the remaining years (following HM Treasury Green Book guidance). Again, this table has been updated to reflect the revised PVs, based on updated input assumptions for Global Growth, Relative Decline of Europe and Low Cost is King.

The tables show, based on our S-CGE modelling and the inputs supplied to us by the AC, that the economic impact of a second runway at Gatwick is forecast to be considerable across all scenarios. If all the effects which are modelled are realised, the PV of the GDP impacts could approach £100bn in the most favourable passenger flow scenario and, as demonstrated by the figure above, the long-term impact of the schemes could be to add nearly 1.0% to the level of GDP. It is clear that the variation in forecast PVs across the scenarios is significant. The Relative Decline of Europe and Global Fragmentation scenarios have similar PVs, and are significantly below the levels in other scenarios.

In most cases, the analysis below considers all five of the passenger flow scenarios, in order to show how impacts differ across the different assumptions for passenger flows in the AC's alternative scenarios for the development of the aviation sector. In the interest of brevity, and where the choice of passenger scenario is unlikely to alter the findings materially, we present detailed analysis for only one of the scenarios. In this case, the Assessment of Need scenario is used as the example. Table 10 demonstrates the degree to which **the findings from the analysis are driven by the underlying input assumptions provided by the AC**. Changing the underlying assumptions on passenger flow growth is sufficient to more than triple the modelled economic impact which the additional capacity generates.

*Table 10: LGW 2R Present Value of real GDP impacts, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Total** | 73.3 | 93.1 | 41.8 | 124.3 | 29.4 |

*Source: PwC analysis*

In addition, at the AC's request, we have also provided the PVs of the forecast total real GDP impact for each of the scenarios for a 60 year appraisal period starting from the opening date of the scheme, in 2025. These are displayed in Table 11 below.

*Table 11: LGW 2R Present Value of real GDP impacts, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Total** | 89.0 | 114.7 | 62.8 | 127.4 | 41.7 |

*Source: PwC analysis*

## 6.4 Drivers of GDP impact

The previous section demonstrates the range of GDP impacts provided by the LGW 2R scheme under the five different passenger scenarios. In this section, we describe the key drivers of these impacts and the underlying economic mechanisms that lead to the results.

### 6.4.1 Impact by GDP component

*GDP components and transmission mechanisms*

We begin by breaking down the change in GDP into its constituent parts. One way to measure GDP is on an "expenditure basis", which means accounting for the expenditure by households and businesses in the UK. The expenditure measure is made up of a number of components according to the "National Accounting Identity" (NAI). This can be expressed as follows:

$$\begin{aligned} Real\ GDP = {} & Real\ Consumption + Real\ Investment + Real\ Government\ Consumption\ and\ Investment \\ & + Real\ Net\ Trade + Real\ Passenger\ Flow\ Exports - Real\ Passenger\ Flow\ Imports \end{aligned}$$

Usually, trade and passenger flow impacts are accounted for together in expressing the NAI. This is because passenger flow impacts form part of trade (in particular, additional passenger spending within the UK is regarded as an export and additional passenger spending outside the UK is regarded as an import). However, since passenger flow impacts are such an important part of this research, we have separated passenger flow effects from trade. This means that Real Net Trade in the equation above is net of passenger flow impacts.

Figure 7 below breaks down the forecast GDP impacts into their component parts for the LGW 2R scheme (using the Assessment of Need scenario to illustrate). The impacts can be summarised as follows:

- **Real consumption.** The most substantial forecast impact of the LGW 2R scheme is seen in consumption. In the initial phase, before the runway is open, consumption falls marginally. This occurs because agents anticipate future improvements in productivity and therefore substitute away from current economic activity to additional activity in future. However, this drop is insignificant in the context of the overall impact of the LGW 2R scheme, and in the long-term real consumption is forecast to increase well beyond the level that it would have been in the absence of the LGW 2R scheme. This is because the higher productivity generated by the increase in capacity is expected to increase household income, and therefore allows higher consumer spending.

- **Real investment.** The overall impact of the operational phase of the LGW 2R scheme on real investment is forecast to be limited, with the majority of the investment occurring during the construction phases. A small dip in investment is seen in the early years of operation, but this is reversed towards the end of the period with the total change being roughly neutral. There are two key drivers underlying this effect: firstly, the removal of the capacity constraint is expected to generate a large transfer from the airline sector to consumers, as the potential to charge economic rents on landing slots is reduced (see Section 6.4.3.4). This reduces the incentive to invest in the airline sector following the opening of the new runway. Secondly, as agents in the model are rational and forward-looking, they predict that greater returns on investment will be possible towards the end of the period as the airport reaches capacity and the full productivity benefits materialise – this is known in the model as a *confidence effect* (see below). This incentivises them to defer investment from the early operational phases to the end of the period studied, giving rise to the small temporary fall in investment.

| | |
|---|---|
| **Confidence effect** | A key feature of the model is that economic agents (consumers and firms) are "forward-looking", in the sense that they form expectations of future economic variables (such as interest rates, the price level and output) and adjust their behaviour accordingly. Specifically, the model assumes that agents form "rational expectations" (Muth, 1961) [119], meaning that the firms and households within the model assume that the predictions generated by the model are correct. In forward-looking models like this one, "confidence effects" can be important. In the context of airport expansion, the confidence effect means that agents foresee that airport improvements will have a positive impact on profits and output. |

The forecast increased level of investment later in the period consists of a mix of both domestic and foreign direct investment (FDI). The increased level of economic activity associated with the LGW 2R scheme incentivises other sectors of the economy, as well as the aviation sector, to invest. Our model results suggest that investment will rise in the majority of the business sectors captured in the S-CGE model. However, the precise mix of domestic and foreign investment is too difficult to predict as appropriate data are not available at the regional level. The forecast long-term increase in investment is also partly driven by ongoing maintenance activities at the enhanced airport facilities.

- **Real government consumption and investment.** In the operational phase, government consumption is unchanged relative to the baseline. This is due to the assumed "Harberger closure rule" (described in detail in Appendix B), which states that net government expenditure remains constant i.e. any government receipts (outgoings) are transferred to (from) consumers. Overall the level of taxes paid rises in the model (see Section 6.7 for more detailed fiscal results), this increase being attributable to higher levels of economic output. Despite not directly contributing to an increase in the level of GDP, this has a positive impact through the *government expenditure effect* explained below:

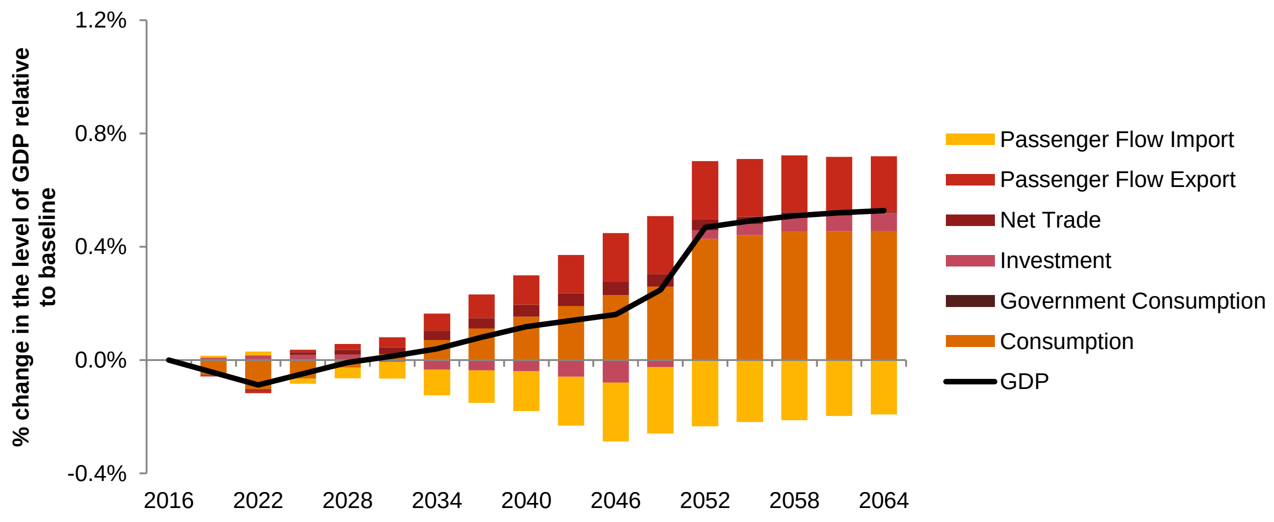
[119] Muth, J.F., (1961). Rational Expectations and the Theory of Price Movements, *Econometrica*, Vol. 29, No. 3, pp. 315-335.

| | |
|---|---|
| **Government expenditure effect** | The expansion of the aviation sector generates receipts to government in the model via Air Passenger Duties. Moreover, higher levels of GDP raise government revenues from general taxation. Under the "Harberger closure rule" adopted for this work (see Appendix B), these increased tax receipts are "handed back" to consumers via lump-sum transfers. As consumption increases as a result, this places further upward pressure on aggregate demand and GDP. |

- **Real net trade.** Figure 7 demonstrates that the overall impact of the increase in airport capacity is a fall in net trade, excluding the impact of changing passenger spending patterns. Although UK firms experience an improvement in international competitiveness and exports increase substantially, this generates wealth, part of which will be spent by households on increasing their consumption. The increase in household consumption within the UK is forecast to lead to an increase in imported consumer goods. Businesses also use imports, in the case of the manufacturing sector, they are processed and turned into exports, if businesses are able to produce and source imports more efficiently, this will be better for their overall productivity.
  Overall the UK's terms of trade improves. This is because the price level in the UK is forecast to fall as the increased productivity associated with UK aviation sector expansion allows goods and services produced in the UK to be sold more cheaply. Exports therefore expand. An improvement in the terms of trade could in turn signal a reduction in imports. However, part of the boost to productivity is associated with UK businesses being better able to source production inputs from overseas – greater air connectivity allows businesses to link with a wider range of suppliers and get better quality products and improved deals. The impact of openness on domestic productivity is established within the econometric analysis. Also, the underlying expansion in output in the UK economy means that more imports will be required for consumption in the domestic market (household incomes rise, so demand rises).

- **Real passenger flow imports and exports.** Due to the importance of changing passenger flows in our analysis, Figure 7 also shows separately the contribution of passenger flow imports (spending by UK residents abroad) and passenger flow exports (spending by foreign visitors within the UK) to overall real GDP. In conventional "National Accounting Identity" treatments these effects would be captured within changes in net trade. The passenger flow impacts are explained in full below. At a high level, the overall impact of passenger flows on GDP is determined by the net impact of these two different effects. Figure 7 shows that both are forecast to have substantial impacts on overall GDP, although the net impact is considerably smaller.

*Figure 7: LGW 2R Breakdown of real GDP impacts, Assessment of Need scenario*




*Source: PwC analysis*

## *6.4.2 Impact by sector*

Table 12 shows the forecast change in sectoral real GDP as a result of the increase in aviation capacity associated with a second runway at Gatwick, over the period 2020-2060. These figures are based on the

Assessment of Need passenger flow scenario and show the percentage difference in each year from the corresponding baseline scenario. The relative sizes of these sectors is given in Section 3.4.

*Table 12: LGW 2R Breakdown of impact on the level of real GDP by sector, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and mining** | -0.4% | 0.0% | 0.6% | 0.9% | 1.1% |
| **Manufacturing** | -0.1% | 0.3% | 0.9% | 1.5% | 1.4% |
| **Utilities** | -0.4% | 0.0% | 0.5% | 0.8% | 1.1% |
| **Construction** | -0.9% | 0.1% | 0.1% | 1.3% | 1.5% |
| **Retail and wholesale trade** | -0.2% | -0.2% | -0.2% | -0.4% | -0.3% |
| **Air passenger transport and freight** | 0.8% | 3.4% | 7.2% | 21.0% | 15.1% |
| **Other freight** | -0.2% | -0.4% | -0.7% | -1.7% | -1.2% |
| **Other passenger transport** | 0.2% | -0.4% | -0.7% | -2.6% | -1.8% |
| **Accommodation and food services** | -0.1% | 0.1% | 0.5% | 0.8% | 0.9% |
| **Other services** | -1.0% | -0.5% | 0.0% | -0.2% | 0.4% |
| **Health, education and public spending** | 0.1% | 0.1% | 0.0% | -0.1% | -0.1% |

*Source: PwC analysis*

The most significant change is seen in the air passenger transport and freight sector, which is forecast to be more than 15.1% larger than in the baseline scenario by the end of the period. This is unsurprising given the direct boost to this sector which the reduction in the capacity constraint allows. The magnitude of the change is greater than the simple increase in passenger flows, which is approximately 5% towards the end of the period. This highlights the fact that the increase in capacity is expected to lead to a change in passenger mix, with a shift towards higher value, long-haul passengers.

Aside from the air passenger transport and freight sector, any sectoral growth is relatively small, with the magnitude of the change being no greater than +/- 2.5% of sector size in the baseline by the end of the period.

Of the remaining sectors, those with strong international linkages, most notably agriculture and manufacturing, are forecast to grow relatively more substantially than the others as a result of the increase in capacity. This is due to a decline in the cost of air transport, leading to sector-specific increases in productivity and international competitiveness, and subsequently an increase in output. Accommodation and food services are also forecast to grow significantly, due to the increase in demand generated through the increase in passenger flows. The efficiency benefits for non-aviation sectors are expected to be magnified through the *reorganisation effect*, whereby they shift their production processes towards air transport.

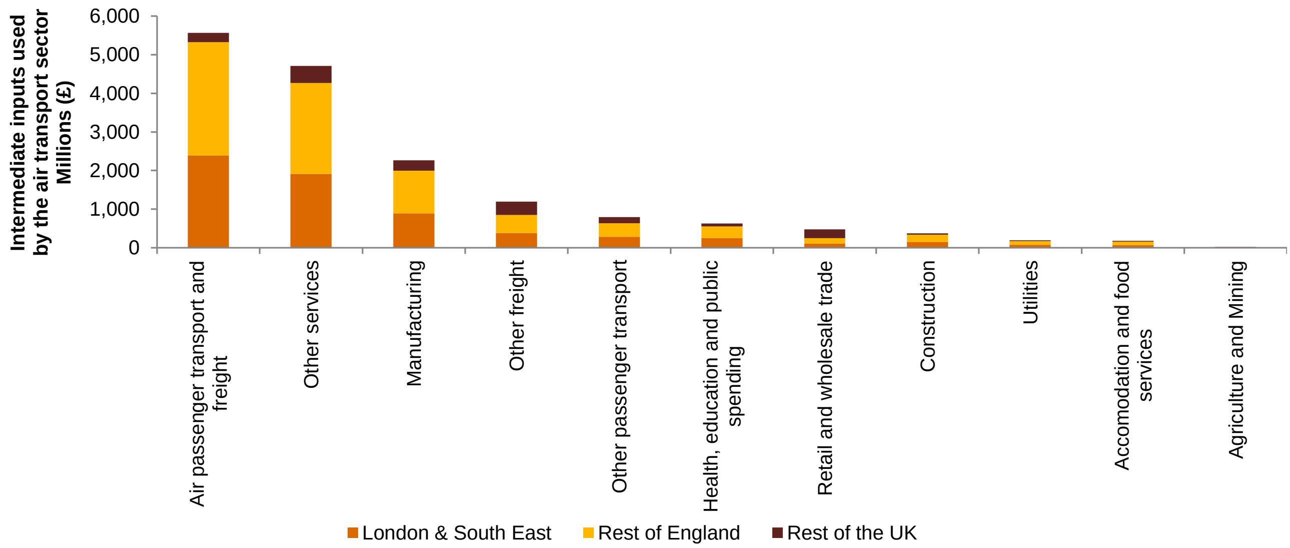
| | |
|---|---|
| **Reorganisation effect** | SACTRA identifies a "reorganisation effect" as input substitution within the production system and logistics of the firm to take advantage of lower transport costs. Although transport costs are not modelled explicitly in the S-CGE framework, a key strength of the S-CGE model is that firms will automatically reorganise their production processes in response to changes in input prices (be they wages, rental on capital or the prices of intermediate inputs). This means, for example, that as prices of intermediate inputs fall (for instance as a result of the firms becoming more efficient as a result of the productivity effect discussed below), firms will be able to reorganise their activities to make efficient use of the cheaper inputs, thereby increasing GDP. |

The two sectors which are forecast to contract the most are other freight and other passenger transport, which between them represent all non-air transportation and storage. This is because these sectors are substitutes for air transportation, and therefore see a fall in demand as the cost of air transportation falls. It should be noted that these results are the average impacts, and so do not capture sub-sectoral variation. For example, it is likely that freight forwarders who rely on air freight may benefit from an increase in capacity, while over longer distances the two sectors may be stronger substitutes.

Retail and wholesale trade GDP is also forecast to shrink marginally. This is due to declining transport margins increasing competition and subsequently reducing profitability. This leads to a negative price effect which more than offsets the reduction in input costs generated by cheaper air transport, leading to a decline in the GDP of the sector. A final small reduction is also forecast for the public sector, as a small proportion of workers move to the private sector as a result of higher wages.

Figure 8 below demonstrates the distribution of spending by the air transport sector in 2010, by sector. This helps to explain the findings above, particularly in the forecast growth of manufacturing, which features prominently in the supply chain of the air transport sector, and will therefore experience an increase in demand as the sector expands, in addition to the benefits from international linkages previously explained. The wholesale and retail trade sector is a material receiver of expenditure from air transport, although this is still relatively modest in relation to the size of that sector, and therefore is not sufficient to reverse the contraction explained above. The second largest receiver of expenditure is the Other Services sector, although given the size of this sector (which includes financial, professional and business services), this is a reasonably moderate effect in relative terms.

*Figure 8: Distribution of intermediate inputs used by the air transport sector in 2010*




*Source: PwC analysis*

As shown in Table 13, GDP in the freight sector is forecast to increase by 2.6% in 2060, relative to the baseline scenario. This implies that the impact on the freight sector is larger compared to the impact on other sectors, but lower than the impact on the air passenger transport sector. This relatively large impact is due to the strong linkage between the air freight and air passenger transport sector in the supply chain and labour market. This ensures that positive effects within the air transport sector have a disproportionately large impact on air freight.

*Table 13: LGW 2R Breakdown of impact on the level of real GDP of the air freight sector, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Impact on air freight GDP (%)** | 0.0% | -0.6% | 0.3% | 1.4% | 2.6% |

*Source: PwC analysis*

Please refer to Box 1 below for a more detailed discussion of the air freight sector.

**Box 1: The air freight sector**

*Air freight*

The air freight, or air cargo, sector refers to goods transported by aircraft, whether by dedicated freighters or in the belly-hold of passenger aircraft.

The GVA of the UK air freight sector is currently £87m, or less than 0.01% of total the economy's total GVA.[120] In 2011, £116bn worth of goods were transported by air freight between the UK and non-EU countries, around 35% of the UK's extra-EU trade by value, and in total air freight was one fifth of all trade by value.[121] These are large proportions considering that air freight represents a very small proportion of tonnage of all freight, and is due to the nature of goods and produce usually transported by air freight, which tend to be high value and low volume, such as the jewellery or high-tech sectors. Industries that are time-sensitive are also large users of air freight, such as pharmaceutical products. Air freight is currently estimated to provide approximately 39,000 jobs in the UK.

*Market outlook*

Boeing's 2013 forecast[122] reported that world air cargo traffic has slowed since 2004, having only grown 2.0% per year on average since then, relative to the historical trend of 6.7% between 1981 and 2004. According to Boeing, this slowdown was mainly down to the global economic downturn and the rising price of fuel, but within this time period there has been volatility; a 12.50% fall in traffic between mid-2008 and mid-2009 was followed by an 18.5% surge in 2010, followed by another contraction in 2011.

Despite this deceleration in growth, Boeing forecasts that world air cargo traffic will double by 2031 and grow at a rate of 5.2% per annum over the next 20 years, and that air freight will average 5.3% annual growth, measured in real revenue tonne-kilometres. Asia will lead the industry in terms of highest average annual growth rates, whereas the mature Northern American and European markets will be reflected in slower and lower rates.

Boeing also estimates that the number of aircraft in the worldwide freighter fleet will increase by more than 80% during the next 20 years, in reaction to the growth in demand for air cargo services. It is envisaged that large freighters will play an increasing role and represent 36% of this enlarged fleet today compared to 22% a decade ago; large freighters can take advantage of greater capability and efficiency that they offer to manage the increase in demand without proportionally increasing the number of aircraft. Globally, cargo revenue represents around 15% of total air transport revenue. However, some airlines earn nearly 40% of their revenue from freight.

*Inclusion in the model and potential impacts*

In the S-CGE model, air freight is split out from the Transportation and Storage Sector in order to more accurately estimate the impact of the change in airport capacity on specific subsets of the aviation sector. The split has been created primarily using data from the Annual Business Survey published by the Office for National Statistics (ONS), giving the sub-sectoral breakdown across a number of areas, including number of employees, GVA and intermediate consumption.

We would expect an airport expansion in the model to feed through via wider economic impacts and affect the air freight sector in a positive way. Expansion at Heathrow or Gatwick would initially affect belly-hold cargo; belly-hold accounts for the majority of air freight in the UK, but new options would also be opened up for dedicated freighters.

In the S-CGE model, increased connectivity at an airport fosters the flow of passengers, which includes business passengers, resulting in an increase in trade. New long-haul routes in particular have the potential to

[120] ONS Annual Business Survey

[121] DfT (2013) 'Aviation Policy Framework' https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/153776/aviation-policy-framework.pdf

[122] Boeing (2013) World Air Cargo Forecast 2012-2013 http://www.aia-aerospace.org/assets/Boeing_World_Air_Cargo_Forecast_2012-2013.pdf

open up new export markets. Demand for freight is pro-cyclical and likely to track movements in trade as local businesses become better connected to global markets. On the supply-side, air freight and passenger flows are inextricably linked as much air freight travels in the belly-hold of passenger aircrafts; this is particularly relevant for new markets where demand is not yet predictable or established. Airport expansion would enable the increase in passenger flows that is forecast until 2050 and therefore would also imply more capacity for belly-hold freight, which may in turn even lower the cost of exporting goods.

For dedicated air freighters, a key issue is to maintain the express delivery industry, which they dominate. The express industry is supported primarily by the availability of night flights, the regime of which may be affected by an expansion. The DfT concluded in July 2014 that it would not make any significant changes to the current restrictions on the night flight regime at Gatwick, Heathrow or Stansted before the AC publishes its final report. Research undertaken by Oxford Economics[123] estimated that the express industry contributed £2.3bn to UK GDP and 82,000 jobs in 2010 and suggested that restricting night flights could have a negative employment impact.

At present, the majority of air freight infrastructure resides at Heathrow airport, which handles 86% of all UK belly-hold passenger cargo,[124] and many freight operators are based there. An increase in demand for air freight, facilitated by additional airport capacity, would raise the question of whether any activity would be substituted away from Heathrow to Gatwick, and whether Gatwick would be required to invest in freight infrastructure in order to take on some of the increase in demand.

### *6.4.3 Impact by effect*

To further understand the impacts, we now examine in detail the four key effects associated with the operation of the LGW 2R scheme which we modelled as set out above:

1. Passenger flows;
2. Productivity;
3. Frequency benefits; and
4. TEE.

The PV of each of these effects, for each passenger scenario, can be seen in Table 14 below. Again, this table reflects the updated inputs for the Global Growth, Relative Decline of Europe and Low Cost is King scenarios. The table demonstrates that for the LGW 2R scheme the change in passenger flow is forecast to have a negative impact across each passenger scenario[125], while the greatest impact is forecast to be felt through the productivity and TEE effects. The inputs which drive each of these forecast effects and how they impact on overall GDP are explored in greater details below.

The PV estimations below are heavily influenced by the time trend of the inputs, which determine whether the majority of the benefit is experienced at the beginning or the end of the period studied. This motivates households to shift their economic activity towards the time periods where they get the greatest return on their expenditure. While this doesn't affect the long-run impact on the level of GDP, it has important implications for the PV estimations as benefits experienced in later time periods are heavily discounted relative to earlier ones.

*Table 14: LGW 2R Present Value of real GDP impacts, by effect and scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Passenger Flows** | -2.3 | -20.5 | -8.3 | -32.7 | -6.6 |

[123] Oxford Economics (2011) 'The Economic Impact of Express Carriers in Europe', http://www.gacag.org/images/gacag/pdf/The%20Economic%20Impact%20of%20Express%20Operations%20in%20the%20United%20Kingdom.pdf

[124] Freight Transport Association (2014) 'Sky High Value', http://www.fta.co.uk/export/sites/fta/_galleries/downloads/air_freight/Skyhighweb.pdf

[125] Please note that the "passenger flows" effect here refers to the overall GDP impact of changes in passenger flow. This captures a broader range of effects on GDP which result from changes in passenger flows than the direct spending impact as outlined in Table 14.

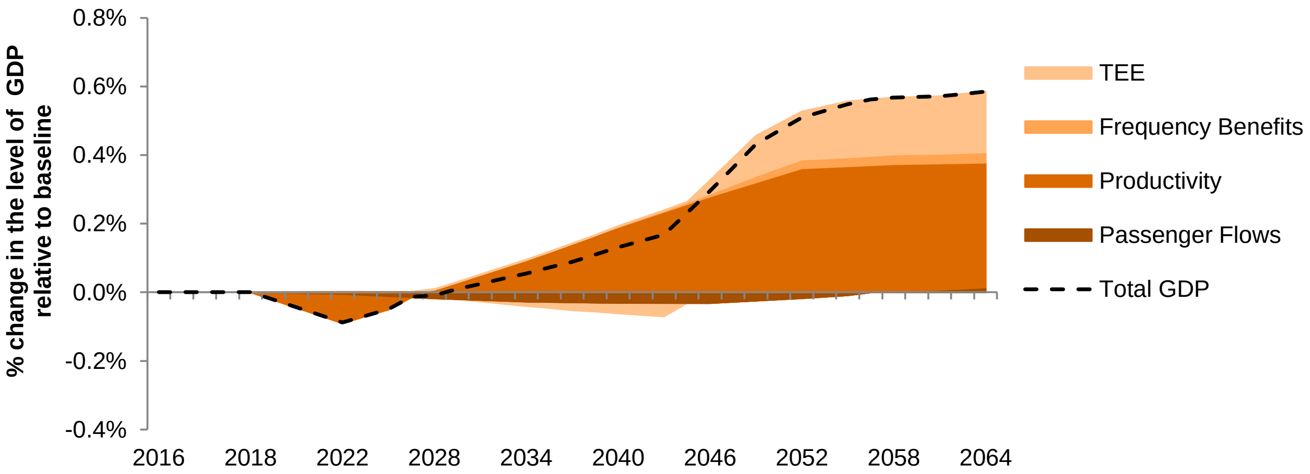
| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Productivity** | 52.1 | 47.7 | 22.3 | 90.1 | 17.9 |
| **Frequency Benefits** | 3.6 | 10.0 | 3.5 | 9.6 | 2.7 |
| **TEE** | 20.0 | 55.9 | 24.2 | 57.3 | 15.3 |
| **Total** | **73.3** | **93.1** | **41.8** | **124.3** | **29.4** |

*Source: PwC analysis*

Figure 9 below splits out the forecast real GDP impacts into these components over time. We show the results for the Assessment of Need scenario in order to illustrate the impacts; Table 14 demonstrates that the direction and relative magnitude of each effect are reasonably consistent across all passenger scenarios.

The early years of the operational phase of the LGW 2R scheme are dominated by the productivity effect. This initially sees a slight contraction in GDP as rational, forward-looking agents delay economic activity until the runway opens, before increasing in magnitude steadily. From the mid-2040s the TEE effect is forecast to become positive and significant, eventually contributing roughly one-third of the overall GDP impact. Passenger flow impacts are estimated to be negative up to around 2060, although they are expected to make a positive contribution to GDP beyond that time. A full description of the passenger flow impacts is provided below, but at a high level, the result that Gatwick passenger flow impacts are forecast to be low is driven by the relatively large additional passenger spend outside the UK. Finally, frequency benefits are also forecast to have an impact towards the end of the period, but the magnitude of this impact is relatively small.

*Figure 9: LGW 2R Effect-by-effect impacts on the level of real GDP, Assessment of Need scenario*




*Source: PwC analysis*

We now examine the passenger flow, productivity, frequency benefits and TEE impacts in detail, considering each in turn.

### 6.4.3.1 Effect 1: Passenger flows

*Inputs*

The passenger flow data are taken from the AC's demand forecasts produced using a version of the DfT's aviation forecasting model. More information on the model and approach is contained in the consultation document forecasts reports[126], and technical appendix 3 of the Interim Report[127].

In this section, we briefly describe the estimated passenger flows under each of the AC's passenger flow scenarios, which act as direct inputs into the S-CGE model and also inform our analysis of productivity effects (i.e. Effect 2). Passenger flows affect the results of the S-CGE analysis by determining:

- The size of the aviation sector;
- Changes in productivity; and
- The level and nature of additional passenger spending, inside and outside of the UK.

*Data input description*

Table 15 summarises the total forecast UK passenger flows across the five scenarios, in 2050, for the Do Minimum baseline scenario and the LGW 2R scheme. This highlights that there is a wide range in the number of additional passengers in the UK system as a whole which the additional capacity enables. This ranges from as little as 9m (397m to 406m in Global Fragmentation) to as much as 44m

*Table 15: LGW 2R and Do Minimum Total UK passenger flows in 2050, by scenario (millions of passengers)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Do Minimum** | 405.6m | 456.7m | 418.4m | 458.0m | 396.6m |
| **LGW 2R** | 421.0m | 484.6m | 440.5m | 501.9m | 405.9m |
| **Increase** | 15.4m | 27.9m | 22.1m | 43.9m | 9.3m |

*Source: Airports Commission*

In addition to the total UK passenger numbers, the characteristics of these passengers and their associated spending patterns are important in determining the impact on real GDP. The AC did not provide forecasts of the split between inbound and outbound passengers in the future. For the purpose of this analysis we have agreed in conjunction with the AC to assume that the balance of inbound and outbound passengers and their associated spending patterns remain at their existing levels in the event of airport expansion. Any difference from this assumption in reality would have an impact on the magnitude of the estimated impact on GDP.

The ONS Travel Trends publication contains information on the number of inbound and outbound trips made through Gatwick in 2011[128]. This demonstrates that, through Gatwick, 7.8m passengers made outbound trips from the UK (17% of UK total), but only 2.9m passengers made inbound trips to the UK (13% of UK total). Using data from the Tourism Satellite Accounts[129], it can be estimated that these trips through Gatwick led to £5.2bn additional expenditure by UK passengers outside the UK, and only £2.7bn additional expenditure in the UK by passengers from abroad. In addition, UK passengers travelling abroad spent an estimated £4.1bn in the UK on their outbound trip. Overall therefore, spending due to passenger flows through Gatwick in 2011 were associated with approximately £6.8bn of expenditure in the UK compared to £5.2bn outside the UK.

However, only £2.7bn of the expenditure in the UK (that which relates to passengers travelling from abroad) could be seen as additional demand. The remaining £4.1bn is likely to largely displace household consumption in the UK which would have otherwise occurred in the absence of air transport through Gatwick. This

[126] See: Department for Transport (DfT) (2013) *UK Aviation Forecasts 2013*. London: Department for Transport.

[127] See: Department for Transport (DfT) (2014) *Appendix 3: Technical Appendix to the Airports Commissions Interim Report*. London: Department for Transport.

[128] Office for National Statistics (ONS) (2011) *UK Travel Trends, 2011*. Available at: http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-269632

[129] Office for National Statistics (ONS) (2013) *Tourism Satellite Accounts 2010*. http://www.ons.gov.uk/ons/rel/tourism/tourism-satellite-account/index.html

displacement of domestic consumption means that the net impact of passenger spending associated with Gatwick in 2011 is likely to have been negative. This pattern will have important implications for the GDP impact of additional passenger flows resulting from the LGW 2R scheme.

*Nature of passenger flow change*

This sub-section looks in more detail at two specific elements of the passenger flow input data:

- The time profile of the increases in passenger flows forecast by the AC; and
- How the increase in passenger flow is expected by the AC to vary by type of passenger.

Table 16 below summarises the first of these elements, by showing the forecast change in passenger numbers over time, from 2011-2050. There is a large increase in the total number of UK passengers across all passenger scenarios relative to 2011, with overall increases of between 86% and 130%, between 2011 and 2050. It should be borne in mind that the additional capacity created by the second runway at Gatwick would be in the region of 40-45m passengers per year by 2050, and that under all passenger scenarios this capacity would be highly utilised by this date. The information in Table 15 above shows that the size of the increase in total UK passenger flows relative to the Do Minimum is often significantly below this, highlighting that a substantial share of the additional demand at Gatwick is forecast to be redirected from existing UK airports. This would also have important implications for the net impact of additional passenger spending, as any additional inbound expenditure due to increased passenger flows through Gatwick would partly be offset through falling expenditure associated with other airports. The same effect would apply to additional expenditure outside the UK due to an increase in the number of outbound trips.

*Table 16: LGW 2R Total UK passenger flows from 2011 to 2050, by scenario (millions of passengers)*

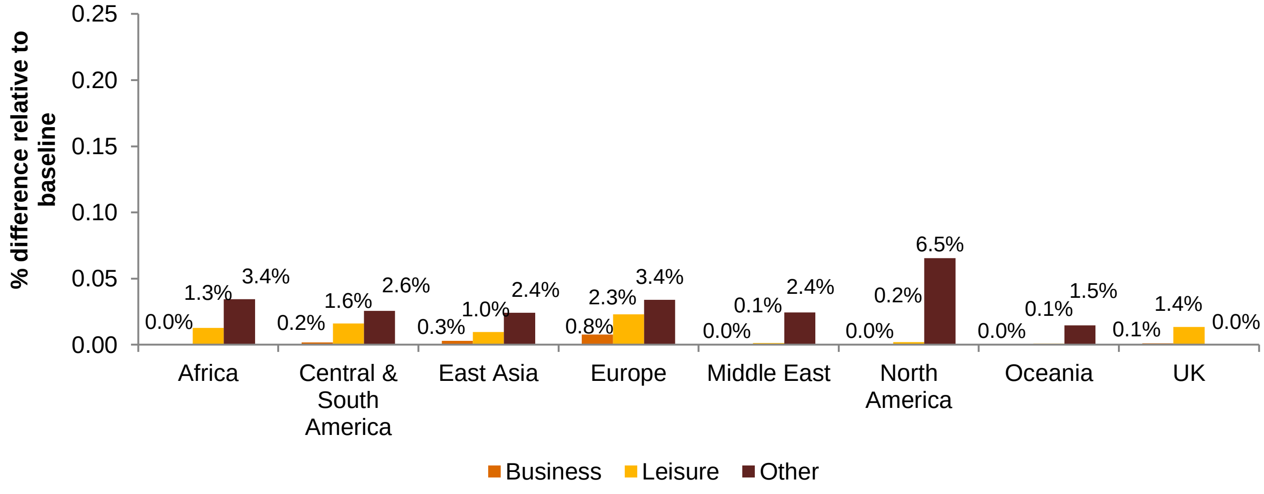
| | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| **Assessment of Need** | 217.8 | 256.8 | 312.6 | 363.8 | 421.0 |
| **Global Growth** | 217.8 | 267.9 | 338.8 | 418.3 | 484.6 |
| **Relative Decline of Europe** | 217.8 | 259.6 | 321.2 | 377.1 | 440.5 |
| **Low Cost is King** | 217.8 | 268.2 | 357.5 | 435.5 | 501.9 |
| **Global Fragmentation** | 217.8 | 250.4 | 303.3 | 351.5 | 405.9 |

*Source: AC demand forecast*

Figure 10 below demonstrates how passenger flows have been forecast by the AC to change by type of passenger (business, leisure, or other - which primarily comprises international transfer passengers) and destination region. Changes in the forecast passenger mix have an important impact on the level of connectivity generated. This chart demonstrates that the majority of the increases in passenger flows forecast by the AC for the LGW 2R scheme, relative to the Do Minimum, are for leisure and international transfer passengers. The largest relative increases can be seen in journeys to and from North America, although there is some growth across all regions. There are also significant increases in trips to other global destinations such as East Asia, Central & South America and Africa.

The AC's forecasts suggest that new capacity will result in an increase in international transfers, which might also improve the feasibility of long-haul routes (e.g. by providing a critical mass of traffic which in turn might result in high frequency, long-haul flights being provided to a greater range of destinations in a cost effective manner). This would have important implications for the UK's international connectivity. The productivity benefits of additional long-haul traffic are captured through the econometric analysis in the modelling in Effect 2.

*Figure 10: LGW 2R Change in PAX in 2050 relative to Do Minimum, by type and region, Assessment of Need scenario*




*Source: Airports Commission*

**Box 2: Multipliers on inbound and outbound passenger flows**

To understand the passenger flow impacts, it is helpful to illustrate the different types of 'multipliers' observed in the S-CGE model associated with passenger spending patterns. There are four different multipliers relating to the decision to travel and the decision to trade (Bond, 2008; Vellas, 2011):

1. UK exports: positive multiplier through UK-based supply chain;
2. UK imports: negative multiplier as displaces domestic consumption;
3. Foreign inbound tourists: positive multiplier from additional passenger spending; and
4. UK outbound tourists: negative multiplier as displaces consumption.

When a UK resident travels on a holiday overseas, they will spend money in the foreign country which will be a positive gain for that country. However, this money will be taken out of the UK and not spent on UK goods and services, so this implies a negative multiplier for the UK economy.

A key finding of the model is that the positive multiplier generated by foreign passenger flow spending is smaller than the cost to the UK economy of an additional UK resident travelling overseas. This is because of the strong downstream linkages that the purchase of domestic non-passenger-related products has in the UK economy versus the weaker linkages of foreign passenger consumption. This finding is consistent with that of other studies. For example, the Scottish government for Scotland, Hermannssonn (2011) for Northern Ireland and California Economic Strategy Panel (2009) for the US state all suggest that passenger expenditure multipliers tend to be lower than the economy-wide average.

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[130] Bond, H. (2008). Estimating the economic benefits of event tourism: a review of research methodologies, IMPACTS 08, University of Liverpool, Liverpool.

[131] Vellas, F. (2011). The Indirect Impact of Tourism, Third Meeting of T20 Tourism Ministers Paris, 25 October, 2011.

[132] Hermannsson, K., Lisenkova, K., McGregor, P., & Swales, J. (2010). An HEI disaggreagated input-output table for Northern Ireland.

[133] California Economic Strategy Panel, 2011. "Using Multipliers to Measure Economic Impact." Available at: http://www.labor.ca.gov/panel/pdf/Using_Multipliers_to_Measure_Economic_Impacts.pdf

### *Impact on GDP*

Box 2 above summarises the different multipliers on passenger spending within and outside the UK, which previous research has uncovered. The process through which the direct impact of this effect is multiplied throughout the economy, as with other inputs captured within the model, is called a *multiplier effect*.

| | |
|---|---|
| **Multiplier effect** | The increase in output in both the airline sector and the wider economy will mean that across the whole economy there will be more demand for inputs from suppliers. This positively affects the downstream supply chain. This means that the positive aggregate demand effects are multiplied. This will be combined with a further knock-on impact on aggregate demand as workers employed will spend more on goods and services in the UK economy. |

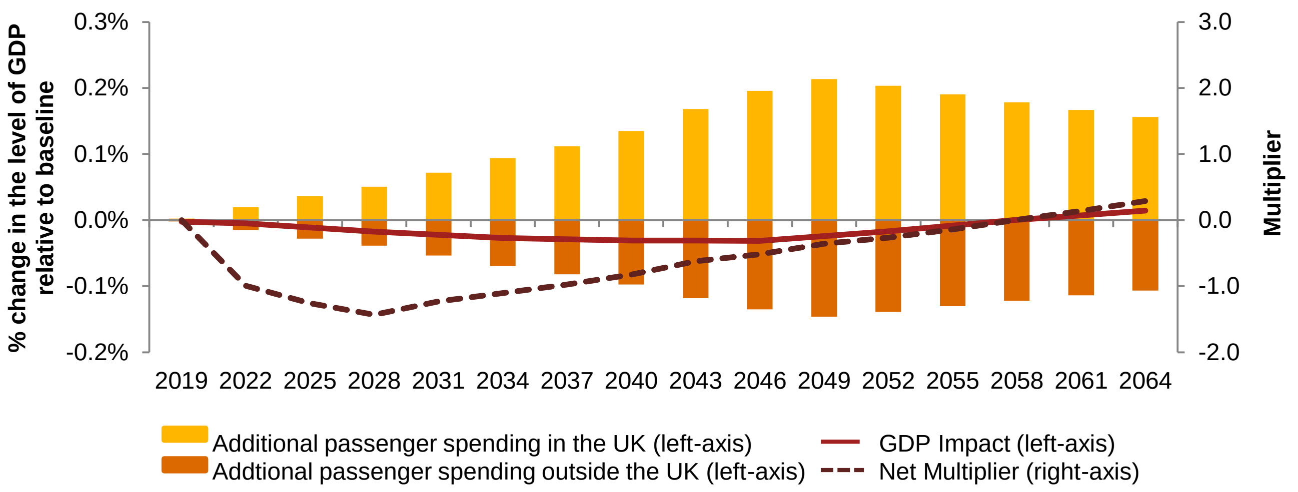
With this understanding of the passenger flow changes summarised in Box 2 above, it is straightforward to appreciate the GDP impacts of these passenger flows.

Figure 11 demonstrates the GDP impacts of the Gatwick scheme from the effects of passenger flows, along with the passenger expenditure input. For brevity, we present the Assessment of Need scenario.

For the LGW 2R scheme, passenger flow impacts on real GDP are estimated to be negative until the 2060s. The reason for this is that, although passenger flow expenditure effects within the UK are larger than those outside the UK, the difference is modest – the passenger flow expenditure "surplus" generated by the Gatwick scheme is relatively small. Given that, as explained above, the passenger expenditure multiplier outside the UK is greater than the multiplier inside the UK, the overall effect is to reduce GDP in the case of the Gatwick scheme. As the net change in spend is positive, but the GDP impact is negative

Figure 11 demonstrates that the resultant multiplier on the change in passenger expenditure is negative. From the mid-2040s, inbound passenger flow expenditure in the UK grows more quickly than expenditure outside the UK, so that the negative GDP impact of passenger flows diminishes.

*Figure 11: LGW 2R Input, real GDP impact and implied multiplier for additional passenger flows, Assessment of Need scenario*




*Source: PwC analysis*

Although the overall GDP effects of increased passenger flows in the assessment of need scenario are negative, the increase in foreign inbound passenger expenditure will still have positive effects on UK GDP – it is just that they are offset, by increased spending overseas by UK residents who travel abroad. As described above, Gatwick currently facilitates more expenditure outside of the UK than inside the UK, once displacement of existing expenditure is taken into an account.

Inbound passenger spending is an important source of foreign exchange and are equivalent to exported goods or services in this sense. This effect occurs on the demand-side of the economy: inbound passengers will spend money on a range of goods and services in the UK economy (e.g. hotels, restaurants, the retail sector etc.)

Increased flows of “exports” can have important supply-side effects. The sectors of the economy associated with passenger flows will expand as a result of the increase in passenger spending and these sectors will need to hire more workers and invest more to support any expansion. The labour market associated with passenger expenditure is important for the UK economy as it provides a range of low-skilled and school leaver jobs and can facilitate working on a part-time basis. These types of jobs are often taken up by the long-term unemployed. If the number of inbound passengers increases, this can also have positive upstream effects for those sectors that supply goods and services to relevant sectors for servicing these additional passengers (e.g. the manufacturing or agriculture sectors). Overall the model suggests a small, but permanent increase in productivity resulting from the supply-side expansion associated with inbound passenger flows.

There are also spending benefits for the UK economy associated with UK residents travelling overseas. Before travelling, UK residents purchase items from UK businesses e.g. airline tickets, clothes etc. The ONS TSA data suggests about one-third of all expenditure from UK outbound tourists is spent in the UK rather than overseas. This geographic distribution is reflected with the S-CGE modelling.

#### *6.4.3.2 Effect 2: Productivity*

As discussed previously, the construction of an airport scheme can stimulate an external positive supply-side change in the economy. This is because an airport scheme will lead to improved transport connectivity which in turn provides a benefit to those businesses that use air transport. The drivers of these benefits are called productivity effects. No specific data inputs are presented in this section because, as explained below, the productivity effects are driven by passenger flows.

*Econometric analysis*

We use econometric analysis to estimate the link between international trade and passenger numbers. This relationship is used in the S-CGE framework to proxy productivity effects. As explained in Chapter 4, the key results are that a 10% increase in passenger numbers is associated with a:

- 2.37%-2.93% increase in exports of goods
- 5.81%-6.12% increase in imports of services
- 2.48%-2.97% increase in exports of services.

We were not able to establish a significant econometric relationship between passenger numbers and UK goods imports.

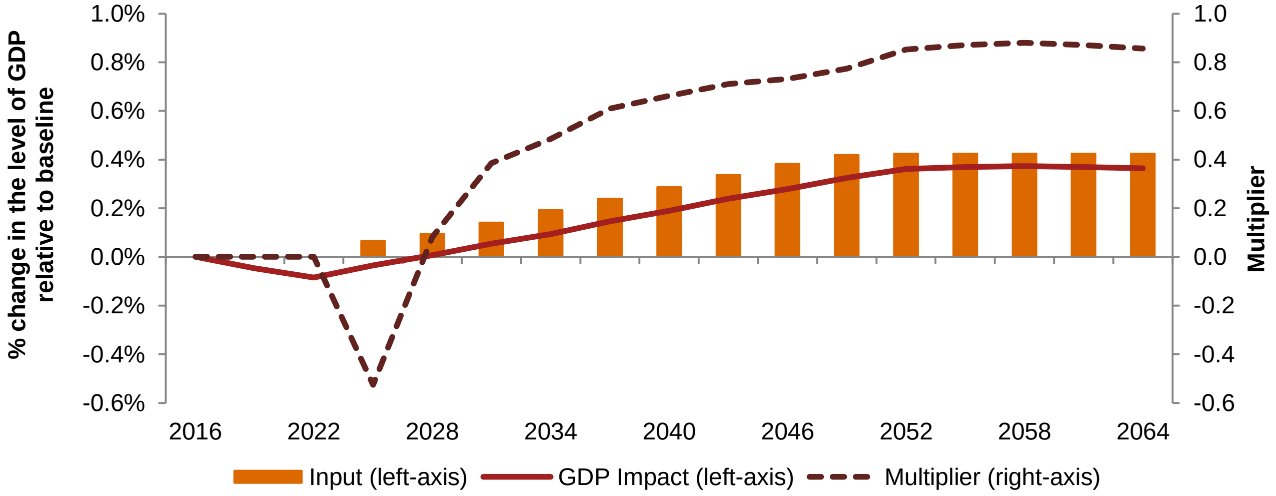
*GDP impact*

Figure 12 below summarises the productivity inputs estimated through the relationships identified above, and the impact on GDP which these are forecast to have. Figure 12 demonstrates that the magnitude of the productivity improvement is forecast to increase steadily throughout the first half of the operational phase, before flattening out as the airport reaches capacity. The growth of productivity is linked to increased business usage of air transport services. The rationale behind the improvement in productivity is given in Chapter 2. Business usage of air transport evolves in line with the AC passenger forecasts set out above. After an initial dip, the forecast real GDP impact follows this trend reasonably closely, eventually leading to an increase in GDP of just under 0.4% per year, relative to the baseline scenario.

Also evident is that the magnitude of the GDP impact is less than the value of the input. This is representative of some “crowding out” in the economy, as more productive sectors expand at the expense of less productive ones. The sectors that use the highest proportion of air transport experience the greatest productivity gains. Wages will rise in these sectors as they seek to attract new workers to enable them to expand. Similarly, they also need to raise the returns they offer to capital investors to attract new investment funding. Increases in both wages and the cost of investment capital contribute to a diffusion of the initial productivity gains associated with the expansion in air transport.

In addition, the marginal propensity of firms and households to consume goods and services from outside of the UK ensures that a share of the GDP benefit leaks out of the economy. These diffusion and leakage effects are reflected in the multiplier, which is shown on the right-hand axis to remain less than one. The multiplier increases throughout the period as the sustained productivity benefits lead to capital accumulation which further increases productivity. As a result, the GDP impacts at the end of the period are greater, relative to the size of the input, than at the beginning.

*Figure 12: LGW 2R Productivity input, real GDP impact and implied multiplier, Assessment of Need scenario*




*Source: PwC analysis*

### *6.4.3.3 Effect 3: Frequency benefits*

In order to limit our analysis to those inputs which have a measurable economic impact, our modelling has reflected only the frequency benefits which accrue to business passengers, and which therefore can be interpreted as being likely to have positive productivity effects. In reality, the time savings experienced by some leisure passengers could lead to a productivity increase, but this is unlikely to represent a substantial share of these benefits, and they have not been included in our modelling.

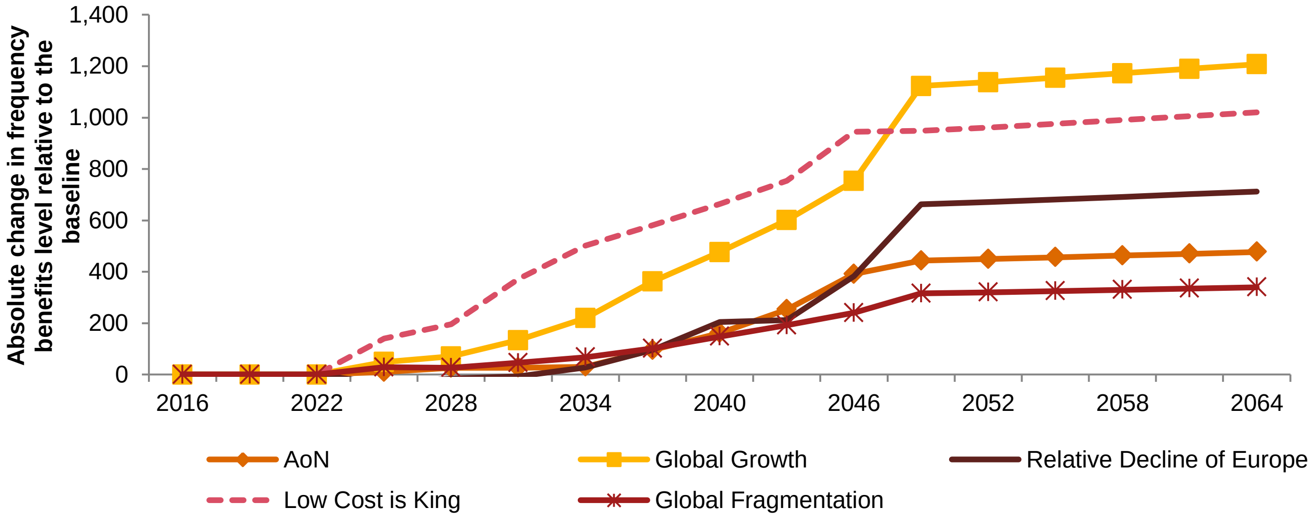
*Inputs*

The AC provided us with estimates of frequency benefits to be used as inputs to the S-CGE model. These inputs have been produced by the AC demand forecasts, and are estimated by combining estimates of the value of time with the forecast time benefits from increased frequency. The effects shown in the figure below refer to businesses only. Frequency benefits contribute to increased connectivity for businesses and can facilitate improvements in productivity. This in turn can lead to increases in profitability and in additional investment in the long-term.

Figure 13 below shows the frequency benefits for the five scenarios. This demonstrates that there are significant differences across scenarios. These differences tend to be correlated with differences in the passenger flows as discussed above.

As shown in Figure 13, the AC's forecast frequency benefits are highest under the Low Cost is King scenario, up to 2049 and largest for Global Growth thereafter. Frequency benefits in the Decline of Europe scenario display a noticeable increase in the late 2040s.

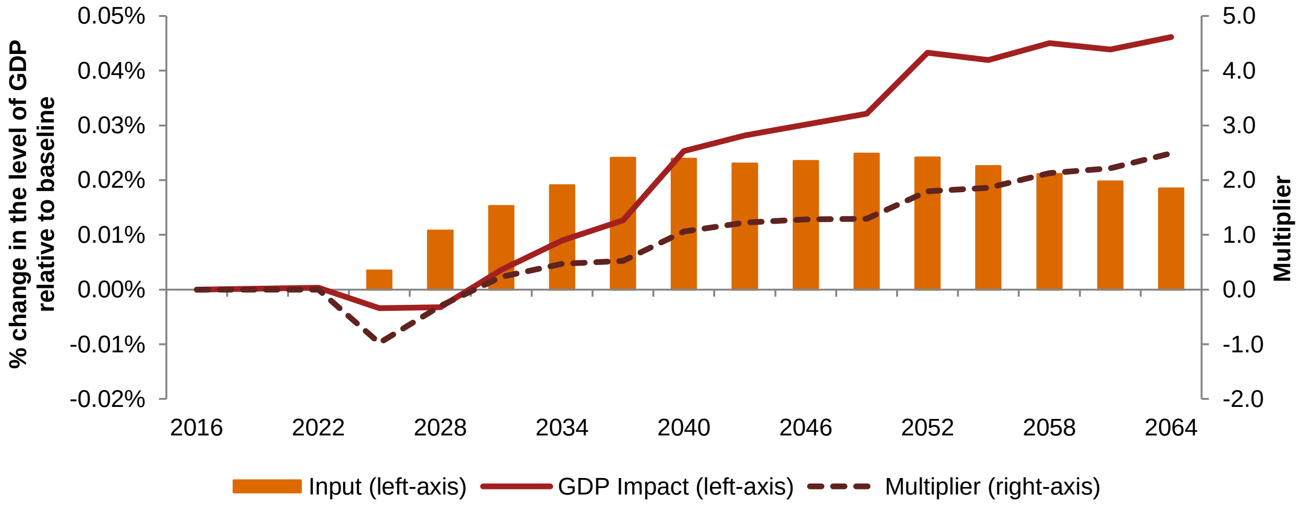
*Figure 13: LGW 2R   Frequency benefits, by scenario*




*Source: PwC analysis*

Compared to the previous effects described above, the frequency benefits are modest in magnitude, reflecting the underlying inputs provided by the AC. As a result, the estimated GDP impact of these inputs is also modest, at less than 0.05% of GDP under the Assessment of Need passenger flow scenario, as shown in Figure 14 below. The multiplier on the frequency benefit inputs is greater than one by the end of the period. This occurs because the forecast improvements in efficiency experienced by producers in the early periods of operation incentivise higher levels of investment. This in turn leads to further productivity increases and subsequently a long-run impact on GDP which is greater than the value of the input.

*Figure 14: LGW 2R   Input, GDP impact and multiplier effect for frequency benefits, Assessment of Need scenario*




*Source: PwC analysis*

### 6.4.3.4 *Effect 4: TEE*

*Inputs*

Chapter 4 outlined how the AC have provided estimates of the TEE impacts, which capture the impact of the expansion in airport capacity on air fares. Specifically, the AC TEE impacts show that the cost of travel falls once new capacity is introduced, and this results in a transfer of money from producers (airlines) to consumers (air passengers). Scarcity rents which producers could charge for use of the airport when it was capacity constrained are reduced, leading to benefits for consumers through lower air fares. It should be emphasised that the estimated changes in consumer and producer surplus are relative to the level of consumer and producer surplus that would be expected in the absence of capacity expansion (rather than being compared to today's levels of producer and consumer surpluses).

Table 17 below summarises the AC's forecast undiscounted consumer and producer surplus elements[134] of the TEE benefits, under the five passenger flow scenarios[135], incorporating the updated inputs provided by the AC for the Global Growth, Relative Decline of Europe, and Low Cost is King scenarios. It is evident from the table that much of the estimated increase in consumer surplus is a transfer from producers, and that where there are forecast to be larger consumer surplus gains these are typically accompanied by higher producer surplus losses across scenarios. As a result, it is clear that the net impacts of these two effects are small in comparison to the absolute consumer and producer surplus changes. The absolute magnitude of the individual impacts are £2-7bn in 2050, which is substantially larger than the frequency benefit effects outlined in Figure 13 above which are between £0.3-1.5bn at the same date. The overall magnitude of the consumer and producer surplus changes are lower in the Assessment of Need, Relative Decline of Europe and Global Fragmentation scenarios than in the Global Growth and Low Cost is King scenarios. This is consistent with the passenger flow forecasts described above.

*Table 17: LGW 2R Consumer and Producer Surplus impacts relative to the Do Minimum, by scenario*

| | | Change in Consumer Surplus (£m) | Change in Producer Surplus (£m) | TEE net welfare change (£m) |
|---|---|---|---|---|
| **Assessment of Need** | **2030** | 166 | -181 | -15 |
| | **2050** | 2,773 | -2,622 | 151 |
| **Global Growth** | **2030** | 473 | -503 | -29 |
| | **2050** | 7,409 | -6,658 | 752 |
| **Relative Decline of Europe** | **2030** | 57 | -57 | 0 |
| | **2050** | 2,761 | -2,831 | -70 |
| **Low Cost is King** | **2030** | 570 | -563 | 7 |
| | **2050** | 5,666 | -3,976 | 1,690 |
| **Global Fragmentation** | ***2030*** | *63* | *-76* | -13 |
| | ***2050*** | *1,944* | *-1,993* | -49 |

*Source: AC demand forecasts*

### *Impact on GDP*

Figure 15 and Figure 16 show the size of the input and GDP impact of these consumer and producer surplus changes for the Assessment of Need scenario, which is again selected for illustrative purposes. Also presented is the implied multiplier for each effect, which captures the ratio between the size of the input and the forecast impact.

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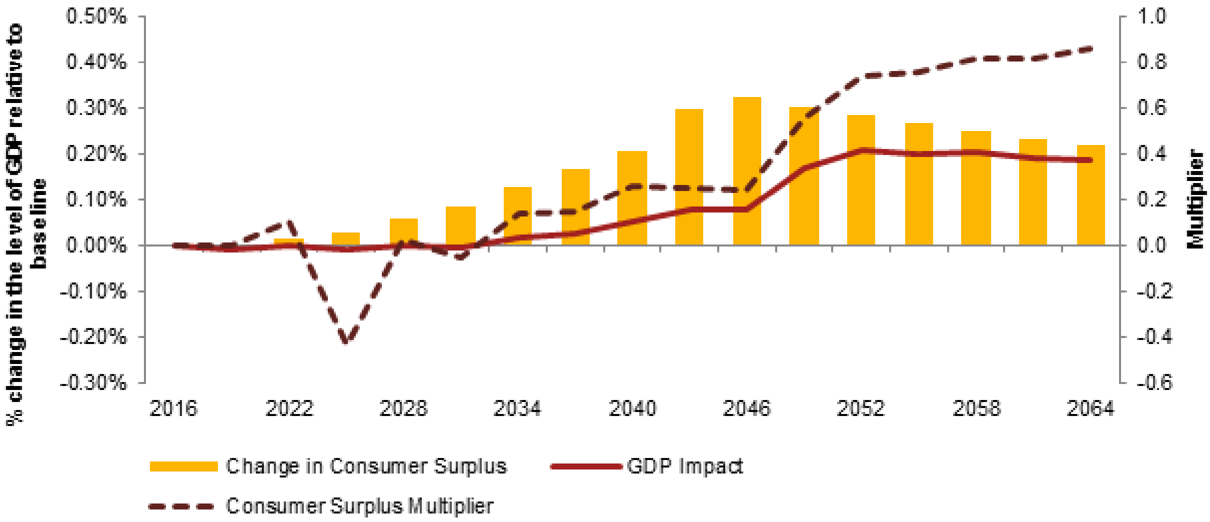
[134] Please note that in the interest of internal consistency, Figure 15 presents the undiscounted inputs to the S-CGE model in two illustrative years. For a full description of the TEE inputs, please see the Transport Economic Efficiency Technical Appendix, available on the Airports Commission website.

[135] It is also important that the taxation impacts are captured in the modelling framework. The S-CGE model has a full description of taxation structures in the UK, and therefore it is important that inputs to the model are **gross** of tax impacts. We have, therefore, incorporated producer and consumer surplus changes **prior** to the levy of taxes.

*Figure 15: LGW 2R Consumer surplus input, GDP impact and implied multiplier, Assessment of Need scenario*




*Source: PwC analysis*

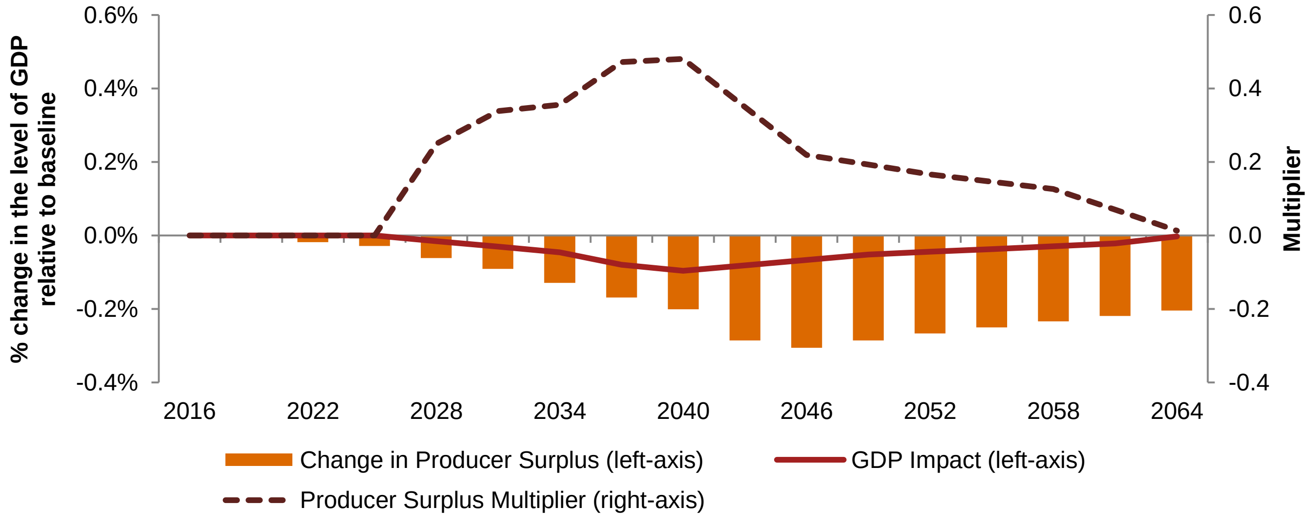
Looking first at consumer surplus only in Figure 15 the GDP impact of the change in consumer surplus is shown to be reasonably modest until the mid-2040s, then becoming increasingly significant towards the end of the period. This occurs as consecutive periods of positive impact lead to re-investment of economic gains and increased capital accumulation. This generates a sustained increase in the level of GDP through a persistent positive impact on productivity, even as the relative magnitude of the impact begins to diminish from the early 2050s. For the final few periods analysed, there is a forecast increase of nearly 0.2% of GDP, representing a multiplier of 0.6-0.8 on the value of the input. The fact that this multiplier is less than one (i.e. the positive impact on GDP is less than the value of the input) demonstrates that some of the increase in consumer demand is crowded out through a rise in the price level – the *price rebound effect*. This result is typical when using a general (relative to partial) equilibrium approach.

| | |
|---|---|
| **Price rebound / diffusion effect** | As real GDP and aggregate demand increase, upward pressure is exerted on prices. As prices rise there is a nominal, positive inflation effect. As noted above, inflation effects could be particularly strong in the aviation sector. The price rebound effect is important in ensuring that the economy ultimately reaches a new, stable equilibrium. In particular, there are a number of positive "cumulative" forces at play in the S-CGE framework (e.g. the confidence effect described above in section 6.4.1). The effect of increasing prices keeps the economy "in check" and prevents economic activity from spiralling ever-upwards. |

Figure 16 shows the equivalent pattern for the producer surplus input and impact. The time profile of the input is similar, with a rise through to the mid-2040s as the airport reaches capacity, followed by a relative decline. However, there are two distinct differences in the nature of the forecast GDP impacts. Firstly, unlike the consumer surplus effect, the reduction in GDP closely tracks the time profile of the input, with an initial decline which gradually reduces in magnitude from the early 2050s. This occurs as the reduction in surplus represents the removal of excess profits generated through scarcity rents in the airline sector. As this does not substantially alter the national level of savings and investment, there is no significant change in the long-run productive potential of the economy, and subsequently the negative GDP impact diminishes with the magnitude of the negative input.

Secondly, the impact on the level of GDP by the end of the period is substantially lower in absolute terms than the consumer surplus impact, despite the level of input being similar. By the end of the period, the forecast reduction in the level of GDP associated with this effect is below 0.1%, less than half the size of the forecast increase generated by the consumer surplus effect. The reverse is true for the period up to the mid-2040s, where the forecast impact of the producer surplus effect builds up more quickly than that of the consumer surplus effect. These two trends lead to the net impact seen in Figure 17 where TEE effects are forecast to have a negative impact on GDP up to the mid-2040s and a substantial positive effect thereafter.

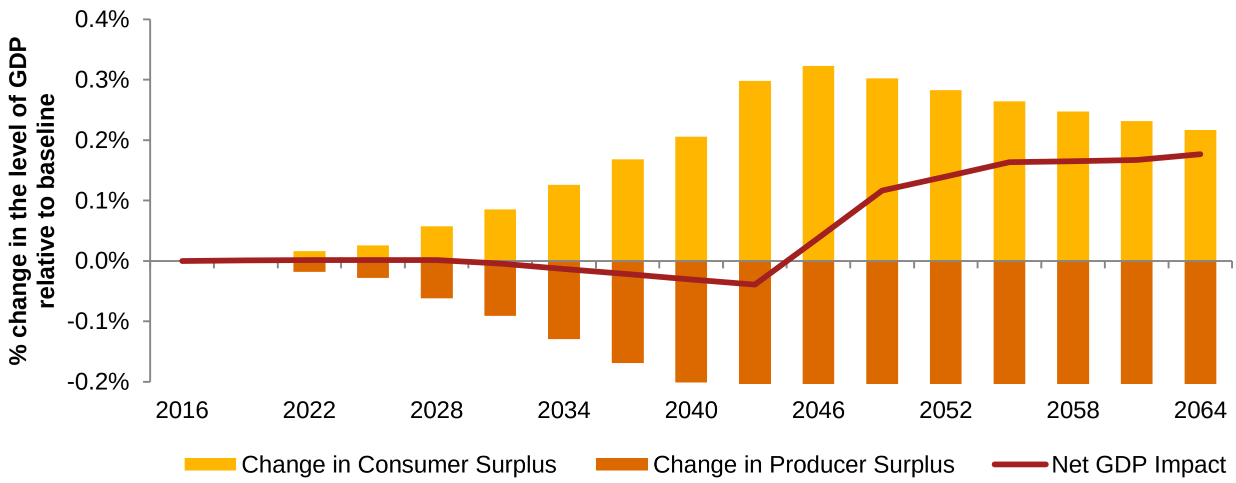
*Figure 16: LGW 2R   Producer surplus input, GDP impact and implied multiplier, Assessment of Need scenario*




*Source: PwC analysis*

Figure 17 shows the combined impact of the consumer and producer effects, along with the two inputs. This illustrates that the absolute magnitudes and time profiles of the two inputs are relatively similar, with the consumer surplus effect being only marginally larger. However, after an initial dip, the GDP impact is forecast to become substantially positive towards the end of the period, as the multiplier effect of the change in consumer surplus increases.

*Figure 17: LGW 2R   Combined TEE inputs and net GDP impact, Assessment of Need scenario*



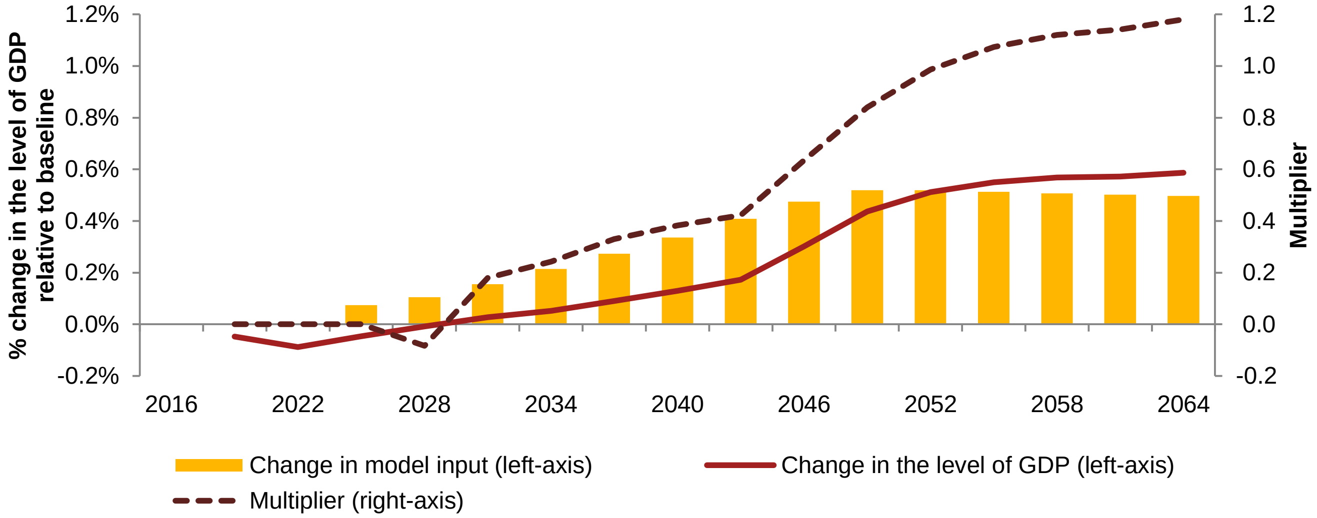

*Source: PwC analysis*

### *6.4.3.5 Combined inputs and GDP impact*

Each of the effects outlined above contributes to the projected overall impact of the LGW 2R scheme on the level of GDP. Combining the inputs and GDP impacts of each effect gives an estimate of the overall GDP multiplier of the model inputs – this is shown in Figure 18 below. It is evident here that the value of the inputs increases until the late 2040s before gradually declining, while the impact on the level of GDP continues to rise throughout the period and exceeds the value of the inputs from the mid-2050s. This leads to the overall multiplier continually rising, eventually reaching a value of nearly 1.2.

This demonstrates that the full GDP impact of an input will not exclusively be felt in the years in which they have a direct effect. For example, increases in household spending or productivity in the early years of the analysis are expected to result in an increase in investment. This investment is expected to lead to long-run productivity gains which increase the level of GDP in all future years. In addition, agents within the model recognise that the increase in capacity will yield positive demand (through increased household and passenger spending) and supply (through increased productivity) effects. This motivates them to delay economic activity until later years, thus dampening the GDP impact in the early years of the analysis and accentuating it in the later years.

*Figure 18: LGW 2R combined model inputs and GDP impact, Assessment of Need scenario*




*Source: PwC analysis*

There are two important considerations that should be noted alongside this multiplier effect:

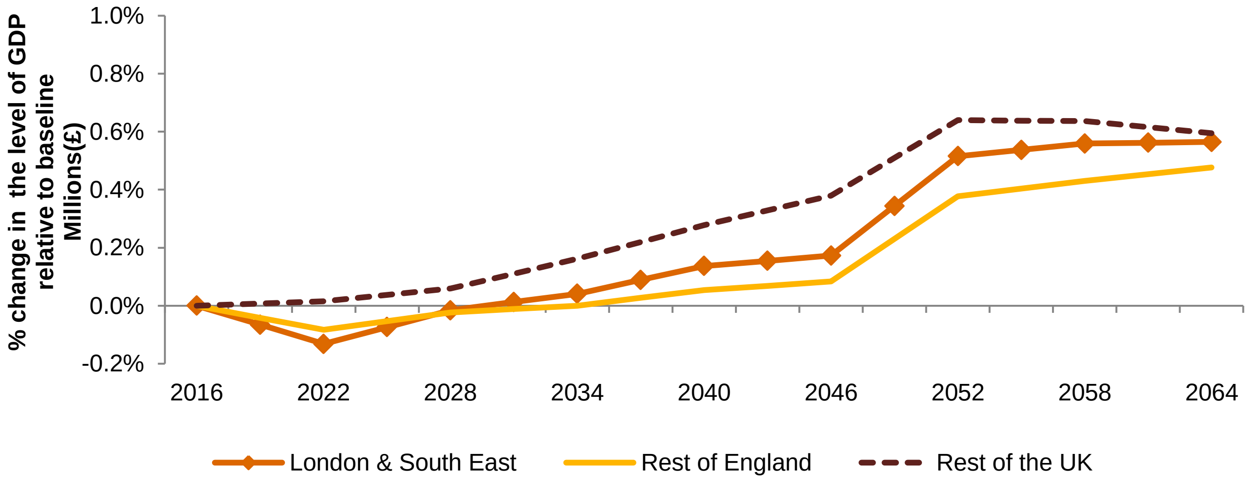
- The S-CGE model captures a wider range of impacts (such as price effects and feedback loops to non-aviation users, and the wider benefits of wage and skill growth) which increase the scope of our estimates beyond what would normally be captured using other techniques that do not fully account for changes in economic behaviour (e.g. input-output analysis). Therefore, while the magnitude of some the effects generated by the S-CGE model (e.g. passenger spending), may be smaller than comparable estimates that take limited or no account of diffusion, the S-CGE model will pick up a broader range of effects which may or may not lead to a larger overall impact.
- These multipliers are "net" in the sense that they capture both displacement of economic activity from sectors of the economy that do not have strong direct or indirect linkages with the aviation sector and, as described above, also include the costs of airline expansion. Our study for the AC (3. Local Economy: Literature Review) illustrated a range of multiplier estimates relating to airport impact assessments, the majority of which were larger than 1 – this is because they are "gross" multipliers and do not fully factor in the range of effects described above.

## *6.5 Impact by region*

Figure 19 provides the forecast GDP impacts over time, by region. For brevity, the information provided is only for the Assessment of Need scenario. Table 18 shows the PVs of the scheme by region, for each of the five scenarios. This table reflects the updated assumptions. As stated above, the regions are defined as:

- London & South East, which is made up of the London and South East NUTS 1 regions (or "Government Office Regions");
- The Rest of England, which is made up of all other NUTS 1 regions in England (East of England, East Midlands, North East, North West, South West, West Midlands, Yorkshire and the Humber); and
- The Rest of the UK, which is made up of Northern Ireland, Scotland and Wales.

*Figure 19: LGW 2R regional GDP impacts, Assessment of Need scenario*




*Source: PwC analysis*

*Table 18: LGW 2R Present Value of regional real GDP impacts, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **London & South East** | 25.5 | 32.8 | 15.7 | 77.1 | 11.0 |
| **Rest of England** | 36.7 | 32.2 | 14.4 | 29.9 | 10.8 |
| **Rest of the UK** | 11.2 | 28.0 | 11.7 | 17.2 | 7.6 |

*Source: PwC analysis*

Table 18 demonstrates that all three regions are forecast to experience positive GDP impacts across all five passenger flow scenarios as a result of the LGW 2R scheme. Given the scheme's location, it is not surprising that London & South East generally enjoys a large increase in GDP from the scheme. However, the figure demonstrates that in percentage terms, the largest increase in the Assessment of Need scenario is actually seen in Rest of the UK, despite this region experiencing the smallest benefit in PV terms.

There are a number of reasons why benefits are modelled as dispersing across all regions of the economy. Primarily, the majority of impacts are national effects and therefore benefit all regions, such as productivity improvements brought by cheaper imports and better access to export markets, as well as the reduction in the cost of air travel due to the assumed fall in air fares. Although passengers who land at Heathrow and Gatwick spend disproportionately in London & South East, the model captures the degree to which the spending by these passengers is dispersed across the other parts of the UK. Further, the increase in air transport capacity in London & South East will diffuse to the other UK regions through inter-regional trade. For example, London & South East exports insurance and financial services to the other UK regions whereas it imports manufacturing products from the other UK regions. As the London & South East economy expands due to the increase in air capacity, London will begin to import more manufacturing from the other UK regions. This will have a positive impact on GDP in the other UK regions, which will, in turn, lead to an increase in demand for imports from London & South East in sectors such as financial services, which will have a positive impact on GDP in London & South East. Also, any rise in activity within London & South East which is not common across all regions, will cause an increase in the price level in that region. This could crowd out other activity, tending to cause it to relocate to other regions.

Finally, while many of the positive effects are distributed evenly across regions, the negative impact of the decline in producer surplus is expected to affect London & South East disproportionately due to the relatively high share of the aviation sector which is headquartered there. Although the economic impact may be dispersed across all regions, the majority of the reduction in gross operating surplus resulting from this effect would be experienced in London. This would occur because a greater number of airlines are registered in London than any other region for accounting reasons, and this region therefore receives an above-average share of profits from the industry.

This also contributes to the time trend of the difference between London & South East and the Rest of the UK, with London & South East forecast to achieve a relative catch-up in the final few periods, as the magnitude of the producer surplus decline decreases.

In addition to direct effects, the regional distribution of impacts can be explained by “agglomeration” and “cumulative causation” forces identified in the New Economic Geography literature. These effects are outlined in Box 3 below.

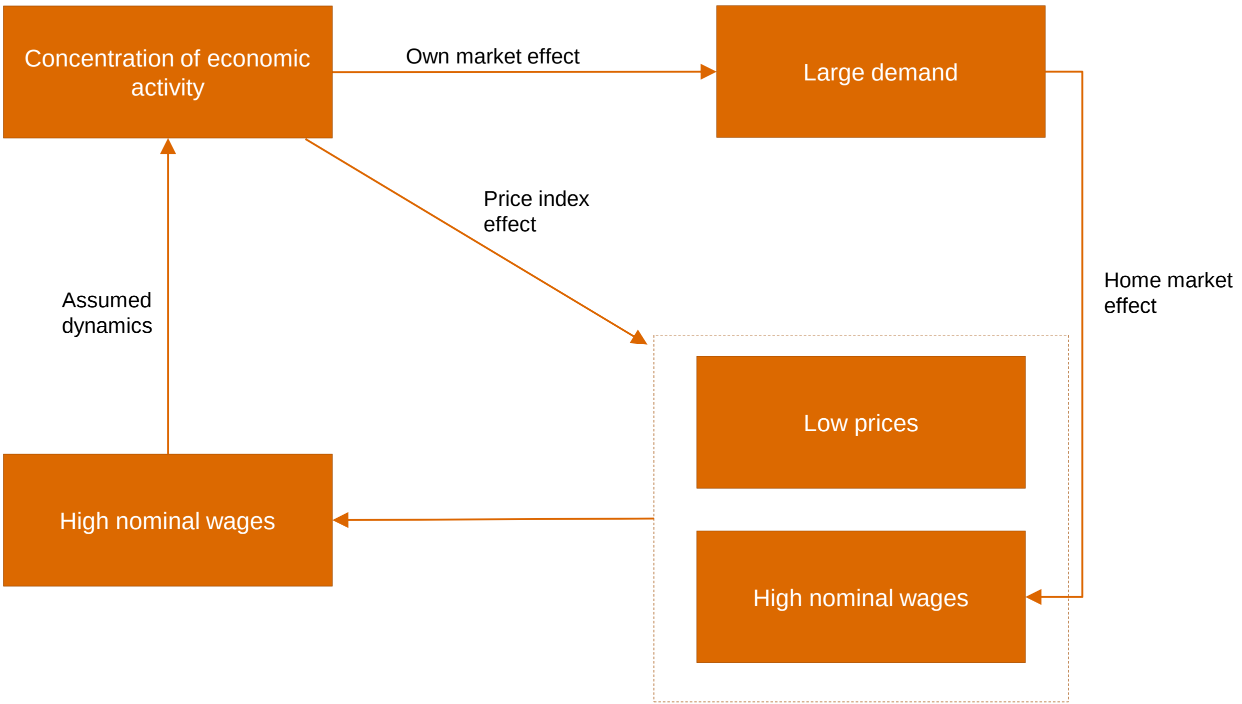
**Box 3: Agglomeration and cumulative causation**

As described in Chapter 2, the S-CGE framework has a regional structure with imperfect competition, meaning that agglomeration will be an inherent or 'endogenous' feature of the model that can follow from any of the modelled effects described above. These key agglomeration impacts are considered in detail in Chapter 2 and Appendix A. In particular, the model implies the following effects (these are explained in general terms later in this chapter):

- **Own Market Effect.** The expanded aviation sector in London & South East generates demand, which makes London & South East a more attractive place for businesses to locate;
- **The Home Market Effect.** The expanded airport facilities lead to increases in employment in London & South East (as described above). This increases nominal wages in London & South East, which makes the region more attractive as a place to work; and
- **The Price Index Effect.** Prices may be lower in regions with denser economic activity because distances between consumers and suppliers are lower on average, resulting in lower transport costs. Whilst this precise effect is not present in the S-CGE framework, an analogous effect – which has the same implication – does exist. In particular, higher economic activity in London & South East which may come about as a result of the airport could give rise to increased competition between firms, which reduces profit margins and prices. These lower prices make London & South East more attractive to consumers and firms.

Between them, these effects generate a process of what Myrdal (1957) calls 'circular causation': the presence of the expanded airport in London & South East generates demand (own market effect) which, by the home market effect, increases local wages. At the same time, the price index effect means that prices on average are lower in this region. These arguments combined imply that real wages in the region are relatively high. Since workers in the S-CGE model are attracted to regions where they can command higher real wages, workers move to London & South East. This reinforces the prominence of the region and so the cycle repeats itself. Figure 20 below illustrates the process.

*Figure 20: Circular causation*



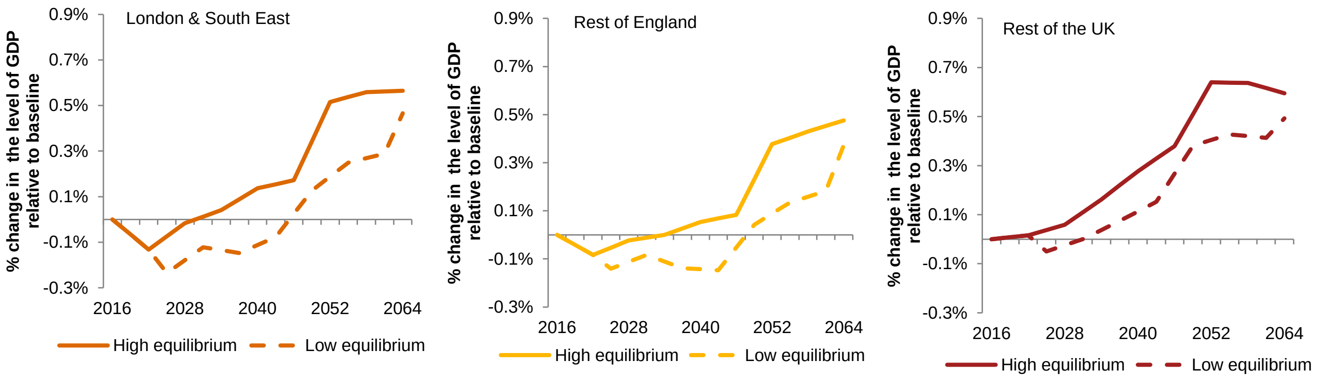

*Source: PwC analysis*

## 6.5.1 *Factors affecting the regional distribution*

As noted in Chapter 2, models based on imperfect competition can give rise to multiple equilibria. The results from the S-CGE model suggest two different equilibrium outcomes for the LGW 2R scheme (a "high scenario" outcome and a "low scenario" outcome) both are consistent with profit maximising behaviour. In addition to the discussion in Chapter 2, Appendix A highlights the key economic theory in relation to multiple equilibria. The multiple equilibria produced by the model are largely borne out of the functional forms in the model used to capture imperfect competition and regional trade.

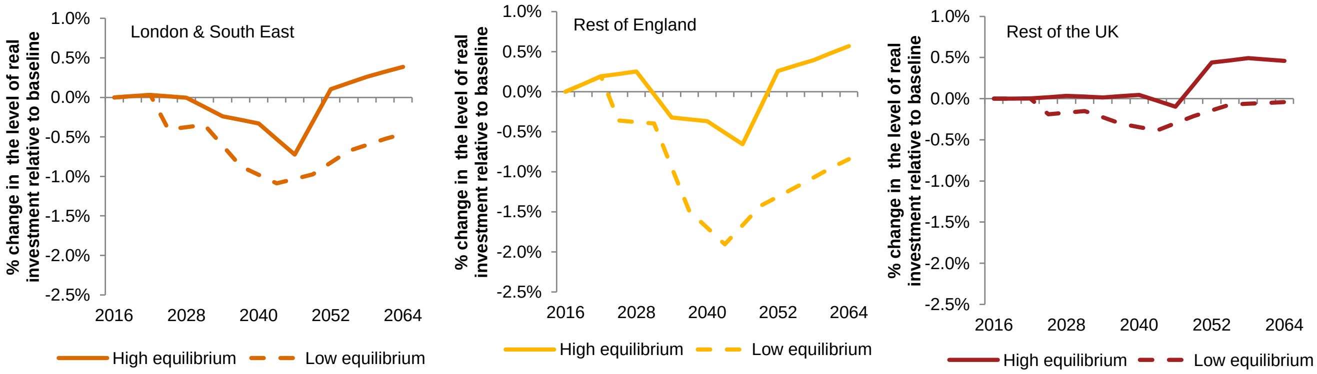
In the "high scenario" outcome for LGW 2R, there is more GDP and investment in each region of the UK than in the low outcome – about 0.1 percentage points in extra GDP is observed in the high outcome relative to the low outcome. However, neither of these outcomes implies a "lock-in" of economic growth in London & South East at the expense of other UK regions. The results for both outcomes suggest a long-term change in the level of real GDP across all regions, with this growth eventually flattening out as the LGW 2R scheme reaches full capacity. The GDP effects are relatively small, but the effects are more pronounced on the different components of GDP, Figure 22 illustrates this from an investment perspective.

*Figure 21: LGW 2R Effect of expansion on the level of real regional GDP in London and South East, Rest of England and the Rest of the UK, multiple equilibria, high and low equilibrium, Assessment of Need scenario*




*Source: PwC analysis*

*Figure 22: LGW 2R Effect of expansion on the level of real regional investment in London and South East, Rest of England and the Rest of the UK, multiple equilibria, high and low equilibrium, Assessment of Need scenario*




*Source: PwC analysis*

The extent to which economic gains are realised by each region is dictated by the pricing behaviour of airlines. In the S-CGE model, each firm has a perception of the consumers' income elasticity of demand for the products that it sells. This perception varies with the level of economic activity. As has been shown in the previous sections, following the introduction of a new airport scheme, the S-CGE model has estimated that economic activity will be higher, and as a result entrepreneurs may perceive this as a good time to enter the market. The reasoning behind this is that customers may be finding it hard to find suppliers for the products they wish to purchase. This may lead to consumers' income elasticity of demand falling (i.e. becoming more inelastic). If the income elasticity of demand falls, firms can charge higher mark-ups and make more profits per unit of output sold.

However, when mark-ups rise the threat of new market entrants will be greater for businesses already operating in the market. This may lead to them to lower their mark-ups to make it less attractive for potential new entrants to enter the market. This effect can potentially offset the factors that might entice firms to enter the market described above and the overall effect on mark-ups could potentially be zero (Carlin and Soskice, 2006)[136] or they could even fall if firms felt that total profits (as opposed to profits per unit of output) could increase.

If businesses are more sensitive to the threat of entry than to existing competition then the perceived income elasticity of demand could be procyclical: this would imply higher margins when the level of economic activity is at a relatively low point (and hence the perceived threat of entry is low, reducing the perceived income elasticity of demand, and encouraging incumbent firms to raise prices and margins) and lower margins when the level of economic activity is at a relatively high point. If businesses are more sensitive to the threat of internal competition from the existing market then their perceived elasticity of demand will be countercyclical. Margins will be lower when output is at a relatively high level and vice versa. Carlin and Soskice note that in the latter case there will be a unique equilibrium. However, in the case where there is a greater sensitivity to the threat of entry there is a possibility that multiple equilibria will occur.

This latter effect is what we observe in the S-CGE model in the high outcome. Firms within the airline sector are willing to accept lower mark-ups to act as a deterrent to new entrants. Overall they make more profits, because the UK aviation market has expanded, but profit per passenger falls.

This reaction is in part triggered by the reduction in producer surplus described in relation to the TEE effects. In the TEE framework, the increase in airport capacity has opened up competition in the UK aviation sector and driven down prices. This has the knock-on effect of driving up demand from households and businesses wishing to travel by air. In the high scenario, incumbent airline firms accept the lower mark-ups that come with the threat of increased competition and as passenger demand rises, they do not seek to increase mark-ups in response. This has a dual effect – new entrants are deterred, and some incumbents will exit the market as they view operating in a market with low mark-ups as not viable or attractive. So the outcome is that there are fewer airlines in operation in the UK market, but the remaining airlines fly to more destinations and at lower prices.

Figure 23 demonstrates this by showing results from the S-CGE model for the number of firms in the air passenger transport sector (in the left-hand chart), and all other sectors (in the right hand chart). Please note that the scales for these charts are intentionally different due to the substantially different scales of the impact.

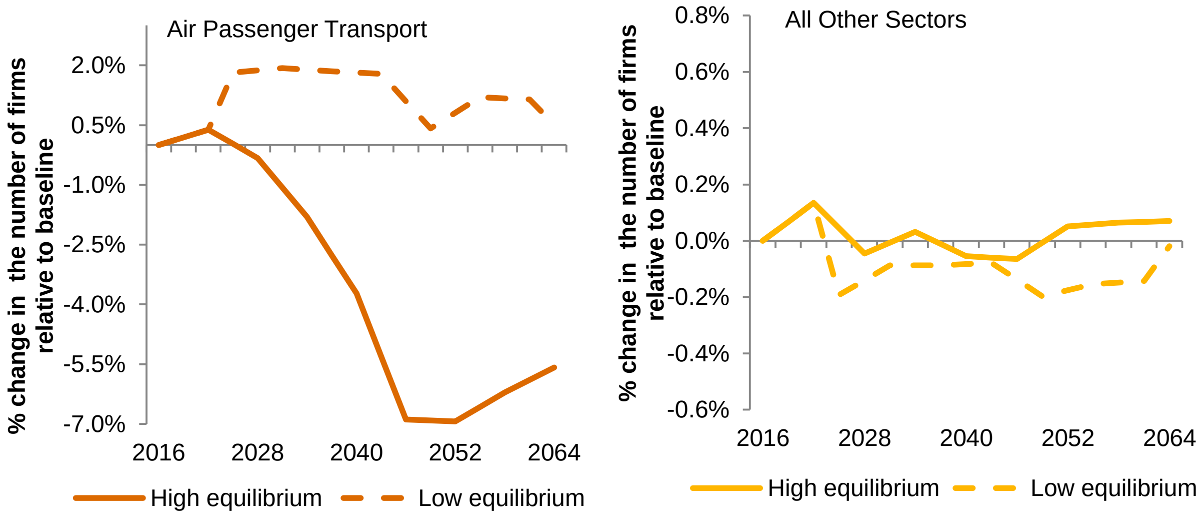
The S-CGE model suggests that in the "high scenario", there is substantial consolidation in the air passenger transport sector, with the number of firms falling by nearly 7.0%. In this scenario the lower prices and mark-ups in the aviation sector benefit other business users, which in turn can reduce their costs and increase their profits. This leads to more firms entering the non-aviation sectors to contest the higher mark-ups there associated with the increased levels of business and consumer activity.

In the "low scenario" the pricing behaviour of airlines is the opposite of that observed in the "high scenario". Air fares initially fall in response to the increase in airport capacity, but in the longer-term they rise in response to increases in demand. This implies that there will be new entrants into the UK aviation sector who will seek to compete away any new potential higher mark-ups back down to the levels before new airport capacity was built. Overall in this scenario there are more firms in the UK aviation market (between 1 and 2% more), but prices are higher and there is less benefit passed on to consumers in the form of lower fares. This means that the overall impact of this scenario on GDP is smaller.

The higher fares in the "low scenario" effectively deter some passengers from using the newly expanded Gatwick airport. This means that the net positive GDP gains observed in the "high scenario" take longer to materialise. In the "low scenario", the negative economic multiplier associated with UK residents flying overseas dominates the other positive wider economic effects. However, once the overall level of flight operations at Gatwick picks up (about 2045 onwards) the gains, even in this low outcome, are substantial, both in London & South East, but also for the rest of the UK economy.

[136] Carlin, W. & Soskice, D. (2004) Marcoeconomics: Imperfections, institutions & polices, Oxford, Oxford University Press

*Figure 23: LGW 2R   Change in number of firms relative to Do Minimum baseline, for Air Passenger Transport (APT) and all other sectors by high and low equilibrium, Assessment of Need scenario*




*Source: PwC analysis*

The results above illustrate that the overall level of UK GDP can differ between the multiple equilibria in the S-CGE model, but the impacts on its relative regional distribution are more limited. Given this, we tested the model to identify those factors that would affect the regional distribution of GDP. We found that the regional distribution of the impact relies heavily on the extent of inter-regional trade linkages specified in the model. As set out in Chapter 4, these linkages have been estimated using standard techniques. Nonetheless, the data on which they have been estimated still presents a source of uncertainty in our modelling, not in terms of the overall scale of the impact, but in terms of which regions will gain relative to others.

Our modelling results suggested that the Rest of England region would be expected to gain more than London & South East in absolute terms, while the Rest of the UK region would also be expected to gain significantly. A sensitivity analysis of the results suggests that by lowering the flows of inter-regional trade linkages by 20.0% (in terms of both regional imports and exports) the pattern of results can be reversed. The results of this exercise are shown in Figure 24 to Figure 27.

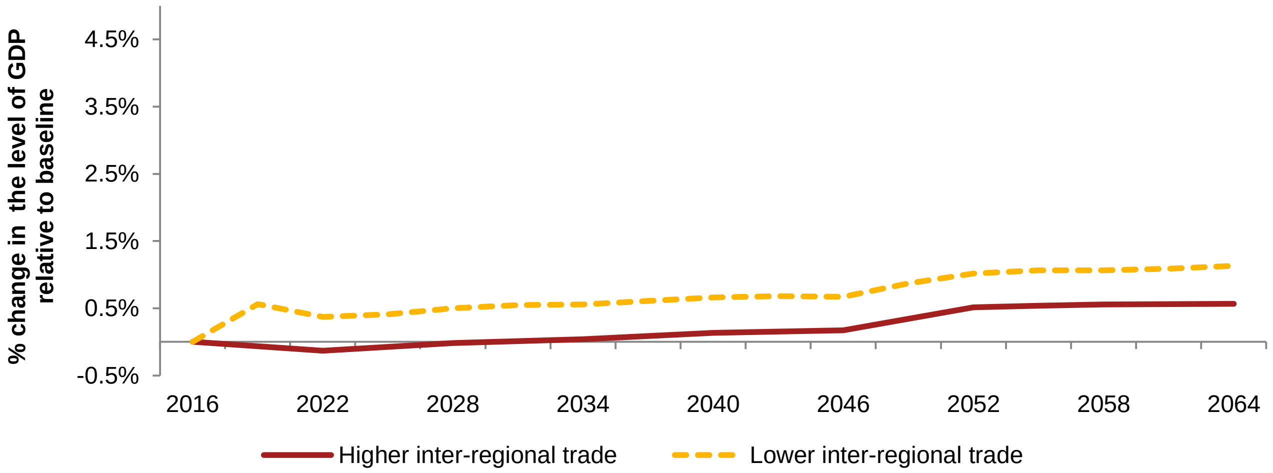
The results suggest that when a lower estimate of UK inter-regional trade linkages is compared to a central estimate the impact on London & South East is 0.53 percentage points higher while the impact on the rest of England is 0.50 percentage points lower, and the Rest of the UK is unaffected. The overall impact on the Rest of the UK and the UK economy as a whole are unchanged. This result is important for two reasons. Firstly it highlights the key determinant of the regional results: the stronger the trade linkages between the different regions of the UK economy, the more likely it is that the benefits of new airport capacity at Gatwick will benefit regions other than London & South East. Secondly it illustrates that, depending on the strength of inter-regional trade linkages, that airport expansion in London & South East could have some negative effects on other UK regions.

Our central estimate implies that the scale of inter-regional UK trade linkages is broadly 150% of international trade linkages and it is difficult to say whether this is realistic or not. However, as outlined above it has been estimated in line with international best practice and has been discussed with various UK Government Departments. At the time of writing this report, as far as we are aware, no better estimate of inter-regional trade flows in the UK exists.

In our sensitivity analysis we vary the level of inter-regional trade by 20%.  However, this variation is not enough to change the sign of the regional trade flow in the underlying data– London and the South East (LSE) still generates a surplus, it is just a lot smaller. By varying inter-regional trade by 20% we have identified a critical tipping point whereby the pattern of spatial economic benefits reverses (RUK gains more that LSE in this sensitivity test).

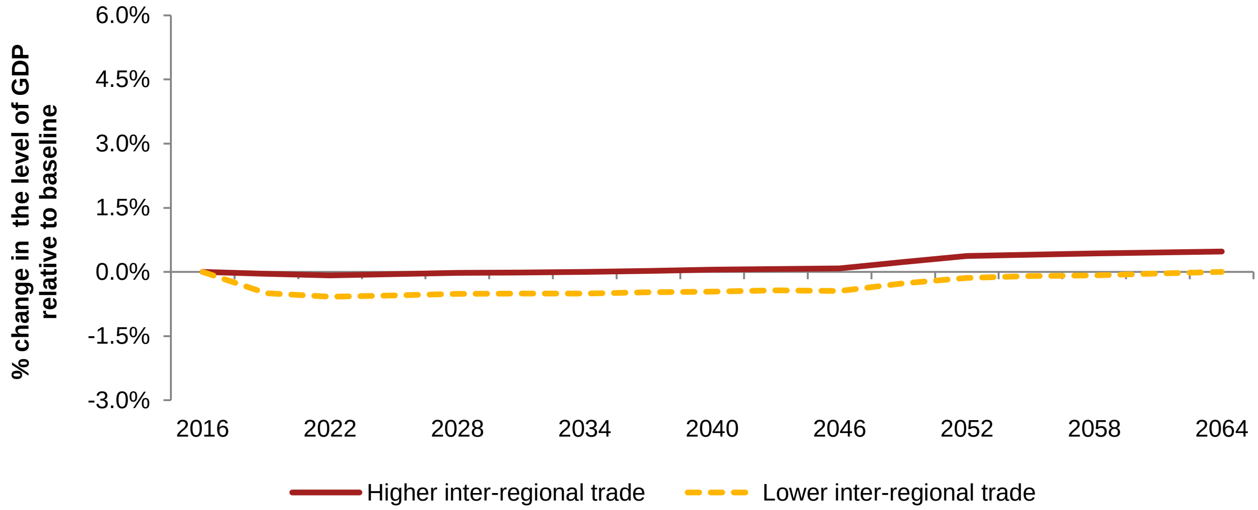
However, if we had estimated inter-regional trade to be 5% higher than it had been, we would not have seen the reversal in the spatial distribution of the results. What matters is the absolute magnitude of inter-regional trade. The modelling is showing that there is a tipping point i.e. when LSE exports less to RUK. However, if we lower the trade flows by 20% then the implication would be that GVA per capita in LSE would be well below the levels reported by the ONS. So we are less cautious in our interpretation.

*Figure 24: LGW 2R impact on the level of real GDP in London & South East by level of inter-regional trade, Assessment of Need scenario*



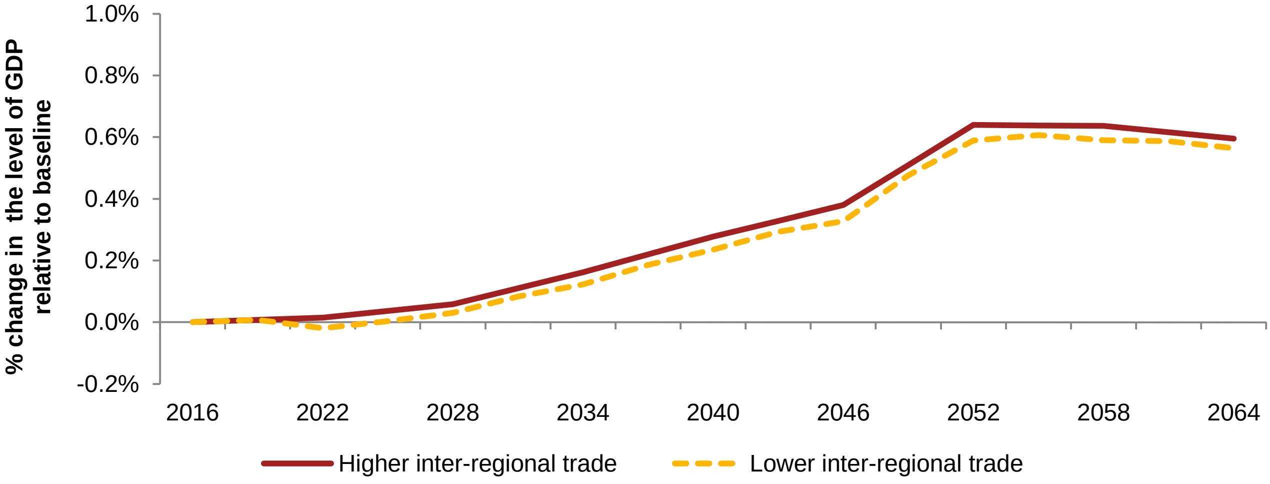

*Source: PwC analysis*

*Figure 25: LGW 2R impact on the level of real GDP in Rest of England by level of inter-regional trade, Assessment of Need scenario*



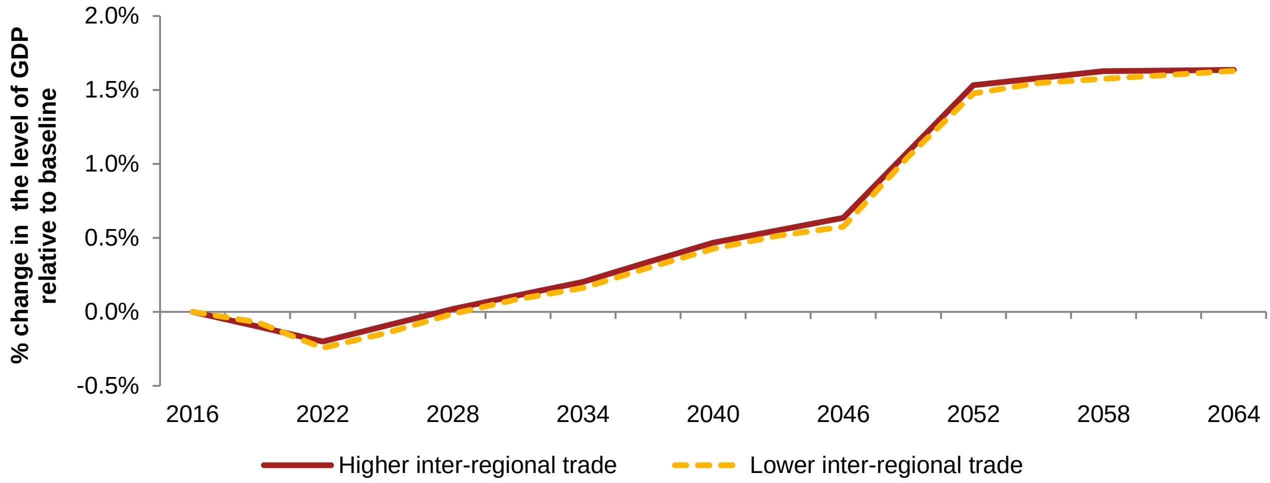

*Source: PwC analysis*

*Figure 26: LGW 2R impact on the level of real GDP in Rest of the UK by level of inter-regional trade, Assessment of Need scenario*




*Source: PwC analysis*

*Figure 27: LGW 2R impact on the level of real GDP in the UK by level of inter-regional trade, Assessment of Need scenario*




*Source: PwC analysis*

## 6.6 Impact of construction

*Construction phase inputs*

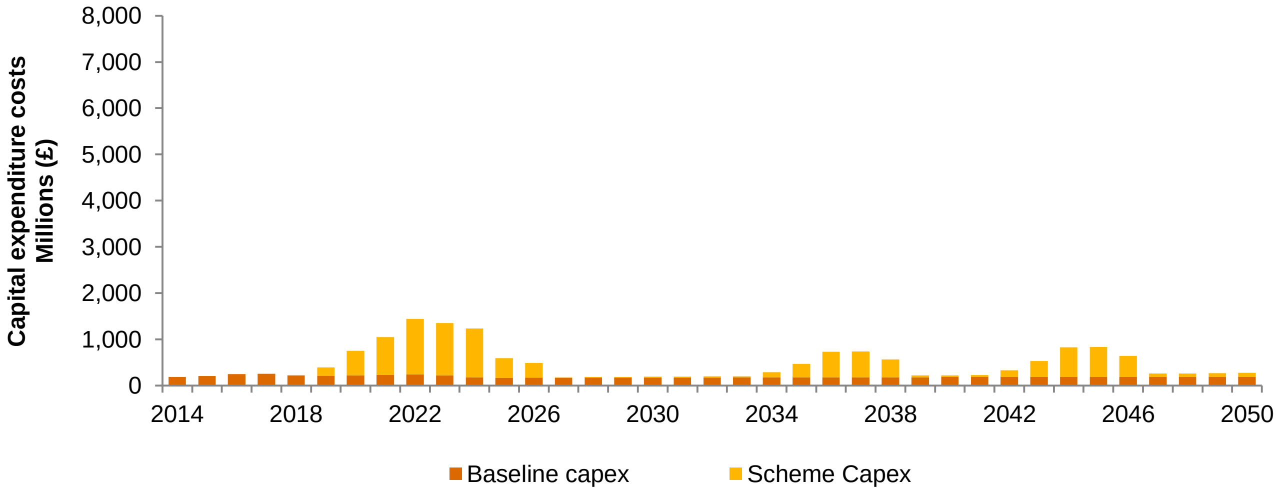
For the LGW 2R scheme, the construction and operational phases overlap to a significant extent. Table 19 shows that the construction phase of the LGW 2R scheme is relatively prolonged, lasting from 2016 to the mid-2040s, and includes three separate sub-periods of heightened activity (the first of which peaks in 2022, the second in 2037 and the third in 2045). Despite the long construction phase, increased operations at the expanded Gatwick Airport start in 2025.

*Table 19: LGW 2R Incremental construction capex costs (£mn, undiscounted and not adjusted for inflation)*

| 2015-2050 | Airport scheme capex | Surface access capex | Total |
|---|---|---|---|
| **LGW 2R** | 10,354 | 768 | **11,122** |

*Source: LeighFisher analysis*

*Figure 28: LGW 2R airport capital expenditure costs*




*Source: LeighFisher analysis*

The following table shows the surface access improvements required:

*Table 20: LGW 2R Surface access capex costs by type (£mn, undiscounted and not adjusted for inflation)*

| 2015-2050 | Road | Rail | Risk & Optimism Bias | Total |
|---|---|---|---|---|
| **LGW 2R** | 533 | - | 235 | **768** |

*Source: LeighFisher analysis*

## *Construction phase impacts*

Our modelling suggests that, despite our assumption that the economy is at near full employment in the baseline scenario and every £1 spent on the LGW 2R scheme must be funded by a reduction of £1 in other parts of the domestic economy (most notably private consumption), the LGW 2R construction activities themselves are likely to have significant GDP impacts. This is because at a high level, shifting economic activity towards construction is estimated to have a net positive impact on economic output because of the strong linkages between construction and the other sectors of the economy. As a result, the positive multiplier impacts from expanding the construction industry outweigh the negative multiplier impacts from the contraction of other sectors as a result of (primarily) reduced consumption to fund investment. The implication is that shifting economic activity away from consumption towards construction raises overall GDP in net terms.

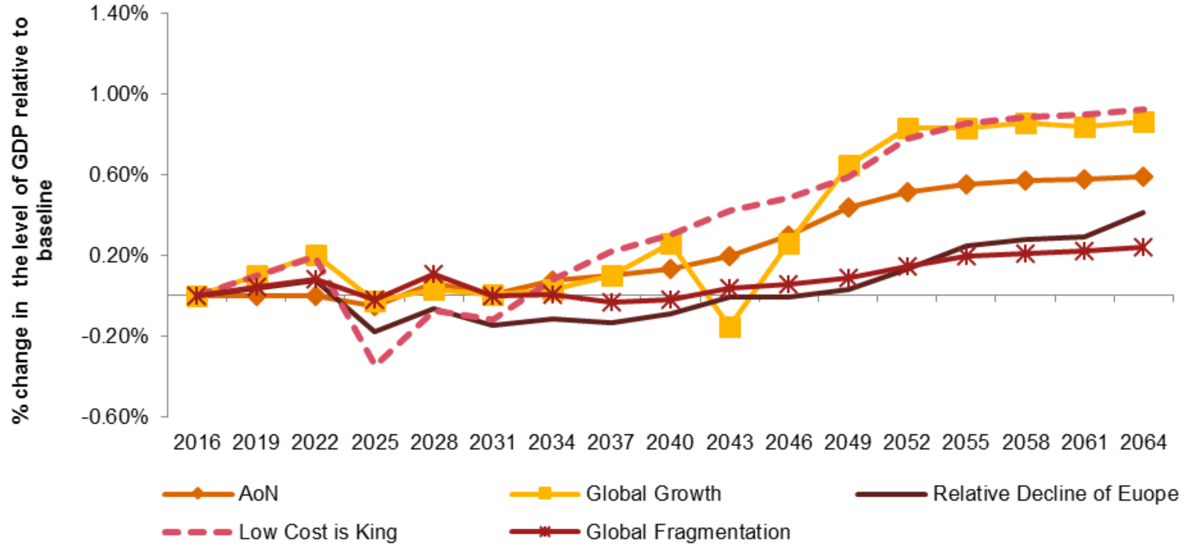
Figure 29 shows the projected real GDP impacts including construction of the LGW 2R scheme, for the different passenger flow scenarios. As before, this reflects the new assumptions provided by the AC for three scenarios. As noted above, the construction and operational phases of the LGW 2R schemes overlap to a significant extent. As a result, it is difficult to observe the GDP impact of the construction phase of the LGW 2R scheme when it is included alongside the other effects. Construction impacts are experienced up until the mid-2040s, and we isolate construction from the other impacts in Figure 29 below. Since the enhancements are relatively gradual and there is a considerable overlap between the construction and operational phases, the GDP impacts across scenarios are dispersed[137].

In order to more clearly isolate the impact of construction on GDP, Figure 30 shows the total projected GDP impact of the Assessment of Need scenario, with the impact of construction and surface access effects included. This clearly demonstrates the overlap between these effects, and the others discussed above. It is also evident

[137] It should be emphasised that it is the fact that the construction and operational phases of the Gatwick scheme **overlap** that gives rise to the dispersion between scenarios: this does not mean that the GDP impacts that relate directly to the Gatwick scheme construction differ across scenarios. Later in this chapter, we specifically identify the impacts that relate to the construction activities. These are very similar across scenarios for each of the different schemes.

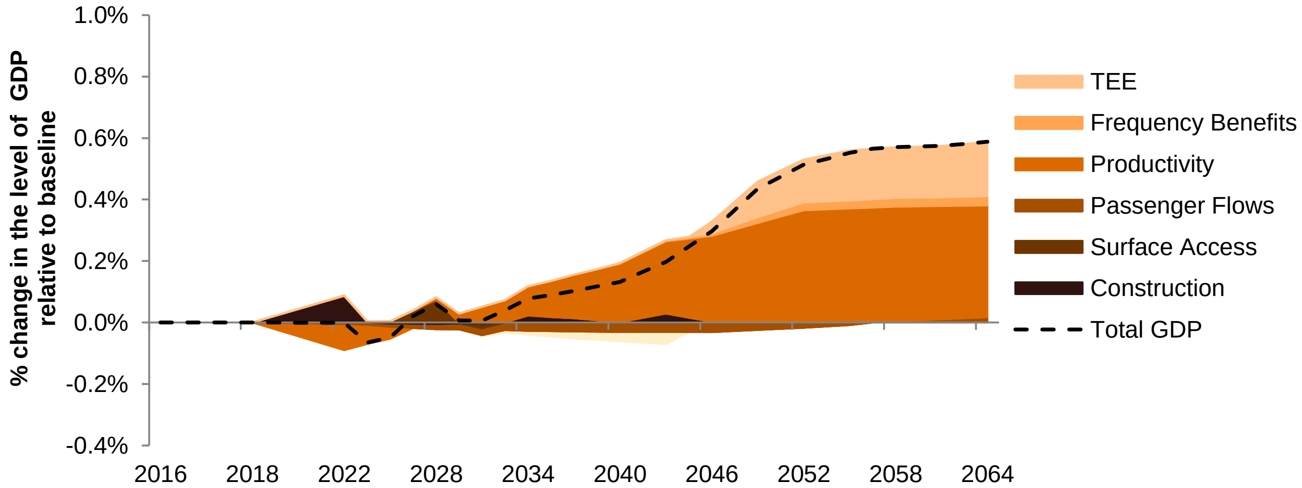
that the magnitude of the construction and surface access impacts is relatively limited, never exceeding an increase of 0.1% on the level of GDP in any given period.

*Figure 29: LGW 2R GDP impacts on the level of real GDP including construction, by scenario*




*Source: PwC analysis*

*Figure 30: LGW 2R Effect-by-effect impacts on the level of real GDP including construction, Assessment of Need scenario*



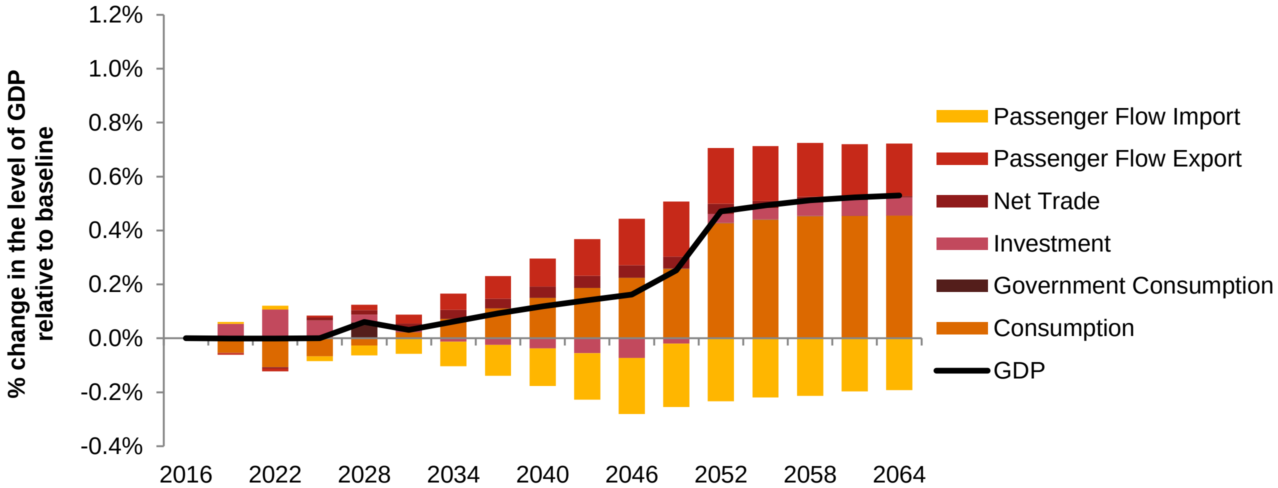

*Source: PwC analysis*

Figure 31 demonstrates how the different components of GDP contribute to the overall change, once construction and surface access effects are included. Unsurprisingly, the positive increases in GDP resulting from construction can be seen through increased investment, with one period of increased government consumption to reflect surface access expenditure (the *investment effect*). Despite the positive construction impact, total GDP is largely unchanged due to a concurrent reduction in consumption. The majority of this is due to forward-looking households and business in the S-CGE model postponing economic activity until the capacity constraint is lifted, although some is driven by a shift from consumption to savings in order to finance the investment.

| | |
|---|---|
| **Investment effect** | The investment effect is at its greatest during the construction phases of the scheme. As noted above, even in the long-term, investment remains important and continues to place upward pressure on GDP as a result of continued maintenance and renewals of the enhanced infrastructure, together with the greater level of investment generated from higher confidence and |

the expectation of increased economic output amongst businesses (see *confidence effect* in section 6.4.1).

*Figure 31: LGW 2R Breakdown of real GDP impacts including construction, Assessment of Need scenario*




*Source: PwC analysis*

As Table 21 demonstrates, once the airport is in operation the impact of additional construction phases is modest. To enable a more detailed comparison of the relative magnitudes of each effect, Table 21 summarises the PV of each effect for each passenger scenario, incorporating the latest inputs for Global Growth, Relative Decline of Europe, and Low Cost is King. As we have assumed that the required level of construction and maintenance expenditure does not vary by passenger scenario, the construction and surface access impacts are constant. This shows that under the five passenger scenarios, the modelled combined impact of construction and surface access are no more than 3-10% of the total increase in the level of GDP, and have the smallest impacts of the effects analysed.

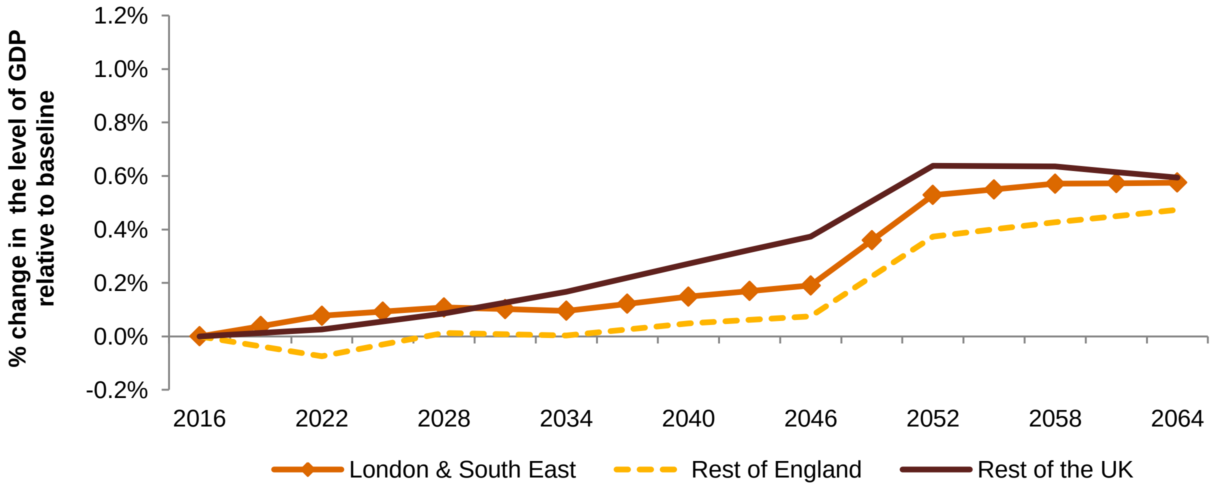
*Table 21: LGW 2R Present Value of GDP impacts including construction, by effect and scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Construction** | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 |
| **Surface Access** | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| **Passenger Flows** | -2.3 | -20.5 | -8.3 | -32.7 | -6.6 |
| **Productivity** | 52.1 | 47.7 | 22.3 | 90.1 | 17.9 |
| **Frequency Benefits** | 3.6 | 10.0 | 3.5 | 9.6 | 2.7 |
| **TEE** | 20.0 | 55.9 | 24.2 | 57.3 | 15.3 |
| **Total** | **76.8** | **96.5** | **45.1** | **127.7** | **32.8** |

*Source: PwC analysis*

Finally, Figure 32 investigates how the regional distribution of GDP impacts change with the addition of construction and surface access effects. In comparison with Figure 19, London & South East can be seen to gain substantially, and on this basis experiences the greatest increase in the level of GDP throughout the 2020s. To a lesser extent, the Rest of England and the Rest of the UK also gain slightly as a result of the construction phase, as the beneficial effects of the additional construction flow throughout the national economy through inter-regional trade.

*Figure 32: LGW 2R regional GDP impacts including construction, Assessment of Need scenario*




*Source: PwC analysis*

*Table 22: LGW 2R Present Value of regional real GDP impacts including construction, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **London & South East** | 29.0 | 37.5 | 16.9 | 79.3 | 15.2 |
| **Rest of England** | 36.6 | 31.5 | 15.5 | 30.7 | 10.3 |
| **Rest of the UK** | 11.2 | 27.5 | 12.6 | 17.7 | 7.4 |

*Source: PwC analysis*

As agreed with the AC, our results are based on the assumption that construction costs are funded “wholly by the domestic private sector”. Box 4 below discusses how the results might have varied if we had made an assumption regarding partial or full foreign investment.

**Box 4: Financing runway expansion schemes - the potential use of foreign investment**

As described in Section 4.7.3.1 we made the assumption in our economic modelling that the construction cost of the three airports schemes was funded “wholly by the domestic private sector”. This assumption was discussed and agreed with the AC and its external advisors. However, it is also possible to assume in the S-CGE model that the airport schemes are fully or partly funded by foreign investors. In this box, we discuss how the results might have varied if we had made an assumption regarding partial or full foreign investment.

The S-CGE model requires the user to identify the source of each airport scheme’s financing – new financing will be sourced from additional investment. In the models baseline, investment markets are assumed to be in equilibrium, investors are assumed to have balanced portfolios and there is no excess supply of capital.[138] So for new investment to be created, rates of return for capital must rise.

[138] The model is capable of proxying the effects of either excess supply or demand in capital markets. For instance, investors may have capital they want to invest, but do not have appropriate opportunities available to them. If this is the case, the rate of return that businesses need offer to investors will be lower. The model can therefore be set up with lower capital returns in different sectors or across the whole economy. Similarly a shortage of investment supply, means that businesses need to raise rates of return to attract scarce capital, so the model could be set up with higher capital returns.

However, it is not clear whether capital markets are generating long-term deviations in investment supply or demand. There were clearly liquidity shortages following the financial crises, but these have now eased. Further, markets will tend to look at capital infrastructure projects on a case by case basis. Airports represent long-term investment opportunities, and so are likely to be resilient to deviations in investment supply or demand. On this basis we make no special assumption about capital market disequilibrium.

The investment needed to build each airport must be supplied by either domestic or foreign investors. As we have seen in Figure 31, if the investment for each scheme is sourced from within the UK then the additional investment required will be sourced from either households (who consume less in response to being offered higher rates of return on their investments) or at the expense of other investment projects (again higher rates of return will need to be offered to attract investment into the airport sector).

The transmission mechanism associated with airport construction is given in Figure 176 in Appendix D of this report. As we note in that figure, if foreign investment is used to finance an airport scheme either as an alternative or complement to domestic investment and it could be competed away from another UK project as there will be international competition for foreign investment.

If foreign investment is used as a direct alternative to domestic investment, then the reduction in household consumption that is observed in our results would not occur. Similarly, it would be less likely that the airport sector would compete domestic investment away from other sectors of the economy.

However, the degree to which foreign investment displaces domestic investment is difficult to calculate and we are only able to make a qualitative assessment. Overall we think the level of displacement would be small for the following reasons:

- The UK is an attractive hub for foreign investment. According to UNCTAD[139], the UK is the number one country for inward FDI stock in Europe, and only the second in the world after the USA. Given the UK's attractiveness foreign investment hub, we think it would be unlikely that
- The implied rate of return for inward investment[140] into the UK decreased to 5% in 2012 from 6% in 2011 and was still lower than the value reported in 2007 (7%). However, overall flows are rising.

These findings can be interpreted in two ways. Firstly, it could be that the UK will remain a well-liked destination for FDI, falling returns could imply that the UK can offer less favourable terms to investors because of its popularity as an investment destination. This means that the UK airport schemes could find it easy to attract foreign investors. Alternatively, the foreign investment community could infer that the UK is a saturated market and that in order to balance their global portfolios they are better off placing their investments in other countries. The scale of FDI is ultimately linked to the rate of return offered to bond holders by each airport scheme.

According to ONS surveys,[141] the main beneficiaries of FDI are the power and utilities sectors, communications, financial services and the manufacturing sector. So if displacement were to occur, it is likely that these sectors would be most affected.

One negative consequence that would be associated with foreign investment can be described as follows. The scale of investment required for each airport scheme will require the body corporate associated with each airport scheme to sell bonds in order to raise capital. This process will be facilitated through investor roadshows and the wider financial sector. If foreign capital is required, international investor roadshows will need to be held and this will require the support of international (rather than UK banks). This could lead to a small leakage in activity from the UK financial sector. But relative to the overall results, this effect would be minimal.

Overall, the assumption made regarding the degree of domestic investment has been designed to be deliberately cautious. If FDI is the primary source of airport finance, the dampening effects of lower household consumption and displacement of domestic investment from other sectors would be less likely to occur and the overall results presented for the construction effect in our report would be larger.

[139] https://www.gov.uk/government/publications/ukti-inward-investment-report-2013-2014/ukti-inward-investment-report-2013-2014--2

[140] Sourced from UK Office for National Statistics, rate of return is calculated as dividends divided by positions.

[141] http://www.ons.gov.uk/ons/dcp171778_351956.pdf

## 6.7 Other economic indicators

### 6.7.1 Impact on welfare

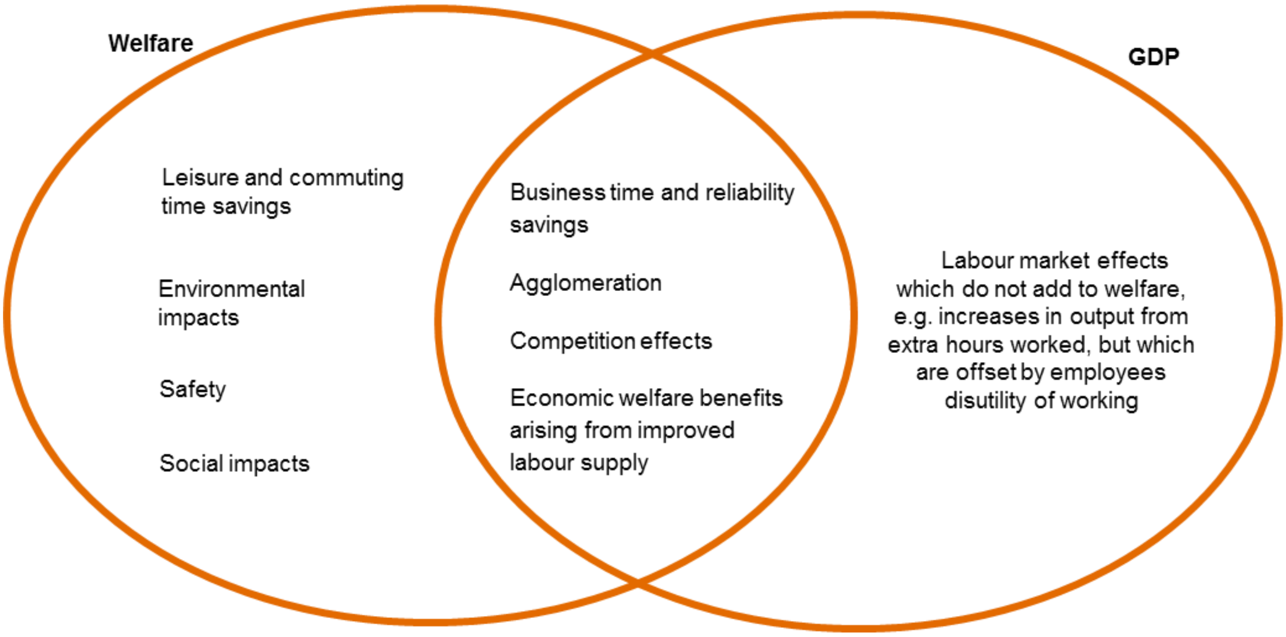
Some of the welfare gains associated with transport improvements do not impact directly on GDP. For example, environmental benefits and time savings to *leisure* travellers are not usually thought to have a direct impact on economic output, despite being clearly valued by consumers and being likely to form part of any measure of economic welfare. Other effects influence GDP, but do not directly impact welfare. For instance, a person joining the labour market will produce output and therefore increase GDP, but the welfare impact to the individual may be lower than the GDP impact since that person has to spend time commuting. The relationship between welfare and GDP is set out in Box 5 below. Box 5 also emphasises that the welfare effects considered as part of this work are not comparable with the concept of welfare that emerges from a conventional transport appraisal.

**Box 5: Relationship between welfare and GDP**

*Welfare in transport appraisal*

The Venn diagram below summarises the relationship between GDP and economic welfare at a general level, and characterises how welfare is usually regarded in conventional transport appraisal. This is taken from the DfT's *Transport, Wider Economic Benefits, and Impacts on GDP* report of 2005.

*Figure 33: Relationship between GDP and economic welfare*




*Source: PwC analysis*

In this framework, factors such as safety improvements and social impacts form part of economic welfare since they are implicitly assumed to enter households' "utility" functions. Extensive empirical evidence - summarised in WebTAG - supports the idea that households value these factors and there are well-established estimates of agents' "willingness to pay" for improvements in these variables.

*Welfare in the S-CGE framework*

In general, it is possible to incorporate these factors into a CGE framework by generalising households' utility functions to capture these effects. For the purposes of this study, however, we have not included these factors in households' utility functions. The reasons for this are to simplify the analysis and allow focus on the purely economic effects. However, this should not be taken to mean that we consider these issues to be less important.

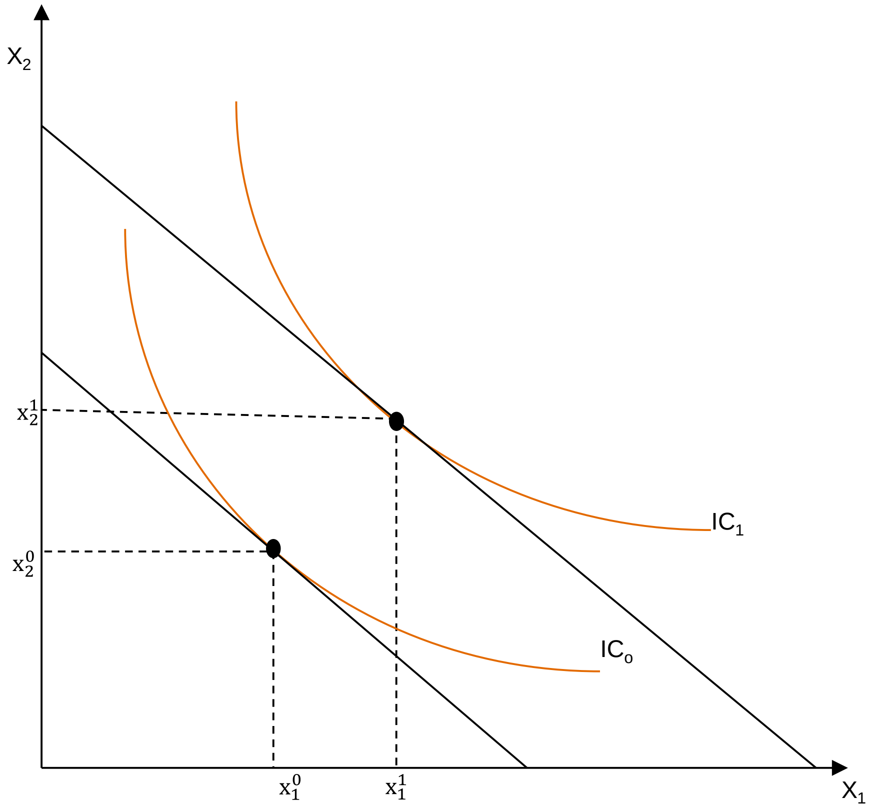
Overall therefore, rather than capturing the welfare effects described in the Venn diagram, welfare effects in the S-CGE framework are associated with consumption of goods/services and leisure (in particular the goods and services produced by the sectors described in Chapter 4).

Welfare is measured in monetary terms in the S-CGE framework using the so-called "Equivalent Variation" (EV), a concept due originally to Hicks (1939). The EV is most easily explained by means of an example. Suppose that the aviation intervention results in a fall in the price of a good. This clearly gives rise to a welfare improvement to consumers. The EV is a measure of how much a consumer would be willing to pay for the welfare improvement of the price change, based on the original set of prices. We use the EV (rather than the "Compensating Variation" or CV which uses the post-expansion set of prices), because the EV is calculated using the original set of prices, which are the same across the passenger flow scenarios. Using the EV therefore provides a like-for-like comparison. If we were to use the CV, any comparison across scenarios would be distorted by the use of different prices.

The EV is illustrated diagrammatically below. As described in Appendix B households' utility is defined as a function of both goods/services consumed and leisure time. Utility can be represented by indifference curves, which show the combinations of goods/services and leisure which deliver the same level of utility. The S-CGE model contains many goods, but to illustrate the interpretation of the EV we use just two goods, $x_1$ and $x_2$. The original level of utility (i.e. before airport expansion) is represented by $IC_0$, and point A represents the original level of consumption on the original budget constraint (which is determined by the original set of prices and income). After the effects have fed through the model, airport expansion and the resulting impacts on the economy allow households to consume more of the two goods and thus attain a higher level of utility, on $IC_1$.

The EV is calculated by taking the original set of prices (we use the original prices in order to ensure that the post-expansion results across the scenarios can be directly compared, as described above), and establishing how much more income households would need in order to increase utility to the post-airport expansion level: $EV = m_1 - m_0 = (p_1x_1^1 + p_2x_2^1) - (p_1x_1^0 + p_2x_2^0) = p_1(x_1^1 - x_1^0) + p_2(x_2^1 - x_2^0)$, where $m_0$ is the value of the consumer's consumption before airport expansion, $m_1$ is the value of the consumer's consumption after airport expansion, $p_1$ is the price of $x_1$ and $p_2$ is the price of $x_2$. This means that the welfare effect or EV can be interpreted as the change in the value of consumption as a result of the airport expansion, based on the original prices.

*Figure 34: Welfare in the S-CGE framework*




*Source: PwC analysis*

*Key issues in comparing welfare across different sources*

It is clear from the preceding discussion that the concept of welfare used in this work is different to the concept used in conventional transport appraisal. Key differences include, but are not limited to, the following:

1. We use the concept of EV to measure the change in consumer welfare, whereas many welfare analyses (e.g. that based on WebTAG) tend to use the change in consumer surplus (in general, these measures will not be the same);

2. We have adopted certain functional form assumptions (for example CES utility, which is widely used in CGE analyses) which may be different to those used in transport appraisal (for example the WebTAG analysis used to derive the TEE effects described above assumes linear demand, and therefore quadratic utility); and

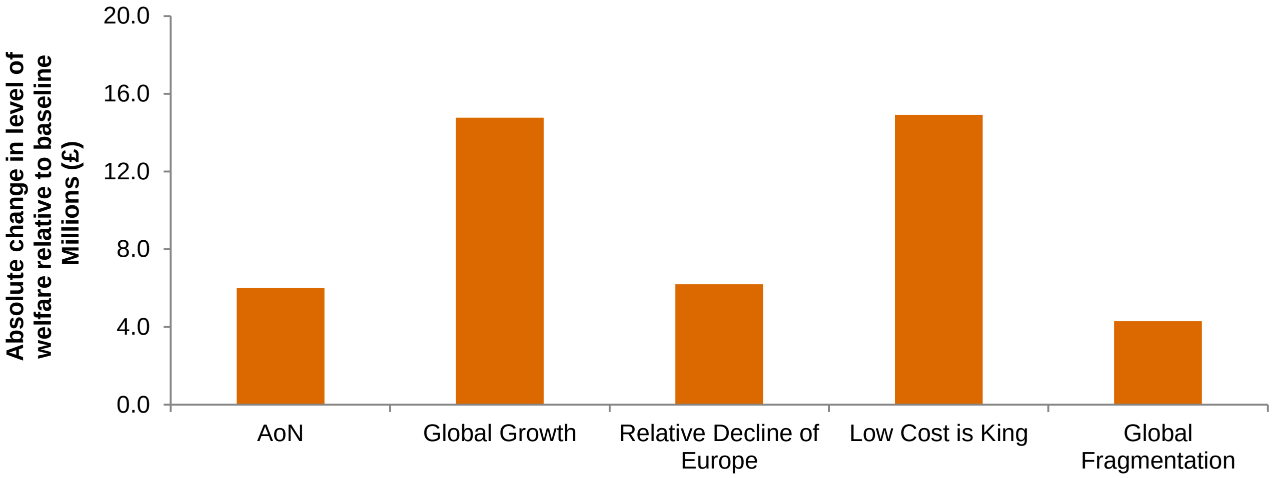
3. We capture "producer surplus" indirectly in our analysis (since households are assumed to own firms), rather than directly (the approach used in conventional transport appraisal).

As such, the welfare outputs described here should not be compared to outputs of conventional transport appraisal.

Whilst these points should be borne in mind, the results of the model to which we now turn are likely to provide a useful indication of the consumer welfare impacts of the airport schemes. Figure 35 shows the change in annualised welfare relative to the baseline across the scenarios.

For the LGW 2R scheme, the largest forecast increase in consumer welfare is observed in the Low Cost is King scenario, closely followed by the Global Growth scenario. The Decline of Europe and Assessment of Need scenario have similar consumer welfare impacts, and the consumer welfare effect is lowest under the Global Fragmentation scenario. This ordering reflects the underlying assumptions about passenger flows, frequency benefits and TEE effects under these scenarios, together with the implied productivity impact. The range of consumer welfare impacts across passenger scenarios reflects the degree to which the additional capacity is modelled as enabling an increase in consumption.

*Figure 35: LGW 2R change in economic welfare (EV) relative to baseline, by scenario*




*Source: PwC analysis*

## 6.7.2 Impact on employment

The S-CGE model measures the net impact on job creation resulting from an airport scheme. Figures on the "direct" job creation at each airport scheme have been supplied to us by the AC and have been produced as part of the Local Economic Impact Assessment.

In the model baseline, UK employment grows at 0.8% per annum in line with long-run ONS population growth estimates. The labour force rises from around 28 million in 2010 to round 37 million in 2060. More details relating to this are provided in Chapter 3. Projected changes in job figures as a result of the LGW 2R scheme are net in the sense that some sectors expand at the expense of others, since as demand for different goods and services increases/falls, different sectors will be able to pay more/less wages, and this entices workers to either enter the labour market or move jobs. Other key features of the labour market in the model are:

- Workers can move between sectors and regions as these expand or contract depending on the level of economic activity. If wages rise in London & South East retail for example, then conceivably a worker from the government sector outside of this region may move into this region and industry to gain from this wage rise;
- If workers move between sectors, it is assumed they need to retrain (e.g. an investment banker cannot become a chef overnight). The model assumes a temporary loss in productivity as people retrain and consequently their wages fall during this period. This decline in wages approximates a degree of labour market rigidity in the model;
- Current patterns of migration flows which limit the flow of workers between regions; and
- The wage sensitivity of migration flows is governed by a separate elasticity parameter.

Results are given in Table 23 below and are again based on the AC's Assessment of Need scenario. The results show that LGW 2R is forecast to generate approximately 90,000 net additional jobs by 2060. A large proportion of jobs are forecast to arise in the air passenger transport and freight sector. These are largely direct jobs on or around the airport site and have been estimated in line with the AC's assessment. The modelled overall net increase in employment associated with the LGW 2R scheme can be explained by the *employment effect* explained below:

| | |
|---|---|
| **Employment effect** | Increased productivity and profitability among UK businesses as a result of the scheme will increase demand for labour and capital, which in turn increases the returns to labour and capital. Higher wages will attract more workers into employment and unemployment will fall (with analogous effects for capital). The strength of this effect will be governed by the availability of potential workers. |

The key results from our modelling suggest that:

- There is a temporary short-term boost in construction jobs;
- The largest modelled overall net gains are observed in the manufacturing and other services sectors. These sectors are the largest in our model, and are relatively trade intensive, and are therefore forecast to gain more as a result of improved aviation links leading to increased trade. The "other services" sector includes key sectors such as financial services, telecommunications and business services. These sub-sectors are all expected to gain due to increased access to air transport enabling their overall trade volumes to increase;
- Accommodation and food services are also forecast to experience a significant increase as a result of increased domestic and foreign passenger demand;
- Other freight employment is expected to decline as there is a shift towards air freight, but these reductions are marginal;
- Public sector job effects are largely forecast to be neutral, but in the long-term the overall proportion of jobs in this sector contracts as workers are assumed to leave for higher wages in other sectors; and
- Better trade links ensure that productivity in the retail sector increases. This leads to an increase in the volume of sales, and subsequently an increase in the level of employment. This effect is very small in relation to the overall size of the retail sector.

*Table 23: LGW 2R Breakdown of impact on net job creation by sector relative to baseline, Assessment of Need scenario (000's of jobs)*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and Mining** | 2.9 | 0.4 | 0.3 | 0.6 | 1.1 |
| **Manufacturing** | 2.5 | 18.5 | 14.3 | 24.3 | 36.9 |
| **Utilities** | 3.3 | 0.4 | 0.0 | -0.1 | -0.3 |
| **Construction** | 5.8 | 1.5 | 0.5 | 1.4 | 1.5 |
| **Retail and wholesale trade** | 1.4 | 0.2 | 0.0 | 1.2 | 1.8 |
| **Air passenger transport** | 0.9 | 8.7 | 18.4 | 24.1 | 42.2 |
| **Air freight** | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 |
| **Other freight** | 0.7 | -0.1 | -0.2 | -0.6 | -1.8 |
| **Other passenger transport** | 0.2 | -1.0 | -1.0 | -0.8 | -1.7 |
| **Accommodation and food services** | 1.2 | 0.8 | 0.7 | 1.9 | 2.5 |
| **Other services** | 1.2 | -0.4 | -0.7 | -1.8 | 9.5 |
| **Health, education and public spending** | 1.7 | 0.5 | -0.2 | -0.8 | -1.6 |
| **Total** | **21.8** | **29.7** | **32.4** | **49.6** | **90.4** |

*Source: PwC analysis*

## *6.7.3 Impact on the number of firms*

Table 24 shows the modelled change in the number of firms by sector as a result of the LGW 2R scheme – these results simply break down the results presented in more detail. The S-CGE model is based on the assumption of imperfect competition, and consumers have a preference for variety in the products they purchase.[142] Through these mechanisms, an increase in potential profits within a sector acts as a signal for new firms to enter and compete these profits away. Therefore the change in the number of firms participating within a sector can be seen as a proxy for the change in available profits as a result of the increase in capacity.

Overall it can be seen that the total number of firms is forecast to remain largely unchanged. This is indicative of the fact that while the whole economy is modelled as gaining from the productivity increases and demand boosts modelled, consumers receive a disproportionate share of the gains due to the substantial increase in consumer surplus, at the expense of producer surplus. This can be specifically seen in Table 24 where the air passenger transport and freight sector, which absorbs the producer surplus reduction, is the only sector to see an expected substantial fall in the number of firms. The majority of other sectors, which experience the productivity benefits of cheaper air passenger transport, are expected to exhibit higher total profits which encourage new entrants into the market. The results presented in Table 24 demonstrate that firms in the air passenger transport sector are expected to respond to the reduction in available operating surplus through consolidation in order to retain the economies of scale required to remain competitive and achieve an appropriate margin. Section 6.5.1 outlines an alternative possible equilibrium whereby firms do not consolidate, but instead maintain margins through reductions in investment, therefore leading to long-term relative price increases. The loss of efficiency implied by this alternative behaviour means that this is a lower long-term growth scenario at a national level. The scale of the effect is best seen by comparing with the size of the sector in Section 3.4.

[142] Please see Appendix B for a full description of the model's structure, and list of relevant references.

*Table 24: LGW 2R Change in number of firms by sector relative to baseline, Assessment of Need Scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and Mining** | 0.0% | 0.1% | 0.2% | 0.4% | 0.5% |
| **Manufacturing** | 0.2% | 0.2% | 0.5% | 0.7% | 0.7% |
| **Utilities** | 0.0% | 0.0% | 0.2% | 0.4% | 0.5% |
| **Construction** | 1.1% | -0.2% | -0.3% | 0.0% | 0.2% |
| **Retail and wholesale trade** | 0.0% | 0.0% | -0.1% | -0.2% | -0.2% |
| **Air passenger transport and freight** | 0.4% | -0.8% | -3.7% | -6.9% | -6.0% |
| **Other freight** | 0.0% | 0.0% | 0.0% | 0.0% | -0.1% |
| **Other passenger transport** | 0.0% | 0.1% | 0.1% | 0.2% | 0.1% |
| **Accommodation and food services** | 0.0% | 0.0% | 0.1% | 0.2% | 0.3% |
| **Other services** | 0.0% | -0.1% | -0.1% | -0.1% | 0.0% |
| **Health, education and public spending** | 0.1% | 0.1% | -0.1% | -0.2% | -0.2% |
| **Total** | **0.1%** | **0.0%** | **-0.1%** | **0.0%** | **0.1%** |

*Source: PwC analysis*

### 6.7.4 Impact on house prices

Table 25 shows the projected house price impacts for the LGW 2R scheme. The overall effects are negligible pat the level that our modelling is conducted at. Airports expansion may affect house prices in the direct proximity, but our analysis is not granular enough to capture this.

During the construction phases, there is expected to be a very small increase in house prices – mainly in London & South East – as a result of higher levels of output and hence wages in the economy.

By the end of the period, the model suggests a similarly small reduction in house prices. This is due to a diversion of investment activities by households – instead of investing in homes in the rental market, a larger proportion of their investment portfolio will be invested in UK businesses as returns to business investment rise following the expansion in GDP. This puts a small amount of downward pressure on house prices.

*Table 25: LGW 2R Real house price impact relative to baseline, Assessment of Need scenario (baseline = 100)*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **London & South East** | 100.1 | 100.0 | 99.9 | 99.9 | 99.9 |
| **Rest of England** | 100.1 | 100.0 | 100.0 | 99.8 | 99.9 |
| **Rest of the UK** | 99.9 | 100.0 | 100.0 | 99.9 | 100.0 |

*Source: PwC analysis*

### 6.7.5 Impact on net taxes

Table 26 shows the net tax impacts for the LGW 2R scheme. During the construction phases, there is a small but significant increase in net taxes as a result of higher incomes, for example from construction workers and firms.

The initial impact, during the construction phase, is large, at £ 3.6 bn in 2020 (0.13% of baseline net taxes). There is a decline in the impact, in relative terms, in the operational phase. The change in net tax in 2030 is £3.2bn in 2030 (0.08% of baseline net tax) and this increases to £5.2 bn in 2060 (but is still only 0.06% of baseline net tax).

*Table 26: LGW 2R Change in net taxes relative to the baseline, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Total UK impact (£mn)** | 3,563 | 3,190 | 3,198 | 3,896 | 5,203 |
| **UK impact (% of net tax in baseline)** | 0.13% | 0.08% | 0.07% | 0.06% | 0.06% |

*Source: PwC analysis*

## 6.8 Testing the results – sensitivity analysis

### 6.8.1 Systematic sensitivity analysis

The S-CGE model is based on assumptions for a range of elasticities. Systematic Sensitivity Analysis (SSA) is a method of testing the influence of the model elasticities on the results. This is carried out using Monte Carlo analysis. This process is outlined in Box 6 below.

The results of the Systematic Sensitivity Analysis are shown in Figure 36 below. The average difference between the central estimate and each of the upper and lower bound estimates is between 0.05 and 0.1% of GDP. This range defines the confidence interval for the degree to which different modelling assumptions could generate different results. Any variation outside of this could only be driven by changes in the model inputs. This range remains reasonably constant throughout the period studied, demonstrating that the time profile of the impacts is determined primarily by the time profile of the inputs, rather than assumptions made during the modelling.

**Box 6: Systematic Sensitivity Analysis**

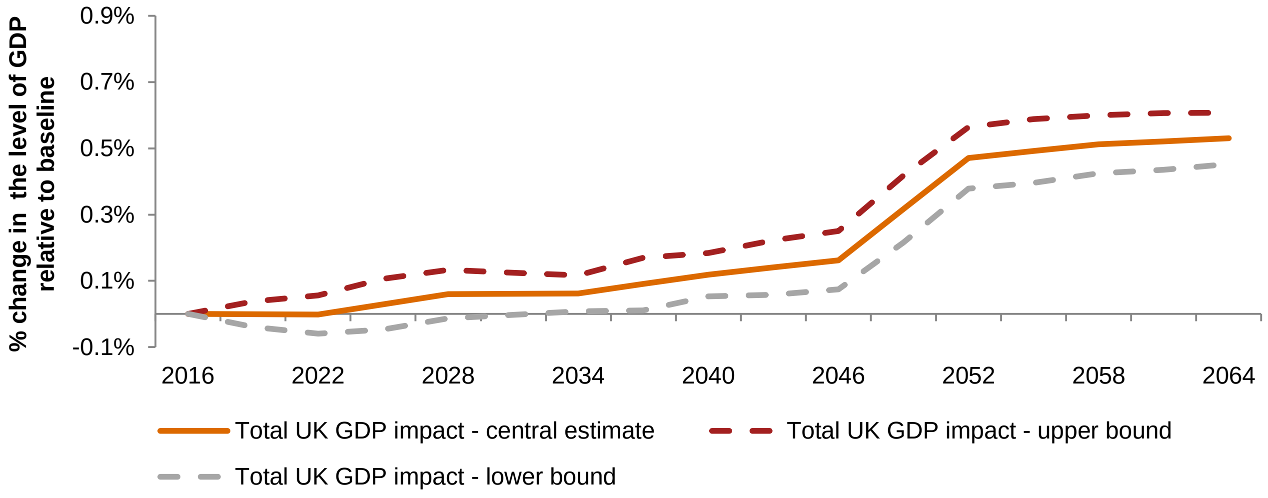
- First, we specify a range for each of the elasticities in the model. These ranges are based on the estimated values in academic literature. These are shown in Table 27;
- We then generate a value for each elasticity by randomly sampling from within the corresponding specified ranges. We assume that each elasticity is uniformly distributed within the specified range, i.e. any value within the range is equally likely to be selected;
- We then solve the model for each combination of elasticities, and calculate the impact on the UK economy. This is repeated for 100 randomly generated combinations of elasticities; and
- Finally, the model results are then aggregated for all 100 combinations, and these are then expressed in the form of *95% confidence intervals*, i.e. the upper- and lower-bounds within which the result can be expected to lie 95 times out of 100.

*Table 27: Specified ranges for elasticities varied in the SSA*

| Parameter | Description | Central Range |
|---|---|---|
| **Price elasticity of inbound passenger flows** | Change in inbound passenger expenditure with a change in domestic price levels in all regions | 1.1897 (+/- 0.3) |
| **Price elasticity of outbound passenger flows** | Change in outbound passenger expenditure with a change in domestic price levels in all regions | 1.3825 (+/- .77) |
| **Elasticity in the main passenger flows nest** | Change in passenger expenditure across products with a change in relative prices | 0.5 (+/- 0.25) |
| **Elasticity in day visits nest – between regions** | Change in inbound day-visit passenger expenditure between regions with a change in price levels between regions | 1 (+/- 0.25) |
| **Elasticity in domestic passenger nest – between regions** | Change in total inbound passenger expenditure between regions with a change in price levels between regions | 1 (+/- 0.25) |
| **Elasticity in overseas passenger nest – between modes** | Change in outbound day-visit passenger expenditure between regions with a change in price levels between regions | 1 (+/- 0.25) |
| **Inter-temporal elasticity of substitution** | Change in consumption and saving patterns over time with a change in interest rates | 0.2 (+/- 0.05) |
| **Elasticity between labour and leisure** | Change in labour supply with a change in wages | 0.5 (+/- 0.125) |
| **Elasticity between products in utility** | Change in the composition of households consumption basket with a change in relative prices | 1 (+/- 0.05) |
| **Elasticity of unemployment to real wages** | Change in unemployment rates with a change in real wages | 0.2 (+/- 0.4) |

The results of the Systematic Sensitivity Analysis are shown in Figure 36:

*Figure 36: LGW 2R – Systematic Sensitivity Analysis results, Assessment of Need scenario*



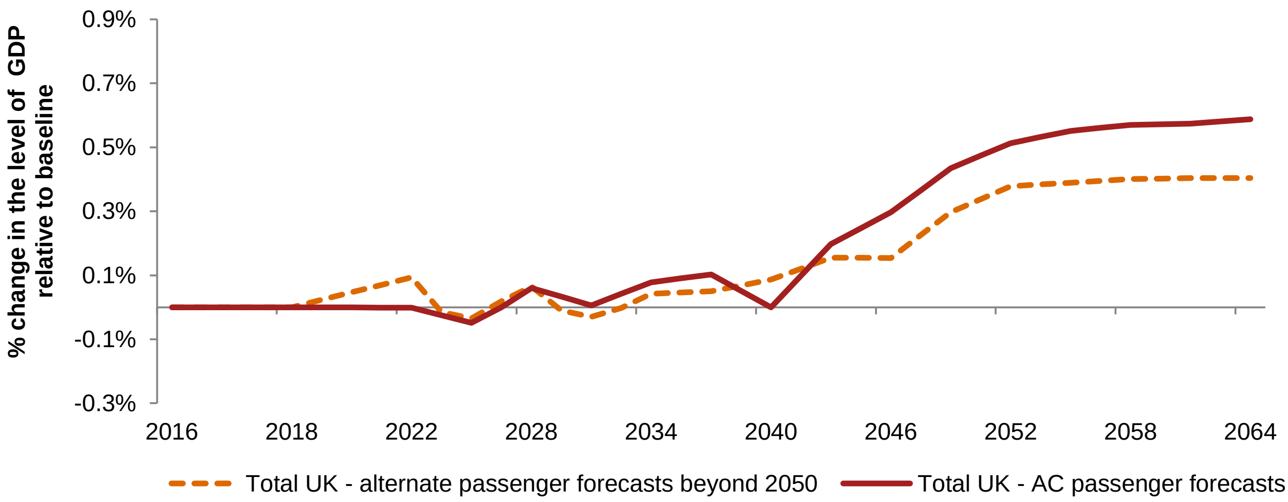

*Source: PwC analysis*

## *6.8.2 Testing the effect of alternate passenger numbers forecasts beyond 2050*

The AC demand forecasts provide passenger number estimates beyond 2050 based on an extrapolation of underlying trends in the previous years. We test the impact of this assumption by using alternate passenger number estimates beyond 2050, i.e. where we assume that passenger numbers beyond 2050 grow at the same rate as the baseline, i.e. the "do minimum" scenario.

Figure 37 below presents the results based on the two different model assumptions. The average difference in the GDP impact in the 14 year period from 2050 to 2064 between the original forecasted GDP impact and the GDP impact estimated with the alternate passenger numbers is 0.2%. Note that this difference begins to manifest in 2040, when the passenger numbers begin to differ only in 2050. This is because the forward-looking agents in the model begin to make adjustments in their spending and investment patterns ahead of any change in passenger numbers, and therefore in this alternate scenario, the lower passenger numbers from 2050 onwards has a lower impact on GDP in the previous years. Please note that this sensitivity test includes the construction effect.

*Figure 37: LGW 2R –Testing the effect of alternate passenger numbers forecasts beyond 2050, Assessment of Need scenario*




*Source: PwC analysis*

### 6.8.3 *Testing passenger additional spending assumptions*

In this section, we consider the sensitivity of the results of our analysis to changes in the following assumptions:

- the split between inbound and outbound passenger flows; and
- expenditure per passenger per visit.

These assumptions impact on the results of the modelling (particularly GDP) through Effect 1: Passenger flow expenditure. The other three effects do not change in response to changes in these assumptions[143].

The next sub-section sets out the original assumptions in respect of the inbound-outbound passenger flow split and the revised assumptions made for the purposes of the sensitivity analysis. We then consider the original assumptions on expenditure per passenger and the revised assumptions made for the sensitivity analysis. Finally, we present the results of the sensitivity analysis.

All assumptions tested in this section relate to changes to the inputs to the S-CGE model that have been provided by the Airports Commission, rather than any changes to the S-CGE model itself.

*Inbound-outbound passenger flow split*

The passenger flow expenditure effect in the S-CGE model is driven by, amongst other things, the relative size of the spending of UK residents abroad (which reduces UK GDP) and foreign residents' spending in the UK (which increases GDP in the UK). In turn, inbound expenditure is driven by inbound passenger flow numbers and outbound expenditure is driven by outbound passenger flows.

The AC provided us with total passenger flow data under different airport expansion options and scenarios, but did not provide a forecast into whether these passengers are inbound or outbound. In order to assess the passenger flow expenditure effects, it is therefore necessary to make assumptions about the balance between inbound and outbound passenger flows.

For our main analysis we agreed with the AC that the growth of inbound and outbound passengers (and their associated spending) for each scheme should be assumed to be proportional to the existing inbound-outbound split for the relevant airport (specifically the levels in 2011). For example, if the inbound-outbound split at the relevant airport was 60%-40% in 2011, and the number of passengers were forecast to grow by 10m, inbound passenger growth would be assumed to be 6m and outbound growth would be assumed to be 4m. Mathematically, this means that growth across the UK airports system in inbound passenger numbers is assumed to be:

$$inbound_t = (H_t - H_0)h_0 + (G_t - G_0)g_0 + (R_t - R_0)r_0$$

where $H_t$ is total passenger numbers at Heathrow in period $t$, $h_0$ is the inbound passenger share at Heathrow in the base year, $G_t$ is total passenger numbers at Gatwick in period $t$, $g_0$ the inbound passenger share at Gatwick in the base year, $R_t$ is total passenger numbers at all other UK airports in period $t$, and $r_0$ is the inbound passenger share at all other UK airports in the base year. The subscript *0* represents the base year in all cases. Outbound passenger numbers are simply the difference between total and inbound passenger numbers. Data from the CAA and the International Passenger Survey was used to calculate the current inbound-outbound split at UK airports.

Alternative assumptions could be made to capture, for example, a more even distribution of growth between inbound and outbound passengers across airports (rather than relying on the current split at each airport). Therefore, the AC asked us to perform a sensitivity test in which each UK airport's inbound-outbound split is

[143] Note, in particular, that Effect 2: Productivity is not affected by these sensitivity tests under the modelling approach we have adopted. This is because, as noted in Chapter 3, the econometric relationship which underpins the productivity effect is based on the relationship between total passenger numbers (as opposed to inbound or outbound flows) and international trade volumes. We consider that it is appropriate that the econometric relationship is estimated on the basis of total passenger numbers since productivity effects are likely to be experienced as a result of both UK residents travelling abroad (for example, UK residents may learn from suppliers, customers, and/or competitors when outside of the UK) and foreign residents travelling to the UK (for example, foreign residents may share knowledge and/or technology with UK individuals and firms during visits to the UK).

proportional to the inbound-outbound split of London-system airports taken together. The AC have asked us to test this assumption in order to see how results might change as a result, it is not based on any evidence or forecasts which suggests that this might be likely in the future. Specifically, this asked us to look at the effects of assuming that the growth of inbound and outbound passengers (and their associated spending) at all airports is proportional to the existing inbound-outbound split across Heathrow, Gatwick and Stansted airports combined, the largest three London airports[144]. Mathematically, this means that growth across the UK airports system in inbound passenger numbers is assumed to be,

$$inbound_t = \{(H_t - H_0) + (G_t - G_0) + (R_t - R_0)\}a_0 = (A_t - A_0)a_0$$

where $A_t$ is total passenger numbers across the UK airport system and $a_0$ is the inbound-outbound split across Heathrow, Gatwick and Stansted airports.

The inbound share $a_0$ is based on International Passenger Survey data and is estimated to be 42%. This means that it is assumed that inbound passenger growth at all airports individually (and across the system as a whole) is 42% of forecast total passenger growth.

This sensitivity analysis is designed to test how the results change with different assumptions – it is not suggested that this is a realistic scenario for future development. The results of the S-CGE modelling using this alternative assumption are set out in the results sub-section below.

*Passenger spending assumptions*

Another key determinant of the passenger flow expenditure effect in the S-CGE model is expenditure per passenger per visit (both inbound and outbound). Expenditure per passenger per visit has been estimated on the basis of ONS/TSA data, presented in the tables below.

For the original analysis presented in the main document, it was agreed that expenditure per passenger per visit would be calculated for each world region (Europe, Asia, North America and Others) as follows:

- take spend per visitor per day across all regions (i.e. a single global average); and
- multiply by the average length of visit (in days) for each region.

This exercise was undertaken in respect of inbound and outbound trips separately. Under this approach, differences in spending by passengers from different world regions are captured by how their lengths of stay differ. Importantly, this approach was applied in respect of *each* expenditure category[145] allowing us to model *where* in the economy the expenditure of inbound visitors takes place. This is in keeping with the S-CGE framework, which recognises that 'where' expenditure takes place in the economy matters, as well as the overall level of expenditure (the model recognises this by acknowledging that different sectors interact with other parts of the economy through backward linkages in different ways). This approach allows us to preserve detail of the TSA/ONS data and avoid losing the nuances contained within it. We felt this to be the most appropriate approach after careful consideration of the TSA data.

Another approach is to calculate expenditure per passenger per visit for each world region such that it also reflects differences in average expenditure *per day* across different geographies. At the request of the AC, we have therefore run a sensitivity test in which expenditure per passenger is calculated for each world region as follows:

[144] We have used the share across Heathrow, Gatwick and Stansted since data is only available for these airports (data is unavailable for London Luton and London City airports). These three airports account for more than 90% of London-system and therefore likely provide a reasonable representation of the London-system split.

[145] The expenditure categories are: agriculture, forestry and fishing; mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply; water supply, sewerage, waste management and remediation activities; construction; wholesale and retail trade, repair of motor vehicles and motorcycles; passenger transport (exc. air passengers); accommodation and food service activities; information and communication; financial and insurance activities; real estate activities; professional, scientific and technical activities; public administration and defence, compulsory social security; education; human health and social work activities; arts, entertainment and recreation; other service activities; activities of households as employers, undifferentiated goods and services; air freight; all other freight; air passenger transport; and overseas expenditure.

- take spend per visitor per day across each region individually (note the difference compared to the original assumption);
- multiply by the average length of visit (in days) for each region; and
- apply the expenditure proportions from the TSA/ONS data.

These tables demonstrates the substantial differences between regions. These are primarily driven by differences in length of visit (with passengers travelling further typically visiting for longer), with some additional variation occurring due to differences in average spend per day. The high spend by visitors from 'Other' countries is largely driven by passengers arriving from the Middle East.

*Table 28: Regional spending - inbound passengers*

| | Europe | Asia | North America | Others |
|---|---|---|---|---|
| **Average spend per visit** | £448.1 | £1,393.4 | £871.6 | £1,367.0 |
| **Average length of visit (days)** | 5.9 | 16.7 | 8.3 | 12.8 |
| **Average spend per day** | £75.8 | £83.7 | £104.8 | £106.5 |

*Source: ONS/TSA, PwC analysis*

*Table 29: Regional spending – outbound passengers*

| | Europe | Asia | North America | Others |
|---|---|---|---|---|
| **Average spend per visit** | £452.7 | £1,008.2 | £1,119.7 | £945.5 |
| **Average length of visit (days)** | 7.9 | 26.3 | 14.0 | 18.0 |
| **Average spend per day** | £57.0 | £38.3 | £80.2 | £52.6 |

*Source: ONS/TSA, PwC analysis*

The key difference, therefore, between this alternative assumption and the original assumption is that:

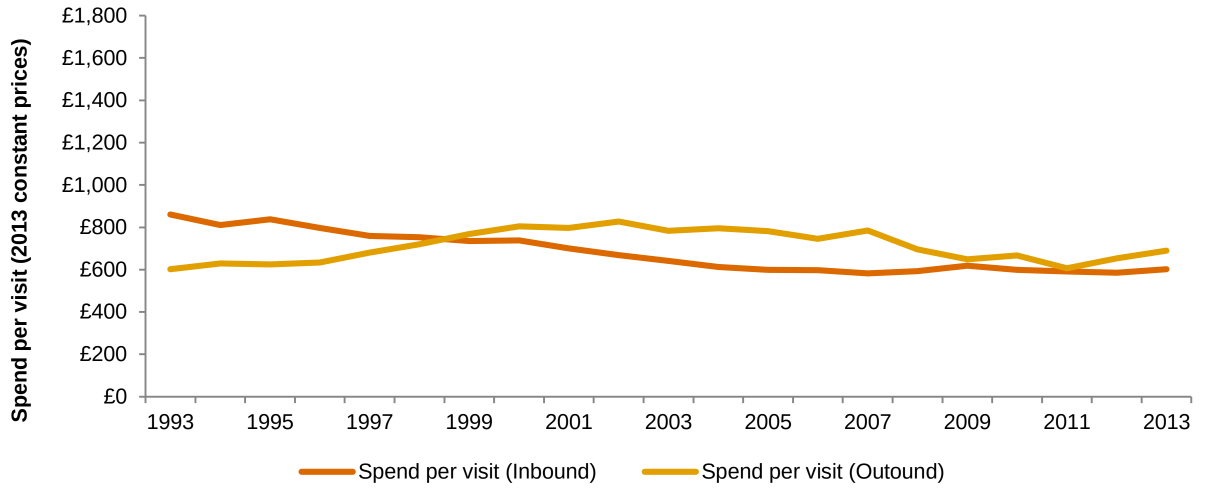
- this alternative approach captures differences in average spend across geographies, but does not fully capture spending differences across product categories; whereas
- the original approach captures differences in average spend across product categories, but does not fully capture differences in average spend across geographies.

Note that these assumptions are strictly alternatives to one another. The results of the S-CGE modelling from adopting this alternative assumption are set out in the results sub-section below. As explained in detail later, the choice of assumption does not have a significant impact on the expenditure inputs that are incorporated into the model, or the resulting GDP impacts.

Finally, we note that the AC has asked us to assume that passenger spend per visit is constant in real terms over the time period under consideration. While it is possible that passenger spend per visit could rise as populations become wealthier, this does not appear to be consistent with the evidence. For example, Figure 38 below shows real inbound and outbound passenger spend per visit since 1993. Between 1993 and 2013, inbound spend per visit actually fell by a third in real terms (despite strong global absolute and per-capita income growth). Outbound spend in 2013 was similar to its 1993 level in real terms (whilst the late 1990s saw moderate growth, the figures subsequently fell back).

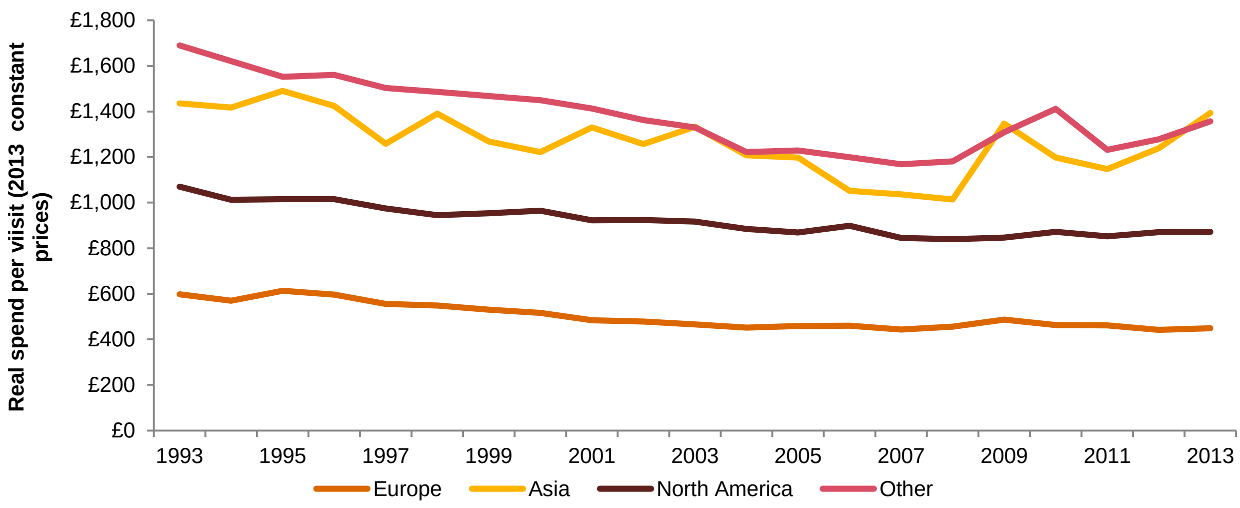
The reasons for the decline in inbound spend per visit could include the growth of low-cost air travel within Europe which may have provoked more frequent, but potentially shorter, trips involving less expenditure. This is borne out by the evidence in Figure 38, which shows a decline in real spend per visit among European inbound passengers. Similarly, lower airfares may have opened opportunities for travel among less affluent passengers, who may spend less during their visits.

*Figure 38: Real spend per visit, inbound and outbound visitors (2013 constant prices)*




*Source: ONS, PwC analysis*

*Figure 39: Real spend per visit by region, inbound visitors (2013 constant prices)*



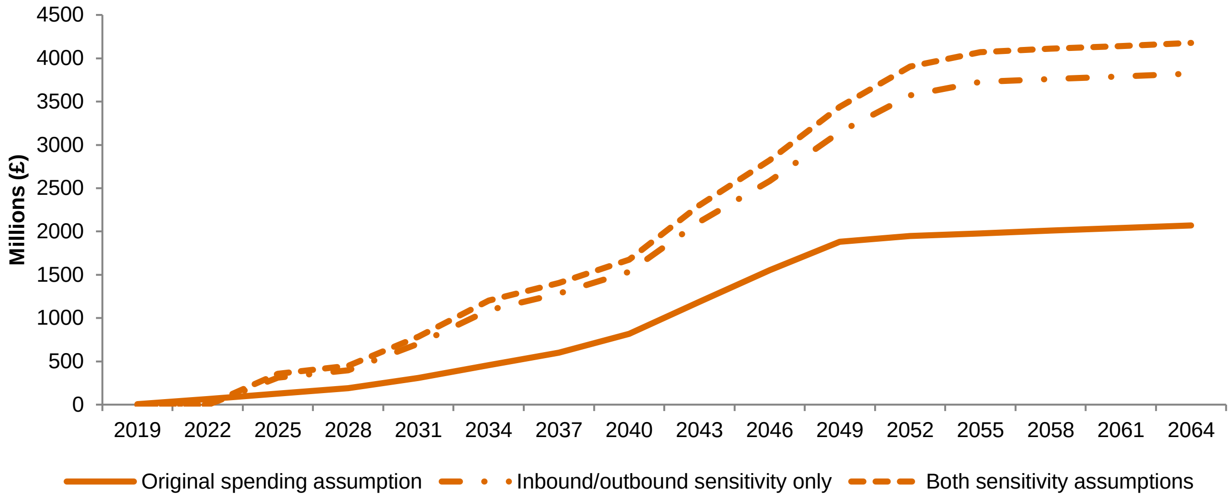

*Source: ONS, PwC analysis*

### *Results of the sensitivity analysis*

The charts below demonstrate the impact of the above sensitivity analysis on the overall GDP impact of the LGW 2R scheme, under the Assessment of Need, Low Cost is King and Global Fragmentation scenarios.

*Assessment of Need*

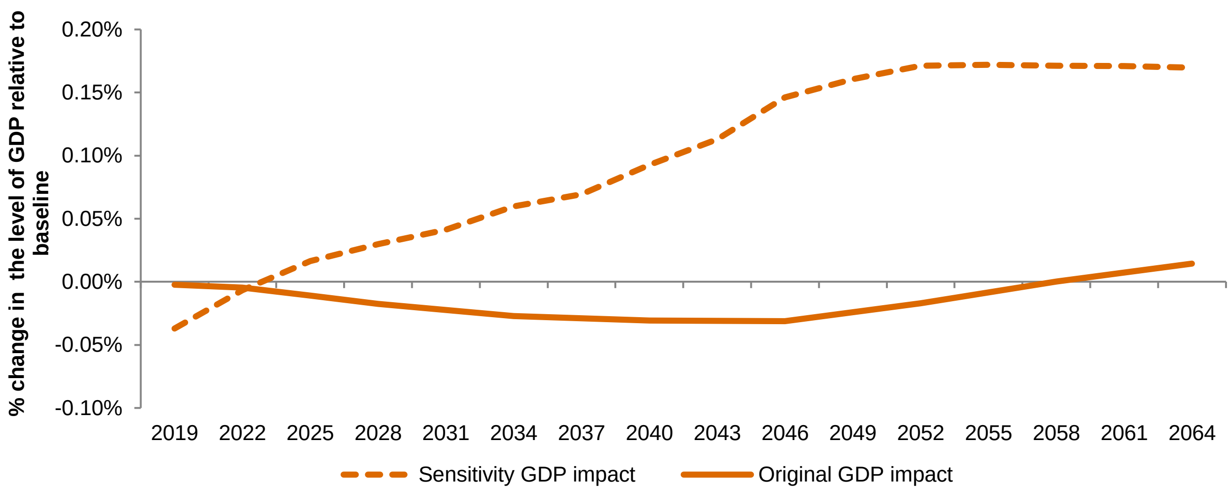
*Figure 40: LGW 2R - Impact of sensitivity assumptions on net additional passenger spending in the UK, Assessment of Need*




*Source: PwC analysis*

Figure 40 shows the impact of the sensitivity assumptions on net passenger spending in the UK for the Assessment of Need scenario. This chart demonstrates a substantial increase in net additional passenger spending, the majority of which is as a result of the change in assumed inbound/outbound passenger mix.

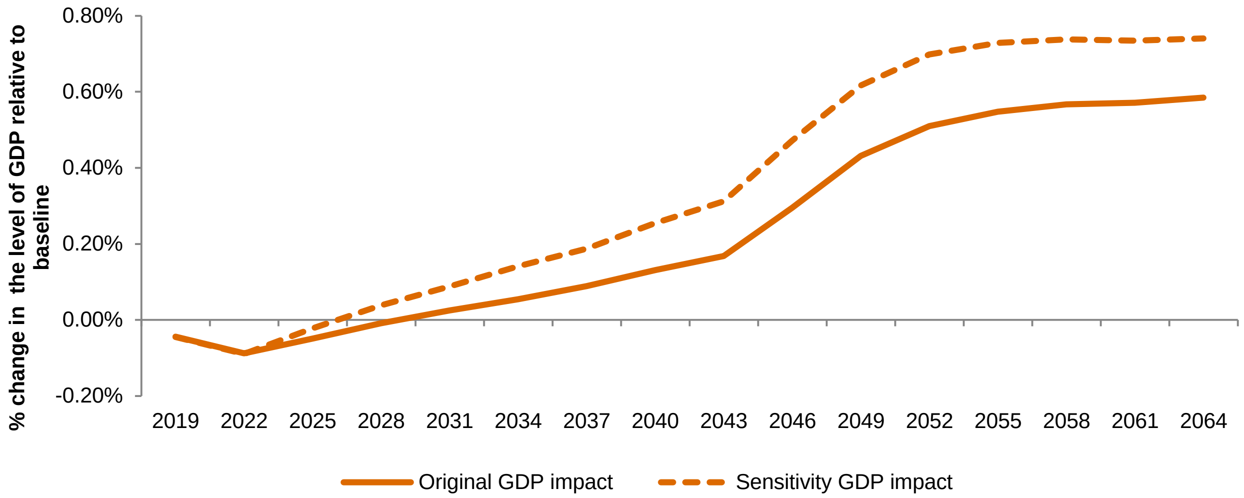
*Figure 41: LGW 2R – Comparing the GDP impact of just the passenger flow effect under different spending assumption, Assessment of Need*




*Source: PwC analysis*

Figure 41 shows how the passenger spend sensitivity affects the GDP impact of the corresponding passenger flow effect (as opposed to the GDP results that combine all effects). The original passenger spending assumptions lead to a negative GDP impact for the majority of the period studied (see Figure 9 in Section 6.4.3.1 for the original result). The result of the sensitivity analysis is for there to be a substantial positive impact on the level GDP. The magnitude of the impact grows throughout most of the period studied, before remaining relatively constant at roughly 0.15% of GDP from 2050. This positive impact reflects the sensitivity's increase in inbound passengers who contribute positively to the UK economy (and conversely the reduction in outbound passengers).

*Figure 42: LGW 2R – Comparing the overall GDP impact under different spending assumptions, Assessment of Need*

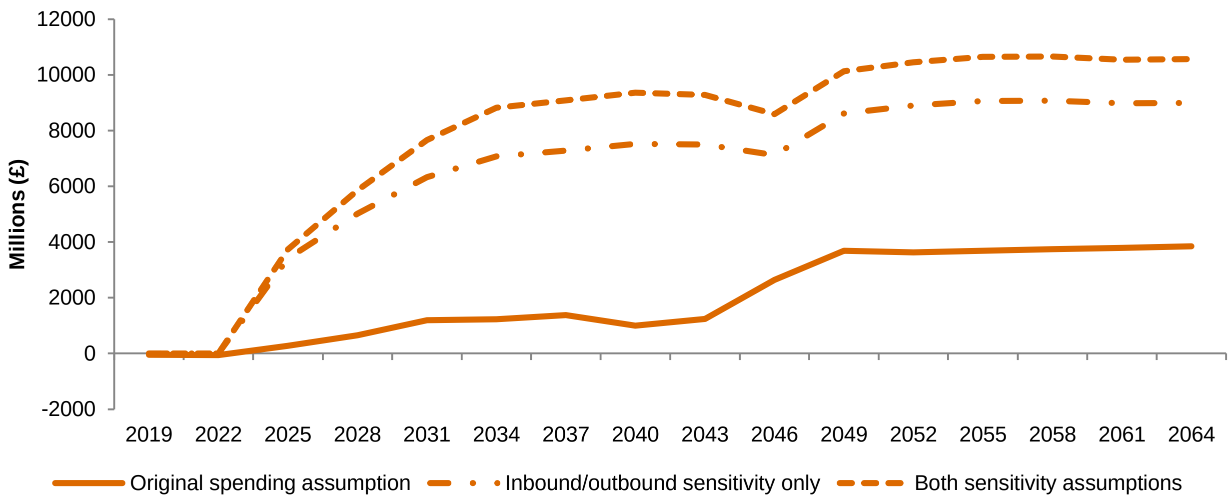



*Source: PwC analysis*

Figure 42 provides the results of this sensitivity test on the overall impact of the LGW 2R scheme, under the Assessment of Need scenario. This impact is shown to be particularly significant during the first half of the appraisal period, more than doubling the net economic impact of the scheme in 2040. In the long-run the overall economic impact is shown to increase by about a fifth, from 0.6% of GDP to 0.75%. The sensitivity test does not materially impact on the time profile of the economic impact of the scheme, which rises most substantially between 2040 and 2050 as the expanded airport reaches capacity.

*Low Cost is King*

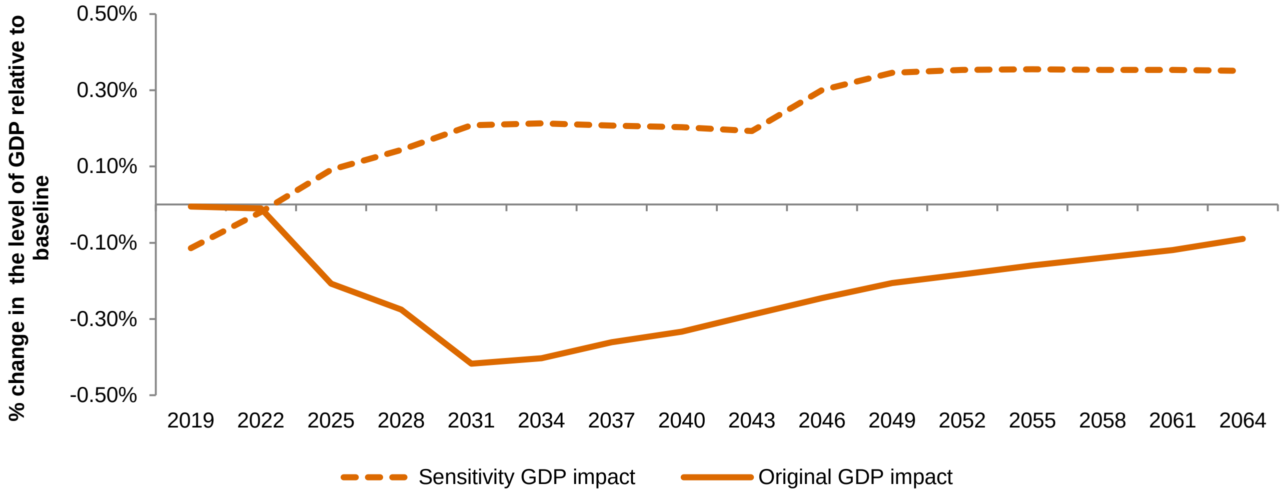
*Figure 43: LGW 2R - Impact of sensitivity assumptions on net additional passenger spending in the UK, Low Cost is King*




*Source: PwC analysis*

We also applied the sensitivity assumptions to the Low Cost is King passenger scenario, the scenario which leads to the greatest increase in passenger flow. Figure 43 shows the impact of the sensitivity assumptions on net passenger spending in the UK. This chart demonstrates that the majority of the increase in spending is a result of the change to the assumed inbound/outbound passenger mix.

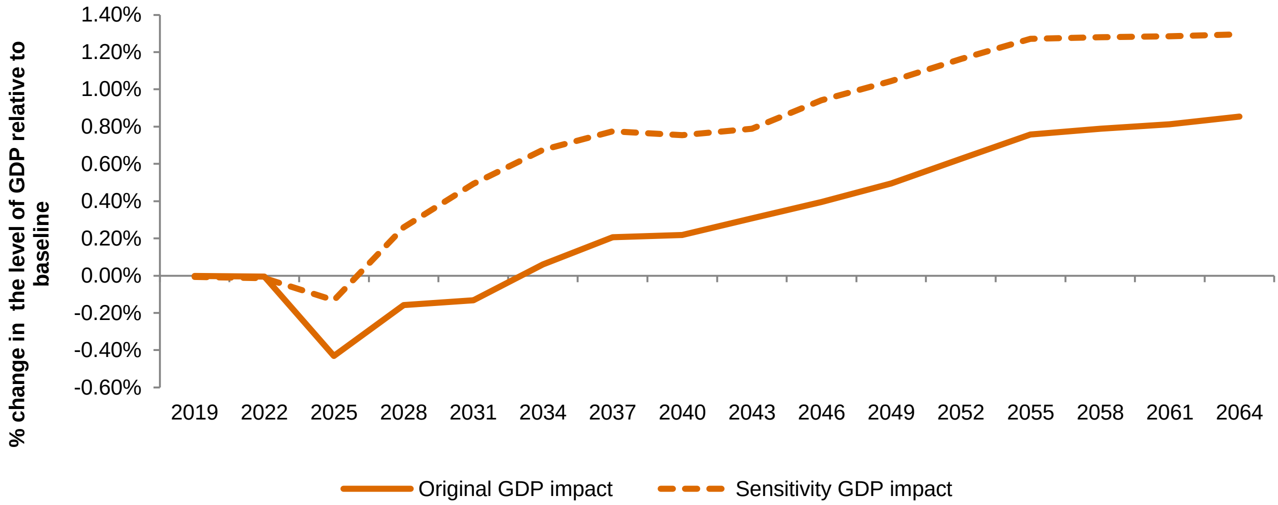
*Figure 44: LGW 2R – Comparing the GDP impact of just the passenger flow effect under different spending assumption, Low Cost is King*




*Source: PwC analysis*

Under this sensitivity, the impact on GDP is positive throughout the period studied. This is again predominantly driven by the greater number of inbound passengers. The impact here is more significant than under the Assessment of Need scenario, with a negative GDP impact converted into a positive one. The greater impact of the sensitivity under the Low Cost is King scenario is due to the larger number of additional passengers which it involves. The baseline assumptions highlighted the impact of increased outbound traffic, with this being substantially changed by the sensitivity.

*Figure 45: LGW 2R – Comparing the overall GDP impact under different spending assumptions, Low Cost is King*

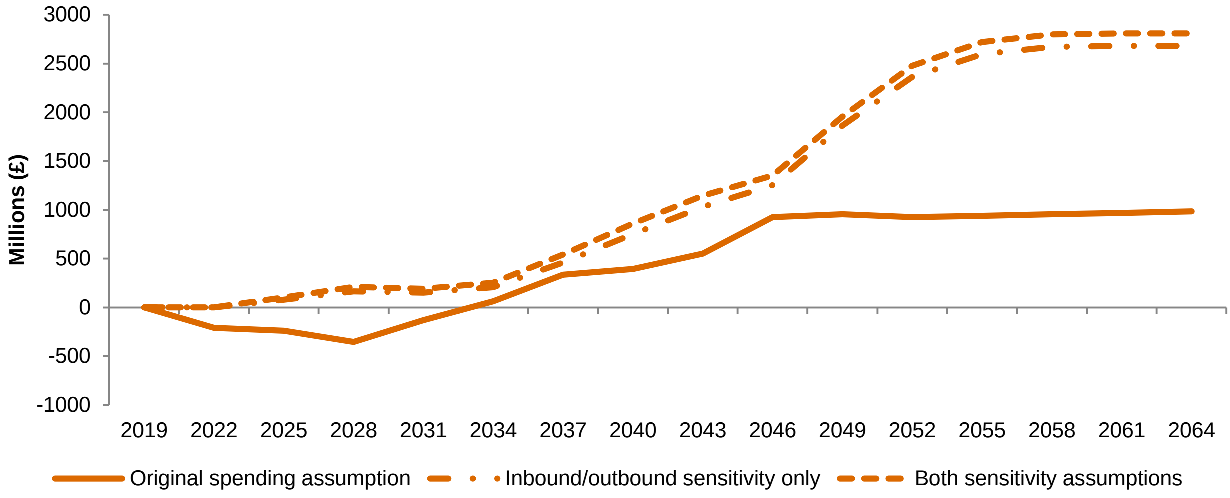



*Source: PwC analysis*

As with the Assessment of Need passenger scenario, the sensitivity has a very material impact on the economic impact of the additional capacity. Figure 45 shows the effect of the sensitivity on the aggregate GDP result. In the long run, the sensitivity increases the forecast impact on GDP from around 0.8% to 1.3%. It is also worth noting that the negative impact on GDP in the 2020s (that was present in the original GDP impact, due to the sudden increase in outbound passengers) is significantly smaller, and does not last as long.

### *Global Fragmentation*

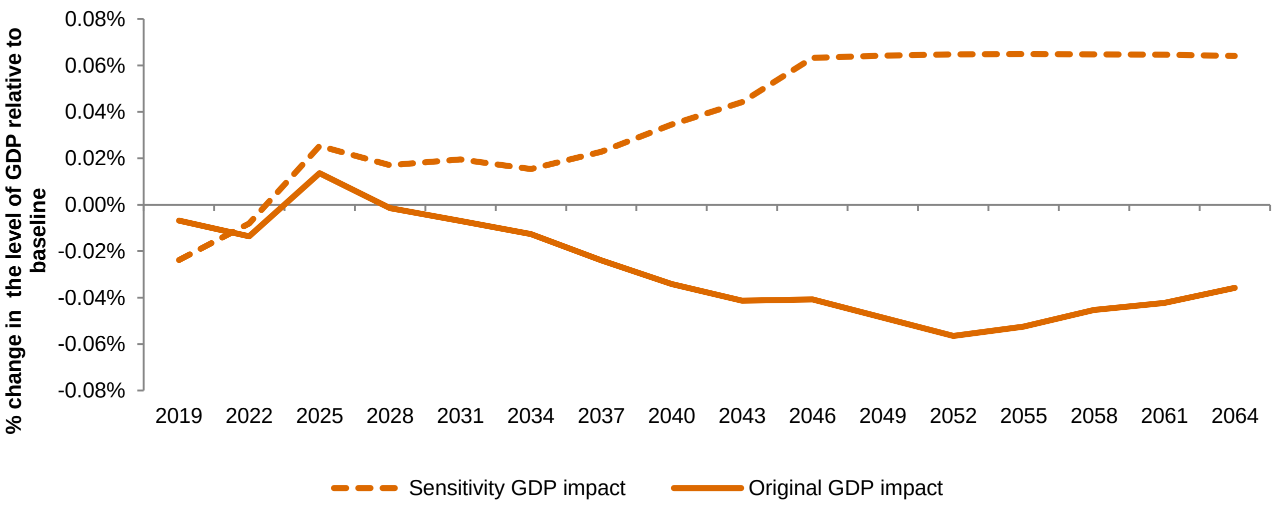
*Figure 46: LGW 2R - Comparing the GDP impact of just the passenger flow effect under different spending assumption, Global Fragmentation*




*Source: PwC analysis*

Figure 46 shows the impact of the sensitivity on net passenger spending in the UK, under the Global Fragmentation passenger flow scenario. As shown in Section 6.4.3.1, the incremental number of passengers under the LGW 2R scheme is lowest under the Global Fragmentation scenario. This chart demonstrates that the majority of the increase in GDP is due to the asssumed change in the inbound/outbound passenger mix.

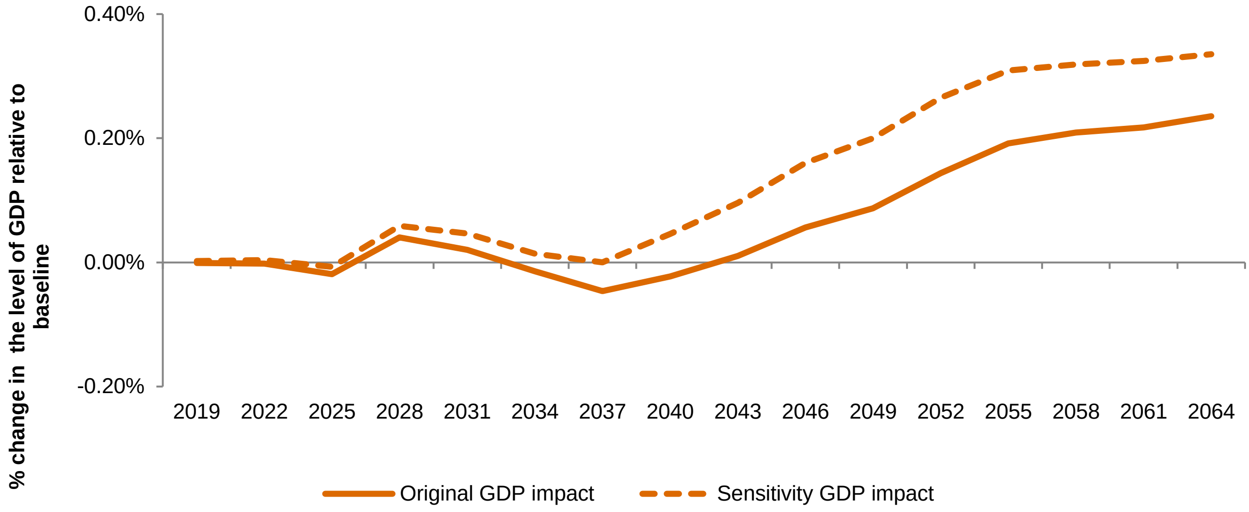
*Figure 47: LGW 2R – Comparing the GDP impact of just the passenger flow effect under different spending assumption, Global Fragmentation*




*Source: PwC analysis*

Figure 47 demonstrates the GDP impact of just the passenger flow effect, under the original and revised sensitivity assumptions. As a result of the lower passenger numbers in this scenario, the impact of the sensitivity is at its smallest, adding no more than 0.1% to the level of GDP forecast using the baseline passenger spend assumptions. The impact is once again positive, and is again sufficient to turn a small negative impact (-0.04% in 2064) into a small positive one (0.06% in 2064).

*Figure 48: LGW 2R – Comparing the overall GDP impact under different spending assumptions, Global Fragmentation*




*Source: PwC analysis*

Although less substantial than under the other passenger flow scenarios, the sensitivity again has a noticeable positive impact on the overall impact of the LGW 2R scheme on GDP. Under the sensitivity, this impact reaches 0.34% of GDP towards the end of the period studied, compared to 0.24% under the original assumptions. These values are calculated based on a 60 year appraisal period starting 2019.

*Table 30: LGW 2R – Present Value of real GDP impacts, by effect and scenario with and without sensitivity (£bn, 2014 prices)*

| | Assessment of Need | Low Cost is King | Global Fragmentation |
|---|---|---|---|
| **Passenger Flows** | -2.3 | -42.8 | -6.6 |
| ***Passenger Flows (Sensitivity)*** | *22.5* | *50.3* | *8.7* |
| **Productivity** | 52.1 | 90.3 | 17.9 |
| **Frequency Benefits** | 3.6 | 8.7 | 2.7 |
| **TEE** | 20.0 | 46.2 | 15.3 |
| **Total** | **73.3** | **102.4** | **29.4** |
| ***Total (Sensitivity)*** | ***98.2*** | ***195.5*** | ***44.6*** |

*Source: PwC analysis*

Table 30 summarises the impact which the sensitivity test has on the PV of the impact of the scheme. This is again shown to be highly significant, particularly under the Low Cost is King passenger flow scenario, where the PV of the economic impact is nearly doubled from £102.4bn to £195.5bn over the 60 years from 2019. Given the current lower share of inbound passengers at London Gatwick it is clear that this sensitivity represents a substantial increase in passenger numbers. The sensitivity also increases the total PV by more than 50% in the Global Fragmentation scenario, and by more than a third under the Assessment of Need scenario. These results show, particualrly under high growth and signincant changes to airline busienss model scenario, that the inbound/outbound passenger mix is an important driver in determining the economic impact of the scheme, previously outlined in Section 6.4.3.1.

### *6.8.4 Testing the impact of the passenger mix at the different London airports*

Figure 49 below shows the result of an additional sensitivity test on the passenger characteristic assumptions, testing the impact of profiling the additional passengers under the LGW 2R scheme such that they share the same characteristics as those currently using London Heathrow. It should be emphasised that the overall number of passengers assumed at Gatwick is the same as above (and as provided by the AC): the sensitivity tests considered here are wholly in respect of the *characteristics* of passengers using the airport. The sensitivity test, which has been undertaken on the instruction of the AC, is not based on forecasts but simply designed to test the sensitivity of the modelling results to changes in assumptions. The test involves the following changes to underlying assumptions:

1. The mix of inbound & outbound passengers – Heathrow currently has a greater share of inbound passengers than Gatwick: around 49% compared to 29% according to the latest ONS Travel Trends statistics. Therefore, as part of this sensitivity test for Gatwick, we assume that (whilst overall passenger numbers at Gatwick are unchanged) the inbound-outbound split of new (not existing) passengers is increased to the level observed in respect of Heathrow, and then projected forward throughout the period under consideration using the same proportion.

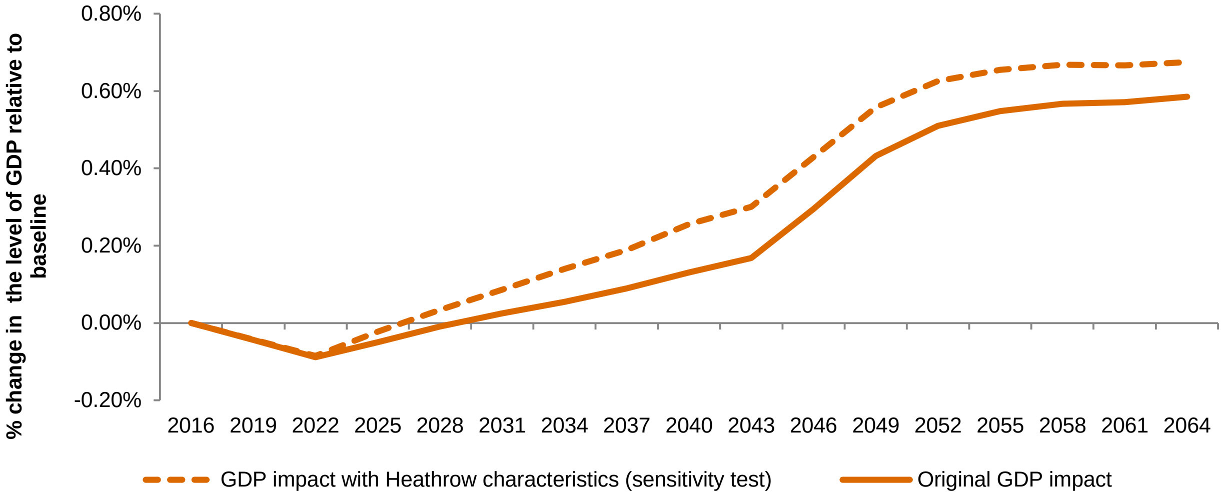
2. The distribution of passengers across regions – The passenger mix among world regions differs significantly between Heathrow and Gatwick. Therefore, as part of this sensitivity test for Gatwick, we assume that (whilst overall passenger numbers at Gatwick are unchanged) the distribution of new passengers across different world regions is the same as Heathrow. This reflects the possibility of a greater proportion of long-haul passengers using airport in future.

3. The mix in passenger type – The passenger type mix (i.e. the proportion of charter, domestic, international full-service, international low-cost, transfer and other passengers) also differs significantly between Heathrow and Gatwick. Therefore, as part of this sensitivity test for Gatwick, we assume that (whilst overall passenger numbers at Gatwick are unchanged) the mix in passenger type of new passengers is the same as Heathrow.

It should be noted that we have only considered the effects of these changes on the passenger expenditure effect. The results of this scenario test, presented below, show that this change in the passenger assumptions would increase the impact of the LGW 2R scheme in the Assessment of Need scenario by more than 0.1%, from roughly 0.6% to 0.7% in the long-run. Although substantial, this is less than the effect seen in the sensitivity test above which adjusts only the inbound-outbound passenger mix and the approach to estimating expenditure by region. The reason for this lesser impact is that while the first two characteristics listed above can be expected to increase net passenger expenditure within the UK, the third assumption has an opposing effect through reducing the share of passengers at the airport who arrive or terminate there[146].

[146] More specifically, as a result of the third assumption, the proportion of transfer passengers assumed at Gatwick increases. Since transfer passengers are assumed not to spend money in the domestic economy, the third assumption reduces UK GDP.

*Figure 49: LGW 2R - Comparing the overall GDP impact under different spending assumptions, Assessment of Need*




*Source: PwC analysis*

## *6.8.5 Testing the TEE effect with business passengers only*

The TEE effect reflects the impact of the expansion in airport capacity on airfares. Specifically, the AC demand model forecasts that the cost of air travel falls as capacity at Gatwick increases. This results in a transfer of money from producers (airlines) to consumers (air passengers). Scarcity rents which producers charge for use of the airport when it was capacity constrained are reduced, leading to benefits for consumers through lower cost of travel.

For business passengers, the lower airfares result in a productivity boost, which plays through the wider economy through the transmission mechanisms outlined in Appendix D. This increase in productivity has a direct positive impact on the supply side of the economy. For leisure passengers, this translates into an income effect i.e. a cash transfer back to households that can be spent or saved. This impacts on the economy through an increase in real demand, stimulated by the increase in disposable income.

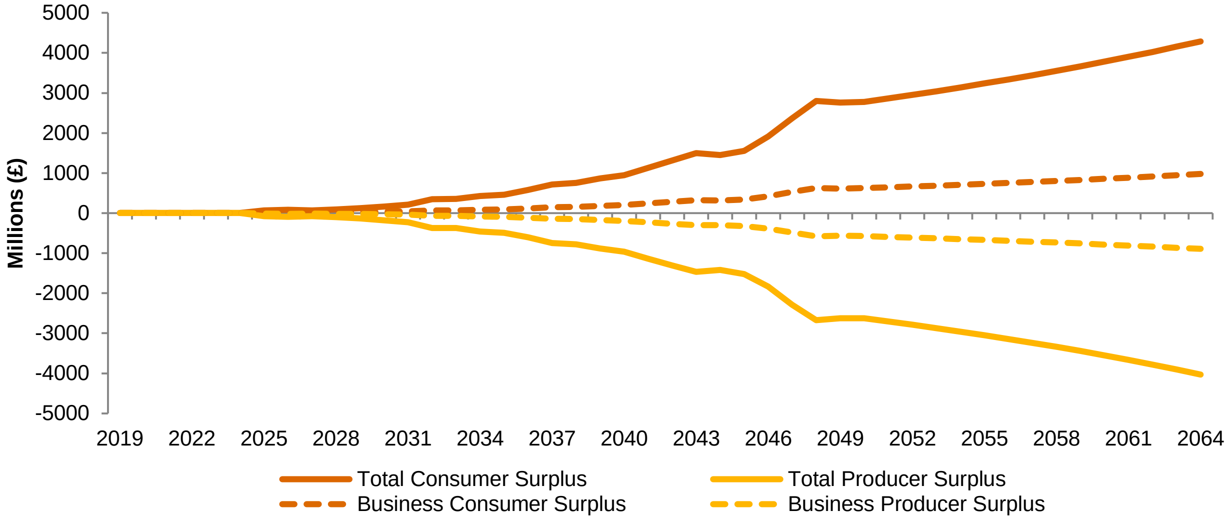
Previously, we have modelled the impact of changes in producer and consumer surplus for all passengers (passengers travelling for both business and leisure purposes), allowing us to understand the full effect of the transfer from producers to consumers as a result of the increased capacity. We test the impact of this assumption by modelling the impact of changes in producer and consumer surplus relating only to business passengers. This allows us to isolate the direct economic impact on the supply side of the economy.

For the Assessment of Need scenario, this section presents:

- the changes in inputs as a result of considering business passengers only;
- the subsequent GDP impact for the TEE effect; and
- the overall GDP impact of LGW 2R scheme (all effects combined).

Figure 50 below summarises the producer and consumer surplus inputs for the TEE effect. The solid lines show the original inputs used, which relate to both business and leisure types of passengers. The dotted line shows the inputs when considering only business passengers. Business passengers represent a smaller proportion of total passengers than leisure passengers. Consequently, by the end of the time period both consumer and producer surplus inputs are around 78% lower. However, consumer surplus fall by slightly less than producer surplus throughout the time period.

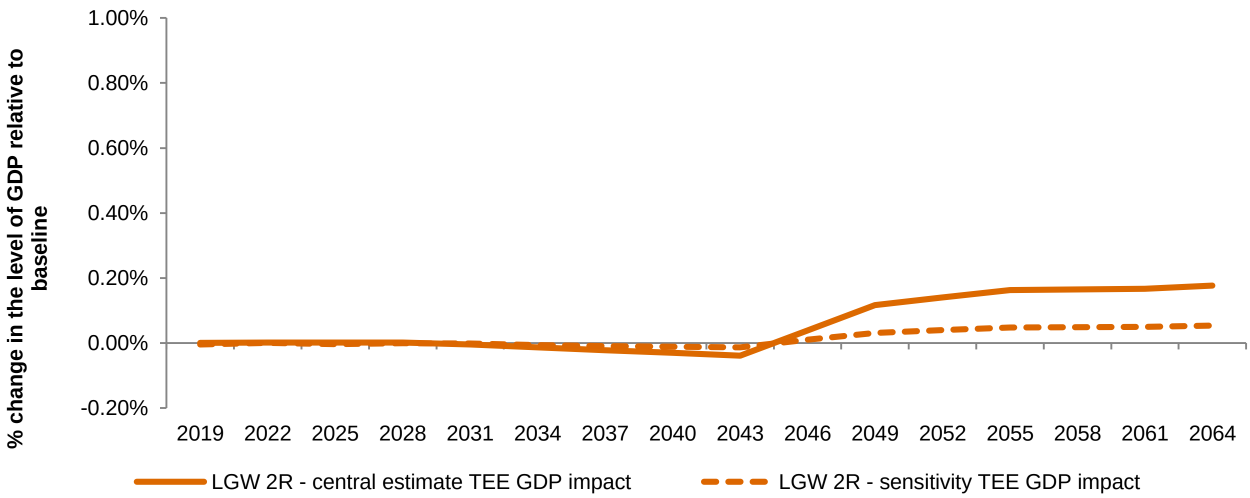
*Figure 50: LGW 2R –TEE inputs for all passengers and for business passengers only, Assessment of Need*




*Source: AC demand forecasts*

As a result of the smaller inputs, the impact of the sensitivity is to reduce the overall magnitude of the TEE effect for both positive and negative periods of GDP impact. Again, the solid line in Figure 51 shows the original GDP impact of the TEE effect, whilst the dotted line shows the impact of the TEE effect when only considering business passengers. The impact of the sensitivity is greatest in the latter half of the period, during which the TEE effect is around a quarter of the original effect, at around 0.05%.

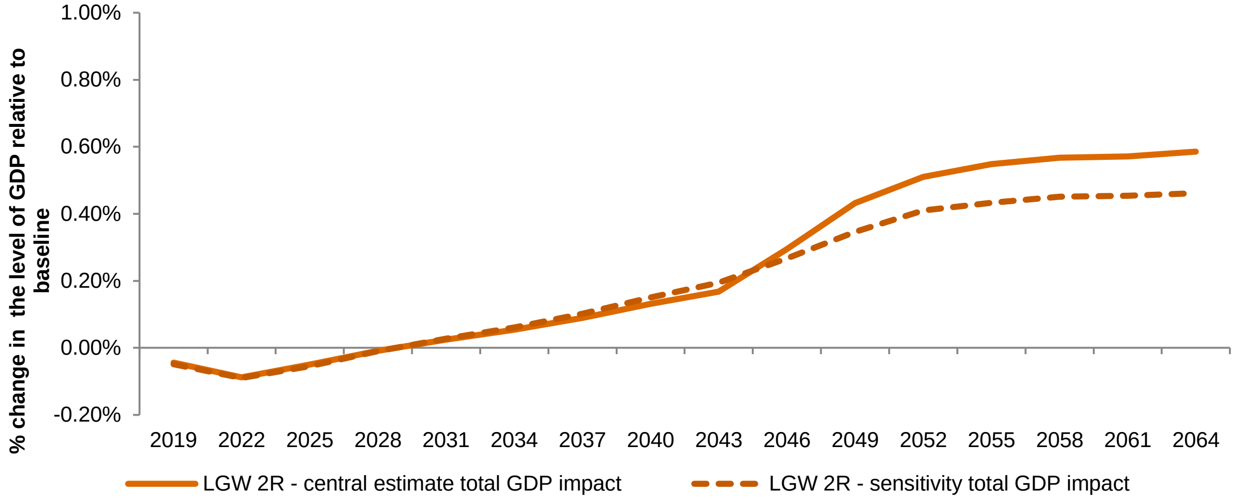
*Figure 51: LGW 2R – Impact of business passenger sensitivity on TEE GDP impact, Assessment of Need*




*Source: PwC analysis*

Figure 52 below shows the impact of the TEE sensitivity on the overall GDP impact of the LGW 2R scheme. Please note that this sensitivity test excludes the impact of construction. As expected, the reduction in the overall GDP impact is equivalent to the reduction in TEE effect GDP impact (0.13% by the end of the time period), which is now lower as a result of the change in the magnitude of model inputs, which now relate only to business passengers, as opposed to business and leisure passengers. The TEE effect was previously a significant component of the airport scheme’s overall GDP impact – 30% by the end of the time period in the original analysis, compared to 12% in the sensitivity.

*Figure 52: LGW 2R – Impact of business passenger sensitivity on overall GDP impact, Assessment of Need*




*Source: PwC analysis*

Table 31 below displays the PVs of the forecast total real GDP impact for the Assessment of Need scenario by effect. It also shows the PV of the business passenger only TEE sensitivity and the new overall total PV. The PV of the TEE effect is significantly lower in the sensitivity, by £14.2bn.

*Table 31: LGW 2R Present Value of real GDP impacts by effect (£bn, 2014 prices)*

| **60 years (2019-2078)** | **LGW2R** |
|---|---|
| **1. Passenger Flows** | -2.3 |
| **2. Productivity** | 52.1 |
| **3. Frequency Benefits** | 3.6 |
| ***4. TEE (original - business and leisure PAX)*** | *20.0* |
| **Total (original: 1+2+3+4)** | **73.4** |
| ***5. TEE (Business PAX only)*** | *5.8* |
| **Total (sensitivity test: 1+2+3+5)** | **59.2** |

*Source: PwC analysis*

Lower airfares represent a decrease in the cost of intermediate inputs for businesses. As a result, the sectors which therefore benefit the most are those which purchase the most from the air passenger transport sector. Excluding travel agents and the air passenger transport sector itself, the three largest beneficiaries are the financial sector, the manufacturing sector, and the information and communication sector. Between them, these sectors represent nearly 50% of air passenger transport intermediate consumption.

### *6.8.6 Testing the effects of alternative labour market assumptions*

Comments raised in relation to an earlier version of this report, published as part of the AC's consultation on "increasing the UK's long-term aviation capacity", made reference to the potential senstivity of the results to the treatment of labour supply. Based on these comments we discussed and agreed with the AC the following two tests:

**Test 1:** creating an assumption where the supply of labour is fixed; and

**Test 2:** testing the assumption where the elasticity that governs the pace at which unemployed workers enter the labour market in response to change in labour market demand and wages.

Together, these two tests will allow us to isolate the impact of the labour supply assumptions applied throughout this report, and demonstrate the sensitivity of the modelling results to changes in this assumption.

*How does the S-CGE model treat labour supply?*
In the S-CGE model, the volume of labour supply adjusts in response to changes in the wage level in two main ways:

1) Workers are able to enter and exit the market, known as the **extensive labour supply margin**.
2) Workers are able to increase or decrease their hours, known as the **intensive labour supply margin**.

Allowing the extensive and intensive margins to adjust assumes that the economy is not always operating at a fixed full employment, in that there are both unemployed and underemployed workers who can enter the market in response to an increase in demand, or vice versa.

In the baseline model, the extensive labour supply margin is based on an elasticity that governs the relationship between out of work income and wages This reaction is known technically as the income effect. The elasticity chosen as an input for this function is taken from a comprehensive literature review of labour supply elasticities by Keane (2011)[147] and also the Mirrlees Review (2011). The elasticity is weighted to reflect male, female and household labour supply decisions. It must also be set at a positive value to reflect the nature of the income effect i.e. as the gap between out of work income and in work income increases, people enter the labour market. On this basis, and to reflect data on flows of entry and exit into the labour market observed in the UK in recent years, we set this value at 0.2 i.e. for every 1% increase in wages, the supply of hours from non-working housheolds increases by 0.2%.

However, the model also generates a substitution effect – households gain additional utility from consuming a greater and wider variety of different products and services. But, they also supply “hours” to the labour market, and will experience a disutility from forgoing leisure time. For each additional hour of work supplied an hour of leisure is forgone. The decline in utility associated with forgone leisure is considered alongside the additional utility gained from earning more money and being able to consume more. Economic theory suggests that as incomes rise consumers have more disposable income and therefore place greater value on leisure time and may even seek to work less –the substitution effect.

In the S-CGE model the substitution effect is determined in a separate equation to the income effect. However, the net outcome regarding the income and substitution effect is determined by the households overall utility maximising function, meaning that the net outcome of these two effects is determined simultaneously.

Each household in the model is also given a “stock of leisure”. The model assumes that in the baseline, households spend one-third of their time at work, and two-thirds of their time not at work i.e. engaging in what we have termed leisure activities, but this would also include basis subsistence activities such as sleeping etc.

There is also an intertemporal element to the labour supply decision. In this context intertemporal substitution is reflected in the Frisch elasticity, which represents the willingness of households to postpone leisure in favour of work during periods of anticipated high wages. The Frisch elasticity is also governed by household preference to smooth consumption – if preferences to smooth consumption are strong then labour supply is less likely to adjust when wages rise. The value of this elasticity is set at 0.4, in line with empirical estimates reviewed by Mirlees (2011).

*Implementing the labour supply tests*
In test 1, which is a test of a fixed labour supply assumption, we change the extensive margin elasticity from 0.2 to zero and also hold the stock of leisure fixed – this means that those households who are out of work do not

147 Keane, M. (2011) “Labour Supply and Taxes: A Survey” Journal of Economic Literature 49:4, 961–1075

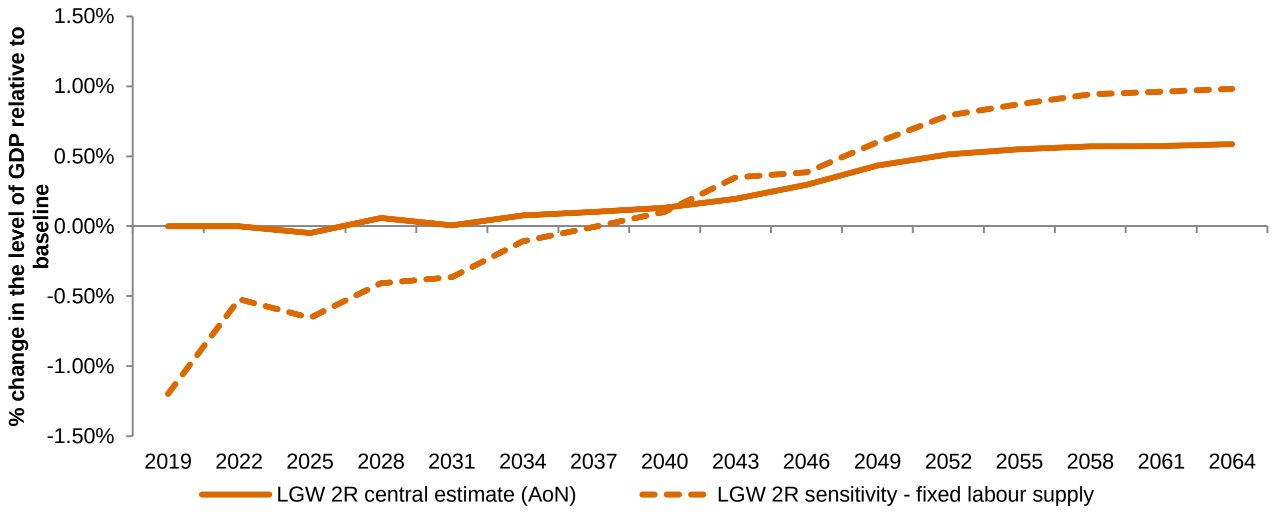
enter the labour market. The intensive margin is also fixed and the model is constrained so that households who are in work will not substitute leisure for additional hours of work. The Frisch elasticity is also set to zero, meaning there is no intertemporal substitution in response to wages.The assumption of a fixed labour supply is extreme, and is highly unlikely to occur in reality, but is implemented to show the magnitude of impact of our assumptions for the labour market.

In test 2 we fix only the extensive margin elasticity. The stock of leisure and the Frish elasticity allow workers to increase hours, but no new households enter the labour market. The difference in results between tests 1 and 2 shows the effects of varying the extensive margin.

### *Test 1: Fixing labour supply*

The result of the fixed labour supply assumption, in which both the extensive and intensive labour supply margins are fixed (i.e. workers can neither enter the market, nor increase their hours) is shown in Figure 53 below.

*Figure 53: LGW 2R – Overall GDP impact of central estimate and fixed labour supply sensitivity test, Assessment of Need*




*Source: PwC analysis*

The results of this sensitivity test are reflective of how restrictive the assumption is. In the early years of the modelling it can be seen that the level of GDP is substantially below both the baseline and central estimate. This is driven primarily by construction spending, which requires firms in the construction sector to offer a material wage premium to attract workers in order to meet demand.

Due to the fixed labour supply, these workers cannot be taken from unemployment or underemployment, and instead must move from employment in other sectors. This wage premium drives up the cost of labour for firms in all sectors, who need to adjust their own wages in order to retain workers in light of the greater compensation offered by the construction sector. This increase in the cost of labour motivates firms to restrict output, and causes the economy to reach a new, lower-output, equilibrium as seen in Figure 53.

Table 32 below breaks down the impact of the trends described above on jobs, by sector. As discussed above, the fixed labour supply condition means that the overall volume of labour supply is unable to change. Therefore, the overall impact on net job creation is zero throughout the time period, with increases in employment in one sector displaced from other sectors. Table 32 shows that the airport expansion results in a significant increase in the number of jobs in the air passenger transport sector, which are drawn primarily out of the manufacturing sector. This is because this is the sector with the most closely aligned wages and skillsets. There is also a short-term boost in employment in the construction sector, due to the airport expansion. By 2050, there are 24,000 more jobs in the airport passenger transport sector, and 23,000 less jobs in the manufacturing sector - which should be a key beneficiary of the airport expansion. There is also a significant fall in the number of jobs in the other services sector in the long-run.

*Table 32: LGW 2R - Breakdown of impact on net job creation by sector relative to baseline for fixed labour supply sensitivity, Assessment of Need scenario (000's of jobs)*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and Mining** | -0.9 | -0.2 | -0.4 | -0.5 | -1.0 |
| **Manufacturing** | -2.1 | -7.4 | -18.6 | -22.9 | -31.9 |
| **Utilities** | -1.0 | -0.1 | 0.0 | 0.1 | 0.3 |
| **Construction** | 5.1 | -0.6 | -0.7 | -1.3 | -1.2 |
| **Retail and wholesale trade** | -0.4 | -0.1 | -0.1 | -1.1 | -1.6 |
| **Air passenger transport** | 0.8 | 8.3 | 17.9 | 23.6 | 41.3 |
| **Air freight** | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 |
| **Other freight** | -0.2 | 0.0 | 0.3 | 0.6 | 1.5 |
| **Other passenger transport** | 0.0 | 0.4 | 1.3 | 0.8 | 1.5 |
| **Accommodation and food services** | -0.4 | -0.3 | -0.9 | -1.7 | -2.2 |
| **Other services** | -0.4 | 0.1 | 0.8 | 1.6 | -8.2 |
| **Health, education and public spending** | -0.5 | -0.2 | 0.3 | 0.7 | 1.4 |
| **Total** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

*Source: PwC analysis*

As the modelling period progresses, the difference between the central estimate and the sensitivity reduces, and eventually the impact on the level of GDP is seen to be higher under an assumption of fixed labour supply scenario. This occurs because it is fixed within the model that the ratio between consumption and investment must remain broadly constant in the long-run[148]. This is not an unreasonable assumption, as historically in the UK this relationship has shown relative long-run stability. However the rise in labour costs, and the associated fall in profitability, which occurs at the beginning of the period is sufficient to break this relationship in the short-run. The only way to meet the assumption is by a substantial increase in investment throughout the second half of the period modelled. This increase drives the greater GDP growth shown in Figure 53.

As this trend is driven purely by the requirements of the model, rather than any real economic effect captured within the inputs, this result should not be interpreted with the same credibility as the previous findings. What the result from the modelling does demonstrate is just how restrictive the assumption of fixed labour supply is. Under this assumption, a demand increase of this size could only be absorbed with a substantial change to long-run economic relationships within the UK. In reality this has not been the experience of UK economic history, where levels of employment have fluctuated in response to short-run changes in demand. This would suggest that completely fixing labour supply is an unrealistic and erroneous sensitivity test, a suggestion which is borne out in the results of the modelling.

### *Test 2: Reducing the extensive margin labour supply elasticity to zero*

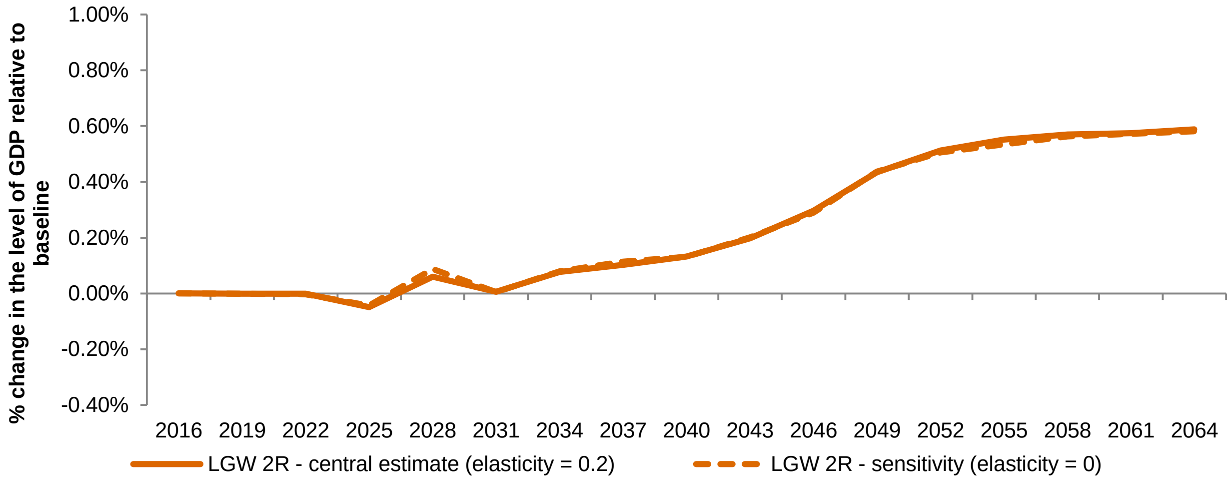
1. Under this assumption, the overall number of workers in the economy remains fixed (i.e. the unemployment rate is fixed). This is done through setting the elasticity of unemployment to real wages to zero. However, the intensive labour supply margin is allowed to adjust, giving workers the ability to move from part- to full-time work, increase their hours, or take additional jobs in response to changes in the wage rate.

[148] This type of fixed long-term relationship within the model is known as a 'terminal condition'

The results of this sensitivity test show that the impact on GDP of either change in assumption is minimal, demonstrating that the GDP impact of the increase in aviation capacity is not sensitive to the number of individuals who can be attracted out of unemployment. Specifically under the fixed extensive labour supply margin, it is shown that the increased demand for labour associated with the expansion in aviation capacity can be handled without expanding the number of workers in the labour force.

These results show that the precise labour supply assumption regarding the extensive margin applied in the central estimate does not have a material impact on the estimated GDP impact. Only an overly-restrictive assumption, such as completely fixed labour supply, causes a substantial change in this estimate.

*Figure 54: LGW 2R - Comparison of the overall GDP impact across different intensive labour supply elasticities, Assessment of Need*




*Source: PwC analysis*

## *6.8.7 Testing the imperfect competition assumption*

So far in the analysis, we have assumed imperfectly competitive markets (the marginal benefits of increasing output, measured by price, are above marginal costs). Thus, an output expansion brought about by reduced costs gives rise to an additional welfare benefit over and above what would be seen in a perfectly competitive framework. In this way, the S-CGE model allows us to depart from the conventional assumption in scheme appraisal of perfect competition, and to capture the real world implications of how most markets in the economy are characterised by effective but imperfect competition. This sensitivity is particularly relevant for the construction phase of the project, and construction effects are included within the analysis.

So direct cost savings associated with, for example, the production process becoming more efficient would be present in a model of perfect competition and are captured in conventional transport appraisal. However, where the market is imperfectly competitive, there are further effects. We therefore re-run the model assumption to test the model results under similar assumptions to those used in conventional welfare analysis. This sensitivity allows us to understand the relative magnitude of the further effects generated under imperfect competition, and compare these to the direct cost savings captured within conventional welfare analysis.

This assumption has been tested each of the three proposed airport schemes, under the Assessment of Need scenario, for all effects (construction, passenger flows, productivity, frequency benefits and TEE).

Under the original assumption of imperfect competition, some of the effects modelled give rise to multiple equilibria in the S-CGE model (an upper and a lower case). This phenomenon, described in detail in Chapter 2 and Appendix B, depends on the nature of competition in markets and the agglomeration effects.

Note that the baseline for this sensitivity (i.e. the projected GDP growth in the absence of new airport capacity) is different from that of the central estimate; the baseline for the sensitivity would reflect a counterfactual with perfect competition and constant returns to scale (CRTS), whereas the baseline for the central estimate would reflect a counterfactual with imperfect competition and increasing returns to scale (IRTS).

Under the central estimate, industries are imperfectly competitive with IRTS. Under this assumption, firms restrict output below the level of market demand in order to drive up prices, and in turn generate a mark-up on their sales, i.e. Cournot competition. Mark-ups are determined by the firms perceived elasticity of demand – these are inversely related, the lower firms perceive the elasticity of demand for their products, the higher mark-ups will be. The market structure suffers from inefficiencies in the short run which may delay the potential benefits from improved access to transport (for example, firms may choose not to pass on the lower costs to consumers in the short run).

However, the short-run effects under this market structure can also facilitate agglomeration. For example, if firms in a particular sector/region decide to raise prices in order to capture additional mark-ups in response to improved transport links, then in the model a concentration of new firms emerges in this sector/region facilitated by the forward and backward linkages inherent in the economy and the rise in economic activity associated with the new transport links.

In contrast, under perfect competition, firms face CRTS and therefore individual firms do not have any market power. Any benefits to firms due to improved transport links are quickly passed on to consumers, and the benefits to the economy accrue immediately. The pass-through of benefits implies that the economic gains associated with improved transport links are likely to be higher under perfect competition.

However, as discussed in Section A.2, there would be no agglomeration with perfect competition. This is because under perfect competition and the presence of transport costs, firms in a sector would spread out in order to minimise the costs of supplying consumers in different location. There would a large number of small production units, each supplying their local customers. The benefits, therefore, are likely to be spread out more evenly across sectors.

The difference between the two scenarios depends on the balance between the delay of benefits of reduced transport costs due to imperfect competition and agglomeration effects. Under perfect competition, if the transport costs gains are outweighed by the loss in agglomeration effects, then the overall impact on GDP is lower. On the other hand, if the transport costs gains are larger than the loss in agglomeration effects, then the overall impact on GDP is higher.

It is not possible to predict in advance which equilibrium will prevail (i.e. whether prices will be higher or lower, or whether the impact will be larger or smaller than the agglomeration benefits under imperfect competition). This is because the impact on the economy, i.e. the equilibrium outcome, will vary based on which sector/region becomes the focal point for convergence. It is difficult to predict which sector/region is likely to emerge as the focal point for convergence, and therefore, it is difficult to predict which equilibrium will prevail (i.e. whether prices will be higher or lower, or whether the spatial effects will aid agglomeration or dispersion), hence the need to consider each of the potential equilibria.

To be consistent with the central estimates presented in the rest of this report, Figure 56 shows the results corresponding to the higher results in terms of GDP effects. This is in line with Aghion *et al*[149] who use firm-level panel data for the UK and find that entry has led to greater innovation and faster total factor productivity growth, and to aggregate productivity growth.

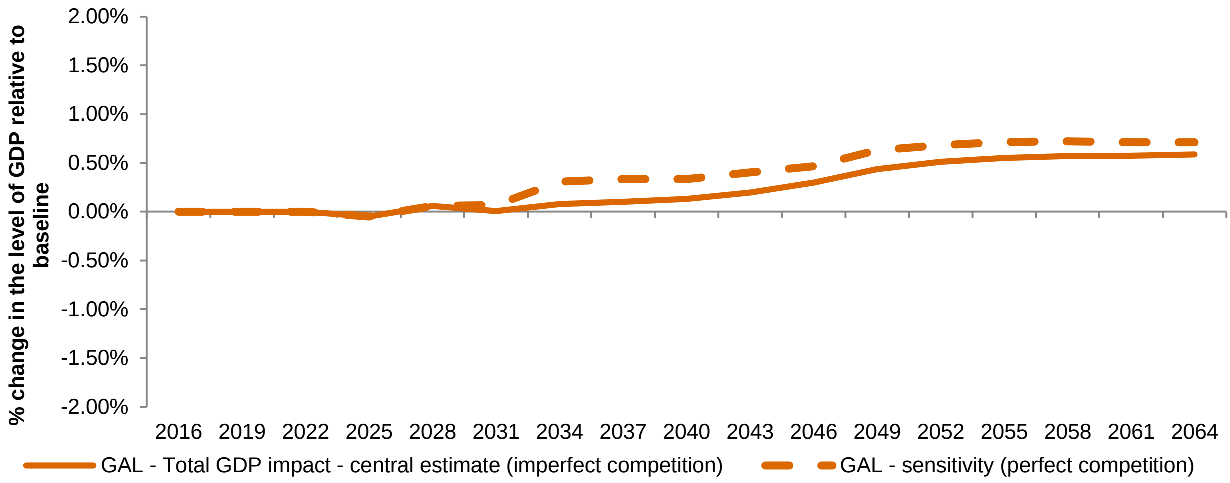
Figure 55 below demonstrates the impact of the perfect competition sensitivity test, on the overall change in the level of GDP for the Assessment of Need scenario. This shows that the change in the level of GDP is greater when perfect competition is assumed. As described above, the implication of this finding is that the transport cost gains are greater than the loss in agglomeration effects. The impact of the different assumption is most significant towards the beginning of the period studied, 2030 to 2040. This occurs as the increased efficiency of the market under perfect competition facilitates the flow of benefits from reduced transport costs more quickly throughout the economy. In addition, the agglomeration benefits which occur under imperfect competition are

[149] Aghion, P., Blundell, R., Griffith, R., Howitt, P., & Prantl, S. (2004). Entry and productivity growth: Evidence from microlevel panel data. Journal of the European Economic Association, 2(2-3), 265-276.

By exploiting a firm-level panel dataset, and using policy reforms that changed entry conditions by opening up the UK economy during the 1980s as natural experiments, Aghion *et al* show that more entry has led to faster total factor productivity growth of domestic incumbent firms and thus to faster aggregate productivity growth.

most substantial towards the end of the time period studied. As a result, the positive impact of perfect competition and CRTS diminishes beyond 2040.

*Figure 55: LGW 2R - Total GDP impact, under imperfect competition & IRTS and perfect competition & CRTS, Assessment of Need scenario*




*Source: PwC analysis*

The impact of the sensitivity test on GDP is further shown through Table 33 below, which outlines the Present Value (PV) of the GDP impacts over the 60 year appraisal period. This shows that under the assumption of perfect competition and CRTS the PV is over £100bn, nearly 40% higher than under imperfect competition and IRTS. The majority of this increase is driven by the increase in GDP towards the beginning of the appraisal period. Changes in the level of GDP are particularly material during these years as they are discounted less heavily than changes towards the end of the appraisal period. In the long-run, after 2060, the increase in the level of GDP is between 10-15% greater under perfect competition and CRTS.

*Table 33: LGW 2R Present Value of Real GDP impacts (£bn, 2014 prices)*

| Scenario | Present Value (£bn) |
|---|---|
| **LGW 2R - central estimate (imperfect competition and IRTS)** | 73.3 |
| **LGW 2R - sensitivity (perfect competition and CRTS)** | 102.2 |

*Source: PwC analysis*

The impact of assuming perfect competition and CRTS, compared with imperfect competition and IRTS can be more substantial at the individual sector level than when looking at GDP as whole. This is because the level of competition in the market, characterised by the existence of mark-ups, varies substantially across sectors. As a result, for the most competitive sectors the assumption can have very little impact, whilst for others the change can be very material. When looking solely at the overall GDP impact these sector differences are aggregated and the effect looks more moderate.

The impact by sector under perfect competition is given in Table 34. This should be compared with Table 34 above, which shows the corresponding data for imperfect competition[150]. Comparing these tables shows that the most substantial positive effects of perfect competition and CRTS are seen in agriculture, manufacturing and construction. These are sectors which are typified by relatively higher mark-ups, and therefore have the greatest potential for efficiency improvements under perfect competition and CRTS. By contrast, no change is seen in

[150] For consistency with previous analysis this table excludes the impact of construction and surface access spending

sectors such as retail and public services which have relatively small mark-ups. The positive impact on air passenger transport is also reduced, although it remains substantially the sector with the greatest growth. This is because the increase in aviation capacity causes substantial agglomeration benefits to occur under imperfect competition and IRTS, which are not possible under perfect competition.

*Table 34: LGW 2R - Breakdown of impact on the level of real GDP by sector under perfect competition, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and mining** | -2.3% | -0.3% | 1.5% | 1.3% | 1.8% |
| **Manufacturing** | -0.5% | 0.3% | 1.3% | 1.8% | 1.8% |
| **Utilities** | -1.8% | -0.2% | 1.2% | 1.0% | 1.4% |
| **Construction** | -2.4% | 0.5% | -0.2% | 2.3% | 2.3% |
| **Retail and wholesale trade** | -0.9% | -0.3% | 0.1% | -0.5% | -0.2% |
| **Air passenger transport and freight** | 3.0% | 3.4% | 5.8% | 8.7% | 11.6% |
| **Other freight** | -0.3% | -0.4% | -0.5% | -1.2% | -0.9% |
| **Other passenger transport** | 0.8% | -0.2% | -0.7% | -1.7% | -1.3% |
| **Accommodation and food services** | -0.5% | 0.1% | 0.7% | 0.9% | 1.1% |
| **Other services** | -2.4% | -0.7% | 0.7% | -0.3% | 0.4% |
| **Health, education and public spending** | 0.2% | 0.0% | -0.1% | -0.1% | -0.1% |

*Source: PwC analysis*

Overall, at a macro level the assumption of perfect competition and CRTS does not yield substantially dissimilar results to imperfect competition and IRTS. Where there are differences and the macro level between the impacts of the two assumptions, these are predominantly driven by increases in GDP being brought forward, with only moderate changes in the level of GDP seen in the long-run. However, when looking at sector-specific results far more variation is seen. Understanding the impact of imperfect competition and IRTS at this level gives greater insight as to likely sectoral reactions to the increase in aviation capacity.

### *6.8.8 Testing the carbon capped passenger scenario*

In our primary analysis, we have based the scenarios on the assumption of a "carbon-traded", rather than a "carbon-capped" emissions policy. As described previously, under both policy assumptions, limits are set on the amount of carbon that can be emitted. These limits may be allocated or sold to firms. However, under the carbon-traded scenario, firms can then trade their allocations: firms emitting less than their allocated limits can sell the remainder of their allocations to firms that are likely to emit more than their allocated limits.

Given the uncertainty of future carbon emissions policy, it is appropriate to test the sensitivity of the results to changes in the carbon assumption. In this section we present results for the LGW 2R scheme under a "carbon capped" emissions policy based on the AC's 'demand reduction' carbon capped scenario. For illustrative purposes, results are presented only for the Assessment of Need scenario.

The overall results for the carbon traded scenario are shown in Table 35 below. The total PV values are calculated for the 60 years following the scheme opening in 2025, and are therefore equivalent to the results presented in Table 11 above. Table 35 also breaks down the impact into the four different effects. This allows comparison of the different mechanisms through which changing emissions policy would affect the economic impact of increasing aviation capacity.

*Table 35: LGW 2R Present Value of real GDP impacts by carbon emissions policy, Assessment of Need scenario (£bn, 2014 prices)*

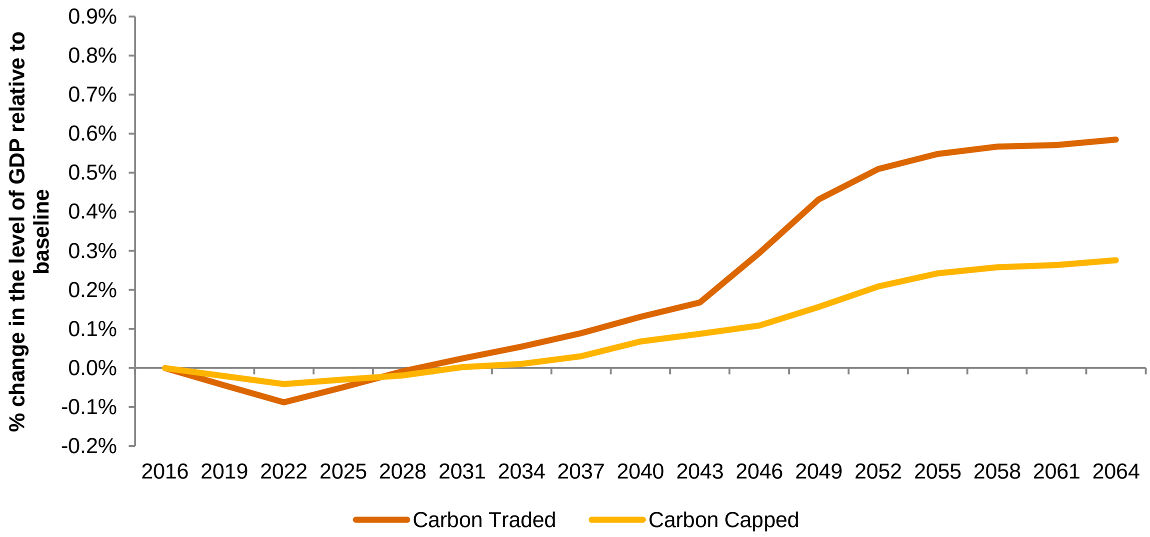
| | Carbon traded emissions policy | Carbon capped emissions policy |
|---|---|---|
| **Passenger Flows** | -2.1 | -8.9 |
| **Productivity** | 61.4 | 34.3 |
| **Frequency Benefits** | 4.6 | 1.6 |
| **TEE** | 25.2 | 16.6 |
| **Total** | **89.0** | **43.6** |

The results in this table highlight that the carbon capped emissions policy leads to a reduction in the PV of economic impact by roughly 50%, from £89bn to £43.6bn. Although this is a substantial reduction, the results of the sensitivity test demonstrate that even under a carbon capped scenario a material positive economic impact will remain in the modelling.

All effects lead to smaller economic impact under a carbon capped emissions policy, although the magnitude of the reduction varies by effect. The most substantial proportional fall is seen in the passenger flow scenario (which falls from -£2.1bn to -£8.9bn) between the scenarios. However, it should be considered that this effect is the net of two much larger opposite impacts: the positive effect of more inbound passengers spending money in the UK, and the negative impact of more outbound UK passengers spending money abroad. This analysis is based on the current inbound/ split, and has not been tested with the alternate inbound/ outbound splits which have been applied in other sensitivity tests. Below we explore the inputs which drive these results in more detail.

Figure 56 provides additional detail by demonstrating how the scale of the GDP impact changes over time as a result of the changing emissions policy scenario. This shows that the carbon capped scenario leads to a lower GDP impact throughout the period studied, with similar time profiles of impact under each scenario. The long-run impact on the level of GDP falls by more than 50%, from 0.58% on the level of GDP to 0.28%.

*Figure 56: LGW 2R - Total GDP impact, under a carbon traded and carbon capped emissions policy scenario, Assessment of Need scenario*




The primary difference between the two scenarios, which drives much of the difference between the results, is the change in the number of additional passengers which the expanded capacity enables. The additional number of passengers under each scenario is given in Table 36 below. This demonstrates that the additional number of passengers in the UK system as a result of the LGW 2R scheme (in 2050) falls from 9.8m under a carbon traded emissions policy to 6.3m under a carbon capped scenario. This fall in overall passenger traffic is the reason for the reduction in the magnitude of economic impact found in Table 35. Please note that Table 36 excludes international transfer passengers, as they are not assumed to have a material impact on the UK economy in this context.

The econometric results presented in Appendix C demonstrate that long-haul flights have a larger impact on UK productivity than flights to Europe. The passenger mix under the carbon capped emissions policy demonstrates a larger number of flights to long-haul destinations such as North America and Oceania, but a more than 50% fall in flights to East Asia, when compared to the carbon traded scenario. The modelling results shown in Appendix C show that flights to and from East Asia have the most substantial impact on productivity.

As a result, the change in passenger mix in the carbon capped scenario does not have a substantial positive impact on economic activity to offset the decline in passenger numbers. This can be seen in Table 35, which shows that the fall in economic impact from the productivity effect, which is driven by the passenger mix, is similar to that from the TEE effect, which is not. Together these two effects account for the vast majority of the change in economic activity as a result of the scheme.

*Table 36: LGW 2R, Additional UK-wide passengers in 2050 relative to the Do Minimum, by carbon emissions policy, Assessment of Need Scenario*

| Region of destination/ origin | Carbon traded emissions policy | Carbon capped emissions policy |
|---|---|---|
| **Africa** | 0.4m | 0.4m |
| **Central & South America** | 0.3m | 0.2m |
| **East Asia** | 0.7m | 0.3m |
| **Europe & Channel Islands** | 7.7m | 4.9m |
| **Middle East** | 0.1m | 0.0m |
| **North America** | 0.1m | 0.3m |
| **Oceania** | 0.0m | 0.1m |
| **UK** | 0.6m | 0.3m |
| **Total** | **9.8m** | **6.4m** |

Finally, Table 37 captures the regional distribution of the economic impact of the LGW 2R scheme, under both the carbon traded and carbon capped policy scenarios. Due to the larger share of passengers which flow through the London airport system under the carbon capped scenario, the London & the South East share of benefits is larger (41% compared with 35%). However, this effect is not large as the benefit even of air traffic going through the London system is largely national in nature, i.e. businesses all over the country feel the benefit of increased connectivity and openness, and a substantial share of passengers' expenditure is outside of London & the South East. As a result, benefits continue to be well distributed across the country, if marginally more focussed on London.

*Table 37: LGW 2R Present Value of regional real GDP impacts by carbon policy, Assessment of Need scenario (£bn, 2014 prices)*

| Region of destination/ origin | Carbon traded emissions policy | Carbon capped emissions policy |
|---|---|---|
| **London & the South East** | 30.9 | 17.9 |
| **Rest of England** | 44.5 | 20.7 |
| **Rest of UK** | 13.6 | 4.9 |

| | | |
|---|---|---|
| **Total** | **89.0** | **43.6** |

### *6.8.9 Testing the results using the AC's welfare-based productivity assessment*

As a further sensitivity, the AC instructed us to model the outputs from its conventional welfare-based welfare analysis to see how they would play out in an S-CGE framework. This sensitivity has been undertaken to better understand the interactions in the economy that might occur in a welfare-based assessment (this is done for the Assessment of Need scenario only).

The AC's welfare-based analysis focusses on the following wider impacts:

- Increasing productivity through trade;
- Increasing productivity through the formation of new business agglomerations and strengthening existing business agglomerations;
- Impact on government's tax revenue from increases in wages associated with the rise in GDP observed in response to airport expansion; and
- Increasing output by exposing domestic firms to more competition.

Table 38 describes these effects in further detail and explains how we have incorporated them into the S-CGE framework. Table 39 shows the PV of the inputs provided by the Airports Commission.

*Table 38: AC welfare impacts*

| Impact | Description[151] | Incorporation into the S-CGE framework |
|---|---|---|
| **Increasing productivity through trade** | According to the AC, "airport expansion provides increased connectivity in the form of better access to foreign markets and thus, facilitates trade between the UK and the rest of the world. This impact on trade is exclusive to aviation and thus, is not covered in standard transport guidance. Exports to other countries encourage knowledge and technology transfers from international firms and also allows British firms to exploit economies of scale by selling to larger international markets. In addition to the knowledge transfers, imports from other countries also increase the level of competition in the market and leads to the removal of inefficient firms and a more efficient use of resources. These effects result in an increase in the overall level of productivity in trade-related sectors of the economy, which has been captured in the trade benefits". | The AC has provided us with estimates of the productivity increases as a result of higher trade. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |
| **Increasing productivity through formation agglomerations and strengthening existing agglomerations** | According to the AC, "the change in connectivity offered by airport expansion attracts businesses which benefit from the better international links as well as their supply chains to cluster around the airports. This leads to the creation of agglomerations around the airports, leading to productivity increases in these sectors through knowledge and technology spillovers as well as access to and developing larger input markets and labour markets. These changes in productivity have been captured in the agglomeration effects". | The AC has provided us with estimates of the productivity increases as a result of agglomeration effects. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |

151 Descriptions have been taken from the Airports Commission's *Wider Economic Impact Note* shared with PwC on 18 April 2015.

| | | |
|---|---|---|
| **Impact on government's tax revenue from people moving to better suited and higher paid jobs** | According to the AC, "the changes in productivity arising from the agglomeration effects in particular sectors increases the returns to labour in these sectors and thus, attracts some workers to move to better suited more productive jobs in the clusters surrounding the airports. The increase in productivity of the workers translates into higher wages in a competitive market and thereby increases the taxes paid by these workers. These impact on the government's tax revenue" | The AC has provided us with estimates of the impact on government's tax revenues from people moving jobs. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |
| **Increasing output by exposing domestic firms to more competition** | According to the AC, "the expansion also results to a reduction in the cost of production for firms that use air transport as an input and thus, allows them to profitably increase the level of output they produce. These benefits for firms that operate in perfectly competitive markets are captured in the direct benefits to business users. However, since the calculations for direct benefits assumes perfect competition, similar effects for firms in imperfectly competitive markets are missed out. These impacts of increase in output in imperfectly competitive markets are captured here". | The AC has provided us with estimates of the impact on firms' outputs in imperfectly competitive markets. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |

*Source: Airports Commission and PwC analysis*

*Table 39: LGW 2R Present Value of real GDP impacts by effect (£bn, 2014 prices)*

| | Assessment of Need |
|---|---|
| Increasing productivity through trade | 6.3 |
| Increasing productivity through formation agglomerations and strengthening existing agglomerations | 0.6 |
| Impact on government's tax revenue from people moving to better suited and higher paid jobs | 0.1 |
| Increasing output by exposing domestic firms to more competition | 1.1 |
| **Total** | **8.1** |

*Source: Airports Commission*

The results of this sensitivity when welfare inputs are used as inputs to the S-CGE model are presented in Figure 57. The graph shows the combined GDP effects of all of the impacts described in Table 38 and compares the results to the central estimates presented above.

Under this alternative set of inputs, the GDP impacts are modest between the opening of the scheme and the mid-2040s. This reflects the underlying inputs provided by the AC, and in particular the feature that much of the aviation activity growth under the scheme takes place from 2040. Under this sensitivity, the long run effect is to increase GDP by around 0.2%.

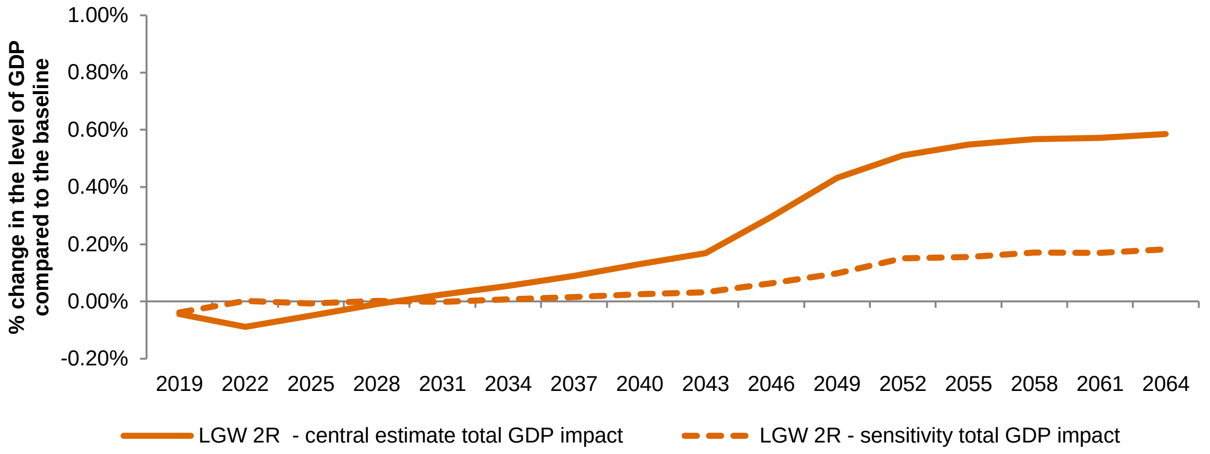
The broad patterns are similar when the welfare inputs are used, with the impacts increasing gradually as aviation flows rise. The two key differences between this sensitivity and the central estimate are as follows:

- **Overall scale of the effect.** The scale of the estimate using the welfare inputs is approximately one third of the central estimate. The smaller scale is to be expected for a number of reasons. Firstly, the welfare analysis abstracts from important effects that have been taken into account in the central estimate, notably TEE and passenger flow impacts. Secondly, the AC approach to estimating the productivity effects of trade uses elasticity evidence which is *partial equilibrium* in nature. In contrast, the central estimate captures the relationship between trade and GDP in *general equilibrium*.

- **No reduction in GDP in the 2020s.** The estimate using welfare inputs does not display an initial reduction in GDP in the 2020s, in contrast to the central estimate. Again, this is due to the fact that some of the effects are not present in the welfare inputs. In particular, whilst under the central estimate the net expansion of outbound passenger flow expenditure reduces GDP, this effect is not modelled as part of the welfare inputs.

Please note that this analysis is entirely separate to the previous modelling undertaken on this effect, and should be seen as complementary rather than additional.

*Figure 57: LGW 2R – Impact of welfare -based productivity assessment on overall GDP*



# 7 Heathrow Airport Extended Northern Runway results

'This chapter presents the results of our analysis of the LHR ENR scheme and describes the underlying transmission mechanisms through which the various effects described in previous chapters are forecast to impact on the economy. The chapter proceeds as follows:

- Section 7.1 provides a summary of the results;
- Section 7.2 presents the total GDP impacts;
- Section 7.3 sets out the present values of the GDP impacts;
- Section 7.4 explains the drivers of the GDP impacts;
- Section 7.5 sets out the impacts by region;
- Section 7.6 presents the construction impacts;
- Section 7.7 provides the results for other economic impacts; and
- Section 7.8 describes a number of sensitivities.

## *7.1 Summary of results*

This section provides an overview of some of the key results emerging from the S-CGE framework for the LHR ENR scheme and describes, at a high-level, the underlying economic mechanisms that drive the results. Depending on the scenario, by 2050, the level of GDP is forecast to be around 0.4% to 1.0% higher than in the baseline scenario (as discussed in Chapter 5, the economy is assumed to grow at 2.75% in per annum in the baseline scenario, which is consistent with HM Treasury's long-term trend growth assumptions). This is a result of higher net inbound passenger flows[152], increased net trade, and higher consumption and investment. In the Assessment of Need scenario, the scheme is forecast to create 163,000 new jobs by 2050 (of which, approximately 30% are at the airport itself). Each of the regions of the UK considered in this analysis (London & South East, the Rest of England and the Rest of the UK) are expected to experience increases in GDP as a result of the scheme, the extent of the gain depending on the passenger flow scenario considered).

### *7.1.1 Phases of impacts*

The forecast impacts of the LHR ENR scheme are experienced in two phases:

1. The **construction phase**, during which the economic impacts are principally associated with the building activities of the scheme; and
2. The **operational phase**, during which the construction impacts fade but other economic impacts – notably passenger flow, productivity, frequency benefits and TEE (Transport Economic Efficiency) effects – are felt.

For the LHR ENR scheme, the construction and operational phases are very distinct. The construction phase takes place between 2019 and 2026, and the operational phase commences immediately upon project completion.

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[152] i.e more of the additional passenger journeys associated with the scheme originate outside the UK than within the UK

In order to provide a summary of the overall progression of the LHR ENR scheme over time and its forecast wider economic impacts, we consider the impacts in the construction as well as the operational phase of the scheme. In later sections of this chapter, the main emphasis is on the forecast impacts of the scheme excluding construction, since we are primarily interested in the long-term effects of the enhanced aviation linkages created (although we reintroduce construction impacts towards the end of the chapter for completeness).

### *7.1.2 Construction phase effects*

The first forecast impact of the scheme occurs as a direct result of the construction activities. Clearly the construction impacts do not, in themselves, provide reasons for undertaking the scheme. However, the S-CGE model suggests that diverting[153] available resources of the economy towards constructing the airport may have significant economic impacts in its own right.

We have agreed with the AC to assume that the scheme itself is funded wholly by the domestic private sector (although surface access improvements are assumed to be funded by government for the purposes of this report, see below). Therefore, whilst the construction sector expands, this will be offset by reductions in activity elsewhere in the economy. Higher investment returns than those in other parts of the UK economy would be needed in order to attract investment to the scheme which: (i) would encourage households to increase their saving (at the expense of consumption) and (ii) would draw in funds that would otherwise be invested in other projects (although past experience, on which the model is based, suggests that the impact on investment in other projects should be modest).

Airport investment boosts the overall demand for construction. There is a positive multiplier effect that is associated with this expansion[154]. However, there will also be a reduction in both consumption and other forms of investment as the investment funding has to be found from elsewhere in the economy, offsetting the previous effects, as described above. This generates an offsetting negative multiplier effect. In addition to this, in the long-term, borrowers would also have to pay back this money in the future which also generates a negative multiplier.

The overall or “net” effect of shifting the economy towards construction depends on the strengths of the effects described in the preceding paragraph. The model, and the evidence on which the multipliers are based, suggests that the net impact is to increase GDP, since the positive effects of expanding the construction sector outweigh the negative effects of contractions elsewhere. Our modelling suggests that re-orientating the economy towards building the LHR ENR airport scheme might increase GDP by around 0.5% in 2022.

The construction multiplier implied by the ONS UK Supply Use Tables, which are the basis for the S-CGE model, is higher than those for other sectors – this is because the import content is relatively low, and construction has strong inter-linkages with some high value added sectors. The forecast construction impacts of the LHR ENR scheme are effectively the same across the different passenger flow scenarios, since the assumptions for construction costs and phasing are invariant with respect to these scenarios.

The PV of the GDP impact is forecast to be £12.2bn over the 60 year appraisal period (the figure for construction is very similar across the scenarios), compared to costs of £22.2bn[155]. This implies that for every £1 of construction expenditure on the LHR ENR scheme, GDP is forecast to increase by around £0.55 on a present value (PV) basis.

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[153] We use the phrase ‘diverting’ to emphasise that resources for construction of the scheme must come from elsewhere in the economy in the S-CGE framework.

[154] It should be noted that not all of the investment taking place comes from the construction sector. Other sectors will invest too. This is because the economy assumes ‘perfect foresight’ and rational expectations. This means that agents will make an expectation of the future benefits of the new airport. The S-CGE model tends to front load this investment in the results (as it would be rational to capitalise on the gains associated with the expanded runway as early as possible). However, in reality agents may not operate with perfect foresight and rational expectations so we might expect this effect to be more muted and spread out over a longer period of time.

[155] As set out elsewhere in this report, this assumes a 60 year appraisal period with discount rate of 3.5% for the first 30 years and 3.0% for the remaining 30 years.

### *7.1.3 Operational phase effects*

The operational phase for LHR ENR is scheduled to commence immediately after completion of the first construction phase in 2026, and it is in this phase that the long-term economic impacts associated with passenger flows, productivity, frequency benefits and TEE are first felt.

At the outset of the operational phase, there is a very small forecast reduction in GDP of up to 0.1% (depending on the scenario) relative to the baseline scenario. This occurs because households in the model are assumed to be "rational" (make decisions that maximise their welfare) and "forward-looking" (consider their future wellbeing as well as current). In particular, households foresee that the airport expansion will have a positive effect on whole economy GDP once the scheme becomes fully functional. They therefore anticipate increased returns in the future. In order to capitalise on higher returns across the economy, households reduce their consumption in the short-term in order to increase savings, which results in a temporary and modest contraction in output.

It is difficult to be sure whether this effect will materialise in reality and it is possible that the effect will be less pronounced than that implied by the model. However, the assumption of "forward looking" households has been thoroughly investigated within the academic literature and has sound theoretical underpinnings, and in any case is relatively small and transitory.

We now turn to the operational phase effects (passenger flows, productivity, frequency benefits and TEE), and consider the mechanisms through which they may have an impact on GDP, and set out the high-level forecasts implied by the model.

*Passenger flow effects*

One of the most palpable effects expected once the scheme becomes operational is an increase in both UK passenger expenditure outside of the UK and foreign passenger expenditure in the UK. Increased passenger flows expenditures have **direct demand-side effects** that have an impact on GDP – they result in changes in spending by visitors to and from the UK that "flow through" the economy[156], UK passenger expenditure outside of the UK and foreign passenger expenditure in the UK have opposing impacts on GDP:

- UK passenger expenditure outside of the UK represents foregone consumption in the UK. UK passenger expenditure outside of the UK therefore represents a "leakage" from the UK economy, which reduces UK GDP. The S-CGE model suggests that domestic GDP is relatively sensitive to outbound passenger expenditure – the "**UK passenger expenditure outside of the UK multiplier**" is relatively large. This is because the consumption foregone in the UK – for example, a household appliance which is not bought in the UK as the UK resident instead spends the money on meals and accommodation abroad – has strong supply chain linkages into the domestic economy; and
- Foreign passenger expenditure in the UK increases GDP since it increases UK aggregate demand. However, the S-CGE model suggests that domestic GDP is less sensitive to inbound expenditure – the **"foreign passenger expenditure in the UK multiplier"** is relatively small. This is because the inbound expenditure – spending, for example, on accommodation and restaurants in the UK – has weaker linkages into the wider UK economy.

These expenditures also have important "diffusion" effects which dampen the impacts described in the bullet points above. For example, the foreign passenger expenditure in the UK increases prices in the UK, for instance, for accommodation and other goods and services used by visitors and domestic residents, which reins in the overall level of demand.

While the inbound passenger expenditure multiplier is relatively small, inbound passenger spending still provides a boost to the UK economy. It is an important source of foreign exchange and is equivalent to an exported good or service in this sense. This effect occurs on the demand-side of the economy: inbound passengers spend money on a range of goods and services in the UK economy (e.g. hotels, restaurants, retail sector etc.) Increased flows of "exports" can have important supply-side effects. The sectors of the economy

[156] We refer to the passenger flow effects as "demand-side" impacts from international movements of visitors, since they are not associated directly with changes in the productivity of firms (except to the extent that changes in demand may increase or reduce scale economies, generate incentives to invest or otherwise endogenously affect productivity).

associated with inbound passengers will expand as a result of the increase in spending and these sectors will need to hire more workers and invest more to support any expansion. Sectors which service inbound passenger demands are important for the UK economy as they provide a range of low-skilled and school leaver jobs and can facilitate working on a part-time basis. These types of jobs are often taken up by the long-term unemployed. If sectors which service inbound passenger demand expand, this can also have positive upstream effects for those sectors that supply goods and services to these sectors (e.g. the manufacturing or agriculture sectors). Overall the model suggests a small, but permanent increase in productivity resulting from the supply-side expansion associated with inbound passenger demand.

During the first 15 years of operations, the AC estimates that passenger flows associated with the LHR ENR scheme will increase rapidly (19.7m additional passengers are forecast to use the UK system by 2050 in the Assessment of Need scenario). The increase in foreign passenger expenditure in the UK (£4.7bn per annum compared to the baseline scenario in 2040 in the Assessment of Need scenario) is forecast to be significantly larger than the increase in UK passenger expenditure outside of the UK (which is forecast to increase by around £0.5bn per annum on a comparable basis). A full description of the underlying reasons is provided later in this chapter.

Even though the UK passenger expenditure outside of the UK multiplier is greater than the foreign passenger expenditure in the UK multiplier, inbound expenditure to the UK is so much larger than the UK expenditure abroad such that the net impact on UK GDP is forecast to be positive, leading to a 0.1% to 0.2% increase in the level of GDP by 2050, depending on the scenario. The model suggests that for every additional £1 of net passenger flow expenditure, GDP increases by £0.7 in 2050, in the Assessment of Need scenario. The reason that the ultimate impact on GDP is less than the original increase in expenditure is the diffusion effect described above as prices respond to the changes in demand.

The PV of the passenger flow impact for LHR ENR is forecast to be between £17.6bn and £36.3bn over the 60 year appraisal period, depending on the scenario. The PV is highest in the Global Growth scenario, and lowest in the Relative Decline of Europe scenario. These results are driven by the number and type (e.g. inbound or outbound, short-haul or long-haul etc) of passenger.

*Productivity effects*

Improved aviation linkages can improve firms' productivity in a number of ways. For example, better aviation linkages may enable firms to access larger markets, allowing them to exploit scale economies. Less tangibly, but also importantly, by being able to access foreign markets more readily, aviation linkages could allow firms to "learn" from customers and competitors in other countries, helping them to exploit technologies and adopt more efficient "ways of working" (these effects form the basis of the so-called "endogenous growth" literature which has revolutionised the way economists think about how economies grow). Similarly, by facilitating international trade, aviation linkages can allow firms to increase their productivity by importing more efficient equipment and technology from abroad.

An increase in productivity has a direct positive impact on GDP: firms can produce more output for a given amount of resources used as inputs. At the "microeconomic" level (i.e. at the level of individual firms) higher productivity means that it becomes profitable for firms to produce output that was previously unprofitable, so that firms increase the amount they produce. This productivity improvement may be experienced across the economy, and not just by firms in the immediate vicinity of the airport.

In a "partial equilibrium" framework, the effects would end here. In the S-CGE model, however, a number of indirect impacts also come in to play. On the supply-side, firms pass on their increased efficiency to consumers and other producers in the form of lower prices. In addition, increased productivity places upward pressure on wages since workers become more efficient (and hence more valuable to firms), which in turn attracts people into work and reduces unemployment. Both of these effects place further upward pressure on real GDP. On the demand-side, the higher output produced by firms increases demand for intermediate inputs, which also increases GDP.

As with the passenger flow effect, there are also diffusion impacts – effects which limit the net impact on GDP due to use of scarce resources. The increase in GDP results in higher aggregate demand which places upward pressure on prices. This dampens the size of aggregate demand increases and it is this increase in prices that ultimately keeps the economy "in check" and prevents economic activity from spiralling ever-upwards.

Turning to the results, our model forecasts that the productivity effect associated with the LHR ENR scheme may develop relatively slowly, since the effects are cumulative and it takes time for them to permeate the economy. Ultimately, however, the productivity effect is forecast to be the largest of all of the effects considered in our analysis for the LHR ENR scheme. In 2050, the productivity effect is forecast to add between 0.2% and 0.3% to the level of UK GDP (depending on the scenario). The model suggests that for every additional £1 incorporated into the model as increased productivity, GDP increases by £0.70 in 2050, in the Assessment of Need scenario. The primary reason for the "multiplier" being less than one is that the diffusion impacts of price increases suppresses demand and GDP.

The PV of the productivity impact is forecast to be between £34.9bn and £72.6bn over the 60 year appraisal period (depending on the scenario). The PV is highest in the Global Growth scenario, and lowest in the Decline of Europe scenario, reflecting the differing magnitude of passenger flows between the two scenarios (which drives the size of the productivity impact, see Chapter 4).

*Frequency benefits*

Greater frequency of services can increase firms' productivity, for example by enabling travel at more efficient and/or convenient times, thus reducing the effective travel time. We only consider frequency benefits accruing to businesses – frequency benefits to leisure travellers have been excluded from our analysis since it is unclear whether they will impact directly on GDP. Frequency benefits are an additional, albeit relatively modest, source of economic gains associated with the LHR ENR scheme[157].

Since frequency benefits increase business productivity, the transmission of the effect through the economy is very similar to that described above for the productivity effect. In particular, there is a direct impact as firms are able to increase the amount they produce for a given level of inputs, but there are also indirect effects as the economy responds dynamically (for example as wages increase, as described above). As with the productivity effect described above, diffusion effects ultimately mean that prices rise and keep the economy in check.

The results of the S-CGE model suggest that the frequency benefit effect to businesses associated with the LHR ENR scheme may add between 0.03% and 0.07% to the level of UK GDP by 2050, depending on the scenario. The model suggests that for every additional £1 incorporated into the model as frequency benefits, GDP increases by £1.5 in 2050, in the Assessment of Need scenario.

The PV of the frequency benefits impact is forecast to be between £4.1bn and £9.4bn over the 60 year appraisal period (depending on the scenario). The PV is highest in the Low Cost is King scenario, and lowest in the Global Fragmentation scenario, reflecting the differing magnitude of passenger flows between the two scenarios.

*Transport Economic Efficiency effects*

TEE is the final effect examined in the analysis. Input data provided by the AC assumes that the relaxation of the capacity constraint in the UK aviation sector means that airlines are able to extract less "economic rent" associated with the scarcity of available airline capacity, implying that fares fall, benefiting consumers but with an offsetting effect on airline shareholders. The net impact on real GDP is captured in the TEE effect.

Consumers benefit from the assumed fall in prices (the benefits to consumers of a fall in prices are captured by means of a change in "consumer surplus"). For modelling purposes, we interpret the reduction in price as an increase in households' real incomes or "purchasing power"[158]. This results in increased demand for air travel, and potentially other goods and services in the economy as households' savings from lower fares can be spent elsewhere (this is called the "income effect" of a price change). This increased demand places direct upward pressure on GDP: consumers are willing to pay more for goods and services, meaning that firms are able to produce output profitably that was previously unprofitable, so that output expands. In turn, this has multiplier

[157] The econometric estimation period used to inform the productivity effect did not include any step-changes in frequency benefits. Therefore, frequency benefits were not captured in the coefficients estimated as part of the econometric analysis. This point is considered in more detail in Chapter 4.

[158] For technical reasons, the price impact on consumers is modelled as a change to productivity. See Chapter 4 for more details.

impacts through the supply chain as firms increase their demand for inputs. As GDP and aggregate demand increase, upward pressure is placed on prices – this, again, is the diffusion effect. This dampens the ultimate impact of the effect of the real increase in consumer incomes.[159]

Conversely, airlines are able to extract less economic rent as a result of the reduction in capacity constraints and experience a reduction in profitability as a result of the price fall (a reduction in "producer surplus"). Airlines pay lower dividends to households – the ultimate owners of firms in the model – which places additional downward pressure on GDP. As with the consumer gain, diffusion effects (diffusion tends to *decrease* prices in this case) dampen the ultimate impact on GDP.

The overall impact of the TEE effect depends on:

1. The relative sizes of the gains to consumers and losses to producers; and

2. The relative strength of the multiplier linkages of the gains to consumers and losses to producers.

The sizes of the forecast gains to consumers and losses to airlines have been provided for use in our modelling by the AC. In the Assessment of Need scenario in 2050, the gains to consumers are £6.9bn, compared to the losses to producers of £4.9bn. The S-CGE model suggests that in the same year and scenario, for every £1 of consumer gain, the increase in GDP is £0.70, whilst for every £1 of airline loss the fall in GDP is £0.40. The reason that the GDP loss associated with a £1 reduction in producer surplus is larger (in absolute terms) than the GDP gain associated with a £1 increase in consumer surplus is as follows. The reduced producer surplus results in lower returns to airline shareholders. In the S-GCE model these shareholders are households. However, the households most affected by the reduction in airline profits are amongst the most affluent in the economy, and their consumption does not reduce at the same rate as the boost to consumption associated with the increased consumer surplus since these wealthier households have a higher propensity to save (consumer surplus accrues to a broader set of households, being those who use airlines). For both the consumer gain and the airline loss, the final impact on GDP is less than the original input, reflecting the diffusion effects described above.

On the basis of this information, the results of our analysis suggest that the TEE effect might increase GDP by between 0.1% and 0.4% in 2050, depending on the scenario. The PV of the TEE impact is forecast to be £17.4bn and £71.2bn over the 60 year appraisal period (depending on the scenario). The PV is highest in the Low Cost is King scenario, and lowest in the Global Fragmentation scenario.

### *7.1.4 Overall impact*

The level of GDP in 2050 is forecast to be around 0.4% to 1.0% higher than it would have been in the absence of the LHR ENR scheme, depending on the scenario. When all of the effects are taken together, the PV of the GDP impacts of the LHR ENR scheme is forecast to be between £85.8bn and £187.4bn, excluding construction impacts (depending on the scenario). This rises to £98.0bn to £199.6bn when construction impacts are included. The ratio of the PV of the GDP impacts to the PV of the inputs to the S-CGE model (i.e. the total PV of the net passenger expenditure, productivity, frequency benefits, and TEE inputs) for the LHR ENR scheme is 0.65. This ratio provides an indication of the magnitude of the GDP impact implied by the model, relative to the magnitude of the inputs to the model. The fact that this ratio is less than one is largely a result of the diffusion effects of price rises described above. This illustrates the point made in the introduction that the S-CGE framework does not allow a "free lunch", and many of the impacts we describe are offset by effects working in the opposite direction. The increase in GDP by 2050 is underpinned by:

- Net inbound and passenger spending (UK passenger expenditure outside of the UK is forecast to be 0.1% to 0.2% higher than it otherwise would be and foreign passenger expenditure in the UK is forecast to be 0.2% to 0.4% higher);

[159] There could be an overlap when considering only business passengers, between these benefits and the productivity effects outlined above, as the potential increase in trade could be a reason for business travellers demanding air transport. However, this issue does not occur within our analysis as the econometric relationship has not been estimated over a period where there is a step-change in seat capacity, and therefore does not capture the reverse impact of changes in capacity on demand (please see Section 4 in Appendix C for a full exposition of this).

- Net trade (net trade is forecast to be 0.1% to 0.2% lower than it otherwise would be)[160] while the trade deficit increases the additional flows of imports and exports have facilitated a substantial productivity gain; and
- Consumption (which is forecast to be 0.4% to 1.1% higher).

Among the sectors of the economy, the air passenger transport and freight industry is forecast to experience the largest percentage growth, being a forecast 12.3% higher in GDP terms in 2050 in the Assessment of Need scenario, compared to the baseline scenario. The sector is forecast to grow by more than the increase in passenger numbers in proportional terms, owing to the projected shift towards more high-value and long-haul services. Due to their strong international linkages, the manufacturing and agriculture sectors are also expected to be important beneficiaries: in 2050 manufacturing is forecast to expand by 1.8% relative to the baseline scenario, with agriculture expanding by 1.3% in the same period. The construction sector is also forecast to benefit, with output increasing by 24.1% in 2020 compared to the baseline as a result of airport construction, and by 2.5% in 2050, principally as a result of ongoing maintenance activities at the airport.

The model suggests that the LHR ENR scheme could create 164,000 new jobs by 2050 (both at the airport itself and indirectly in the wider economy) in the Assessment of Need scenario, many of which would be in the aviation and manufacturing sectors. The number of firms in the economy is expected to remain constant in the long run (an analysis by sector is provided in Section 8.7.3).

The LHR ENR scheme would also be expected to have important regional impacts. The model suggests that the benefits would be somewhat concentrated in London & South East, which is forecast to gain by between £32.4bn and £71.5bn in PV terms (excluding construction). Over time, prices in London & South East would be expected to rise relative to other regions as a result of the increased activity. With projected increases in GDP of £38.6bn to £82.2bn and £14.8bn to £31.7bn in PV terms respectively by 2050 the Rest of England and the Rest of the UK also stand to benefit by a significant amount from the schemes. The reason is that productivity impacts are experienced nationally (for example, even firms which do not use the aviation linkages directly may still benefit, since they may be able to "learn" from firms which do seek to increase their productivity by exploiting the improved aviation linkages), and the frequency and TEE benefits would be expected to accrue to all airport users, a large proportion of whom reside outside of London & South East.

The estimated impact of the LHR ENR scheme is in line with the findings from previous studies. For example, analysis of potential airport sites in Sydney found that a new airport carrying up to 54 million passengers in 2060 could increase the level of real GDP in Australia by 1-1.2%[161]. Given the greater increase in passenger flows enabled by the new airport in Sydney, relative to the LHR ENR scheme, one would expect it to have a greater impact on GDP. In addition, the smaller size of the Australian economy, relative to the UK, would ensure that additional passenger flows have a relatively larger impact.

Whilst some of the impacts are less certain than others (see Chapter 5) and the figures are different under alternative scenarios, this illustrates the extent of GDP benefits associated with the LHR ENR scheme.

## *7.2 Total GDP impacts*

This section examines the forecast GDP impacts of the LHR ENR scheme by scenario at a national level. The impacts across the schemes are experienced in two phases. In this analysis we look at only at the effects produced during the operational phase operation of the expanded airport, since we are primarily interested in the effects of improved aviation linkages rather than construction impacts.

Figure 58 summarises the overall forecast impact on the level of real GDP of the operations of the LHR ENR scheme. In all scenarios, operational phase impacts would be expected to increase relatively gradually, reflecting the underlying assumptions embodied in the passenger flow figures supplied to us by the AC. The overall effect of passenger spending itself is positive in GDP terms, and the increase in runway capacity is

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[160] It should be emphasised that this represents the *net* change in trade (excluding tourism/passenger flow impacts). This is underpinned by significant increases in both imports and exports, which have an offsetting effect.

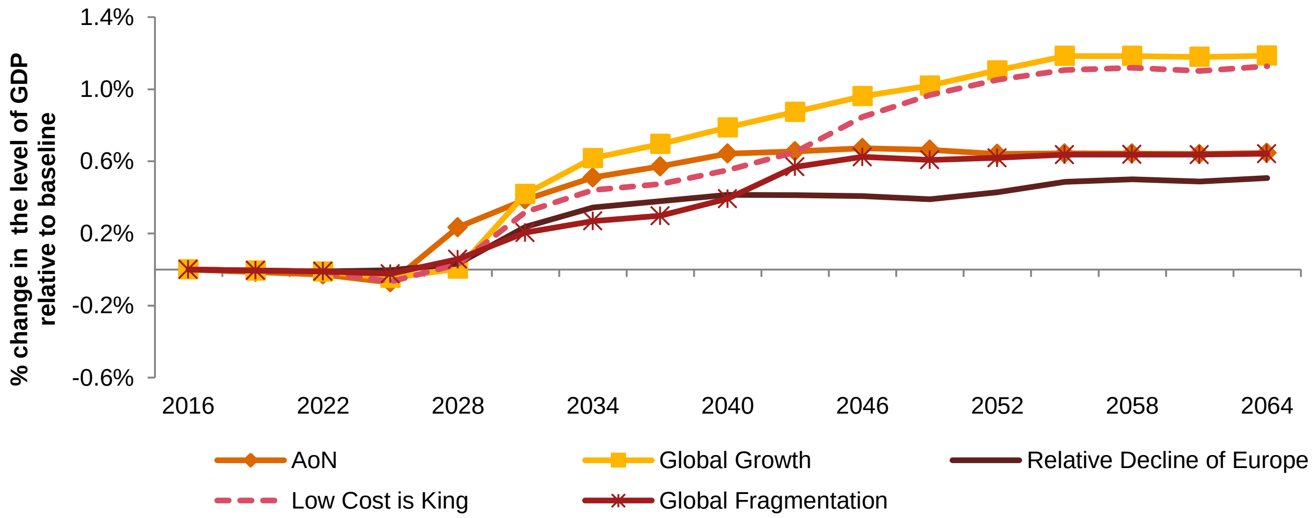
[161] Ernst & Young (2012). *Economic and social analysis of potential airport sites: Sydney Aviation Capacity Study*. Report for the Australian Government Department of Infrastructure and Transport.

expected to increase connectivity and bring with it new business travellers. The increase in business travel would be associated with increased international trade, FDI and inflows of skilled migrant labour. UK businesses can also communicate with international clients more effectively allowing them to build up stronger business relationships (Chapter 2 provides the associated evidence and a more detailed discussion on this topic). By the mid-2030s, the model predicts that the LHR ENR scheme will lead to an increase in real GDP compared to the baseline of 0.3% - 0.6%.The overall impact on GDP is forecast to increase to around 0.4% - 0.9% by the mid-2040s. From the mid-2040s the forecast effects begin to diverge across the scenarios. The Global Growth and Low Cost is King scenarios produce greater effects compared to the Global Fragmentation and Relative Decline of Europe scenarios. By the mid-2050s, the LHR ENR scheme's impacts are forecast to settle at between 0.5% and 1.2% of GDP. The drivers of these GDP effects are: passenger flows; productivity; frequency benefits; and TEE, and are discussed in more detail below. The modelling suggests that any increase in real GDP represents an upward shift in the level of GDP, rather than a permanent effect on the growth rate.

At the outset of the operational phase, there is a forecast modest reduction in GDP of around 0.1%, relative to the baseline scenario. This occurs because households in the model are "forward-looking". In particular, households foresee that the airport will have a positive effect on GDP once the scheme becomes fully functional. They therefore anticipate increased returns in the future. In order to capitalise on these higher returns, households reduce their consumption in the short-term in order to increase savings, which results in a temporary contraction in output.

It is difficult to be sure whether this effect will materialise in reality and it is possible that the effect will be less pronounced than that implied by the model. However, the assumption of "forward looking" households has been thoroughly investigated within the academic literature and has sound theoretical underpinnings. It is therefore important to be aware of the possibility of such an effect, although the timing and magnitude is unclear.

*Figure 58: LHR ENR GDP impacts on the level of real GDP, by scenario*




*Source: PwC analysis*

## 7.3 Present value of GDP impacts

Table 40 below displays the PVs of the forecast total GDP impact for each of the scenarios. All PVs are calculated on the basis of a 60 year appraisal period (from 2019 to 2078) using a 3.5% discount rate for the first 30 years and a 3.0% rate for the remaining years (following HM Treasury Green Book guidance).

The table shows, based on our S-CGE modelling and the inputs supplied to us by the AC, that the economic impact of an extended runway at Heathrow is forecast to be considerable across all scenarios. If all the effects which are modelled are realised, the PV of the GDP impacts could be in excess of £100bn in the most favourable passenger scenario. It is clear that the variation in forecast PVs across the scenarios is significant. The Relative Decline of Europe and Global Fragmentation scenarios have similar PVs, which are lower than those seen in other scenarios. PVs associated with the Global Growth and Low Cost is King scenarios are considerably higher.

In most cases, the analysis below considers all five of the passenger flow scenarios in order to show how impacts differ across the different assumptions for passenger flows in the AC's alternative scenarios for the development of the aviation sector. In the interest of brevity, and where the choice of passenger scenario is unlikely to alter the findings materially, we present detailed analysis for only one of the scenarios. In this case, the Assessment of Need scenario is used as the example Figure 58 demonstrates that this scenario has a moderate overall GDP impact relative to the other four scenarios.

Table 40 demonstrates the degree to which **the findings from the analysis are driven by the underlying input assumptions provided by the AC**. Changing the underlying assumptions on passenger flow growth is sufficient almost to double the modelled economic impact which the additional capacity generates.

The PVs are calculated on a net basis. For instance, they include the airline costs associated with transporting each passenger. However, they should be treated with caution. They are reliant on the aviation sector carrying increased volumes of passengers and depending on economic conditions, these may not materialise as hoped. The scale of the PVs is largely a result of a continual ramping up of passenger flows at Heathrow and it is shown in Figure 58 that this effect increases GDP over time.

*Table 40: LHR ENR Present Value of real GDP impacts, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Total** | 118.3 | 187.4 | 85.8 | 168.6 | 101.8 |

*Source: PwC analysis*

In addition, the AC have asked us to display the PVs of the forecast total real GDP impact for each of the scenarios for a 60 year appraisal period starting from the opening date of the scheme, in 2026. These are displayed in Table 41 below:

*Table 41: LHR ENR Present Value of real GDP impacts, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Total** | 130.6 | 214.4 | 100.8 | 193.6 | 115.0 |

*Source: PwC analysis*

## 7.4 Drivers of GDP impact

The previous section demonstrates the range of GDP impacts provided by the LHR ENR scheme under the five passenger scenarios. In this section, we describe the key drivers of these impacts and the underlying economic mechanisms that lead to the results.

### 7.4.1 Impact by GDP component

*GDP components and transmission mechanisms*

We begin by breaking down the change in GDP into its constituent parts. One way to measure GDP is on an "expenditure basis", which means accounting for the expenditure by households and businesses in the UK. The expenditure measure is made up of a number of components according to the "National Accounting Identity" (NAI). This can be expressed as follows:

$$\begin{aligned} Real\ GDP = {} & Real\ Consumption + Real\ Investment + Real\ Government\ Consumption\ and\ Investment \\ & + Real\ Net\ Trade + Real\ Passenger\ Flow\ Exports - Real\ Passenger\ Flow\ Imports \end{aligned}$$

Usually, trade and passenger flow impacts are accounted for together in expressing the NAI. This is because passenger flow impacts form part of trade (in particular, additional passenger spending within the UK is regarded as an export and additional passenger spending outside the UK is regarded as an import). However, since passenger flow impacts are such an important part of this research, we have separated passenger flow effects from trade. This means that Real Net Trade in the equation above is net of passenger flow impacts.

Figure 59 below breaks down the forecast GDP impacts into their component parts for the LHR ENR scheme. The impacts can be summarised as follows:

- **Real consumption.** The most substantial forecast impact of the LHR ENR scheme is seen in consumption. In the initial phase, before the runway is open, consumption falls marginally. This occurs because agents anticipate future improvements in productivity and therefore substitute away from current economic activity to additional activity in future. However, this drop is insignificant in the context of the overall impact of the LHR ENR scheme and in the long-term real consumption is forecast to increase well beyond the level that it would have been in the absence of the LHR ENR scheme. This is because the higher productivity generated by the increase in capacity is expected to increase household income, and therefore allows higher consumer spending.

- **Real investment.** The overall impact of the operational phase of the LHR ENR scheme on real investment is forecast to be limited, with the majority of the investment occurring during the construction phase. A small dip in investment is seen in the early years of operation, but this is reversed towards the end of the period with the total change being roughly neutral. There are two key drivers underlying this effect: firstly, the removal of the capacity constraint is expected to generate a large transfer from the airline sector to consumers, as the potential to charge economic rents on landing slots is reduced (see section 8.4.3.4). This reduces the incentive to invest in the airline sector following the opening of the new runway. Secondly, as agents in the model are rational and forward-looking, they predict that a greater return on investment will be possible towards the end of the period as the airport reaches capacity and the full productivity benefits materialise – this is known in the model as a *confidence effect* (see below). This incentivises them to defer investment from the early operational phases to the end of the period studied, giving rise to the small temporary fall in investment.

| | |
|---|---|
| **Confidence effect** | A key feature of the model is that economic agents (consumers and firms) are "forward-looking", in the sense that they form expectations of future economic variables (such as interest rates, the price level and output) and adjust their behaviour accordingly. Specifically, the model assumes that agents form "rational expectations" (Muth, 1961) [162], meaning that the firms and households within the model assume that the predictions generated by the model are correct. In forward-looking models like this one, "confidence effects" can be important. In the context of airport expansion, the confidence effect means that agents foresee that airport improvements will have a positive impact on profits and output. |

The forecast increased level of investment later in the period consists of a mix of both domestic and foreign direct investment (FDI). The increased level of economic activity associated with the LHR ENR scheme incentivises other sectors of the economy, as well as the aviation sector, to invest. Our model results suggest that investment will rise in the majority of the business sectors captured in the S-CGE model. However, the precise mix of domestic and foreign investment is too difficult to predict as appropriate data are not available at the regional level. The forecast long-term increase in investment is also partly driven by ongoing maintenance activities at the enhanced airport facilities.

- **Real government consumption and investment.** In the operational phase, government consumption is unchanged relative to the baseline. This is due to the assumed "Harberger closure rule" (described in detail in Appendix B), which states that net government expenditure remains constant i.e. any government receipts (outgoings) are transferred to (from) consumers. Overall the level of taxes paid rises in the model (see Section 7.7.4 for more detailed fiscal results), this increase being attributable to the higher levels of economic output. Despite not directly contributing to an increase in the level of GDP, this has a positive impact through the *government expenditure effect* explained below.

| | |
|---|---|
| **Government expenditure effect** | The expansion of the aviation sector generates receipts to government in the model via Air Passenger Duties. Moreover, higher levels of GDP raise government revenues from general taxation. Under the "Harberger closure rule" adopted for this work (see Appendix B), these increased tax receipts are |

[162] Muth, J.F., (1961). Rational Expectations and the Theory of Price Movements, *Econometrica*, Vol. 29, No. 3, pp. 315-335.

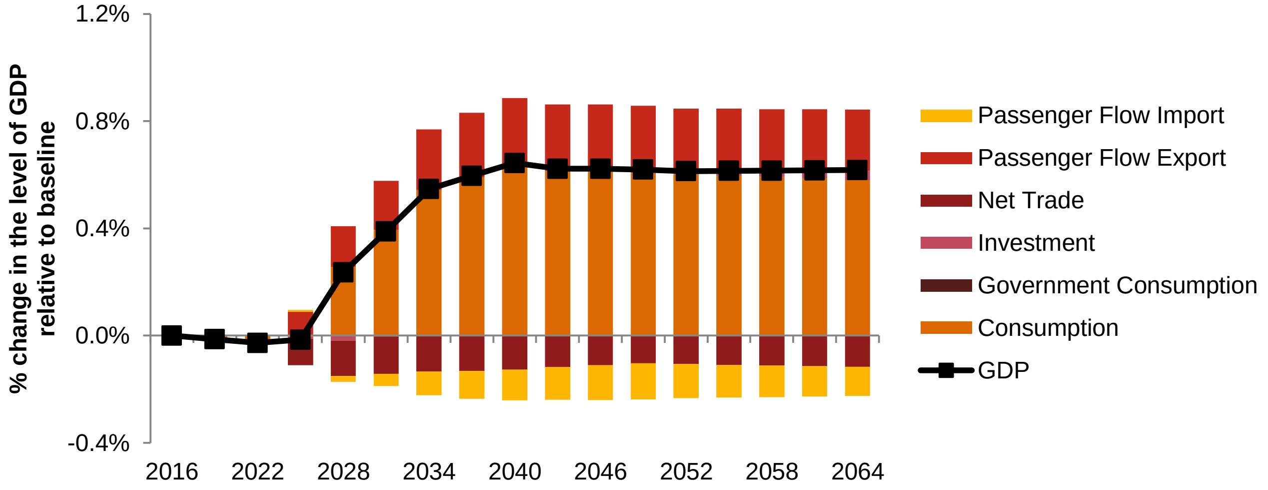
"handed back" to consumers via lump-sum transfers. As consumption increases as a result, this places further upward pressure on aggregate demand and GDP.

- **Real net trade.** Figure 59 demonstrates that the overall impact of the increase in airport capacity is a fall in net trade, excluding the impact of changing passenger spending patterns. Although UK firms experience an improvement in international competitiveness and exports increase substantially, this generates wealth, part of which will be spent by households on increasing their consumption. The increase in household consumption within the UK is forecast to lead to an increase in imported consumer goods. Businesses also use imports, in the case of the manufacturing sector, they are processed and turned into exports, if businesses are able to produce and source imports more efficiently, this will be better for their overall productivity.

  Overall the UK's terms of trade improves. This is because the price level in the UK is forecast to fall as the increased productivity associated with UK aviation sector expansion allows goods and services produced in the UK to be sold more cheaply. Exports therefore expand. An improvement in the terms of trade could in turn signal a reduction in imports. However, part of the boost to productivity is associated with UK businesses being better able to source production inputs from overseas – greater air connectivity allows businesses to link with a wider range of suppliers and get better quality products and improved deals. The impact of openness on domestic productivity is established within the econometric analysis. Also, the underlying expansion in output in the UK economy means that more imports will be required for consumption in the domestic market (household incomes rise, so demand rises).

- **Real passenger flow imports and exports.** Due to the importance of changing passenger flows in our analysis, Figure 59 also shows separately the contribution of passenger flow imports (spending by UK residents abroad) and passenger flow exports (spending by foreign visitors within the UK) to overall GDP. In conventional "National Accounting Identity" treatments these effects would be captured within changes in net trade. The passenger flow impacts are explained in full below. At a high level, the overall impact of passenger flows on GDP is determined by the net impact of these two different effects. Figure 59 that both are forecast to have substantial impacts on overall GDP. The net impact is considerably more moderate, although positive.

*Figure 59: LHR ENR breakdown of real GDP impacts, Assessment of Need scenario*




*Source: PwC analysis*

## *7.4.2 Impact by sector*

Table 42 shows the forecast change in sectoral real GDP as a result of the increase in aviation capacity associated with an extended runway at Heathrow, over the period 2020-2060. These figures are based on the Assessment of Need passenger flow scenario and show the percentage difference in each year from the corresponding baseline scenario figure. The relative sizes of these sectors is given in Section 3.4.

*Table 42: LHR ENR Breakdown of impact on the level of real GDP by sector, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and mining** | 0.5% | 0.7% | 1.3% | 1.3% | 1.3% |
| **Manufacturing** | -0.1% | 1.5% | 1.9% | 1.8% | 1.7% |
| **Utilities** | 0.5% | 0.6% | 1.2% | 1.2% | 1.2% |
| **Construction** | 0.7% | 0.8% | 1.9% | 2.0% | 1.9% |
| **Retail and wholesale trade** | 0.1% | -0.5% | -0.5% | -0.4% | -0.4% |
| **Air passenger transport and freight** | 1.4% | 8.4% | 10.6% | 12.3% | 10.2% |
| **Other freight** | -0.1% | -1.0% | -1.0% | -1.2% | -1.0% |
| **Other passenger transport** | -0.4% | -0.5% | -0.9% | -1.4% | -1.0% |
| **Accommodation and food services** | 0.1% | 0.9% | 1.2% | 1.1% | 1.1% |
| **Other services** | 0.8% | -0.6% | 0.1% | 0.2% | 0.3% |
| **Health, education and public spending** | 0.2% | 0.0% | -0.1% | -0.1% | -0.1% |

*Source: PwC analysis*

Among the sectors of the economy, the air passenger transport and freight sector is forecast to be 12.3% larger than in the baseline scenario by 2050 compared to the baseline scenario. This is unsurprising given the direct boost to this sector which the reduction in the capacity constraint allows.

Sectoral growth elsewhere is relatively moderate compared to this sector, and limited to a magnitude of change being no greater than +/- 2.5% of sector size by the end of the period.

Of the remaining sectors, those with strong international linkages, most notably agriculture and manufacturing, are forecast to grow relatively more substantially than others as a result of the increase in capacity. This is due to a decline in the cost of air transport, leading to sector-specific increases in productivity and international competitiveness, and subsequently an increase in output. Accommodation and food services are also forecast to grow significantly, due to the increase in demand generated through the increase in passenger flows. The efficiency benefits for non-aviation sectors are expected to be magnified through the *reorganisation effect*, whereby they shift their production processes towards air transport.

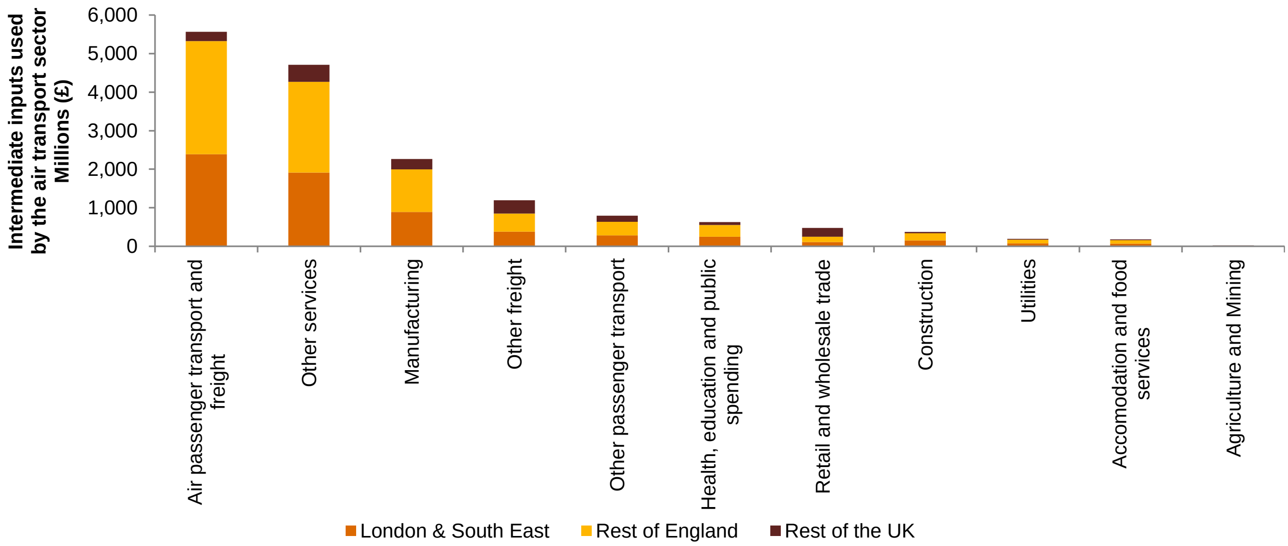
| | |
|---|---|
| **Reorganisation effect** | The SACTRA report identifies a "reorganisation effect" as input substitution within the production system and logistics of the firm to take advantage of lower transport costs. Although transport costs are not modelled explicitly in the S-CGE framework, a key strength of the S-CGE model is that firms will automatically reorganise their production processes in response to changes in input prices (be they wages, rental on capital or the prices of intermediate inputs). This means, for example, that as prices of intermediate inputs fall (for instance as a result of the firms becoming more efficient as a result of the productivity effect discussed below), firms will be able to reorganise their activities to make efficient use of the cheaper inputs, thereby increasing GDP. |

The two sectors which are forecast to contract the most are other freight and other passenger transport, which between them represent all non-air transportation and storage. This is because these sectors are substitutes for air transportation, and therefore see a fall in demand as the cost of air transportation falls. It should be noted that these results are the average impacts, and so do not capture sub-sectoral variation. For example, it is likely that freight forwarders who rely on air freight may benefit from an increase in capacity, while over longer distances the two sectors may be stronger substitutes.

Retail and wholesale trade GDP are also forecast to shrink marginally. This is due to declining transport margins increasing competition and subsequently reducing profitability. This leads to a negative price effect which more than offsets the reduction in input costs generated by cheaper air transport, leading to a decline in the GDP of the sector. A final small reduction is also forecast for the public sector, as a small proportion of workers move to the private sector as a result of higher wages.

Figure 60 below demonstrates the distribution of spending by the air transport sector in 2010, by sector. This helps to explain the findings above, particularly in the forecast growth of manufacturing, which features prominently in the supply chain of the air transport sector, and will therefore experience an increase in demand as the sector expands, in addition to the benefits from international linkages previously explained. The wholesale and retail trade sector is a material receiver of expenditure from air transport, although this is still relatively modest in relation to the size of that sector, and therefore is not sufficient to reverse the contraction explained above. The second largest receiver of expenditure is the Other Services sector, although given the size of this sector (which includes financial, professional and business services), this is a reasonably moderate effect in relative terms.

*Figure 60: Distribution of intermediate inputs used by the air transport sector in 2010*




*Source: PwC analysis*

GDP in the freight sector is forecast to be impacted by up to 2.6% in 2030, going up to 4.9% in 2060. This implies that the impact on the freight sector is larger compared to the impact on other sectors, but lower than the impact on the air passenger transport sector. This relatively large impact is due to the strong linkage between the air freight and air passenger transport sector in the supply chain and labour market. This ensures that positive effects within the air transport sector have a disproportionately large impact on air freight.

Please refer to Box 13 below for a more detailed discussion on the Air Freight sector.

*Table 43: LHR ENR Breakdown of impact on the level of real GDP of the air freight sector, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Impact on air freight GDP (%)** | 0.00% | 2.59% | 3.25% | 3.70% | 4.91% |

*Source: PwC analysis*

**Box 13: The air freight sector**

*Air freight*

The air freight, or air cargo, sector refers to goods transported by aircraft, whether by dedicated freighters or in the belly-hold of passenger aircraft.

The GVA of the UK air freight sector is currently £87m, or less than 0.01% of total the economy's total GVA. In 2011, £116bn worth of goods were transported by air freight between the UK and non-EU countries, around 35% of the UK's extra-EU trade by value, and in total air freight was one fifth of all trade by value. These are large proportions considering that air freight represents a very small proportion of tonnage of all freight, and is due to the nature of goods and produce usually transported by air freight, which tend to be high value and low volume, such as the jewellery or high-tech sectors. Industries that are time-sensitive are also large users of air freight, such as pharmaceutical products. Air freight is currently estimated to provide approximately 39,000 jobs in the UK.

*Market outlook*

Boeing's 2013 forecast reported that world air cargo traffic has slowed since 2004, having only grown 2.0% per year on average since then, relative to the historical trend of 6.7% between 1981 and 2004. According to Boeing, this slowdown was mainly down to the global economic downturn and the rising price of fuel, but within this time period there has been volatility; a 12.50% fall in traffic between mid-2008 and mid-2009 was followed by an 18.5% surge in 2010, followed by another contraction in 2011.

Despite this deceleration in growth, Boeing forecasts that world air cargo traffic will double by 2031 and grow at a rate of 5.2% per annum over the next 20 years, and that air freight will average 5.3% annual growth, measured in real revenue tonne-kilometres. Asia will lead the industry in terms of highest average annual growth rates, whereas the mature Northern American and European markets will be reflected in slower and lower rates.

Boeing also estimates that the number of aircraft in the worldwide freighter fleet will increase by more than 80% during the next 20 years, in reaction to the growth in demand for air cargo services. It is envisaged that large freighters will play an increasing role and represent 36% of this enlarged fleet today compared to 22% a decade ago; large freighters can take advantage of greater capability and efficiency that they offer to manage the increase in demand without proportionally increasing the number of aircraft. Globally, cargo revenue represents around 15% of total air transport revenue. However, some airlines earn nearly 40% of their revenue from freight.

*Inclusion in the model and potential impacts*

In the S-CGE model, air freight is split out from the Transportation and Storage Sector in order to more accurately estimate the impact of the change in airport capacity on specific subsets of the aviation sector. The split has been created primarily using data from the Annual Business Survey published by the Office for National Statistics (ONS), giving the sub-sectoral breakdown across a number of areas, including number of employees, GVA and intermediate consumption.

We would expect an airport expansion in the model to feed through via wider economic impacts and affect the air freight sector in a positive way. Expansion at Heathrow or Gatwick would initially affect belly-hold cargo; belly-hold accounts for the majority of air freight in the UK, but new options would also be opened up for dedicated freighters.

In the S-CGE model, increased connectivity at an airport fosters the flow of passengers, which includes business passengers, resulting in an increase in trade. New long-haul routes in particular have the potential to open up new export markets. Demand for freight is pro-cyclical and likely to track movements in trade as local businesses become better connected to global markets. On the supply-side, air freight and passenger flows are inextricably linked as much air freight travels in the belly-hold of passenger aircrafts; this is particularly relevant for new markets where demand is not yet predictable or established. Airport expansion would enable the increase in passenger flows that is forecast until 2050 and therefore would also imply more capacity for belly-hold freight, which may in turn even lower the cost of exporting goods.

For dedicated air freighters, a key issue is to maintain the express delivery industry, which they dominate. The express industry is supported primarily by the availability of night flights, the regime of which may be affected by an expansion. The DfT concluded in July 2014 that it would not make any significant changes to the current restrictions on the night flight regime at Gatwick, Heathrow or Stansted before the AC publishes its final report. The express industry was estimated to contribute £2.3bn to UK GDP and 82,000 jobs in 2010. Research undertaken by Oxford Economics has suggested that restricting night flights could have a negative employment impact, and removing the availability of next-day delivery services in the UK could reduce GDP by £3bn.

At present, the majority of air freight infrastructure resides at Heathrow airport, which handles 86% of all UK belly-hold passenger cargo, and many freight operators are based there. An increase in demand for air freight, facilitated by additional airport capacity, would raise the question of whether any activity would be substituted away from Heathrow to Gatwick, and whether Gatwick would be required to invest in freight infrastructure in order to take on some of the increase in demand.

### *7.4.3 Impact by effect*

To further understand the impacts, we now examine in detail the four key effects associated with the operation of the LHR ENR scheme which we modelled as set out above:

1. Passenger flows;
2. Productivity;
3. Frequency benefits; and
4. TEE.

The PV of each of these effects, for each passenger scenario[163], can be seen in Table 44 below. The table demonstrates that the greatest impact forecast to be felt is through the productivity and TEE effects. The inputs which drive each of these effects and how they impact on overall forecast GDP are explored in greater detail below.

The PV estimations below are heavily influenced by the time trend of the inputs, which determine whether the majority of the benefit is experienced at the beginning or the end of the period studied. This motivates households to shift their economic activity towards the time periods where they get the greatest return on their expenditure. While this doesn't affect the long-run impact on the level of GDP, it has important implications for the PV estimations as benefits experienced in later time periods are heavily discounted relative to earlier ones.

[163] Please note that the “passenger flows” effect here refers to the overall GDP impact of changes in passenger flow. This captures a broader range of effects on GDP which result from changes in passenger flows than the direct spending impacts.

*Table 44: LHR ENR Present Value of real GDP impacts, by effect and scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Passenger Flows** | 28.3 | 36.3 | 17.6 | 33.3 | 34.8 |
| **Productivity** | 61.7 | 72.6 | 34.9 | 62.2 | 45.6 |
| **Frequency Benefits** | 5.6 | 7.2 | 8.7 | 9.4 | 4.1 |
| **TEE** | 22.6 | 71.2 | 24.7 | 63.8 | 17.4 |
| **Total** | **118.3** | **187.4** | **85.8** | **168.6** | **101.8** |

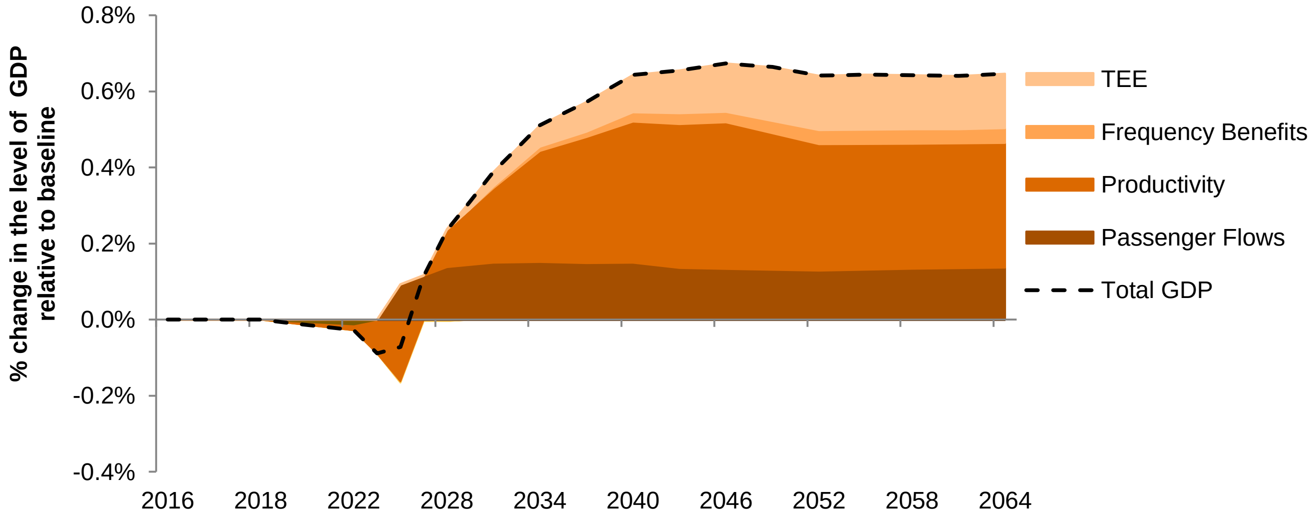
*Source: PwC analysis*

Figure 61 below splits out the forecast real GDP impacts into these components over time. We show the results for the Assessment of Need scenario in order to illustrate these impacts.

Table 44 demonstrates that the direction and relative magnitude of each effect are reasonably consistent across all passenger scenarios.

The early years of the operational phase of the LHR ENR scheme are dominated by the productivity effect. This initially sees a slight contraction in GDP as rational, forward-looking agents delay economic activity until the runway opens, before increasing in magnitude steadily. The effect of passenger flows can also be seen in the early stages as demand for capacity starts to be met with the opening of the new runway. From the mid-2030s, as the scheme becomes operational, the productivity and TEE impacts are forecast to increase rapidly. The TEE effect becomes positive and significant, eventually contributing roughly one-quarter of the overall GDP impact. Passenger flow impacts remain at around one quarter of the effect from the operational phase until the end of our analysis period. Frequency benefits also begin to have an impact in the early 2030s, but the magnitude of this impact is moderate. By 2064, around 50% of the GDP benefits are forecast to be due to productivity effects, approximately 20% are forecast to arise from TEE, and 20% from increased passenger flows. Finally, frequency benefits are also forecast to have an impact, but the magnitude of this impact is relatively small.

*Figure 61: LHR ENR effect-by-effect impacts on the level of real GDP, Assessment of Need scenario*




*Source: PwC analysis*

We now examine the passenger flow, productivity, frequency benefits and TEE impacts in detail, considering each in turn.

### *7.4.3.1 Effect 1: Passenger flows*

The passenger flow data are taken from the AC's demand forecasts produced using a version of the DfT's aviation forecasting model. More information on the model and approach is contained in the consultation document forecasts reports[164], and technical appendix 3 of the Interim Report[165].

In this section, we briefly describe the estimated passenger flows under each of the AC's passenger flow scenarios, which act as direct inputs into the S-CGE model but also inform our analysis of productivity effects (i.e. Effect 2). Passenger flows affect the results of the S-CGE analysis by determining:

- The size of the aviation sector;
- Changes in productivity; and
- The level and nature of additional passenger spending, inside and outside of the UK.

*Data input description*

Table 45 summarises the total UK passenger flows across the five scenarios in 2050 for the Do Minimum baseline scenario and the LHR ENR scheme. There is a wide range in the number of additional passengers in the UK system as a whole which the additional capacity enables, ranging from 14m (418m to 432m in the Relative Decline of Europe scenario) to as much as 34m (457m to 491m in the Global Growth scenario).

*Table 45: LHR ENR and Do Minimum Total UK passenger flows in 2050, by scenario (millions of passengers)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Do Minimum** | 405.6m | 456.7m | 418.4m | 458.0m | 396.6m |
| **LHR ENR** | 425.2m | 490.6m | 432.5m | 489.3m | 414.8m |
| **Increase** | 19.6m | 33.9m | 14.1m | 31.3m | 18.2m |

*Source: PwC analysis*

In addition to the total UK passenger numbers, the characteristics of these passengers and their associated spending patterns are important in determining the impact on real GDP. The AC did not provide forecasts of the split between inbound and outbound passengers in the future. For the purpose of this analysis we have agreed in conjunction with the AC to assume that the balance of inbound and outbound passengers and their associated spending patterns remain at their existing levels in the event of airport expansion. Any difference from this assumption in reality would have an impact on the magnitude of the estimated impact on GDP.

The ONS Travel Trends publication contains information on the number of inbound and outbound trips made through Heathrow in 2011[166]. This demonstrates that, through Heathrow, 9.8m passengers made outbound trips from the UK (22% of UK total), and 9m passengers made inbound trips to the UK (40% of UK total). Differences in spending patterns mean that, despite facilitating more outbound than inbound trips, passengers travelling through Heathrow spent more within the UK than outside it. Using data from the Tourism Satellite Account[167], it can be estimated that these trips through Heathrow led to £6.8bn additional expenditure by UK passengers outside the UK, and £7.3bn additional expenditure in the UK by passengers from abroad. In addition, UK passengers travelling abroad spent an estimated £5.2bn in the UK on their outbound trip. Overall therefore, spending due to passenger flows through Heathrow in 2011 were associated with approximately £12.5bn of expenditure in the UK compared to £6.8bn outside the UK.

However, only £7.3bn of the expenditure in the UK (that which relates to passengers travelling from abroad) could be seen as additional demand. The remaining £5.2bn is likely to largely displace household consumption

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[164] See: Department for Transport (DfT) (2013) *UK Aviation Forecasts 2013*. London: Department for Transport.

[165] See: Department for Transport (DfT) (2014) *Appendix 3: Technical Appendix to the Airports Commissions Interim Report*. London: Department for Transport.

[166] Office for National Statistics (ONS) (2011) *UK Travel Trends, 2011*. Available at: http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-269632

[167] Office for National Statistics (ONS) (2013) *Tourism Satellite Accounts 2010*. http://www.ons.gov.uk/ons/rel/tourism/tourism-satellite-account/index.html

in the UK which would have otherwise occurred in the absence of air transport through Heathrow. This displacement of domestic consumption means that the net GDP impact of passenger spending associated with Heathrow in 2011 is likely to have been less positive than the difference between expenditure within and outside the UK. This pattern will have important implications for the GDP impact of additional passenger flows resulting from the LHR ENR scheme.

*Nature of passenger flow change*

This sub-section looks in more detail at two specific elements of the passenger flow input data:

- The time profile of the increases in passenger flows forecast by the AC; and
- How the increase in passenger flow is expected by the AC to vary by type of passenger.

Table 46 below summarises the first aspect by showing the forecast change in passenger numbers over time from 2011-2050. There is a large increase in the total number of UK passengers across all passenger scenarios relative to 2011, with overall increases of between 90% and 125%, between 2011 and 2050. The growth in passenger flows is relatively consistent over time, but there is an extra ramp up between 2020 and 2030 when the new capacity is first available.

It should be borne in mind that the additional capacity created by an extended runway at Heathrow would be in the region of 40-45m passengers per year by 2050, and that under all passenger scenarios this capacity would be highly utilised by this date. The information in Table 45 above shows that the size of the increase in total UK passenger flows relative to the Do Minimum is often below this, highlighting that a substantial share of the additional demand at LHR ENR is forecast to be redirected from existing UK airports.

*Table 46: LHR ENR Total UK passenger flows from 2011 to 2050, by scenario (millions of passengers)*

| | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| **Assessment of Need** | 217.8 | 256.8 | 327.4 | 378.1 | 425.2 |
| **Global Growth** | 217.8 | 267.9 | 354.1 | 421.8 | 490.6 |
| **Relative Decline of Europe** | 217.8 | 259.6 | 325.7 | 376.5 | 432.5 |
| **Low Cost is King** | 217.8 | 267.9 | 347.4 | 418.3 | 489.3 |
| **Global Fragmentation** | 217.8 | 250.1 | 311.7 | 365.2 | 414.8 |

*Source: AC demand forecasts*

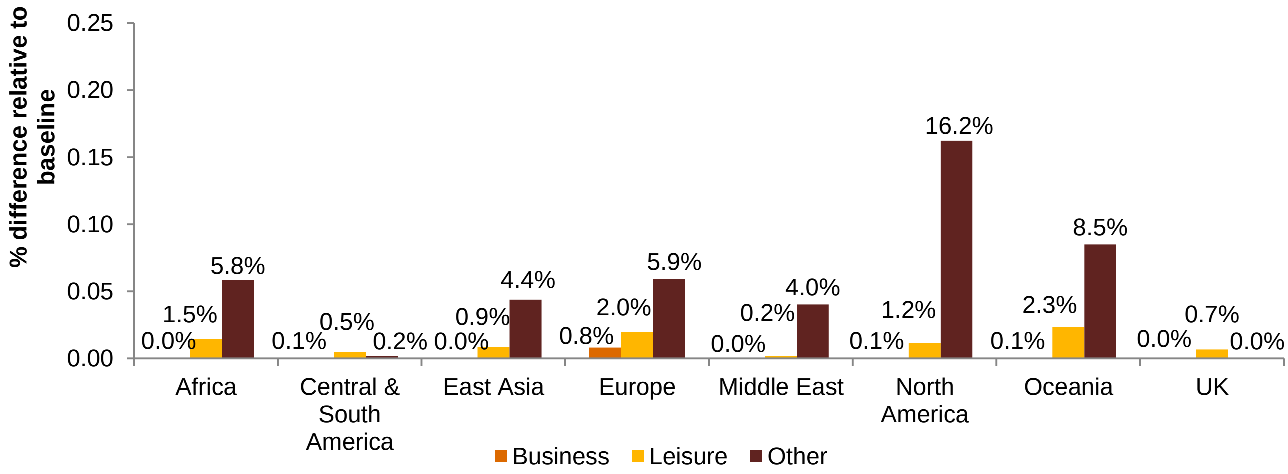
Figure 62 below demonstrates how passenger flows have been forecast by the AC to change by type of passenger (business, leisure, or other - which primarily comprises international transfer passengers), and destination region. Changes in the forecast passenger mix will have an important impact on the level of connectivity generated.

This figure demonstrates that there is some growth across all passenger types as a result of the LHR ENR scheme. The majority of the increases in passenger flows forecast by the AC for the LHR ENR scheme, relative to the Do Minimum, are international transfer and leisure passengers. The largest relative increases can be seen in journeys to and from North America, although there is growth across all regions. There are also significant increases in trips to other global destinations such as Africa, Oceania and East Asia.

The AC's forecasts suggest that new capacity will result in an increase in international transfers, which might also improve the feasibility of long-haul routes (e.g. by providing a critical mass of traffic which in turn might result in high frequency, long-haul flights being provided to a greater range of destinations in a cost effective manner). This would have important implications for the UK's international connectivity. The productivity benefits of additional long-haul traffic is captured through the econometric analysis in the modelling of Effect 2.

*Figure 62: LHR ENR change in PAX in 2050 relative to Do Minimum, by passenger type and region, Assessment of Need scenario*

Give




*Source: Airports Commission*

**Box 14: Multipliers on inbound and outbound passenger flows**

To understand the passenger flow impacts, it is helpful to illustrate the different types of 'multipliers' observed in the S-CGE model associated with passenger spending patterns. There are four different multipliers relating to the decision to travel and the decision to trade (Bond, 2008; Vellas, 2011):

1. UK exports: positive multiplier through UK-based supply chain;
2. UK imports: negative multiplier as displaces domestic consumption;
3. Foreign inbound tourists: positive multiplier from additional passenger spending; and
4. UK outbound tourists: negative multiplier as displaces consumption.

When a UK resident travels on a holiday overseas, they will spend money in the foreign country which will be a positive gain for that country. However, this money will be taken out of the UK and not spent on UK goods and services, so this implies a negative multiplier for the UK economy.

A key finding of the model is that the positive multiplier generated by foreign passenger flow spending is smaller than the cost to the UK economy of an additional UK resident travelling overseas. This is because of the strong downstream linkages that the purchase of domestic non-passenger expenditure products has in the UK economy versus the weaker linkages of foreign passenger consumption. This finding is consistent with that of other studies. For example, the Scottish government for Scotland, Hermannssonn (2011) for Northern Ireland and California Economic Strategy Panel (2009) for the US state all suggest that passenger expenditure multipliers tend to be lower than the economy-wide average.

### *Impact on GDP*

To understand the passenger flow impacts, it is helpful to illustrate the different "multipliers" observed in the S-CGE model (Bond, 2008; Vellas, 2011)[168][169] for passenger expenditure inside and outside the UK. These are

[168] Bond, H. (2008). Estimating the economic benefits of event tourism: a review of research methodologies, IMPACTS 08, University of Liverpool, Liverpool.

[169] Vellas, F. (2011). The Indirect Impact of Tourism, Third Meeting of T20 Tourism Ministers Paris, 25 October, 2011.

discussed in Box 14 above. The process through which the direct impact of this effect is multiplied throughout the economy, as with other inputs captured within the model, is called a *multiplier effect*.

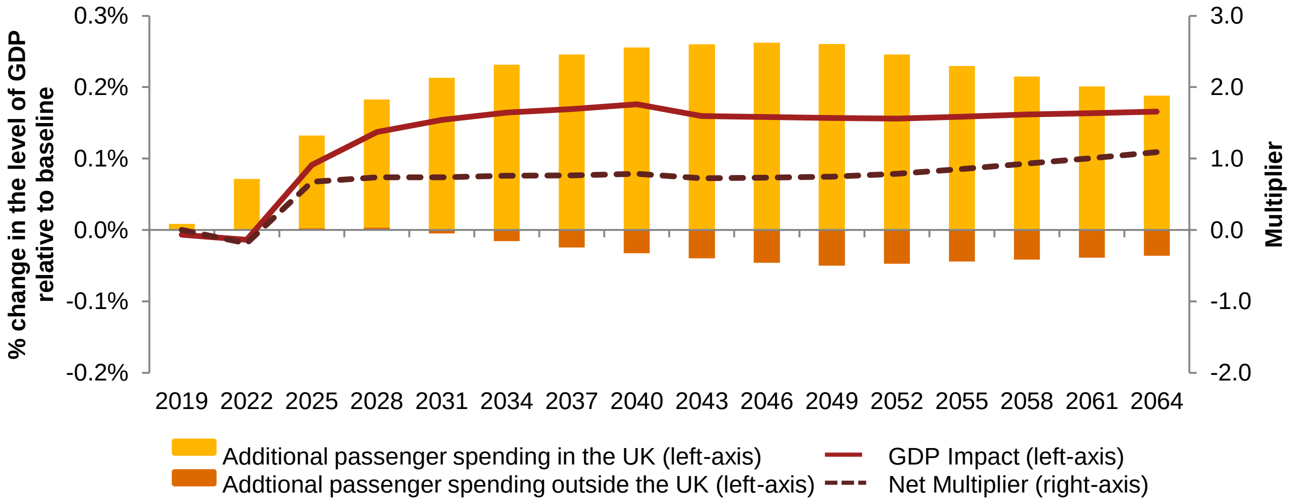
| | |
|---|---|
| **Multiplier effect** | The increase in output in both the airline sector and the wider economy will mean that across the whole economy there will be more demand for inputs from suppliers. This positively affects the downstream supply chain. This means that the positive aggregate demand effects are multiplied. This will be combined with a further knock-on impact on aggregate demand as workers employed will spend more on goods and services in the UK economy. |

With an understanding of the passenger flow changes summarised in Box 14 above, it is straightforward to appreciate the GDP impacts of these passenger flows. Figure 63 demonstrates the GDP impacts from the passenger flow effects, along with the passenger expenditure inputs. For brevity, we present only the Assessment of Need scenario.

During the first 15 years of the scheme, the AC estimates that passenger flows under the LHR ENR scheme will increase rapidly. The increase in passenger expenditure within the UK (£4.7bn per annum compared to the baseline scenario in 2040 in the Assessment of Need scenario) is estimated to be significantly larger than the increase in passenger expenditure outside the UK (passenger expenditure outside the UK is estimated to increase by around £0.5bn per annum on a comparable basis). This net increase in passenger expenditure within the UK reflects Heathrow's status as supporting a relatively large proportion of inbound visitors compared to other UK airports, and the relatively high amount they are expected to spend in the UK relative to the leakage of spending associated with outbound passengers.

Even though the passenger expenditure multiplier outside the UK is greater than the  multiplier inside the UK, inbound expenditure is so much larger than the outbound expenditure under the LHR ENR scheme that the net impact on UK GDP is estimated to be positive, leading to a 0.08% to 0.21% increase in the level of GDP by 2050.  The model suggests that for every additional £1 of net inbound passenger expenditure, GDP increases by £0.8. The reason that the ultimate impact on GDP is less than the original increase in expenditure is the diffusion effect described above, as prices respond to the changes in demand.

*Figure 63: LHR ENR Passenger Flows input, real GDP impact and implied multiplier, Assessment of Need scenario*




*Source: PwC analysis*

Inbound passenger spending is an important source of foreign exchange and is equivalent to exported goods or services in this sense. This effect occurs on the demand-side of the economy: inbound passengers will spend money on a range of goods and services in the UK economy (e.g. hotels, restaurants, the retail sector etc.) Increased flows of "exports" can have important supply-side effects. The sectors of the economy associated with passenger flows will expand as a result of the increase in passenger spending and these sectors will need to hire more workers and invest more to support any expansion. The labour market associated with passenger expenditure is important for the UK economy as it provides a range of low-skilled and school leaver jobs and can facilitate working on a part-time basis. These types of jobs are often taken up by the long-term unemployed. If the number of inbound passengers increases, this can also have positive upstream effects for those sectors that supply goods and services to relevant sectors for servicing these additional passengers (e.g. the manufacturing or agriculture sectors). Overall the model suggests a small, but permanent increase in productivity resulting from the supply-side expansion associated with inbound passenger flows.

There are also spending benefits for the UK economy associated with UK residents travelling overseas. Before travelling, UK residents purchase items from UK businesses e.g. airline tickets, clothes etc. The ONS TSA data suggests about one-third of all expenditure from UK outbound tourists is spent in the UK rather than overseas. This geographic distribution is reflected with the S-CGE modelling.

#### *7.4.3.2 Effect 2: Productivity*

As discussed previously, the construction of an airport scheme can stimulate an external positive supply-side effect in the economy. This is because an airport scheme can lead to improved transport connectivity which in turn provides a benefit to those businesses that use air transport. The drivers of these benefits are productivity effects associated with the improved connectivity. No specific data inputs are presented in this section because, as explained below, the productivity effects are driven by the same forecast passenger flows provided to us by the AC as described in the previous section.

*Econometric analysis*
To evaluate how forecast changes in passenger flows might result in increased productivity and hence economic activity, we used econometric analysis to estimate the link between international trade and passenger numbers. This relationship is used in the S-CGE framework to proxy productivity effects. As explained in Chapter 4, the key results are that a 10% increase in passenger numbers is associated with a:

- 2.37%-2.93% increase in exports of goods;
- 5.81%-6.12% increase in imports of services; and
- 2.48%-2.97% increase in exports of services.

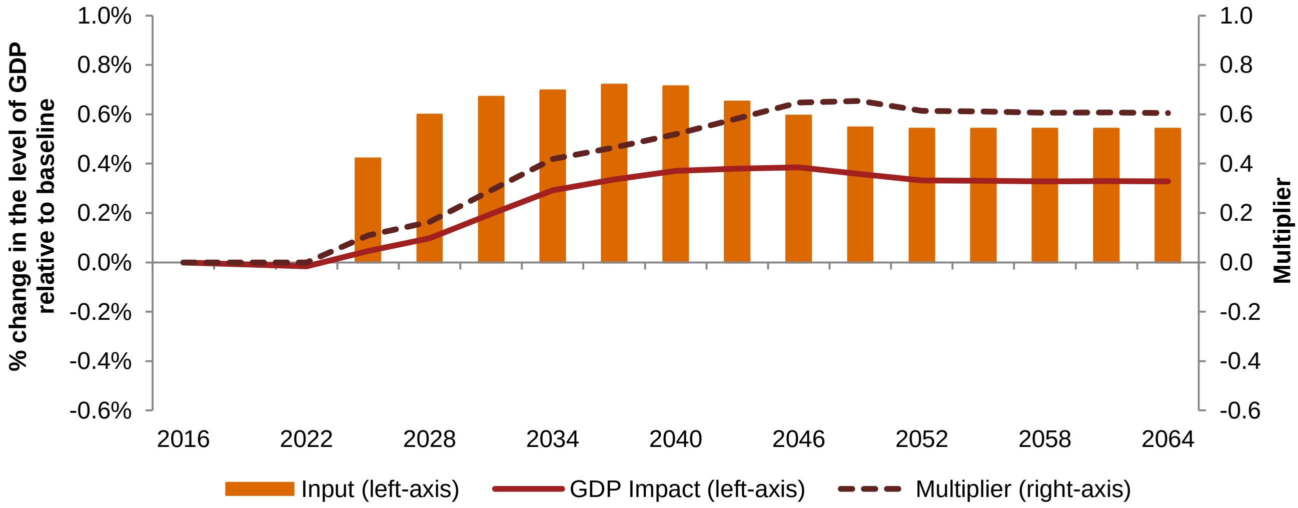
We were not able to establish a significant econometric relationship between passenger numbers and UK goods imports.

*GDP impact*
Figure 64 below summarises the productivity inputs estimated through the relationships identified above, and the impact on GDP which these are forecast to have. The chart demonstrates that the magnitude of the productivity improvement is forecast to increase steadily throughout the first half of the operational phase, before flattening out as the airport reaches capacity. After an initial dip, the forecast real GDP impact follows this trend reasonably closely, eventually leading to an increase in GDP of around 0.4% per year, relative to the baseline scenario. Although the productivity effect develops relatively slowly, ultimately it is the largest of all the effects considered in the analysis for LHR ENR.

Also evident is that the magnitude of the GDP impact is less than the value of the input. This is representative of some “crowding out” in the economy, as more productive sectors expand at the expense of less productive ones. The sectors that use the highest proportion of air transport experience the greatest productivity gains. Wages rise in these sectors as they seek to attract new workers to enable them to expand. Similarly, they also need to raise the returns they offer to capital investors to attract new investment funding. Increases in both wages and the cost of investment capital contribute to a diffusion of the initial productivity gains associated with the expansion in air transport.

In addition, the marginal propensity of firms and households to consume goods and services from outside of the UK ensures that a share of the GDP benefit leaks out of the economy. These diffusion and leakage effects are reflected in the multiplier, which is shown on the right-hand axis to remain less than one. The multiplier increases throughout the period as the sustained productivity benefits lead to capital accumulation which further increases productivity. As a result, the GDP impacts at the end of the period are greater, relative to the size of the input, than at the beginning.

*Figure 64: LHR ENR Productivity input, real GDP impact and implied multiplier, Assessment of Need scenario*




*Source: PwC analysis*

### *7.4.3.3 Effect 3: Frequency benefits*

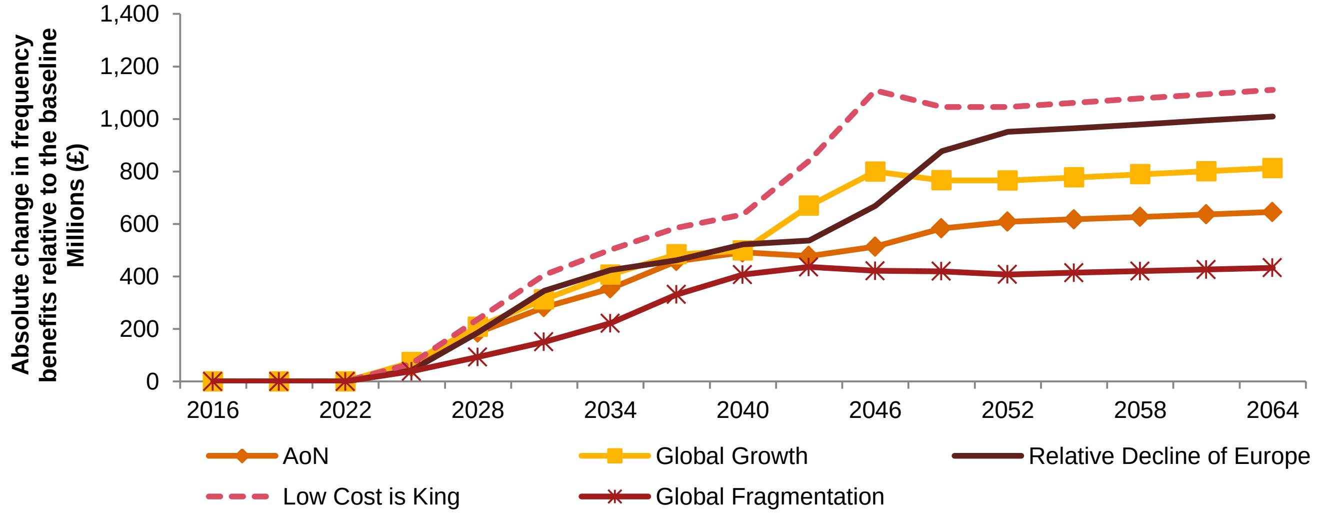
In order to limit our analysis to those inputs which have a measurable economic impact, our modelling has reflected only the frequency benefits which accrue to business passengers, and which therefore can be interpreted as being likely to have positive productivity effects. In reality, the time savings experienced by some leisure passengers could lead to a productivity increase, but this is unlikely to represent a substantial share of these benefits, and they have not been included in our modelling.

*Inputs*

The AC provided us with estimates of frequency benefits to be used as inputs to the S-CGE model. These inputs have been produced by the AC demand forecasts, and are estimated by combining estimates of the value of time with the forecast time benefits from increased frequency. The effects shown in the figure below refer to businesses only. Frequency benefits contribute to increased connectivity for businesses and can facilitate improvements in productivity. This in turn can lead to increases in profitability and in additional investment in the long-term.

Figure 65 below shows the cash value of frequency benefits for the five scenarios. There are significant differences across scenarios. These differences tend to be correlated with differences in the passenger flows as discussed above. As shown in Figure 65 the AC's forecast frequency benefits are highest under the Low Cost is King scenario, which peak in 2049. All scenarios follow a similar trajectory, although they differ in magnitude, before levelling out post-2050. At its largest in the 2060s, the difference in frequency benefits between the scenario with the largest and smallest values is in excess of £0.5bn per annum.

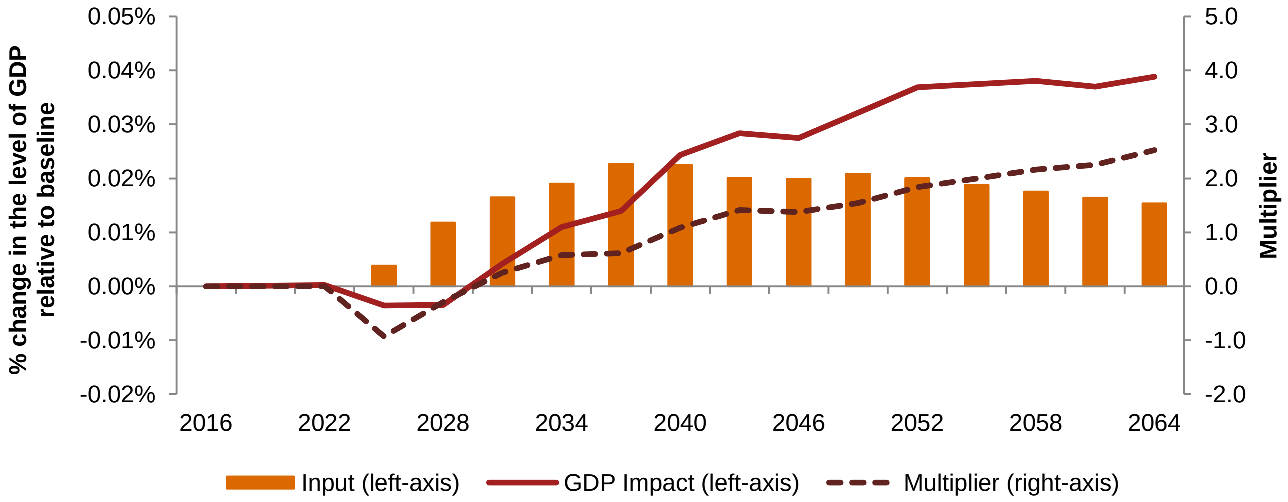
*Figure 65: LHR ENR Frequency Benefits, by scenario*




*Source: Airports Commission*

Compared to previous effects described above, frequency benefits are modest in magnitude, reflecting the underlying inputs provided by the AC. As a result, the estimated GDP impact of these inputs is also at modest 0.05% of GDP under the Assessment of Need passenger flow scenario. The multiplier on the frequency benefit inputs is greater than one by the end of the period. This occurs because the forecast improvements in efficiency experienced by producers in the early periods of operation incentivise higher levels of investment. This in turn leads to further productivity increase and a long-run impact on GDP which is greater than the value of the input.

*Figure 66: LHR ENR Frequency Benefits input, GDP impact and multiplier effect, Assessment of Need scenario*




*Source: PwC analysis*

### 7.4.3.4 *Effect 4: TEE*

*Inputs*

Chapter 4 outlined how the AC have provided estimates of the TEE impacts, which capture the impact of the expansion in airport capacity on air fares. Specifically, the ACTEE impacts show that the cost of travel falls once new capacity is introduced, and  this results in a transfer of money from producers (airlines) to consumers (air passengers). Scarcity rents which producers could charge for use of the airport when it was capacity constrained are reduced, leading to benefits for consumers through lower air fares.  It should be emphasised that the estimated changes in consumer and producer surplus are relative to the level of consumer and producer surplus that would be expected in the absence of capacity expansion (rather than being compared to today's levels of producer and consumer surpluses).

Table 47 below summarises the AC's forecast undiscounted consumer and producer surplus elements[170] of the TEE benefits, under the five passenger flow scenarios[171]. It is evident from the tables that much of the estimated increase in consumer surplus is a transfer from producers and that where there are forecast to be larger consumer surplus gains these are typically accompanied by higher producer surplus losses across scenarios. As a result, the net impact of these two effects is small in comparison to the absolute consumer and producer surplus changes. The absolute magnitude of the individual impacts is £2-7bn in 2050, which is substantially larger than the frequency benefit effects outlined above, which are between £0.5-1.5bn at the same date. The overall magnitudes of consumer and producer surplus changes are lower in the Assessment of Needs, Relative Decline of Europe and Global Fragmentation scenarios than in the Global Growth and Low Cost is King scenarios. This is consistent with the passenger flow forecasts described above.

*Table 47: LHR ENR Consumer and Producer Surplus impacts relative to the Do Minimum, by scenario*

| | | Change in Consumer Surplus (£m) | Change in Producer Surplus (£m) | TEE net welfare change (£m) |
|---|---|---|---|---|
| **Assessment of Need** | **2030** | 628 | -594 | 34 |
| | **2050** | 2,255 | -1,604 | 651 |
| **Global Growth** | **2030** | 924 | -841 | 83 |
| | **2050** | 6,388 | -5,025 | 1,363 |
| **Decline of Europe** | **2030** | 413 | -327 | 86 |
| | **2050** | 2,588 | -2,167 | 420 |
| **Low Cost is King** | **2030** | 717 | -583 | 134 |
| | **2050** | 6,812 | -5,547 | 1,265 |
| **Global Fragmentation** | **2030** | 414 | -411 | 3 |
| | **2050** | 1,999 | -1,726 | 272 |

*Source: PwC analysis*

### *Impact on GDP*

Figures 67 to 69 show the impact of these two effects separately and the combined. The absolute magnitudes and time profiles of the two inputs are relatively similar, with the consumer surplus effect being only marginally larger.

These figures show the size of the input and GP impact of these consumer and producer surplus changes for the Assessment of need scenario, which is again selected for illustrative purposes. Also presented is the implied multiplier for each effect, which captures the ratio between the size of the input and the forecast impact.

Looking first at consumer surplus only in Figure 67, the GDP impact of the change in consumer surplus is shown to be reasonably modest until the mid-2040s, then becoming increasingly significant towards the end of the period. This occurs as consecutive periods of positive impact lead to re-investment of economic gains and increased capital accumulation. This generates a sustained increase in the level of GDP through a persistent positive impact on productivity, even as the relative magnitude of the impact begins to diminish from the early 2050s. For the final few periods analysed, this is a forecast increase of nearly 0.2% of GDP, representing a

[170] Please note that in the interest of internal consistency, presents the undiscounted inputs to the S-CGE model in two illustrative years. For a full description of the TEE inputs, please see the Transport Economic Efficiency Technical Appendix, available on the Airports Commission website.

[171] It is also important that the taxation impacts are captured in the modelling framework. The S-CGE model has a full description of taxation structures in the UK, and therefore it is important that inputs to the model are **gross** of tax impacts. We have, therefore, incorporated producer and consumer surplus changes **prior** to the levy of taxes.

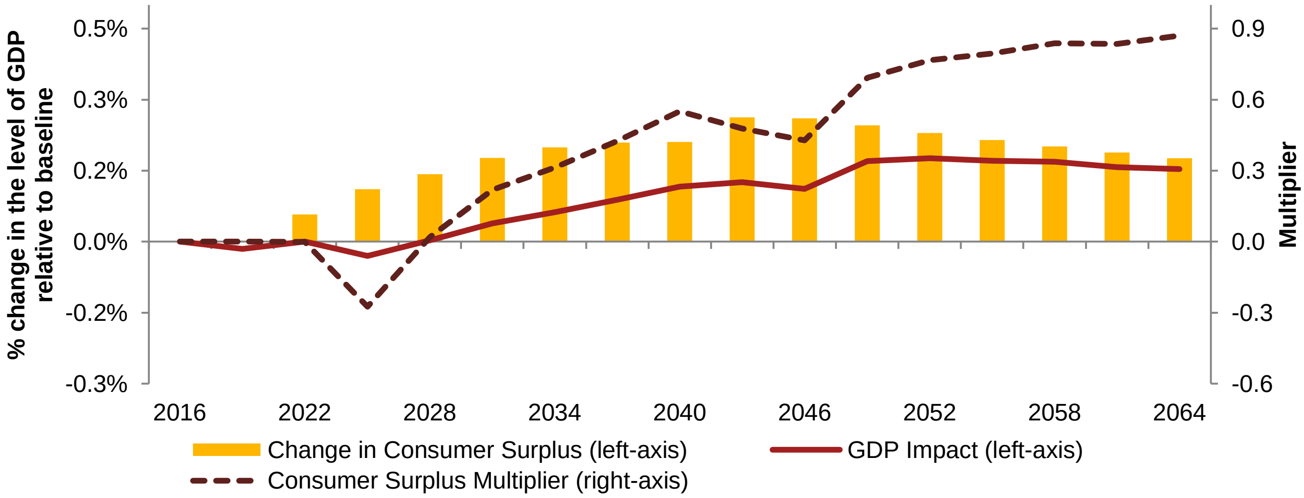
multiplier of 0.6-0.8 on the value of the input. The fact that this multiplier is less than one (i.e. the positive impact on GDP is less than the value of the input) demonstrates that some of the increase in consumer demand is crowded out through a rise in the price level – the *price rebound effect*. This result is typical when using a general (relative to partial) equilibrium approach.

| | |
|---|---|
| **Price rebound/diffusion effect** | As real GDP and aggregate demand increase, upward pressure is exerted on prices. As prices rise there is a nominal, positive inflation effect. As noted above, inflation effects could be particularly strong in the aviation sector. The price rebound effect is important in ensuring that the economy ultimately reaches a new, stable equilibrium. In particular, there are a number of positive "cumulative" forces at play in the S-CGE framework (e.g. the confidence effect described above). The effect of increasing prices keeps the economy "in check" and prevents economic activity from spiralling ever-upwards. |

Figure 68 the equivalent pattern for the producer surplus input and impact. The time profile of the input is similar, with a rise through to the mid-2040s as the airport reaches capacity, followed by a relative decline. However, there are two distinct differences in the nature of the forecast GDP impacts. Firstly, unlike the consumer surplus effect, the reduction in GDP closely tracks the time profile of the input, which an initial decline which gradually reduces in magnitude from the early 2050s. This occurs as the reduction in surplus represents the removal of excess profits generated through scarcity rents in the airline sector. As this does not substantially alter the national level of savings and investment, there is no significant change in the long-run productive potential of the economy, and subsequently the negative GDP impact diminishes with the magnitude of the negative input.

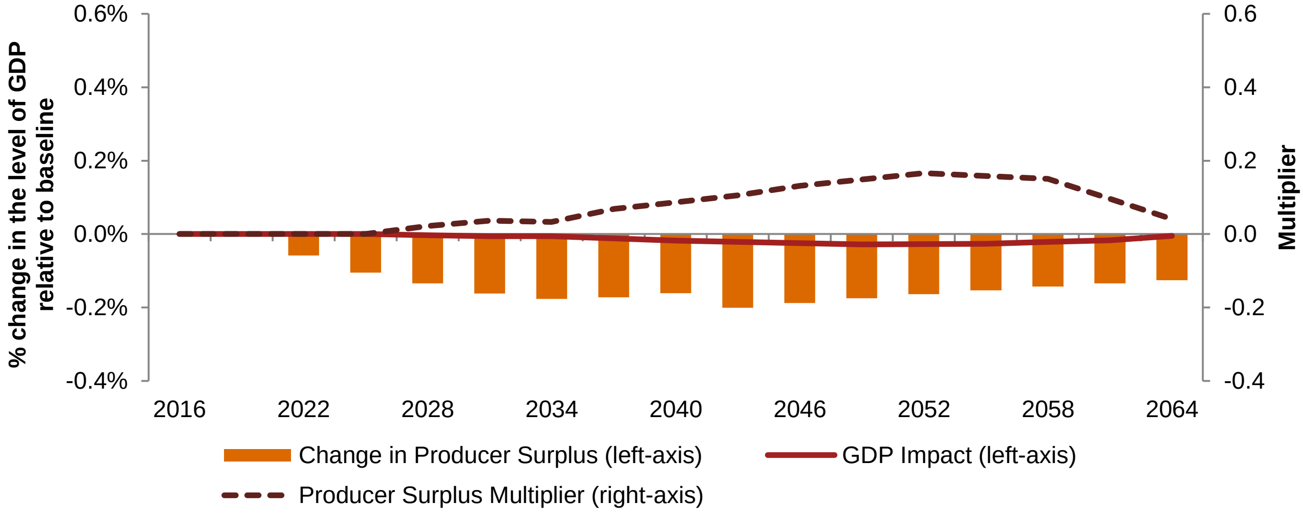
Secondly, the impact on the level of GDP by the end of the period is substantially lower in absolute terms than the consumer surplus impact, despite the level of input being similar. By the end of the period, the forecast level of GDP associated with this effect is below 0.1%, less than half the size of the increase generated by the consumer surplus effect.

*Figure 67: LHR ENR Consumer surplus input, GDP impact and implied multiplier, Assessment of Need scenario*




*Source: PwC analysis*

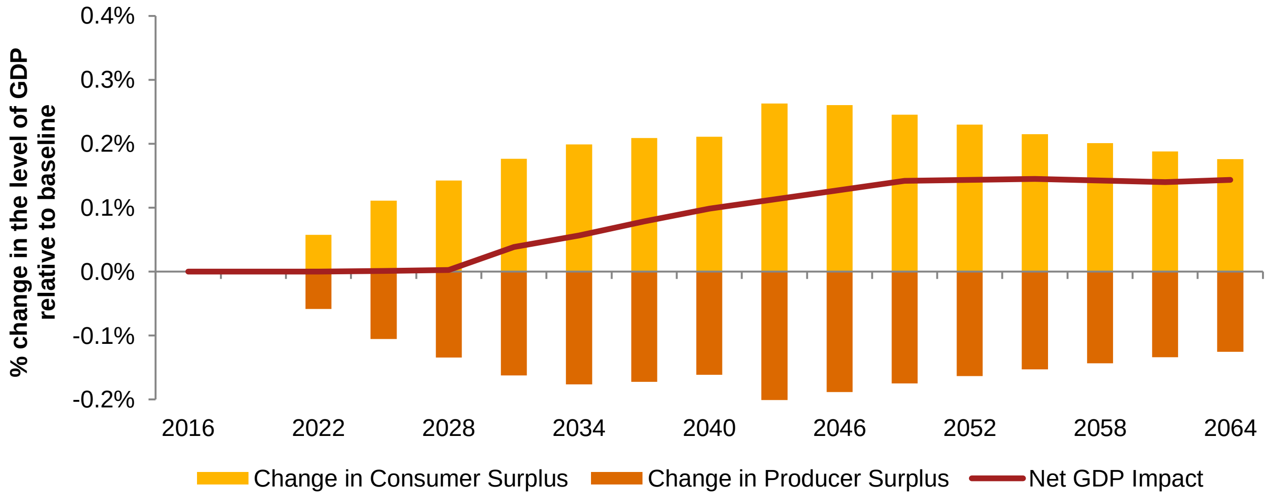
*Figure 68: LHR ENR Producer surplus input, GDP impact and implied multiplier, Assessment of Need scenario*




*Source: PwC analysis*

These two trends lead to the net impact seen in Figure 69, which shows the combined forecast GDP impact of these two effects, along with the two inputs. This reiterates that the absolute magnitudes and time trends of the two inputs are relatively similar, with the consumer surplus effect being only marginally larger. The GDP impact becomes substantially larger towards the end of the period, as the multiplier effect of the change in consumer surplus increases. The intuitive explanation for this is that the reduced producer surplus results in lower returns to airline shareholders. In the S-CGE model these shareholders are households. However, the households most affected by the reduction in airline profits are amongst the most affluent in the economy, and their consumption does not reduce at the same rate as the boost to consumption associated with the increased consumer surplus (which accrues to a broader set of households, being those who use airlines).

*Figure 69: LHR ENR combined TEE inputs and net GDP impact, Assessment of Need scenario*



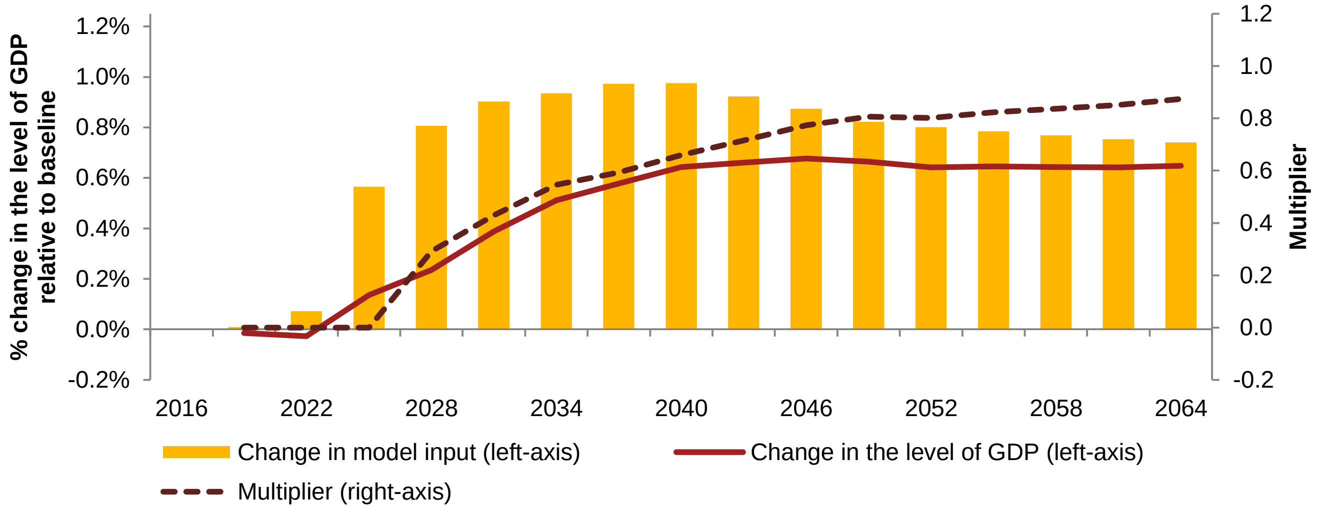

*Source: PwC analysis*

### *7.4.3.5 Combined inputs and GDP impact*

Each of the effects outlined above contributes to the overall impact of the LHR ENR scheme on the level of GDP. Combining the inputs and GDP impacts of each effect gives an estimate of the overall GDP multiplier of the model inputs – this is shown in Figure 70 below. This shows that the value of the inputs peaks in the early 2040s before gradually declining, while the impact on the level of GDP gradually rises before levelling off in the late 2040s. This leads to the multiplier rising from 0.4 in 2030 to 0.8 in 2060.

This demonstrates that the full GDP impact of an input will not exclusively be felt in the years in which they have a direct effect. For example, increases in household spending or productivity in the early years of the analysis are expected to result in an increase in investment. This investment is expected to lead to long-run productivity gains which increase the level of GDP in all future years. In addition, agents within the model recognise that the increase in capacity will yield positive demand (through increased household and passenger spending) and supply (through increased productivity) effects. This motivates them to delay economic activity until later years, thus dampening the GDP impact in the early years of the analysis and accentuating it in the later years.

*Figure 70: LHR ENR combined model inputs and GDP impact, Assessment of Need scenario*




*Source: PwC analysis*

There are two important considerations that should be noted alongside this multiplier effect:

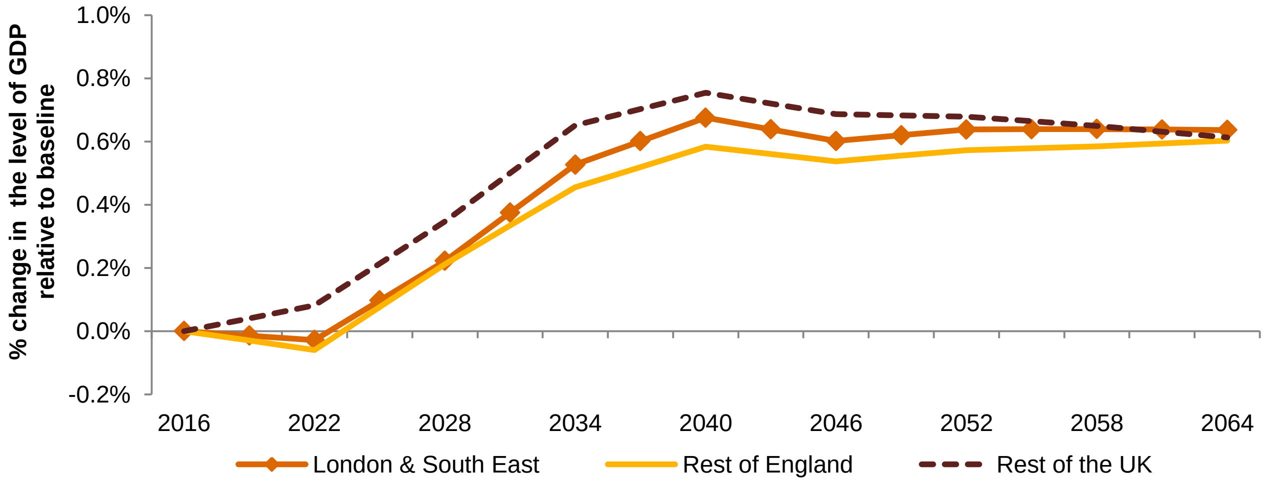
- The S-CGE model captures a wider range of impacts (such as price effects and feedback loops to non-aviation users, and the wider benefits of wage and skill growth) which increase the scope of our estimates beyond what would normally be captured using other techniques that do not fully account for changes in economic behaviour (e.g. input-output analysis). Therefore, while the magnitude of some the effects generated by the S-CGE model (e.g. passenger spending), may be smaller than comparable estimates that take limited or no account of diffusion, the S-CGE model will pick up a broader range of effects which may or may not lead to a larger overall impact.
- These multipliers are "net" in the sense that they capture both displacement of economic activity from sectors of the economy that do not have strong direct or indirect linkages with the aviation sector and, as described above, also include the costs of airline expansion. Our study for the AC (3. Local Economy: Literature Review) illustrated a range of multiplier estimates relating to airport impact assessments, the majority of which were larger than 1 – this is because they are "gross" multipliers and do not fully factor in the range of effects described above.

## 7.5 Impact by region

Figure 71 provides the forecast GDP impacts over time, by region for the Assessment of Need scenario. Table 48 shows the PVs of the scheme by region, for each of the five scenarios. As stated above the regions are defined as follows:

- London & South East, which is made up of the London and South East NUTS 1 regions (or "Government Office Regions");
- The Rest of England, which is made up of all other NUTS 1 regions in England (East of England, East Midlands, North East, North West, South West, West Midlands, Yorkshire and the Humber); and
- The Rest of the UK, which is made up of Northern Ireland, Scotland and Wales.

*Figure 71: LHR ENR regional GDP impacts, Assessment of Need scenario*




*Source: PwC analysis*

*Table 48: LHR ENR Present Value of regional real GDP impacts, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **London & South East** | 46.9 | 71.5 | 32.4 | 64.7 | 39.7 |
| **Rest of England** | 52.3 | 82.2 | 38.6 | 72.2 | 45.6 |
| **Rest of the UK** | 19.1 | 33.7 | 14.8 | 31.7 | 16.5 |

*Source: PwC analysis*

Table 48 demonstrates that all three regions are forecast to experience positive GDP impacts across all five passenger scenarios as a result of the LHR ENR scheme. Given the scheme's location, it is not surprising that London & South East generally enjoys a large increase in GDP from the schemes. However, Figure 71 demonstrates that in percentage terms the largest increase in the Assessment of Need scenario is actually seen in Rest of the UK, despite this region experiencing the smallest benefit in PV terms.

There are a number of reasons why benefits are modelled as dispersing across all regions of the economy. Primarily, the majority of impacts are national effects and therefore benefit all regions, such as productivity improvements brought by cheaper imports and better access to export markets, as well as the reduction in the cost of air travel due to the assumed fall in air fares. Although passengers who land at Heathrow and Gatwick spend disproportionately in London & South East, the model captures the degree to which the spending by these passengers is dispersed across the other parts of the UK. Further, the increase in air transport capacity in London & South East will diffuse to the other UK regions through inter-regional trade. For example, London & South East exports insurance and financial services to the other UK regions whereas it imports manufacturing products from the other UK regions. As the London & South East economy expands due to the increase in air capacity, London will begin to import more manufacturing from the other UK regions. This will have a positive impact on GDP in the other UK regions, which will, in turn, lead to an increase in demand for imports from London & South East in sectors such as financial services, which will have a positive impact on GDP in London & South East. Also, any rise in activity within London & South East which is not mirrored in other regions, causes an increase in the price level in that region. This could crowd out other activity, tending to cause it to relocate to other regions.

Finally, while many of the positive effects are distributed evenly across regions, the negative impact of the decline in producer surplus is expected to affect London & South East disproportionately due to the relatively high share of the aviation sector which is headquartered there. Although the economic impact may be dispersed across all regions, the majority of the reduction in gross operating surplus resulting from this effect would be experienced in London. This would occur because a greater number of airlines are registered in London than any other region for accounting reasons, and this region therefore receives an above-average share of profits from the industry.

In addition to direct effects, the regional distribution of impacts can be explained by “agglomeration” and “cumulative causation” forces identified in the New Economic Geography literature. These effects are outlined in Box 15 below.

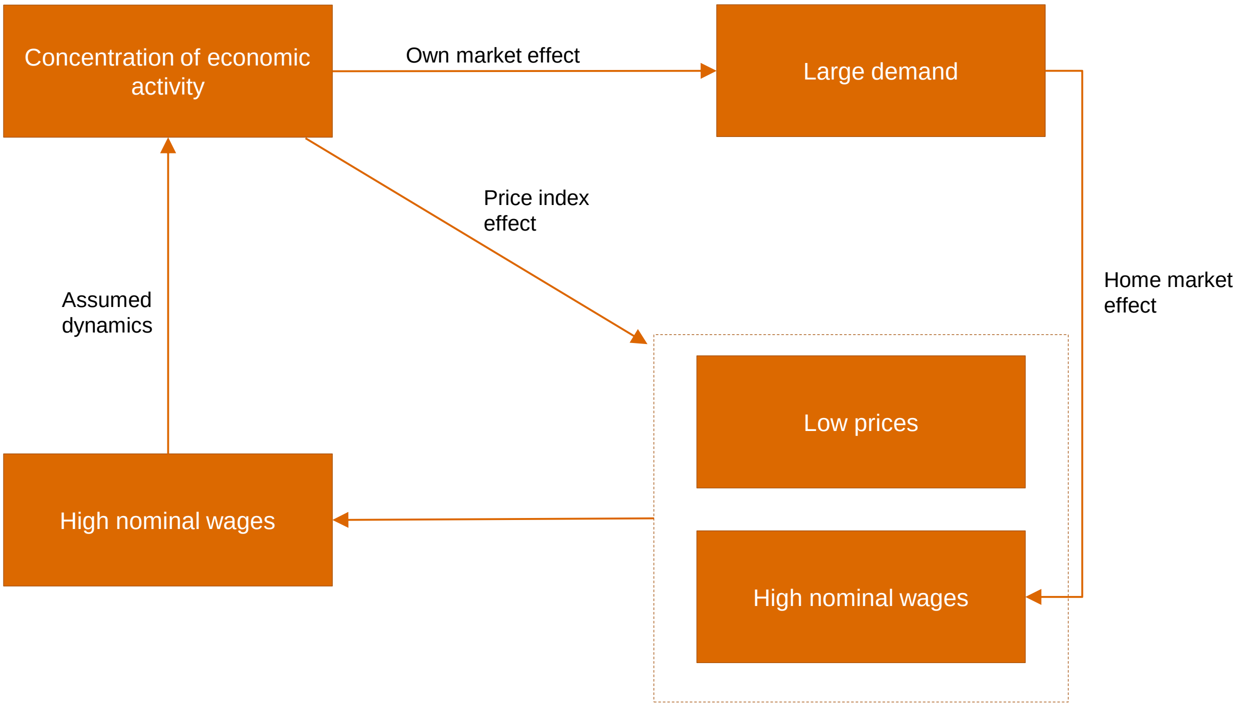
**Box 15: Agglomeration and cumulative causation**

As described in Chapter 2, the S-CGE framework has a regional structure with imperfect competition, meaning that agglomeration will be an inherent or 'endogenous' feature of the model that can follow from any of the modelled effects described above. These key agglomeration impacts are considered in detail in Chapter 2 and Appendix A. In particular, the model implies the following effects (these are explained in general terms later in this chapter):

- **Own Market Effect.** The expanded aviation sector in London & South East generates demand, which makes London & South East a more attractive place for businesses to locate;
- **The Home Market Effect.** The expanded airport facilities lead to increases in employment in London & South East (as described above). This increases nominal wages in London & South East, which makes the region more attractive as a place to work; and
- **The Price Index Effect.** Prices may be lower in regions with denser economic activity because distances between consumers and suppliers are lower on average, resulting in lower transport costs. Whilst this precise effect is not present in the S-CGE framework, an analogous effect – which has the same implication – does exist. In particular, higher economic activity in London & South East which may come about as a result of the airport could give rise to increased competition between firms, which reduces profit margins and prices. These lower prices make London & South East more attractive to consumers and firms.

Between them, these effects generate a process of what Myrdal (1957) calls 'circular causation': the presence of the expanded airport in London & South East generates demand (own market effect) which, by the home market effect, increases local wages. At the same time, the price index effect means that prices on average are lower in this region. These arguments combined imply that real wages in the region are relatively high. Since workers in the S-CGE model are attracted to regions where they can command higher real wages, workers move to London & South East. This reinforces the prominence of the region and so the cycle repeats itself. Figure 72 below illustrates the process.

*Figure 72: Circular Causation*



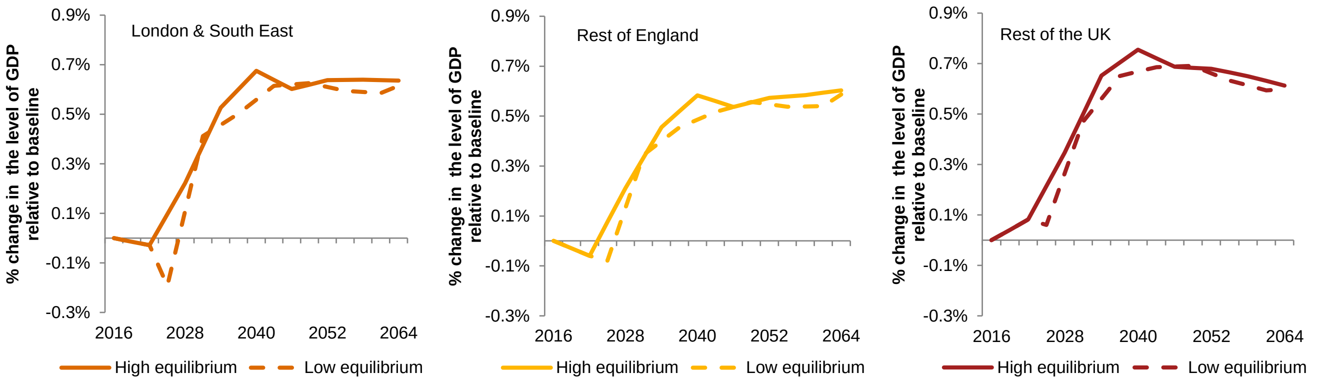

*Source: PwC analysis*

### *7.5.1 Factors affecting the regional distribution*

As noted in Chapter 2, models based on imperfect competition can give rise to multiple equilibria. The results from the S-CGE model suggest two different equilibrium outcomes for the LHR ENR scheme (a "high scenario" outcome and a "low scenario" outcome). Both are consistent with profit maximising behaviour. In addition to the discussion in Chapter 2, Appendix A highlights the key economic theory in relation to multiple equilibria. The multiple equilibria produced by the model are largely borne out of the functional forms in the model used to capture imperfect competition and regional trade.

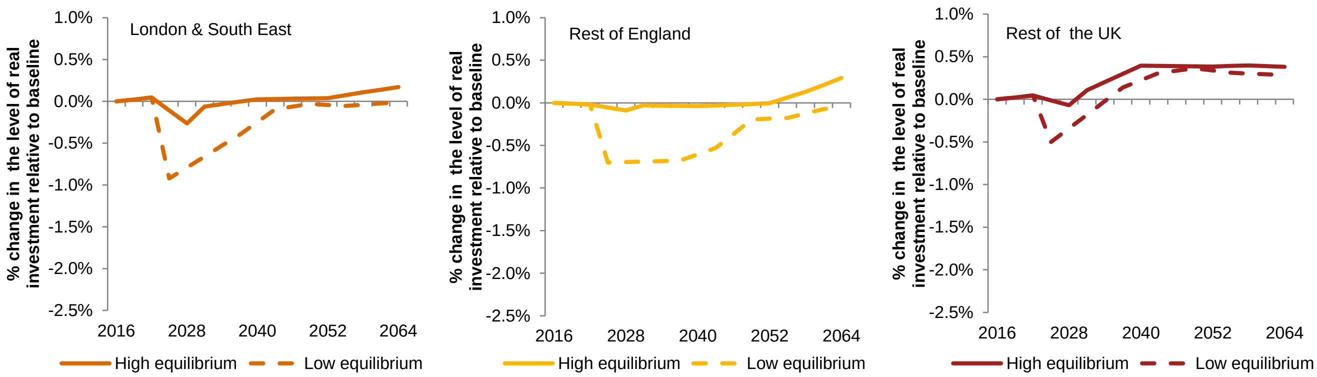
In the "high scenario" outcome for LHR ENR, there is more GDP and investment in each region of the UK than in the low outcome – up to 0.1 percentage points in extra GDP is observed in the high outcome relative to the low outcome. However, neither of these outcomes implies a "lock-in" of economic growth in London & South East at the expense of other UK regions. The results for both outcomes suggest a long-term change in the level of real GDP across all regions, with this growth eventually flattening out as the LHR ENR scheme reaches full capacity. The GDP effects are relatively small, but the effects are more pronounced on the different components of GDP, Figure 74 illustrates this from an investment perspective.

*Figure 73: LHR ENR effect of expansion on the level of real regional GDP in London & South East, Rest of England and Rest of the UK – multiple equilibria, high and low scenarios*




*Source: PwC analysis*

*Figure 74: LHR ENR effect of expansion on the level of real regional investment in London & South East, Rest of England and Rest of the UK – multiple equilibria, high and low scenarios*




*Source: PwC analysis*

The extent to which economic gains are realised by each region is dictated by the pricing behaviour of airlines. In the S-CGE model, each firm has a perception of the consumers' income elasticity of demand for the products that it sells. This perception varies with the level of economic activity. As has been shown in the previous sections, following the introduction of a new airport scheme the S-CGE model has estimated that economic activity will be higher, and as a result entrepreneurs may perceive this as a good time to enter the market. The reasoning behind this is that customers may be finding it hard to find suppliers for the products they wish to purchase. This may lead to consumers' income elasticity of demand falling (i.e. becoming more inelastic). If the income elasticity of demand falls, firms can charge higher mark-ups and make more profits per unit of output sold.

However, when mark-ups rise the threat of new market entrants will be greater for businesses already operating in the market. This may lead to them to lower their mark-ups to make it less attractive for potential new entrants to enter the market. This effect can potentially offset the factors that might entice firms to enter the market described above and the overall effect on mark-ups could potentially be zero (Carlin and Soskice, 2006)[172] or they could even fall if firms felt that total profits (as opposed to profits per unit of output) could increase.

If businesses are more sensitive to the threat of entry than to existing competition then the perceived income elasticity of demand could be procyclical: this would imply higher margins when the level of economic activity is at a relatively low point (and hence the perceived threat of entry is low, reducing the perceived income elasticity of demand, and encouraging incumbent firms to raise prices and margins) and lower margins when the level of economic activity is at a relatively high point. If businesses are more sensitive to the threat of internal competition from the existing market then their perceived elasticity of demand will be countercyclical. Margins will be lower when output is at a relatively high level and vice versa. Carlin and Soskice note that in the latter case there will be a unique equilibrium. However, in the case where there is a greater sensitivity to the threat of entry there is a possibility that multiple equilibria will occur.

This latter effect is what we observe in the S-CGE model in the high outcome. Firms within the airline sector are willing to accept lower mark-ups to act as a deterrent to new entrants. Overall they make more profits, because the UK aviation market has expanded, but profit per passenger falls.

This reaction is in part triggered by the reduction in producer surplus described in relation to the TEE effects. In the TEE framework, the increase in airport capacity has opened up competition in the UK aviation sector and driven down prices. This has the knock-on effect of driving up demand from households and businesses wishing to travel by air. In the high scenario, incumbent airline firms accept the lower mark-ups that come with the threat of increased competition and as passenger demand rises, they do not seek to increase mark-ups in response. This has a dual effect – new entrants are deterred, and some incumbents will exit the market as they view operating in a market with low mark-ups as not viable or attractive. So the outcome is that there are fewer airlines in operation in the UK market, but the remaining airlines fly to more destinations and at lower prices.

Figure 75 demonstrates this by showing results from the S-CGE model for the number of firms in the air passenger transport sector (in the left-hand chart), and all other sectors (in the right hand chart). Please note, the scales for these charts are intentionally different due to the substantially different scales of the impact.

The S-CGE model suggests that in the "high scenario", there is substantial consolidation in the air passenger transport sector, with the number of firms falling by nearly 2.5%. In this scenario the lower prices and mark-ups in the aviation sector benefit other business users, which in turn can reduce their costs and increase their profits. This leads to more firms entering the non-aviation sectors to contest the higher mark-ups there associated with the increased levels of business and consumer activity.

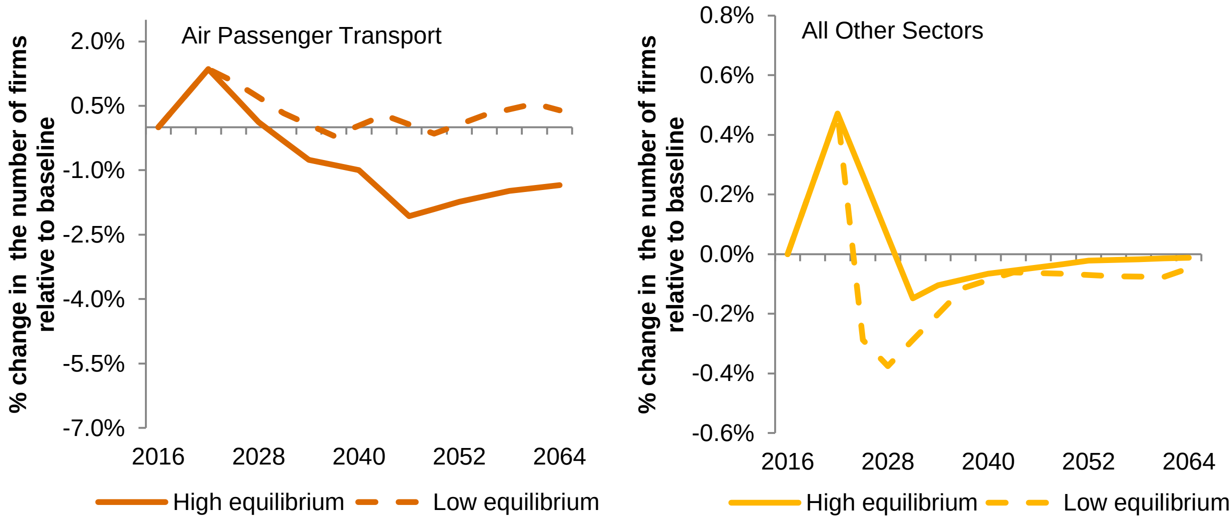
In the "low scenario" the pricing behaviour of airlines is the opposite of that observed in the "high scenario". Air fares initially fall in response to the increase in airport capacity, but in the longer-term they rise in response to increases in demand. This implies that there will be new entrants into the UK aviation sector who will seek to compete away any new potential higher mark-ups back down to the levels before new airport capacity was built. Overall in this scenario there are more firms in the UK aviation market (between 0 and 0.5% more), but prices are higher and there is less benefit passed on to consumers in the form of lower fares. This means that the overall impact of this scenario on GDP is smaller.

The higher fares in the "low scenario" effectively deter some passengers from using the newly expanded Heathrow airport. This means that the magnitude of the GDP gains observed in the "high scenario" is reduced. In the "low scenario", the negative economic multiplier associated with UK residents flying overseas offsets a

[172] Carlin, W. & Soskice, D. (2004) Marcoeconomics: Imperfections, institutions & polices, Oxford, Oxford University Press

greater share of the other positive wider economic effects. However the gains, even in this low outcome, are substantial, not only in London & South East, but also for the rest of the UK economy.

*Figure 75: LHR ENR change in number of firms, relative to Do Minimum, for Air Passenger Transport (APT) and all other sectors by high and low equilibrium, Assessment of Need scenario*




*Source: PwC analysis*

The results above illustrate that the overall level of UK GDP can differ between the multiple equilibria in the S-CGE model, but the impacts on its relative regional distribution are more limited. Given this, we tested the model to identify those factors that would affect the regional distribution of GDP. We found that the regional distribution of the impact relies heavily on the extent of inter-regional trade linkages specified in the model. As set out in Chapter 4, these linkages have been estimated using standard techniques. Nonetheless, the data on which they have been estimated still present a source of uncertainty in our modelling, not in terms of the overall scale of the impact, but in terms of which regions will gain relative to others.

Our modelling results presented Figure 73 suggested that the Rest of England region would be expected to gain more than London & South East in absolute terms, while the Rest of the UK region would also be expected to gain significantly. A sensitivity analysis of the results suggests that by lowering the flows of inter-regional trade linkages by 20.0% (in terms of both regional imports and exports) the pattern of results can be reversed. The results of this exercise are shown in Figures 76 to 79.

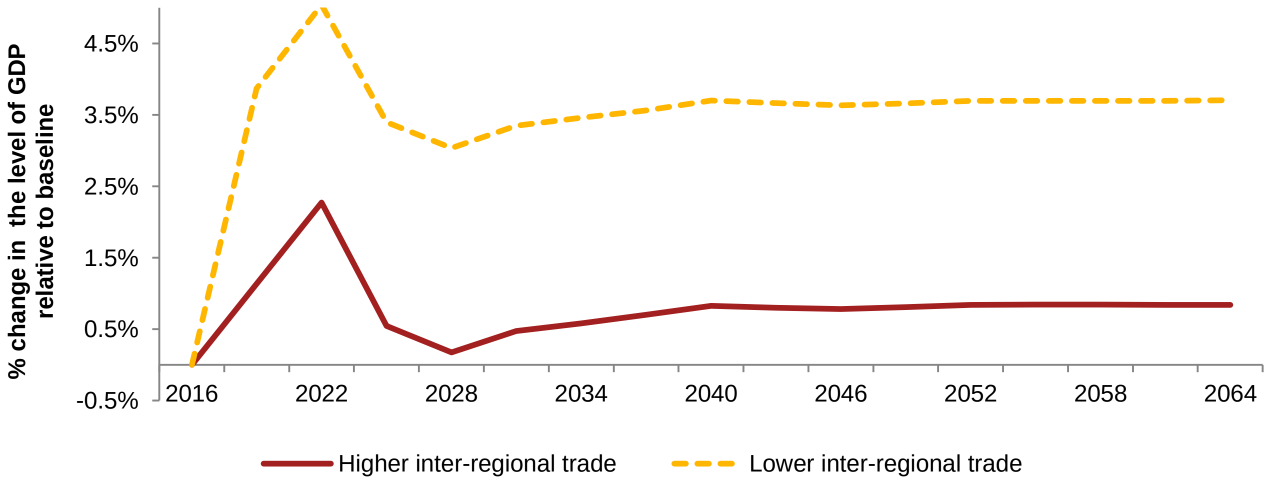
The results suggest that when a lower estimate of UK inter-regional trade linkages is compared to a central estimate the impact on London & South East is 2.8 percentage points higher while the impact on the rest of England is 2.2 percentage points lower, and the Rest of the UK is only marginally lower. The overall impact on the UK economy as a whole is unchanged. This result is important for two reasons. Firstly it highlights the key determinant of the regional results: the stronger the trade linkages between the different regions of the UK economy, the more likely it is that the benefits of new airport capacity at Heathrow will benefit regions other than London & South East. Secondly it illustrates that, depending on the strength of inter-regional trade linkages, that airport expansion in London & South East could have some negative effects on other UK regions.

Our central estimate implies that the scale of inter-regional UK trade linkages is broadly 150% of international trade linkages and it is difficult to say whether this is realistic or not. However, as outlined above it has been estimated in line with international best practice and has been discussed with various UK Government Departments. At the time of writing this report, as far as we are aware, there is no better estimate of inter-regional trade flows in the UK.

In our sensitivity analysis we vary the level of inter-regional trade by 20%. However, this variation is not enough to change the sign of the regional trade flow in the underlying data– London and the South East (LSE) still generates a surplus, it is just a lot smaller. By varying inter-regional trade by 20% we have identified a critical tipping point whereby the pattern of spatial economic benefits reverses (RUK gains more that LSE in this sensitivity test).

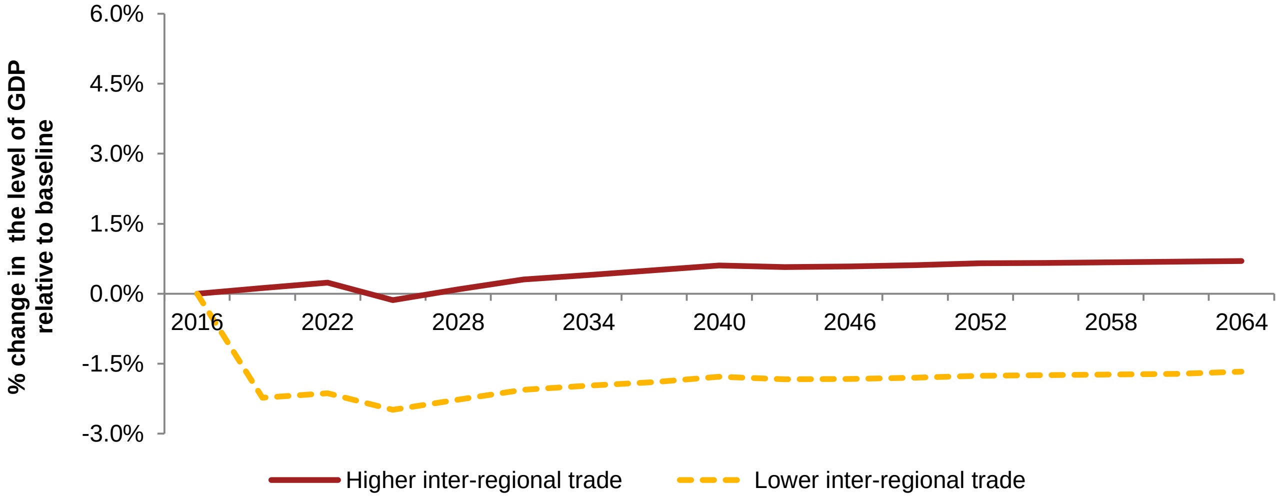
However, if we had estimated inter-regional trade to be 5% higher than it had been, we would not have seen the reversal in the spatial distribution of the results. What matters is the absolute magnitude of inter-regional trade. The modelling is showing that there is a tipping point i.e. when LSE exports less to RUK. However, if we lower the trade flows by 20% then the implication would be that GVA per capita in LSE would be well below the levels reported by the ONS. So we are less cautious in our interpretation.

*Figure 76: LHR ENR impact on the level of real GDP in London & South East by level of inter-regional trade, Assessment of Need scenario*



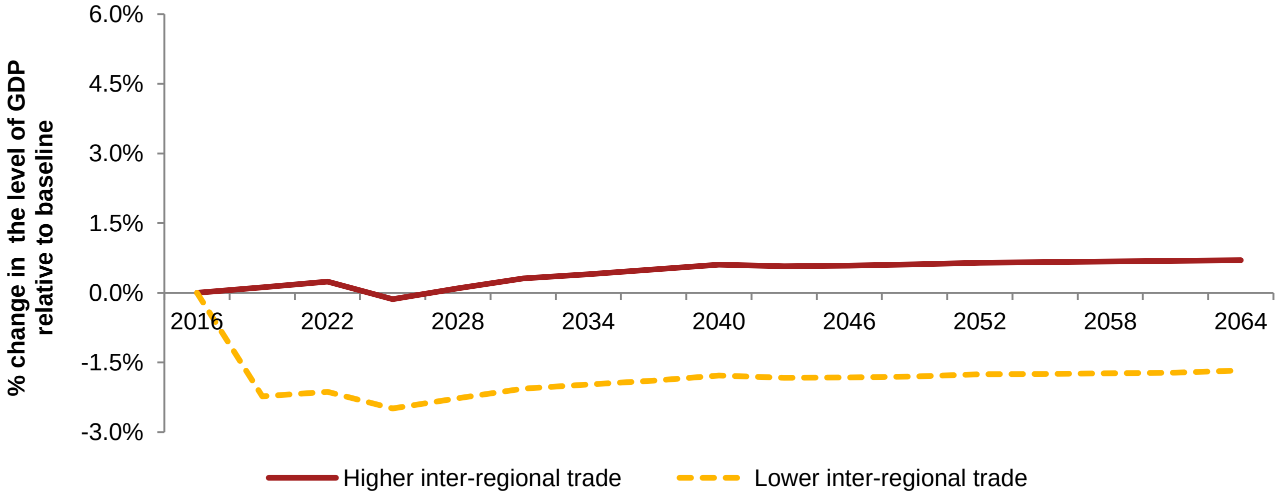

*Source: PwC analysis*

*Figure 77: LHR ENR impact on the level of real GDP in Rest of England by level of inter-regional trade, Assessment of Need scenario*



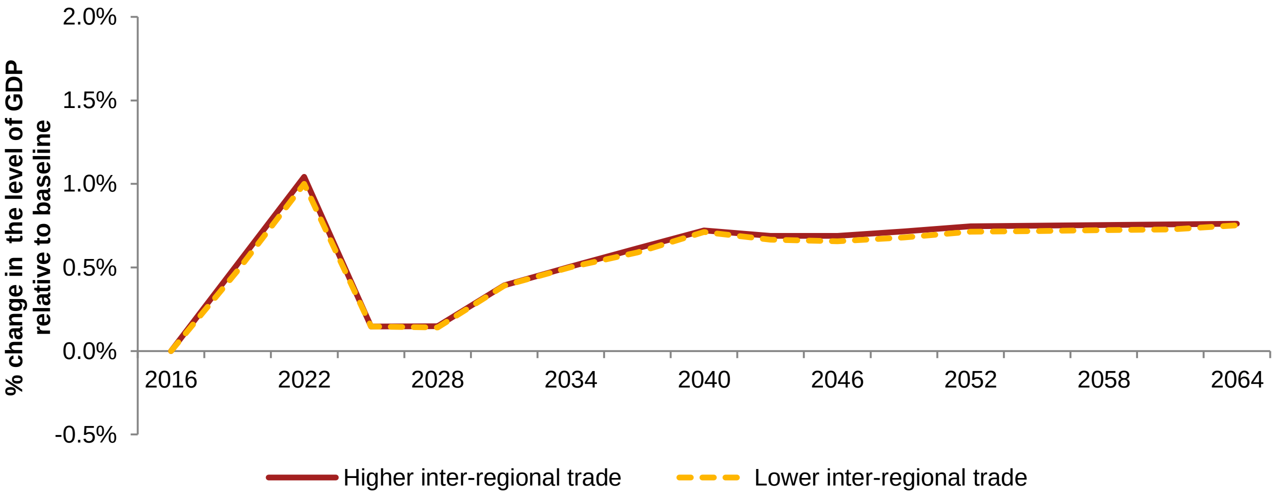

*Source: PwC analysis*

*Figure 78: LHR ENR impact on the level of real GDP in Rest of the UK by level of inter-regional trade, Assessment of Need scenario*




*Source: PwC analysis*

*Figure 79: LHR ENR impact on the level of real GDP in the UK by level of inter-regional trade, Assessment of Need scenario*




*Source: PwC analysis*

## 7.6 Impact of construction

### Construction phase inputs

For the LHR ENR scheme, the construction and operational phases are distinct from each other. Construction of the LHR ENR scheme occurs in a single phase between 2019 and 2026. Increased operations at the expanded Heathrow Airport begin immediately after this phase.

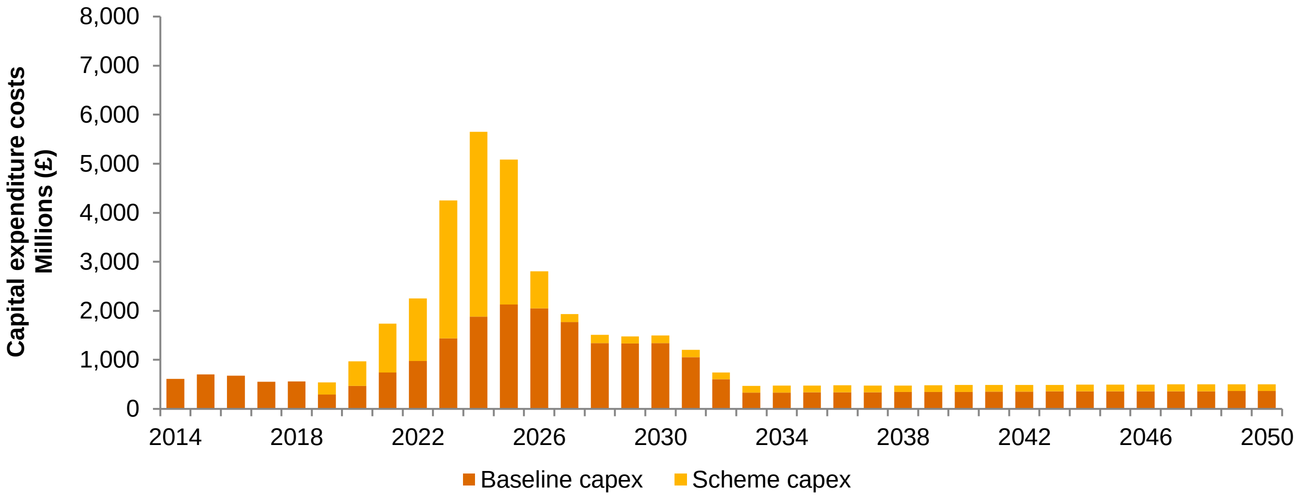
Figure 80 reflects a single, large capital injection between 2019 and 2026, after which there is expected to be a small amount of ongoing capex to cover asset replacement. Table 49 shows the incremental construction costs required for the LHR ENR scheme, which comprise expenditure on airport infrastructure and facilities and the associated surface access.

*Table 49: LHR ENR Incremental construction capex costs (£mn, undiscounted and not adjusted for inflation)*

| 2015-2050 | Airport scheme capex | Surface access capex | Total |
|---|---|---|---|
| **LHR ENR** | 16,714 | 5,481 | **22,194** |

*Source: LeighFisher analysis*

*Figure 80: LHR ENR airport capital expenditure costs*




*Source: LeighFisher analysis*

Around 80% of the capital expenditure for the LHR ENR scheme relates to road expenditure, with the requirement to place the M25 into a tunnel being a significant component. Further investment in strategic roads and reconfigurations of local roads are required. It is assumed that all of this investment would be required prior to the scheme's opening date in 2026.

*Table 50: LHR ENR Surface access capex costs by type (£mn, undiscounted and not adjusted for inflation)*

| 2015-2050 | Road | Rail | Risk & Optimism Bias | Total |
|---|---|---|---|---|
| **LHR ENR** | 3,191 | 533 | 1,756 | **5,481** |

*Source: LeighFisher analysis*

## *Construction phase impacts*

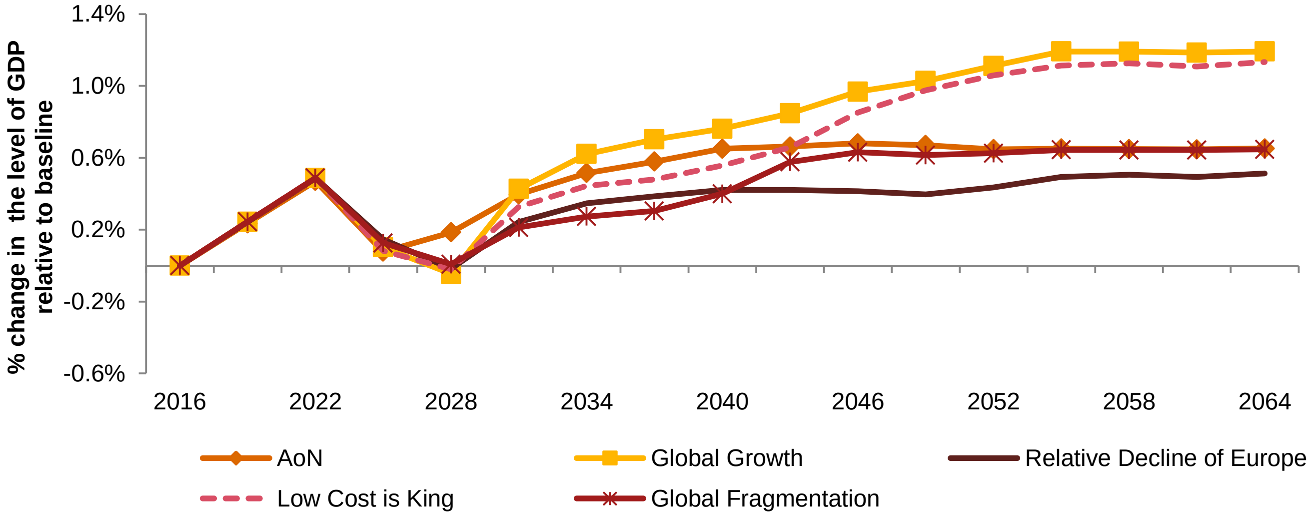
Our modelling suggests that despite our assumption that the economy is at near full employment in the baseline scenario and every £1 spent on the LHR ENR scheme must be funded by a reduction of £1 in other parts of the domestic economy (most notably private consumption), the LHR ENR construction activities themselves are likely to have significant GDP impacts. This is because at a high level, shifting economic activity towards construction is estimated to have a net positive impact on economic output because of the strong linkages between construction and the other sectors of the economy. As a result, the positive multiplier impacts from expanding the construction industry outweigh the negative multiplier impacts from the contraction of other sectors as a result of (primarily) reduced consumption to fund investment. The implication is that shifting economic activity away from consumption towards construction raises overall GDP in net terms.

Figure 81 shows the projected real GDP impacts of the LHR ENR scheme, for the different passenger flow scenarios when the impacts of construction are included. The profiles of the impact of the five scenarios remain the same, except that there is an initial spike relating to construction activities, which results in a forecast GDP impact of around 0.5% compared to the baseline scenario.

In order to more clearly isolate the impact of construction on GDP, Figure 82 shows the total projected GDP impact of the Assessment of Need scenario, with the impact of construction and surface access effects included.

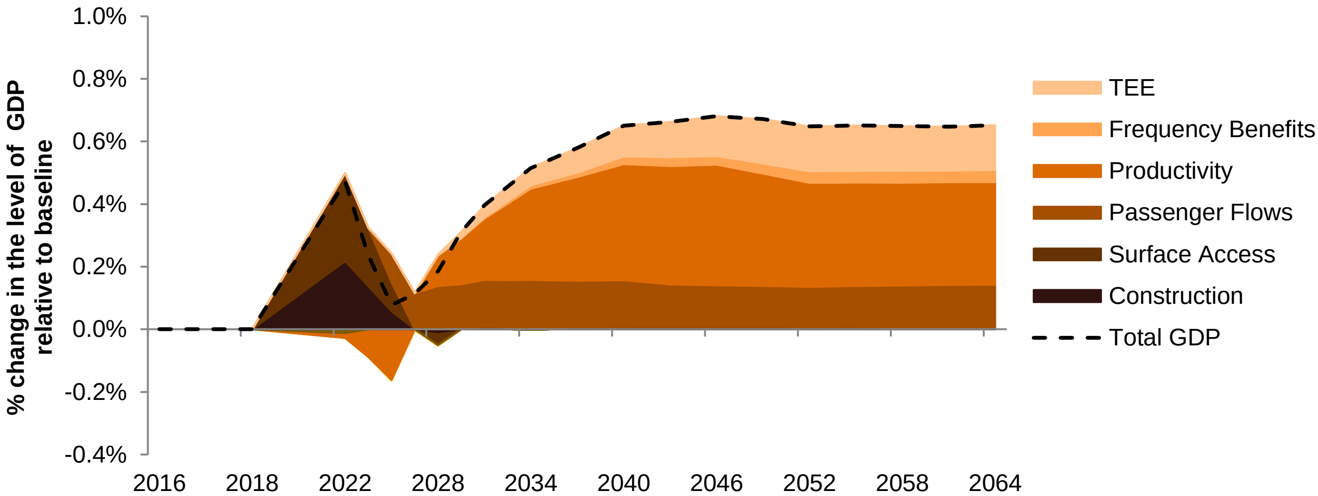
The impact of construction is clearly distinguishable from other effects and relatively short-term; after 2030 there are no direct effects realised from construction activities.

*Figure 81: LHR ENR GDP impacts on the level of real GDP including construction, by scenario*




*Source: PwC analysis*

*Figure 82: LHR ENR effect-by-effect impacts on the level of real GDP including construction, Assessment of Need scenario*

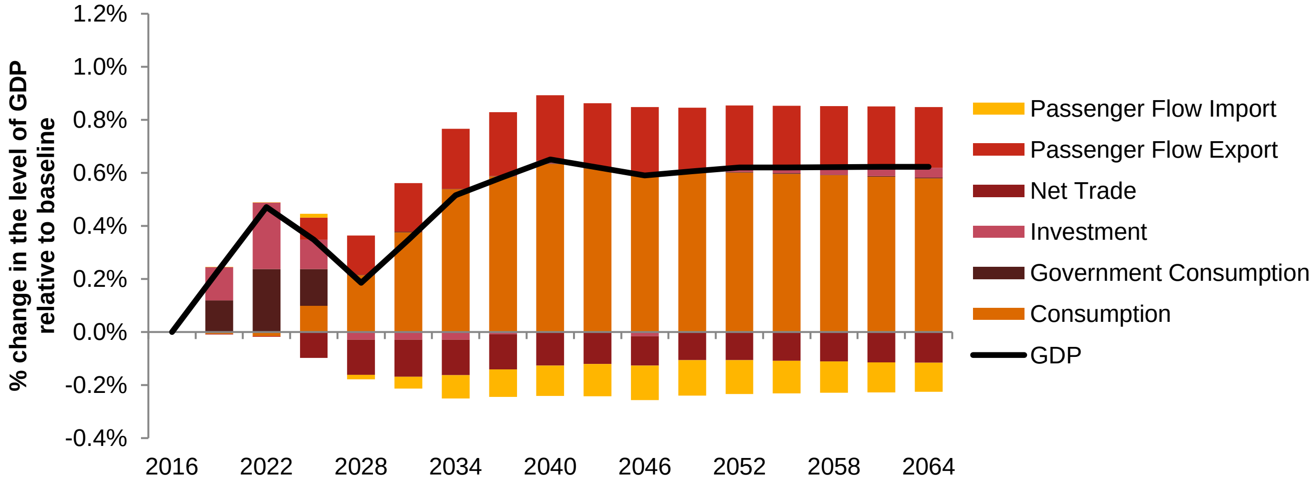



*Source: PwC analysis*

Figure 82 demonstrates how the different components of GDP contribute to the overall change, once construction and surface access effects are included. Unsurprisingly, the positive increases in GDP resulting from construction can be seen through increased investment, with a few periods of increased government consumption to reflect surface access expenditure (the *investment effect*). Despite the positive construction impact, total GDP is largely unchanged due to a concurrent reduction in consumption. The majority of this is due to forward-looking agents postponing economic activity until the capacity constraint is lifted, although some is driven by a shift from consumption to savings in order to finance the investment.

| | |
|---|---|
| **Investment effect** | The investment effect is at its greatest during the construction phases of the scheme. As noted above, even in the long-term, investment remains important and continues to place upward pressure on GDP as a result of continued maintenance and renewals of the enhanced infrastructure, together with the greater level of investment generated from higher confidence and the expectation of increased economic output amongst businesses (see *confidence effect* in section 8.4.2). |

*Figure 83: LHR ENR breakdown of real GDP impacts including construction, Assessment of Need scenario*




*Source: PwC analysis*

As Figure 82, once the airport is in operation the impact of additional construction phases is modest. To enable a more detailed comparison of the relative magnitudes of each effect, Table 51 summarises the PV of each effect for each passenger scenario. As we have assumed that the required level of construction and maintenance expenditure does not vary by passenger scenario, the construction and surface access impacts are constant. This shows that under the five passenger scenarios, the modelled combined impact of construction and surface access are no more than 6-12% of the total increase in the level of GDP, and have the smallest impacts of the effects analysed.

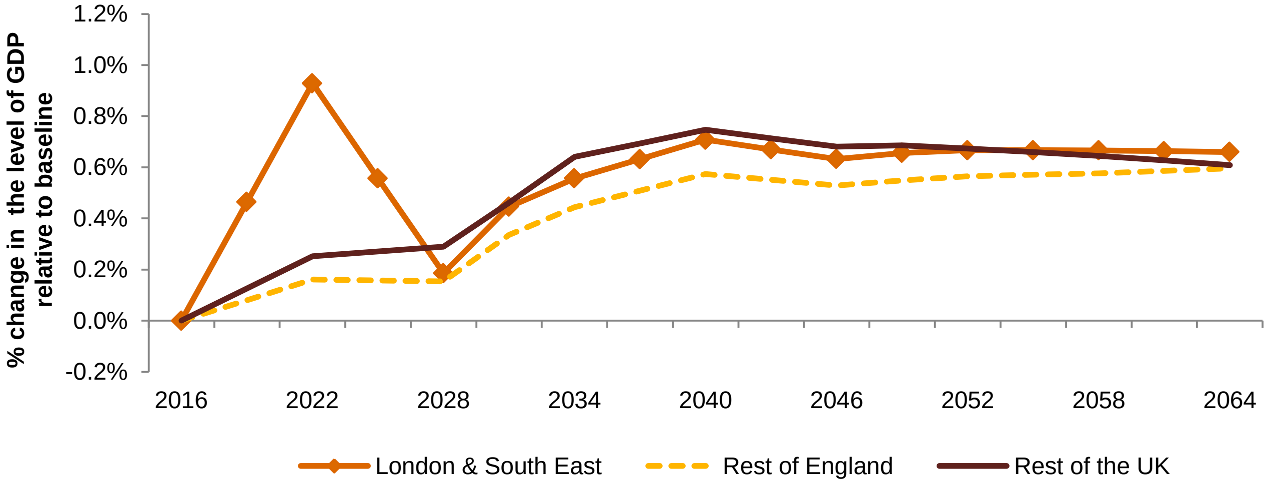
*Table 51: LHR ENR Present Value of GDP impacts including construction, by effect and scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Construction** | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 |
| **Surface Access** | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |
| **Passenger Flows** | 28.3 | 36.3 | 17.6 | 33.3 | 34.8 |
| **Productivity** | 61.7 | 72.6 | 34.9 | 62.2 | 45.6 |
| **Frequency Benefits** | 5.6 | 7.2 | 8.7 | 9.4 | 4.1 |
| **TEE** | 22.6 | 71.2 | 24.7 | 63.8 | 17.4 |
| **Total** | **130.5** | **199.6** | **98.0** | **180.8** | **114.0** |

*Source: PwC analysis*

Finally, Figure 84 investigates how the regional distribution of GDP impacts change with the addition of construction and surface access effects. In comparison with the Rest of England and Rest of UK, London & South East can be seen to gain substantially, and on this basis experiences the greatest increase on the level of GDP throughout the 2020s. To a lesser extent, the Rest of England and the Rest of the UK also gain slightly as a result of the construction phase, as the beneficial effects of the additional construction flow throughout the national economy through inter-regional trade.

*Figure 84: LHR ENR regional GDP impacts including construction, Assessment of Need scenario*




*Source: PwC analysis*

*Table 52: LHR ENR Present Value of regional real GDP impacts including construction, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **London & South East** | 58.2 | 83.6 | 43.7 | 76.9 | 50.9 |
| **Rest of England** | 53.1 | 82.5 | 39.4 | 72.4 | 46.5 |
| **Rest of the UK** | 19.2 | 33.5 | 14.9 | 31.5 | 16.7 |

*Source: PwC analysis*

As agreed with the AC, our results are based on the assumption that construction costs are funded "wholly by the domestic private sector". Box 16 below discusses how the results might have varied if we had made an assumption regarding partial or full foreign investment.

**Box 16: Financing runway expansion schemes - the potential use of foreign investment**

As described in Section 4.7.3.1 we made the assumption in our economic modelling that the construction cost of the three airports schemes was funded "wholly by the domestic private sector". This assumption was discussed and agreed with the AC and its external advisors. However, it is also possible to assume in the S-CGE model that the airport schemes are fully or partly funded by foreign investors. In this box, we discuss how the results might have varied if we had made an assumption regarding partial or full foreign investment.

The S-CGE model requires the user to identify the source of each airport scheme's financing – new financing will be sourced from additional investment. In the models baseline, investment markets are assumed to be in equilibrium, investors are assumed to have balanced portfolios and there is no excess supply of capital.[173] So for new investment to be created, rates of return for capital must rise.

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[173] The model is capable of proxying the effects of either excess supply or demand in capital markets. For instance, investors may have capital they want to invest, but do not have appropriate opportunities available to them. If this is the case, the rate of return that businesses need offer to investors will be lower. The model can therefore be set up with lower capital returns in different sectors or across the whole economy. Similarly a shortage of investment supply, means that businesses need to raise rates of return to attract scarce capital, so the model could be set up with higher capital returns.

However, it is not clear whether capital markets are generating long-term deviations in investment supply or demand. There were clearly liquidity shortages following the financial crises, but these have now eased. Further, markets will tend to look at capital infrastructure projects on a case by case basis. Airports represent long-term investment opportunities, and so are likely to be resilient to deviations in investment supply or demand. On this basis we make no special assumption about capital market disequilibrium.

The investment needed to build each airport must be supplied by either domestic or foreign investors. As we have seen in Figure 118, if the investment for each scheme is sourced from within the UK then the additional investment required will be sourced from either households (who consume less in response to being offered higher rates of return on their investments) or at the expense of other investment projects (again higher rates of return will need to be offered to attract investment into the airport sector).

The transmission mechanism associated with airport construction is given in Figure 176 in Appendix D of this report. As we note in that figure, if foreign investment is used to finance an airport scheme either as an alternative or complement to domestic investment and it could be competed away from another UK project as there will be international competition for foreign investment.

If foreign investment is used as a direct alternative to domestic investment, then the reduction in household consumption that is observed in our results would not occur. Similarly, it would be less likely that the airport sector would compete domestic investment away from other sectors of the economy.

However, the degree to which foreign investment displaces domestic investment is difficult to calculate and we are only able to make a qualitative assessment. Overall we think the level of displacement would be small for the following reasons:

- The UK is an attractive hub for foreign investment. According to UNCTAD[174], the UK is the number one country for inward FDI stock in Europe, and only the second in the world after the USA. Given the UK's attractiveness foreign investment hub, we think it would be unlikely that
- The implied rate of return for inward investment[175] into the UK decreased to 5% in 2012 from 6% in 2011 and was still lower than the value reported in 2007 (7%). However, overall flows are rising.

These findings can be interpreted in two ways. Firstly, it could be that the UK will remain a well-liked destination for FDI, falling returns could imply that the UK can offer less favourable terms to investors because of its popularity as an investment destination. This means that the UK airport schemes could find it easy to attract foreign investors. Alternatively, the foreign investment community could infer that the UK is a saturated market and that in order to balance their global portfolios they are better off placing their investments in other countries. The scale of FDI is ultimately linked to the rate of return offered to bond holders by each airport scheme.

According to ONS surveys,[176] the main beneficiaries of FDI are the power and utilities sectors, communications, financial services and the manufacturing sector. So if displacement were to occur, it is likely that these sectors would be most affected.

One negative consequence that would be associated with foreign investment can be described as follows. The scale of investment required for each airport scheme will require the body corporate associated with each airport scheme to sell bonds in order to raise capital. This process will be facilitated through investor roadshows and the wider financial sector. If foreign capital is required, international investor roadshows will need to be held and this will require the support of international (rather than UK banks). This could lead to a small leakage in activity from the UK financial sector. But relative to the overall results, this effect would be minimal.

Overall, the assumption made regarding the degree of domestic investment has been designed to be deliberately cautious. If FDI is the primary source of airport finance, the dampening effects of lower household consumption and displacement of domestic investment from other sectors would be less likely to occur and the overall results presented for the construction effect in our report would be larger.

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[174] https://www.gov.uk/government/publications/ukti-inward-investment-report-2013-2014/ukti-inward-investment-report-2013-2014--2

[175] Sourced from UK Office for National Statistics, rate of return is calculated as dividends divided by positions.

[176] http://www.ons.gov.uk/ons/dcp171778_351956.pdf

## 7.7 Other economic indicators

### 7.7.1 Impact on welfare

Some of the welfare gains associated with transport improvements do not impact directly on GDP. For example, environmental benefits and time savings to *leisure* travellers are not usually thought to have a direct impact on economic output, despite being clearly valued by consumers and being likely to form part of any measure of economic welfare. Other effects influence GDP, but do not directly impact welfare. For instance, a person joining the labour market will produce output and therefore increase GDP, but the welfare impact to the individual may be lower than the GDP impact since that person has to spend time commuting.

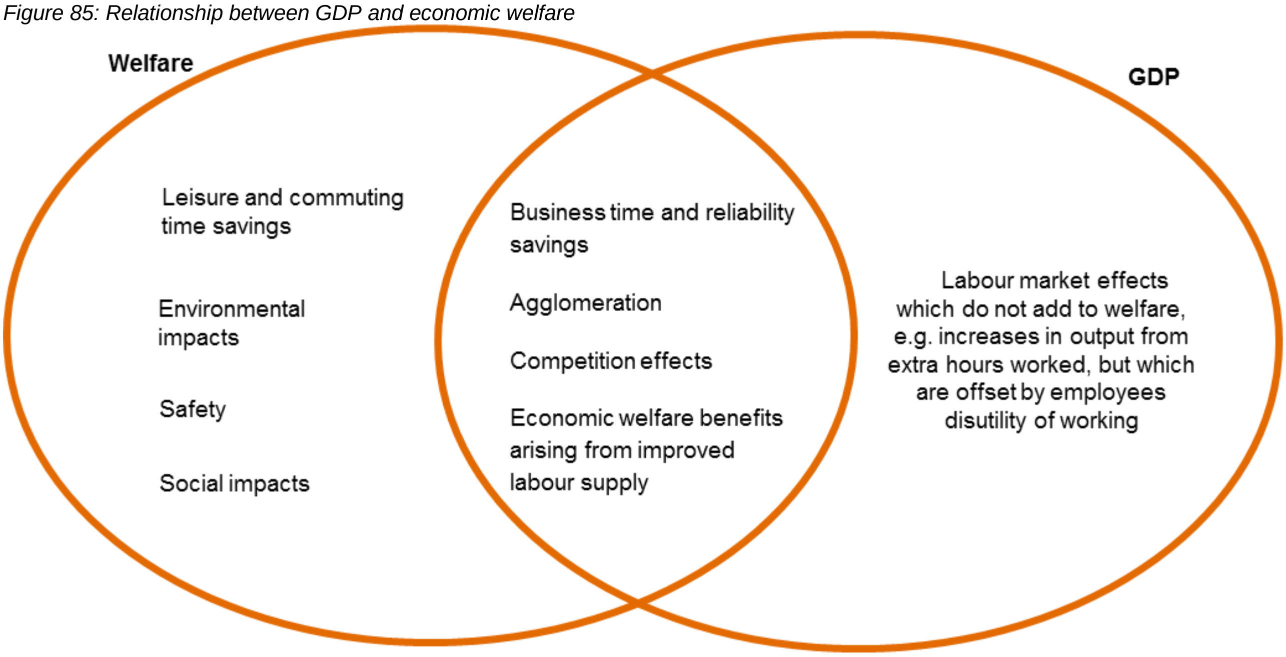
The relationship between welfare and GDP is set out in Box 17 below. Box 17 also emphasises that the welfare effects considered as part of this work are not comparable with the concept of welfare that emerges from conventional transport appraisal.

**Box 17: Relationship between welfare and GDP**

*Welfare in transport appraisal*

The Venn diagram below summarises the relationship between GDP and economic welfare at a general level, and characterises how welfare is usually regarded in conventional transport appraisal. This is taken from the DfT's *Transport, Wider Economic Benefits, and Impacts on GDP* report of 2005.

*Figure 85: Relationship between GDP and economic welfare*




*Source: PwC analysis*

In this framework, factors such as safety improvements and social impacts form part of economic welfare since they are implicitly assumed to enter households' "utility" functions. Extensive empirical evidence - summarised in WebTAG - supports the idea that households value these factors and there are well-established estimates of agents' "willingness to pay" for improvements in these variables.

*Welfare in the S-CGE framework*

In general, it is possible to incorporate these factors into a CGE framework by generalising households' utility functions to capture these effects. For the purposes of this study, however, we have not included these factors in households' utility functions. The reasons for this are to simplify the analysis and allow focus on the purely economic effects. However, this should not be taken to mean that we consider these issues to be less important.

Overall therefore, rather than capturing the welfare effects described in the Venn diagram, welfare effects in the S-CGE framework are associated with consumption of goods/services and leisure (in particular the goods and services produced by the sectors described in Chapter 4).

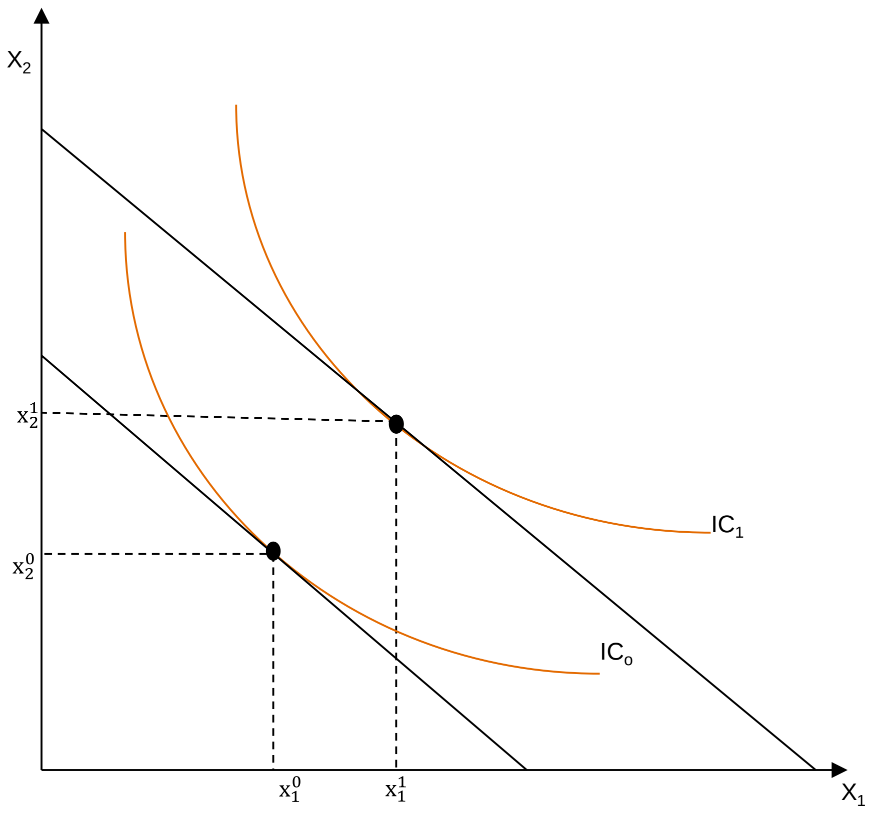
Welfare is measured in monetary terms in the S-CGE framework using the so-called "Equivalent Variation" (EV), a concept due originally to Hicks (1939). The EV is most easily explained by means of an example. Suppose that the aviation intervention results in a fall in the price of a good. This clearly gives rise to a welfare improvement to consumers. The EV is a measure of how much a consumer would be willing to pay for the welfare improvement of the price change, based on the original set of prices. We use the EV (rather than the "Compensating Variation" or CV which uses the post-expansion set of prices), because the EV is calculated using the original set of prices, which are the same across the passenger flow scenarios. Using the

EV therefore provides a like-for-like comparison. If we were to use the CV, any comparison across scenarios would be distorted by the use of different prices.

The EV is illustrated diagrammatically below. As described in Appendix B households' utility is defined as a function of both goods/services consumed and leisure time. Utility can be represented by indifference curves, which show the combinations of goods/services and leisure which deliver the same level of utility. The S-CGE model contains many goods, but to illustrate the interpretation of the EV we use just two goods, $x_1$ and $x_2$. The original level of utility (i.e. before airport expansion) is represented by $IC_o$, and point A represents the original level of consumption on the original budget constraint (which is determined by the original set of prices and income). After the effects have fed through the model, airport expansion and the resulting impacts on the economy allow households to consume more of the two goods and thus attain a higher level of utility, on $IC_1$.

The EV is calculated by taking the original set of prices (we use the original prices in order to ensure that the post-expansion results across the scenarios can be directly compared, as described above), and establishing how much more income households would need in order to increase utility to the post-airport expansion level: $EV = m_1 - m_0 = (p_1x_1^1 + p_2x_2^1) - (p_1x_1^0 + p_2x_2^0) = p_1(x_1^1 - x_1^0) + p_2(x_2^1 - x_2^0)$, where $m_0$ is the value of the consumer's consumption before airport expansion, $m_1$ is the value of the consumer's consumption after airport expansion, $p_1$ is the price of $x_1$ and $p_2$ is the price of $x_2$. This means that the welfare effect or EV can be interpreted as the change in the value of consumption as a result of the airport expansion, based on the original prices.

*Figure 86: Welfare in the S-CGE framework*




*Source: PwC analysis*

*Key issues in comparing welfare across different sources*

It is clear from the preceding discussion that the concept of welfare used in this work is different to the concept used in conventional transport appraisal. Key differences include, but are not limited to, the following:

5. We use the concept of EV to measure the change in consumer welfare, whereas many welfare analyses (e.g. that based on WebTAG) tend to use the change in consumer surplus (in general, these measures will not be the same);

6. We have adopted certain functional form assumptions (for example CES utility, which is widely used in CGE analyses) which may be different to those used in transport appraisal (for example the WebTAG analysis used to derive the TEE effects described above assumes linear demand, and therefore quadratic utility); and

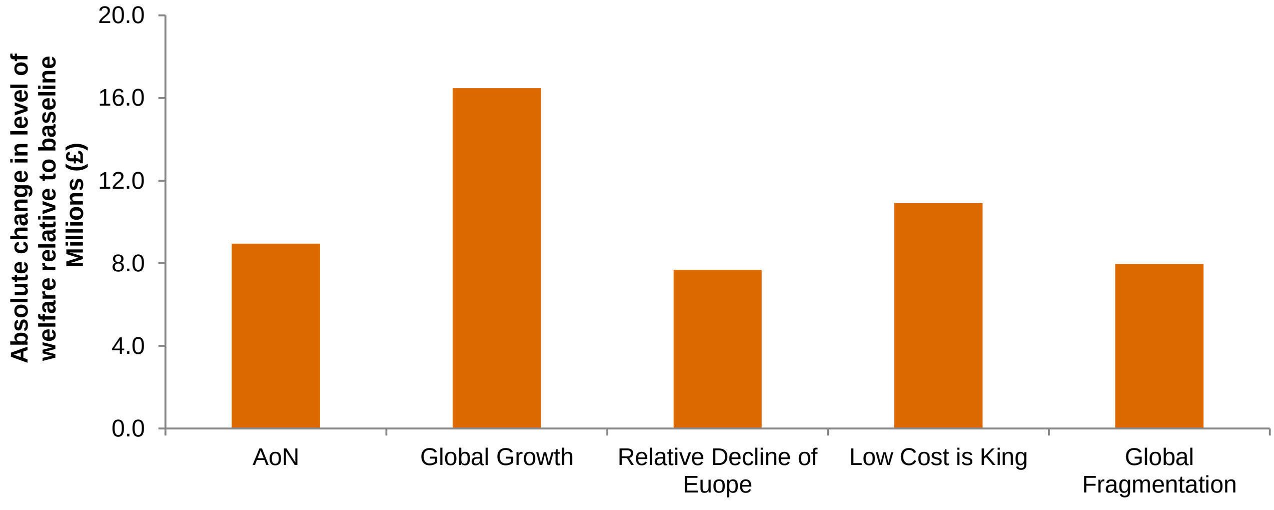
7. We capture "producer surplus" indirectly in our analysis (since households are assumed to own firms), rather than directly (the approach used in conventional transport appraisal).

As such, the welfare outputs described here should not be compared to outputs of conventional transport appraisal.

Whilst these points should be borne in mind, the results of the model to which we now turn are likely to provide a useful indication of the welfare impacts of the airport schemes. Figure 87 shows the change in annualised welfare relative to the baseline across the scenarios.

For the LHR ENR scheme, the largest forecast increase in consumer welfare is observed in the Global Growth scenario. The Low Cost is King state of the world is also associated with large welfare impacts, significantly ahead of the impacts experienced in the remaining scenarios, all of which have similar welfare impacts, according to the model. This ordering reflects the underlying assumptions about passenger flows, frequency benefits and TEE effects under these scenarios, together with the implied productivity impact – all of which ultimately help boost consumption and therefore welfare.

*Figure 87: LHR ENR change in economic welfare (EV) relative to baseline, by scenario*




*Source: PwC analysis*

## *7.7.2 Impact on employment*

The S-CGE model measures the net impact on job creation resulting from an airport scheme. Figures on the "direct" job creation at each airport scheme have been supplied to us by the AC and have been produced as part of the Local Economic Impact Assessment.

In the model baseline, UK employment grows by 0.8% per annum in line with long-run ONS population growth estimates. The labour force rises from around 28 million in 2010 to round 37 million in 2060. More details relating to this are provided in Chapter 3.  Projected changes in job figures as a result of the LHR ENR scheme are net in the sense that some sectors expand at the expense of others, since demand for different goods and services increases/ falls sectors, different sectors will be able to pay more/less wages, and this entices workers to either enter the labour market or move jobs. Other key features of the labour market in the model are:

- Workers can move between sectors and regions as these expand or contract depending on the level of economic activity. If wages rise in London & South East retail for example, then conceivably a worker from the government sector outside of this region may move into this new region and industry to gain from this wage rise;
- If workers move between sectors, it is assumed they need to retrain (e.g. an investment banker cannot become a chef overnight). The model assumes a temporary loss in productivity as people retrain and consequently their wages fall during this period. This decline in wages approximates a degree of labour market rigidity in the model;
- Current patterns of migration flows limit the flow of workers between regions; and
- The wage sensitivity of migration flows is governed by a separate elasticity parameter.

Results are given in Table 53 below and are again based on the AC's Assessment of Need scenario. The results show that LHR ENR is forecast to generate approximately 170,000 net additional jobs by 2060. A large proportion of jobs are forecast to arise in the air passenger transport and freight sector. These are largely direct jobs on or around the airport site and have been estimated in line with the AC's own assessment. The modelled overall net increase in employment associated with the LHE ENR scheme can be explained by the *employment effect* explained below:

| | |
|---|---|
| **Employment effect** | Increased productivity and profitability among UK businesses as a result of the scheme will increase demand for labour and capital, which in turn increases the returns to labour and capital. Higher wages will attract more workers into employment and unemployment will fall (with analogous effects for capital). The strength of this effect will be governed by the availability of potential workers. |

The key results from our modelling suggest that:

- There is a temporary short-term boost in construction jobs;
- The largest modelled overall net gains are observed in the manufacturing and other services sectors. These sectors are the largest in our model and are relatively more trade intensive, and are therefore forecast to gain more as a result of improved aviation links leading to increased trade. The "other services" sector includes key sectors such as financial services, telecommunications and business services. These sub-sectors are all expected to gain due to increased access to air transport enabling their overall trade volumes to increase;
- Accommodation and food services are also forecast to experience a significant increase as a result of increased domestic and foreign passenger demand;
- Other freight employment is expected to decline as there is a shift towards air freight, but these reductions are marginal.
- Public sector job effects are largely forecast to be neutral, but in the long-term the overall proportion of jobs in this sector contracts as workers are assumed to leave for higher wages in other sectors; and
- Better trade links ensure that productivity in the retail sector increases. This leads to an increase in the volume of sales, and subsequently an increase in the level of employment. This effect is small in relation to the overall size of the retail sector.

*Table 53: LHR ENR Breakdown of impact on net job creation by sector relative to baseline, Assessment of Need scenario (000's of jobs)*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and Mining** | 1.3 | 3.5 | 4.2 | 4.7 | 4.2 |
| **Manufacturing** | 29.6 | 30.7 | 45.8 | 69.8 | 75.2 |
| **Utilities** | 5.0 | 3.1 | -0.2 | -1.2 | -1.1 |
| **Construction** | 16.9 | -1.2 | -0.7 | -0.2 | -0.6 |
| **Retail and wholesale trade** | 0.6 | 1.8 | 5.9 | 7.0 | 7.5 |
| **Air passenger transport** | 2.0 | 34.3 | 45.2 | 44.9 | 48.9 |
| **Air freight** | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 |
| **Other freight** | 0.3 | -0.8 | -1.4 | -1.5 | -0.7 |
| **Other passenger transport** | 0.7 | -0.2 | -1.2 | -2.8 | -3.7 |
| **Accommodation and food services** | 5.3 | 6.4 | 8.6 | 15.5 | 9.7 |
| **Other services** | 17.6 | 20.3 | 26.1 | 33.1 | 39.8 |
| **Health, education and public spending** | 0.7 | 0.4 | 2.8 | -6.2 | -6.0 |
| **Total** | **80.1** | **98.6** | **135.4** | **163.3** | **173.7** |

*Source: PwC analysis*

### *7.7.3 Impact on number of firms*

Table 54 shows the modelled change in the number of firms by sector, as a result of the LHR ENR scheme. The S-CGE model is based on the assumption of imperfect competition, and consumers have a preference for variety in the products they purchase. Through these mechanisms, an increase in potential profits within a sector acts as a signal for new firms to enter and compete these profits away. Therefore the change in the number of firms participating within a sector can be seen as a proxy for the change in available profits as a result of the increase in capacity

Overall it can be seen that the total number of firms is forecast to remain largely unchanged. This is indicative of the fact that while the whole economy is modelled as gaining from the productivity increases and demand boosts modelled, consumers receive a disproportionate share of the gains due to the substantial increase in consumer surplus, at the expense of producer surplus. This can be specifically seen in Table 54 where the air passenger transport and freight sector, which absorbs the producer surplus reduction, is the only sector to see an expected substantial fall in the number of firms. The majority of other sectors, which experience the productivity benefits of cheaper air passenger transport, are expected to exhibit higher total profits which encourage new entrants into the market. The results presented below demonstrate that firms in the air passenger transport sector are expected to respond to the reduction in available operating surplus through consolidation in order to retain the economies of scale required to remain competitive and achieve an appropriate margin. Section 8.5.1 outlines an alternative possible equilibrium whereby firms do not consolidate, but instead maintain margins through reductions in investment, therefore leading to long-term relative price increases. The loss of efficiency implied by this alternative behaviour means that this is a lower long-term growth scenario at a national level.

*Table 54: LHR ENR Change in number of firms by sector relative to baseline, Assessment of Need Scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and Mining** | 0.3% | 0.1% | 0.4% | 0.4% | 0.4% |
| **Manufacturing** | 0.5% | 0.5% | 0.7% | 0.7% | 0.7% |
| **Utilities** | 0.1% | 0.0% | 0.3% | 0.4% | 0.4% |
| **Construction** | 3.3% | -1.4% | 0.0% | 0.0% | 0.0% |
| **Retail and wholesale trade** | 0.1% | -0.3% | -0.3% | -0.3% | -0.3% |
| **Air passenger transport and freight** | 1.4% | -0.2% | -1.0% | -1.8% | -1.4% |
| **Other freight** | -0.1% | -0.2% | -0.2% | -0.2% | -0.2% |
| **Other passenger transport** | -0.1% | -0.1% | -0.1% | -0.1% | -0.1% |
| **Accommodation and food services** | 0.0% | 0.2% | 0.3% | 0.3% | 0.3% |
| **Other services** | 0.1% | -0.4% | -0.2% | -0.1% | -0.1% |
| **Health, education and public spending** | 0.2% | 0.0% | -0.2% | -0.2% | -0.2% |
| **Total** | **0.5%** | **-0.3%** | **-0.1%** | **0.0%** | **0.0%** |

*Source: PwC analysis*

Table 55 shows the projected house price impacts for the LHR ENR scheme. During the construction phases, there is expected to be a very small increase in house prices – mainly in London & South East – as a result of higher demand, for example from construction workers. By the end of the period, the model suggests a reduction in house prices, relative to the baseline scenario. However, across the three regions, the reduction is so small as to be negligible (much less than 1% in all regions). This is due to a diversion of investment activities by households – instead of investing in homes in the rental market, a larger proportion of their investment portfolio will be invested in UK businesses as returns to business investment rise following the expansion in GDP. This puts a small amount of downward pressure on house prices.

*Table 55: LHR ENR Real house price impact relative to baseline, Assessment of Need scenario (baseline = 100)*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **London & South East** | 100.12 | 99.94 | 99.85 | 99.85 | 99.86 |
| **Rest of England** | 100.09 | 99.95 | 99.85 | 99.84 | 99.87 |
| **Rest of the UK** | 99.87 | 99.89 | 99.94 | 99.95 | 99.97 |

*Source: PwC analysis*

## *7.7.4 Impact on net taxes*

Table 56 shows the net tax impacts for the LHR ENR scheme. During the construction phases, there is a small but significant increase in net taxes as a result of higher incomes, for example from construction workers and firms.

The initial impact, during the construction phase, is large, at £ 5.8 bn in 2020 (0.21% of baseline net taxes). There is a decline in the impact, in relative terms, in the operational phase. The change in net tax in 2030 is £3.4 bn in 2030 (0.09% of baseline net tax) and this increases to £7.0 bn in 2060 (but is still only 0.08% of baseline net tax).

*Table 56: LHR ENR Change in net taxes relative to the baseline, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| **Total UK impact (£ mn)** | 5,888 | 3,394 | 4,124 | 4,063 | 6,925 |
| **UK impact (% of net tax in baseline)** | 0.21% | 0.09% | 0.09% | 0.06% | 0.08% |

*Source: PwC analysis*

## 7.8 Testing the results – sensitivity analysis

### 7.8.1 Systematic sensitivity analysis

The S-CGE model is based on assumptions for a range of elasticities. Systematic Sensitivity Analysis (SSA) is a method of testing the influence of the model elasticities on the results. This is carried out using Monte Carlo analysis, the steps of which are outlined in Box 18 below.

The results of the Systematic Sensitivity Analysis are shown in Figure 88 below. The average difference between the central estimate and each of the upper and lower bound estimates is between 0.05 and 0.1% of GDP. This range defines the confidence interval for the degree to which different modelling assumptions could generate different results. Any variation outside of this could only be driven by changes in the model inputs. This range remains reasonably constant throughout the period studied, demonstrating that the time profile of the impacts is determined primarily by the time profile of the inputs, rather than assumptions made during the modelling.

## Box 18: Systematic Sensitivity Analysis

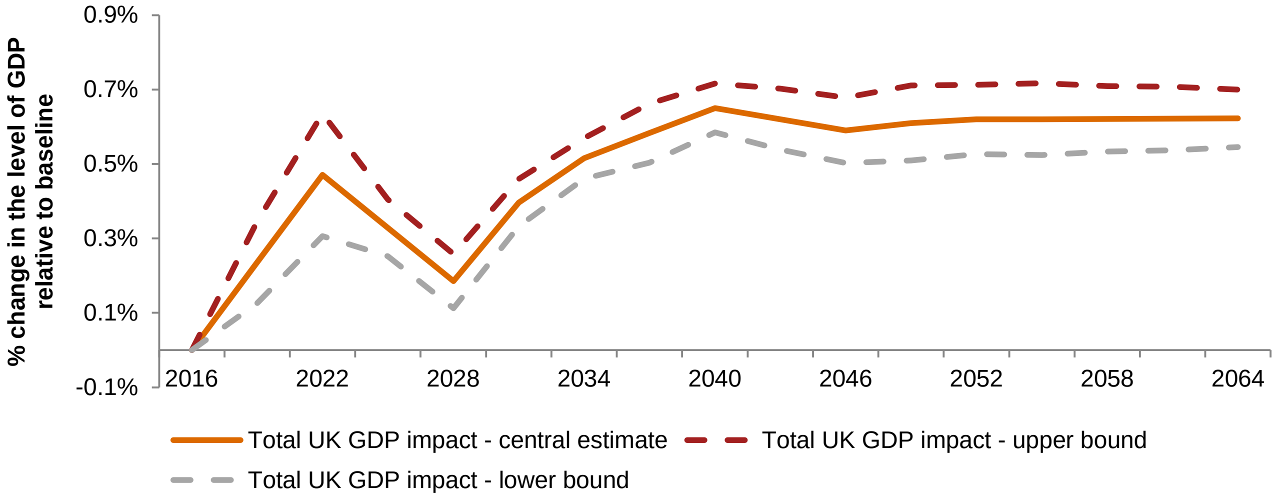
- First, we specify a range for each of the elasticities in the model. These ranges are based on the estimated values in academic literature. These are shown in Table 57;
- We then generate a value for each elasticity by randomly sampling from within the corresponding specified ranges. We assume that each elasticity is uniformly distributed within the specified range, i.e. any value within the range is equally likely to be selected;
- We then solve the model for each combination of elasticities, and calculate the impact on the UK economy. This is repeated for 100 randomly generated combinations of elasticities; and
- Finally, the model results are then aggregated for all 100 combinations, and these are then expressed in the form of *95% confidence intervals*, i.e. the upper- and lower-bounds within which the result can be expected to lie 95 times out of 100.

*Table 57: Specified ranges for elasticities varied in the SSA*

| Parameter | Description | Central Range | Para |
|---|---|---|---|
| **Price elasticity of inbound passenger flows** | Change in inbound passenger expenditure with a change in domestic price levels in all regions | 1.1897 (+/- 0.3) | Price |
| **Price elasticity of outbound passenger flows** | Change in outbound passenger expenditure with a change in domestic price levels in all regions | 1.3825 (+/- .77) | Price |
| **Elasticity in the main passenger flows nest** | Change in passenger expenditure across products with a change in relative prices | 0.5 (+/- 0.25) | Elast |
| **Elasticity in day visits nest – between regions** | Change in inbound day-visit passenger expenditure between regions with a change in price levels between regions | 1 (+/- 0.25) | Elast |
| **Elasticity in domestic passenger nest – between regions** | Change in total inbound passenger expenditure between regions with a change in price levels between regions | 1 (+/- 0.25) | Elast regio |
| **Elasticity in overseas passenger nest – between modes** | Change in outbound day-visit passenger expenditure between regions with a change in price levels between regions | 1 (+/- 0.25) | Elast mode |
| **Inter-temporal elasticity of substitution** | Change in consumption and saving patterns over time with a change in interest rates | 0.2 (+/- 0.05) | Inter- |
| **Elasticity between labour and leisure** | Change in labour supply with a change in wages | 0.5 (+/- 0.125) | Elast |
| **Elasticity between products in utility** | Change in the composition of households consumption basket with a change in relative prices | 1 (+/- 0.05) | Elast |
| **Elasticity of unemployment to real wages** | Change in unemployment rates with a change in real wages | 0.2 (+/- 0.4) | Elast |

The results of the Systematic sensitivity analysis are shown in Figure 88 below.

*Figure 88: LHR ENR – Systematic Sensitivity Analysis results, Assessment of Need scenario*



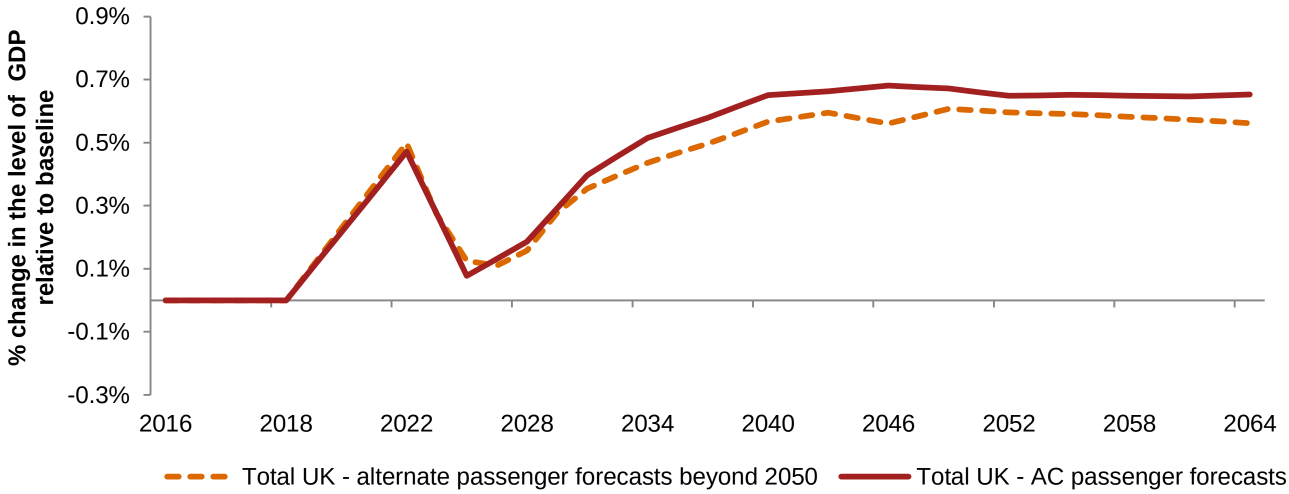

*Source: PwC analysis*

## 7.8.2 Testing the effect of alternative passenger numbers forecasts beyond 2050

The AC demand forecasts provide passenger numbers estimates beyond 2050 based on an extrapolation of underlying trends in the previous years. We test the impact of this assumption by using alternate passenger number estimates beyond 2050, i.e. where we assume that passenger numbers beyond 2050 grow at the same rate as the baseline, i.e. the "do minimum" scenario.

Figure 89 below presents the results based on the two different model assumptions. The average difference in the GDP impact in the 14 year period from 2050 to 2064 between the original forecasted GDP impact and the GDP impact estimated with the alternate passenger numbers is 0.2%. Note that this difference begins to manifest in 2040, when the passenger numbers begin to differ only in 2050. This is because the forward-looking agents in the model begin to make adjustments in their spending and investment patterns ahead of any change in passenger numbers, and therefore in this alternate scenario, the lower passenger numbers from 2050 onwards has a lower impact on GDP in the previous years.

*Figure 89: LHR ENR –Testing the effect of alternate passenger numbers forecasts beyond 2050, Assessment of Need scenario*




*Source: PwC analysis*

## 7.8.3 Testing passenger additional spending assumptions

In this section, we consider the sensitivity of the results of our analysis to changes in the following assumptions:

- the split between inbound and outbound passenger flows; and
- expenditure per passenger per visit.

These assumptions impact on the results of the modelling (particularly GDP) through Effect 1: Passenger flow expenditure. The other three effects do not change in response to changes in these assumptions[177].

The next sub-section sets out the original assumptions in respect of the inbound-outbound passenger flow split and the revised assumptions made for the purposes of the sensitivity analysis. We then consider the original assumptions on expenditure per passenger and the revised assumptions made for the sensitivity analysis. Finally we present the results of the sensitivity analysis.

All assumptions tested in this section relate to changes to the inputs to the S-CGE model that have been provided by the Airports Commission, rather than any changes to the S-CGE model itself.

*Inbound-outbound passenger flow split*

The passenger flow expenditure effect in the S-CGE model is driven by, amongst other things, the relative size of the spending of UK residents abroad (which reduces UK GDP) and foreign residents' spending in the UK (which increases GDP in the UK). In turn, inbound expenditure is driven by inbound passenger flow numbers and outbound expenditure is driven by outbound passenger flows.

The AC provided us with total passenger flow data under different airport expansion options and scenarios, but did not provide a forecast into whether these passengers are inbound or outbound. In order to assess the passenger flow expenditure effects, it is therefore necessary to make assumptions about the balance between inbound and outbound passenger flows.

For our main analysis we agreed with the AC that the growth of inbound and outbound passengers (and their associated spending) for each scheme should be assumed to be proportional to the existing inbound-outbound split for the relevant airport (specifically the levels in 2011). For example, if the inbound-outbound split at the relevant airport was 60%-40% in 2011, and that the number of passengers were forecast to grow by 10m, inbound passenger growth would be assumed to be 6m and outbound growth would be assumed to be 4m. Mathematically, this means that growth across the UK airports system in inbound passenger numbers is assumed to be:

$$inbound_t = (H_t - H_0)h_0 + (G_t - G_0)g_0 + (R_t - R_0)r_0$$

where $H_t$ is total passenger numbers at Heathrow in period $t$, $h_0$ is the inbound passenger share at Heathrow in the base year, $G_t$ is total passenger numbers at Gatwick in period $t$, $g_0$ the inbound passenger share at Gatwick in the base year, $R_t$ is total passenger numbers at all other UK airports in period $t$, and $r_0$ is the inbound passenger share at all other UK airports in the base year. The subscript *0* represents the base year in all cases. Outbound passenger numbers are simply the difference between total and inbound passenger numbers. Data from the CAA and the International Passenger Survey was used to calculate the current inbound-outbound split at UK airports.

Alternative assumptions could be made to capture, for example, a more even distribution of growth between inbound and outbound passengers across airports (rather than relying on the current split at each airport). Therefore, the AC have asked us to perform a sensitivity test in which each UK airport's inbound-outbound split

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[177] Note, in particular, that Effect 2: Productivity is not affected by these sensitivity tests under the modelling approach we have adopted. This is because, as noted in Chapter 3, the econometric relationship which underpins the productivity effect is based on the relationship between total passenger numbers (as opposed to inbound or outbound flows) and international trade volumes. We consider that it is appropriate that the econometric relationship is estimated on the basis of total passenger numbers since productivity effects are likely to be experienced as a result of both UK residents travelling abroad (for example, UK residents may learn from suppliers, customers, and/or competitors when outside of the UK) and foreign residents travelling to the UK (for example, foreign residents may share knowledge and/or technology with UK individuals and firms during visits to the UK).

is proportional to the inbound-outbound split of London-system airports taken together. The AC have asked us to test this assumption in order to see how results might change as a result, it is not based on any evidence or forecasts which suggests that this might be likely in the future. Specifically, this asked us to look at the effects of assuming that the growth of inbound and outbound passengers (and their associated spending) at all airports is proportional to the existing inbound-outbound split across Heathrow, Gatwick and Stansted airports combined, the largest three London airports[178]. Mathematically, this means that growth across the UK airports system in inbound passenger numbers is assumed to be,

$$inbound_t = \{(H_t - H_0) + (G_t - G_0) + (R_t - R_0)\}a_0 = (A_t - A_0)a_0$$

where $A_t$ is total passenger numbers across the UK airport system and $a_0$ is the inbound-outbound split across Heathrow, Gatwick and Stansted airports.

The inbound share $a_0$ is based on International Passenger Survey data and is estimated to be 42%. This means that it is assumed that inbound passenger growth at all airports individually (and across the system as a whole) is 42% of forecast total passenger growth.

This sensitivity analysis is designed to test how the results change with different assumptions – it is not suggested that this is a realistic scenario for future development. The results of the S-CGE modelling using this alternative assumption are set out in the results sub-section below.

*Passenger spending assumptions*

Another key determinant of the passenger flow expenditure effect in the S-CGE model is expenditure per passenger per visit (both inbound and outbound). Expenditure per passenger per visit has been estimated on the basis of ONS/TSA data, presented in the tables below.

For the original analysis presented in the main document, it was agreed that expenditure per passenger per visit would be calculated for each world region (Europe, Asia, North America and Others) as follows:

- take spend per visitor per day across all regions (i.e. a single global average); and
- multiply by the average length of visit (in days) for each region.

This exercise was undertaken in respect of inbound and outbound trips separately. Under this approach, differences in spending by passengers from different world regions are captured by how their lengths of stay differ. Importantly, this approach was applied in respect of *each* expenditure category[179] allowing us to model *where* in the economy the expenditure of inbound visitors takes place. This is in keeping with the S-CGE framework, which recognises that 'where' expenditure takes place in the economy matters, as well as the overall level of expenditure (the model recognises this by acknowledging that different sectors interact with other parts of the economy through backward linkages in different ways). This approach allows us to preserve detail of the TSA/ONS data and avoid losing the nuances contained within it. We felt this to be the most appropriate approach after careful consideration of the TSA data.

Another approach is to calculate expenditure per passenger per visit for each world region such that it also reflects differences in average expenditure *per day* across different geographies. At the request of the AC, we have therefore run a sensitivity test in which expenditure per passenger is calculated for each world region as follows:

[178] We have used the share across Heathrow, Gatwick and Stansted since data is only available for these airports (data is unavailable for London Luton and London City airports). These three airports account for more than 90% of London-system and therefore likely provide a reasonable representation of the London-system split.

[179] The expenditure categories are: agriculture, forestry and fishing; mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply; water supply, sewerage, waste management and remediation activities; construction; wholesale and retail trade, repair of motor vehicles and motorcycles; passenger transport (exc. air passengers); accommodation and food service activities; information and communication; financial and insurance activities; real estate activities; professional, scientific and technical activities; public administration and defence, compulsory social security; education; human health and social work activities; arts, entertainment and recreation; other service activities; activities of households as employers, undifferentiated goods and services; air freight; all other freight; air passenger transport; and overseas expenditure.

- take spend per visitor per day across each region individually (note the difference compared to the original assumption);
- multiply by the average length of visit (in days) for each region; and
- apply the expenditure proportions from the TSA/ONS data.

These tables demonstrates the substantial differences between regions. These are primarily driven by differences in length of visit (with passengers travelling further typically visiting for longer), with some additional variation occurring due to differences in average spend per day. The high spend by visitors from 'Other' countries is largely driven by passengers arriving from the Middle East.

*Table 58: Regional spending - inbound passengers*

| | Europe | Asia | North America | Others |
|---|---|---|---|---|
| **Average spend per visit** | £448.1 | £1,393.4 | £871.6 | £1,367.0 |
| **Average length of visit (days)** | 5.9 | 16.7 | 8.3 | 12.8 |
| **Average spend per day** | £75.8 | £83.7 | £104.8 | £106.5 |

*Source: ONS/TSA, PwC analysis*

*Table 59: Regional spending – outbound passengers*

| | Europe | Asia | North America | Others |
|---|---|---|---|---|
| **Average spend per visit** | £452.7 | £1,008.2 | £1,119.7 | £945.5 |
| **Average length of visit (days)** | 7.9 | 26.3 | 14.0 | 18.0 |
| **Average spend per day** | £57.0 | £38.3 | £80.2 | £52.6 |

*Source: ONS/TSA, PwC analysis*

The key difference, therefore, between this alternative assumption and the original assumption is that:

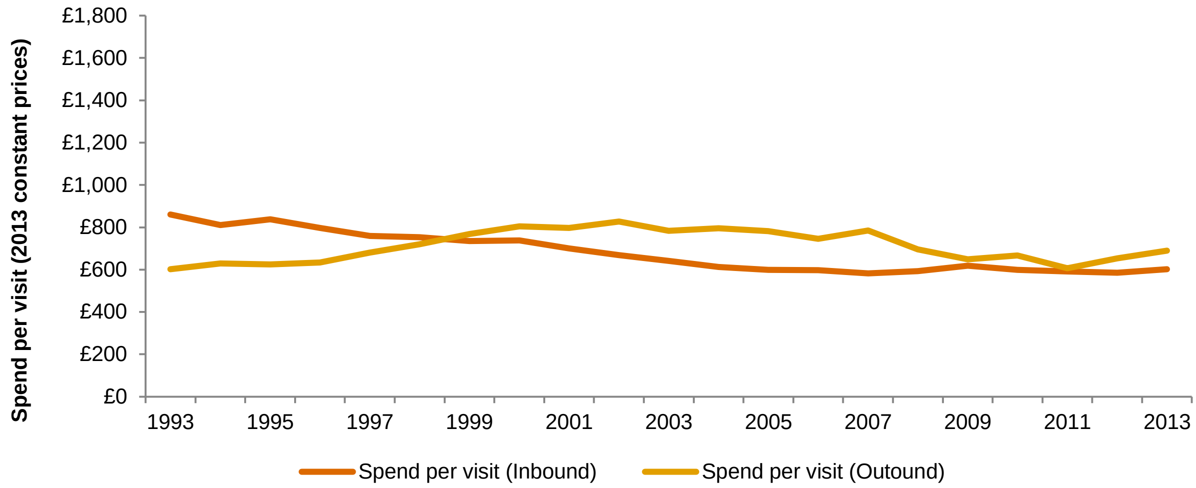
- this alternative approach captures differences in average spend across geographies, but does not fully capture spending differences across product categories; whereas
- the original approach captures differences in average spend across product categories, but does not fully capture differences in average spend across geographies.

Note that these assumptions are strictly alternatives to one another. The results of the S-CGE modelling from adopting this alternative assumption are set out in the results sub-section below. As explained in detail later, the choice of assumption does not have a significant impact on the expenditure inputs that are incorporated into the model, or the resulting GDP impacts.

Finally, we note that the AC has asked us to assume that passenger spend per visit is constant in real terms over the time period under consideration. While it is possible that passenger spend per visit could rise as populations become wealthier, this does not appear to be consistent with the evidence. For example, Figure 90 below shows real inbound and outbound passenger spend per visit since 1993. Between 1993 and 2013, inbound spend per visit actually fell by a third in real terms (despite strong global absolute and per-capita income growth). Outbound spend in 2013 was similar to its 1993 level in real terms (whilst the late 1990s saw moderate growth, the figures subsequently fell back).

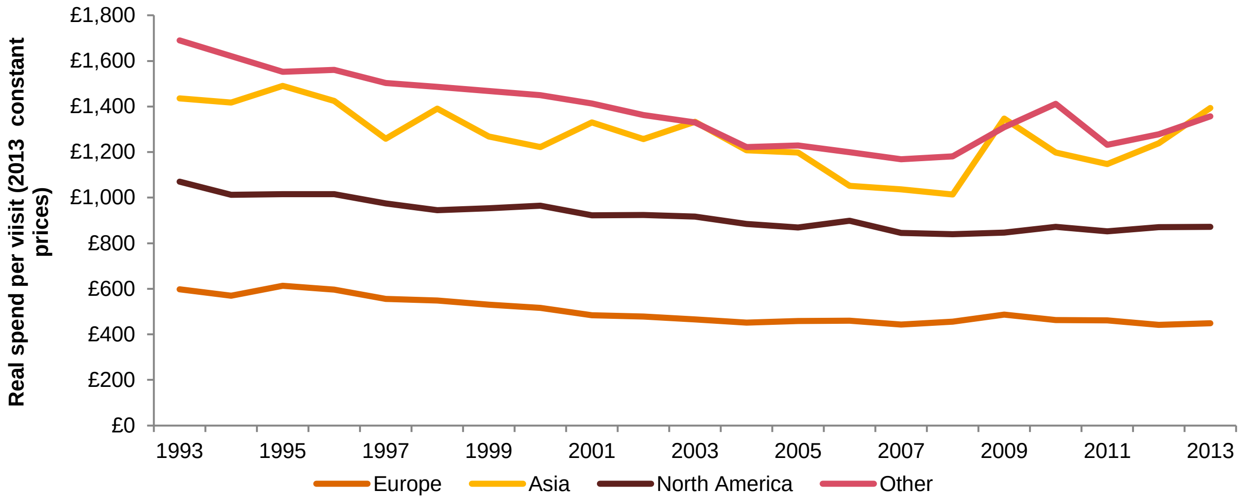
The reasons for the decline in inbound spend per visit could include the growth of low-cost air travel within Europe which may have provoked more frequent, but potentially shorter, trips involving less expenditure. This is borne out by the evidence in Figure 91, which shows a decline in real spend per visit among European inbound passengers. Similarly, lower airfares may have opened opportunities for travel among less affluent passengers, who may spend less during their visits.

*Figure 90: Real spend per visit, inbound and outbound visitors (2013 constant prices)*




*Source: ONS, PwC analysis*

*Figure 91: Real spend per visit by region, inbound visitors (2013 constant prices)*



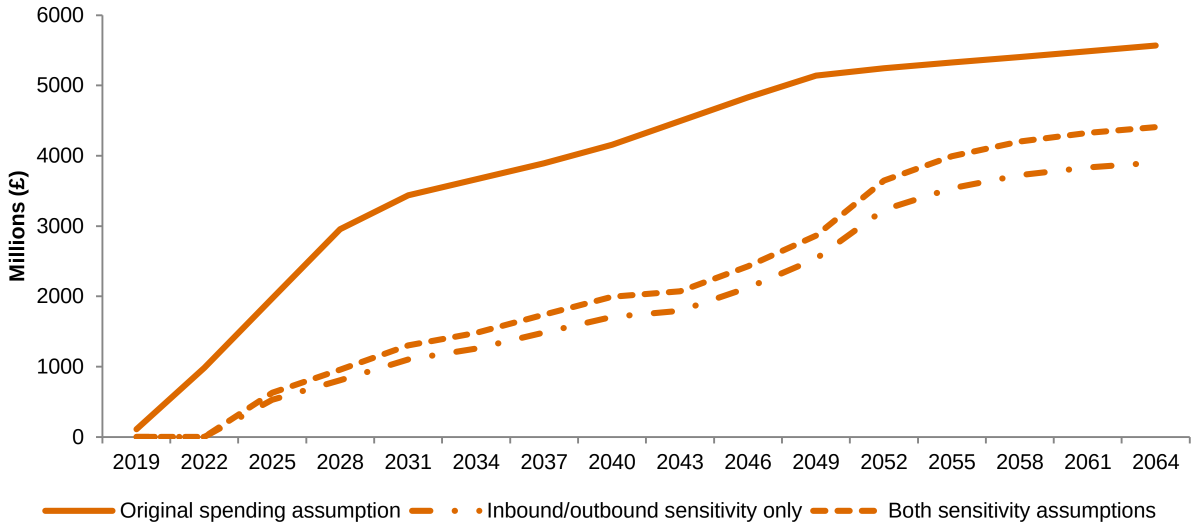

*Source: ONS, PwC analysis*

*Results of the sensitivity*

The charts below demonstrate the impact of the above sensitivity analysis on the overall GDP impact of the LHR ENR scheme, under the Assessment of Need, Low Cost is King and Global Fragmentation scenarios.

*Assessment of Need*

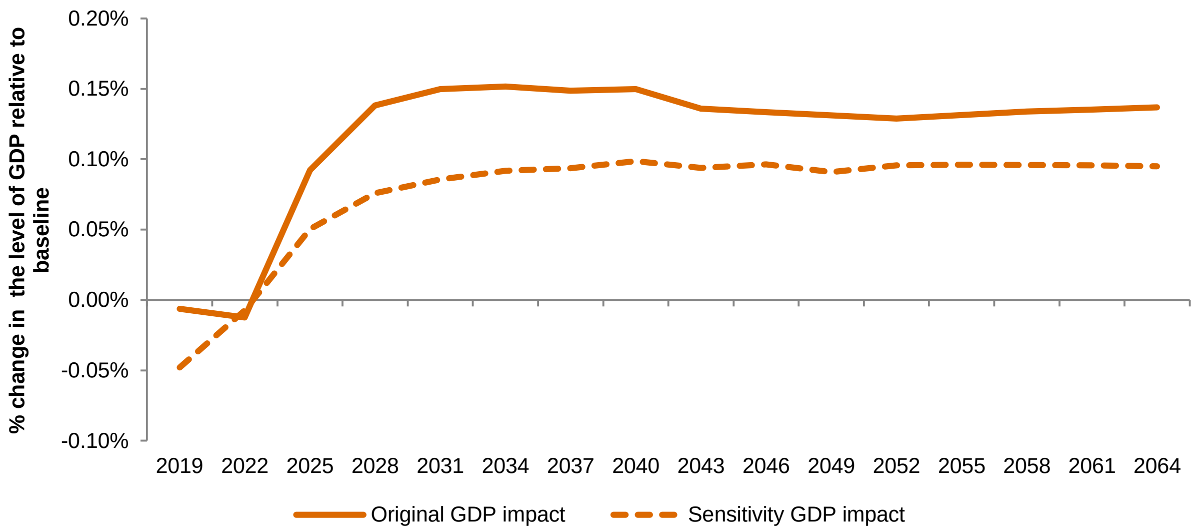
*Figure 92: LHR ENR - Impact of sensitivity assumptions on net additional passenger spending in the UK, Assessment of Need*




*Source: PwC analysis*

Figure 92 shows the impact of the sensitivity assumptions on net passenger spending in the UK for the Assessment of Need scenario. This chart demonstrates a decrease in net additional passenger spending, the majority of which is as a result of the change in assumed inbound/outbound passenger mix.

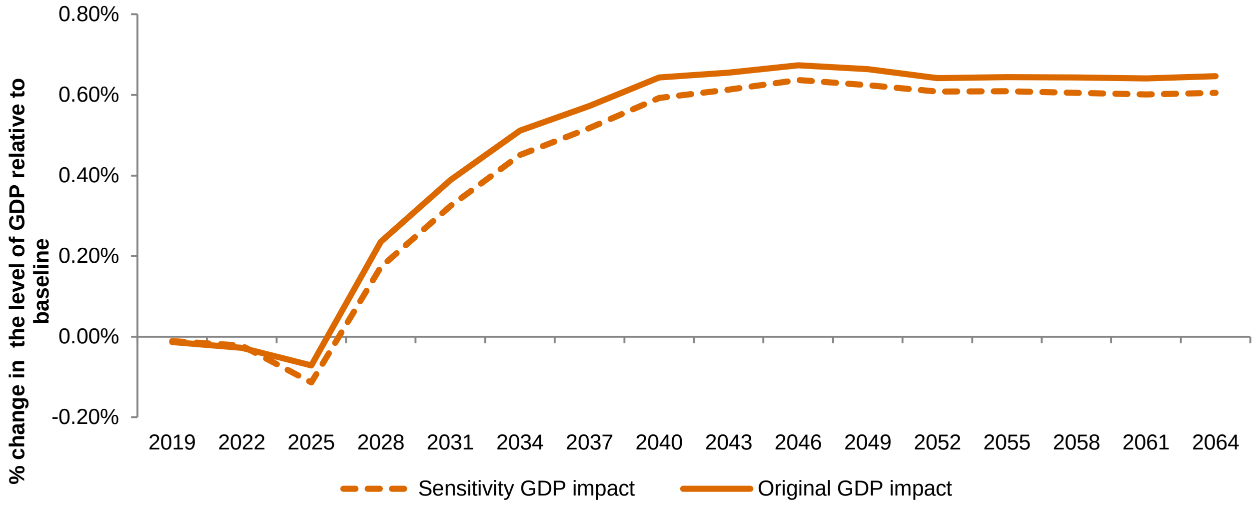
*Figure 93: LHR ENR – Comparing the GDP impact of just the passenger flow effect under different spending assumption, Assessment of Need*




*Source: PwC analysis*

Figure 93 shows how the passenger spend sensitivity affects the GDP impact of the corresponding passenger flow effect (as opposed to the GDP results that combine all effects). The original passenger spending assumptions lead to a positive GDP impact for the majority of the period studied (see Figure 63 in Section 7.4.3.1 for the original result). The result of the sensitivity analysis is for there to be a lower positive impact on the level GDP. The magnitude of the impact grows throughout most of the period studied, before remaining relatively constant at roughly 0.1% of GDP from 2050. The impact of the sensitivity reflects the sensitivity's fall in the proportion of inbound passengers, who contribute positively to the UK economy (and conversely the increase in outbound passengers).

*Figure 94: LHR ENR – Comparing the overall GDP impact under different spending assumptions, Assessment of Need*

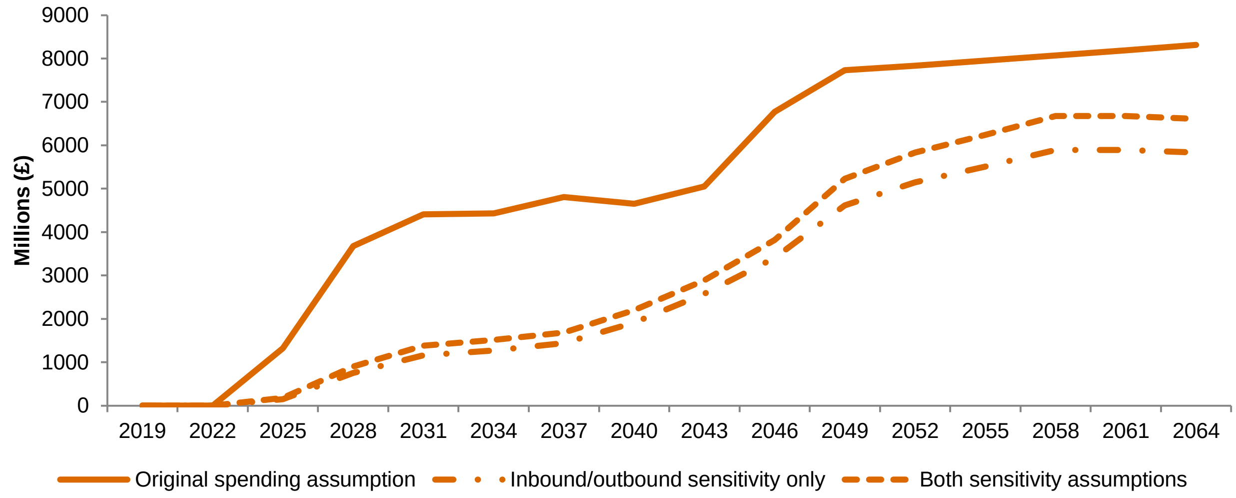



*Source: PwC analysis*

Figure 94 provides the results of this sensitivity test on the overall impact of the LHR ENR scheme, under the Assessment of Need scenario. This impact is relatively insignificant, with the lower GDP impact of the passenger flow effect propotionately affecting the overall GDP impact throughout the time period, by around 0.05%. The sensitivity test does not materially impact on the time profile of the economic impact of the scheme, which rises most substantially between 2040 and 2050 as the expanded airport reaches capacity.

*Low Cost is King*

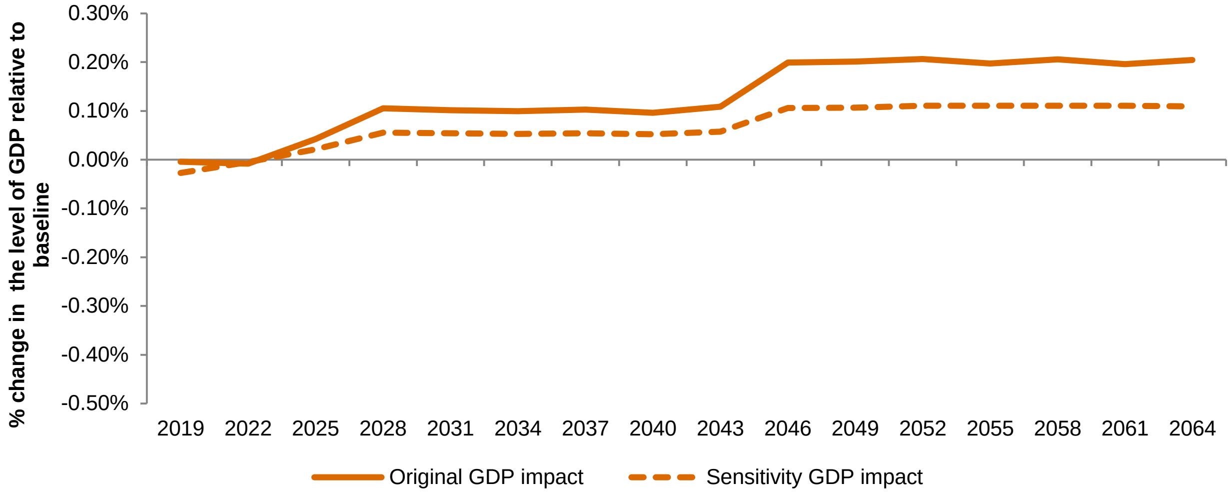
*Figure 95: LHR ENR - Impact of sensitivity assumptions on net additional passenger spending in the UK, Low Cost is King*




*Source: PwC analysis*

We also applied the sensitivity assumptions to the Low Cost is King passenger scenario, the scenario which leads to the greatest increase in passenger flow. Figure 95 shows the impact of the sensitivity assumptions on net passenger spending in the UK. This chart demonstrates that the majority of the decrease in spending is a result of the change to the assumed inbound/outbound passenger mix.

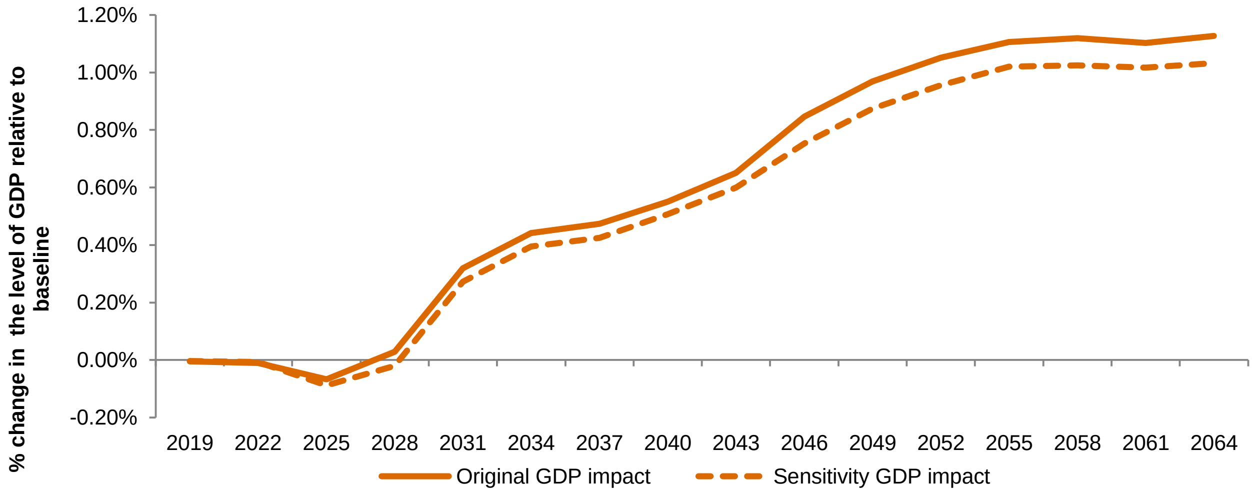
*Figure 96: LHR ENR – Comparing the GDP impact of just the passenger flow effect under different spending assumption, Low Cost is King*




*Source: PwC analysis*

Under this sensitivity, the impact on GDP is positive throughout the period studied. However, the sensitivity has a lower impact on the level of GDP; with the difference between the baseline passenger assumption and the sensitivity diverging over time, so that by the end of the time period the level of GDP is around 0.1% lower. This is predominantly driven by the greater number of outbound passengers. The time profile of the impact is similar to before.

*Figure 97: LHR ENR – Comparing the overall GDP impact under different spending assumptions, Low Cost is King*

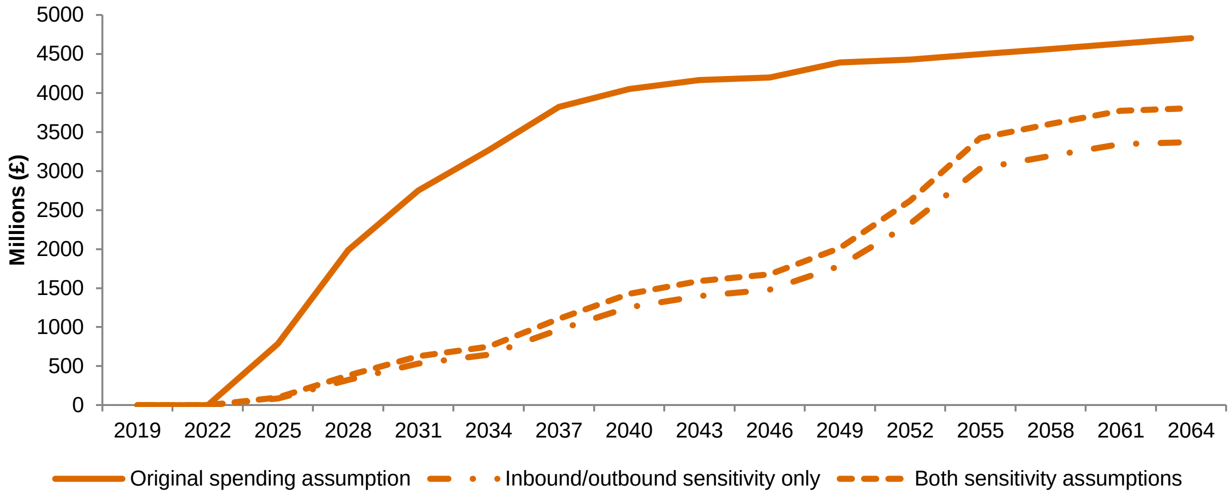



*Source: PwC analysis*

As with the Assessment of Need passenger scenario, the sensitivity does not have a significant impact on the economic impact of the additional capacity. Figure 97 shows the effect of the sensitivity on the aggregate GDP result. In the long run, the forecast impact on GDP is now around 00.1% lower. The negative impact on GDP in the 2020s (that was present in the original GDP impact, due to the sudden increase in outbound passengers) is slightly more prolonged.

*Global Fragmentation*

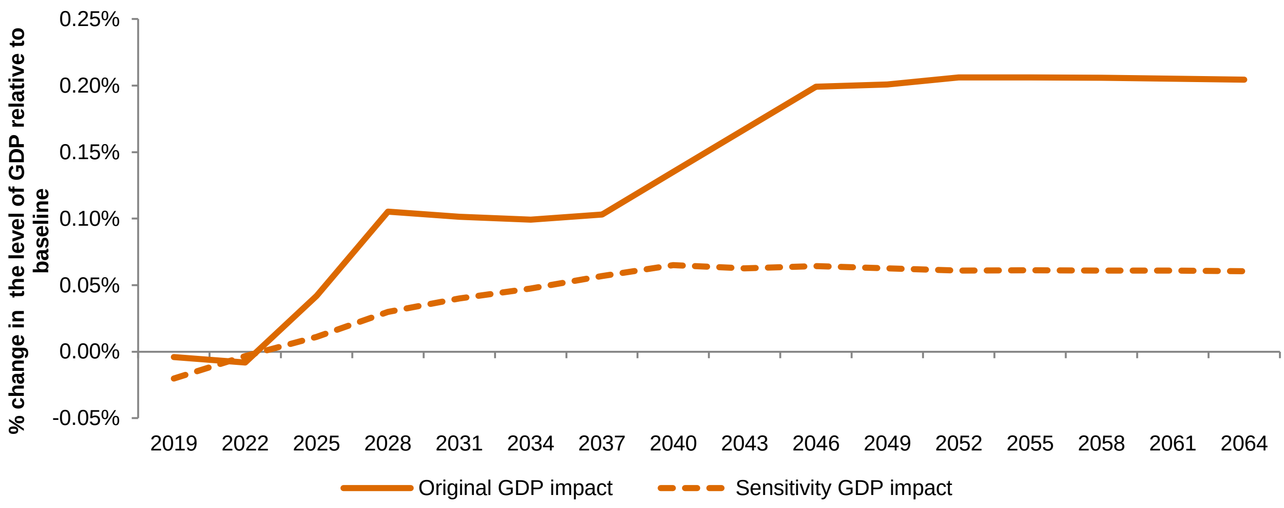
*Figure 98: LHR ENR - Comparing the GDP impact of just the passenger flow effect under different spending assumption, Global Fragmentation*




*Source: PwC analysis*

Figure 98 shows the impact of the sensitivity on net passenger spending in the UK, under the Global Fragmentation passenger flow scenario. As shown in Section 8.4.3.1, the incremental number of passengers under the LHR ENR scheme is lowest under the Global Fragmentation scenario. This chart demonstrates that the majority of the increase in GDP is due to the assumed change in the inbound/outbound passenger mix.

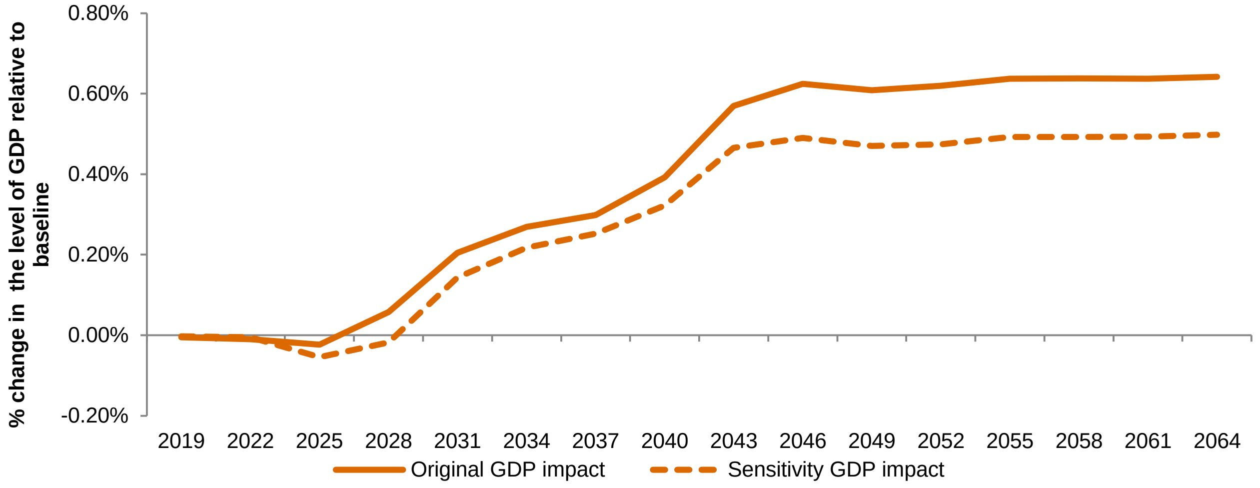
*Figure 99: LHR ENR – Comparing the GDP impact of just the passenger flow effect under different spending assumption, Global Fragmentation*




*Source: PwC analysis*

Figure 99 shows the GDP impact of just the passenger flow effect, under the original and revised sensitivity assumptions. The impact of the sensitivity is at its largest in this scenario, reducing the level of GDP forecast by around 0.15% bye end of the time period. The impact is still positive, with the exception of the initial years, but the time profile differs.

*Figure 100: LHR ENR Comparing the overall GDP impact under different spending assumptions, Global Fragmentation*




*Source: PwC analysis*

The sensitivity has a proportionately lower impact on the overall impact of the LHR ENR scheme on GDP. Under the sensitivity, this impact reaches 0.5% of GDP towards the end of the period studied, compared to 0.64% under the original assumptions. These values are calculated based on a 60 year appraisal period starting 2019.

*Table 60: LHR ENR – Present Value of real GDP impacts, by effect and scenario with and without sensitivity (£bn, 2014 prices)*

| | Assessment of Need | Low Cost is King | Global Fragmentation |
|---|---|---|---|
| **Passenger Flows** | 28.3 | 33.3 | 34.8 |
| ***Passenger Flows (Sensitivity)*** | *16.2* | *15.5* | *9.9* |
| **Productivity** | 61.7 | 62.2 | 45.6 |
| **Frequency Benefits** | 5.6 | 9.4 | 4.1 |
| **TEE** | 22.6 | 63.8 | 17.4 |
| ***Total*** | ***118.3*** | ***168.6*** | ***101.8*** |
| **Total (Sensitivity)** | **106.2** | **150.9** | **76.9** |

*Source: PwC analysis*

Table 60 summarises the impact which the sensitivity test has on the PV of the impact of the scheme. This is again shown to be significant, particularly under the Global Fragmentation passenger flow scenario, where the PV of the economic impact is reduced by around £25bn. The sensitivity reduces the total PV under all scenarios. These results show that the inbound/outbound passenger mix is an important driver in determining the economic impact of the scheme, previously outlined in Section 8.4.3.1.

## *7.8.4 Testing the TEE effect with business passengers only*

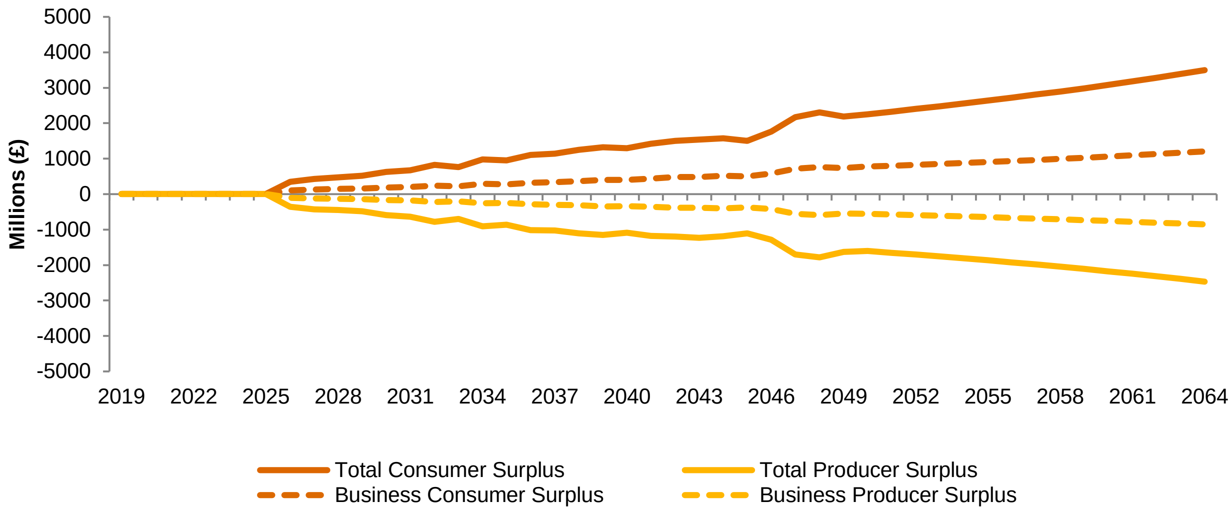
The TEE effect reflects the impact of the expansion in airport capacity on airfares. Specifically, the AC demand forecasts assume that the cost of air travel falls as capacity at Heathrow increases. This results in a transfer of money from producers (airlines) to consumers (air passengers). Scarcity rents which producers charge for use of the airport when it was capacity constrained are reduced, leading to benefits for consumers through lower cost of travel. For business passengers, the lower airfares result in a productivity boost, which plays through the wider economy through the transmission mechanisms outlined in Appendix D. For leisure passengers, this translates into an income effect i.e. a cash transfer back to households that can be spent or saved.

Previously, we have modelled the impact of changes in producer and consumer surplus for all passengers (passengers travelling for both business and leisure purposes), allowing us to understand the full effect of the transfer from producers to consumers as a result of the increased capacity. We test the impact of this assumption by modelling the impact of changes in producer and consumer surplus relating only to business passengers. This allows us to isolate the direct economic impact on the supply side of the economy. For the Assessment of Need scenario, this section presents:

- the changes in inputs as a result of considering business passengers only;
- the subsequent GDP impact for the TEE effect; and
- the overall GDP impact of LHR ENR scheme (all effects combined).

Figure 101 below summarises the producer and consumer surplus inputs for the TEE effect. The solid lines show the original inputs used, which relate to both business and leisure types of passengers. The dotted line shows the inputs when considering only business passengers. Business passengers represent a smaller proportion of total passengers than leisure passengers. Consequently, by the end of the time period both consumer and producer surplus inputs are around 66% lower.

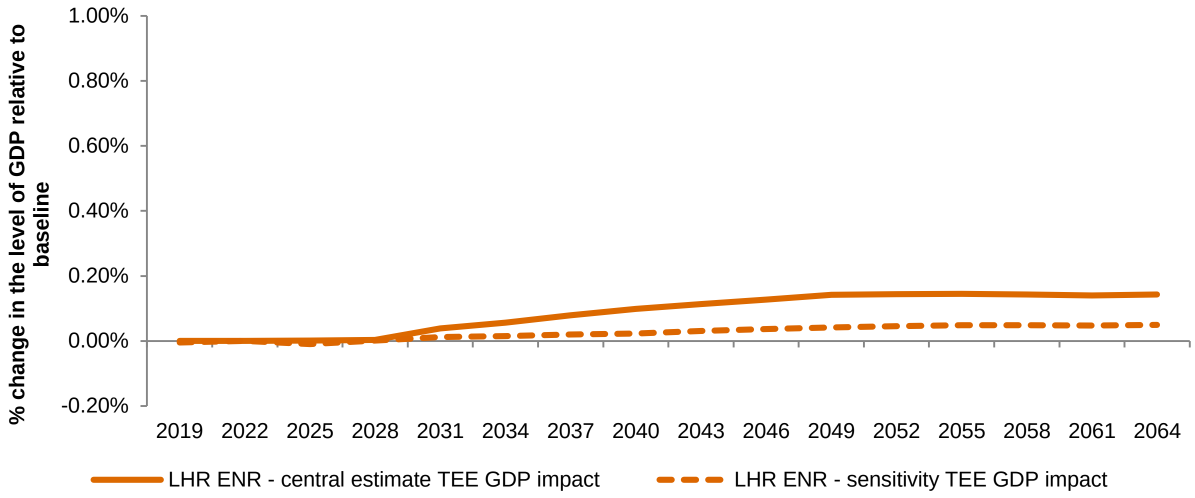
*Figure 101: LHR ENR –TEE inputs for all passengers and for business passengers only*




*Source: AC demand forecasts*

As a result of the smaller inputs, the impact of the sensitivity is to reduce the overall magnitude of the TEE effect for both positive and negative periods of GDP impact. Again, the solid line shows the original GDP impact of the TEE effect, whilst the dotted line shows the impact of the TEE effect when only considering business passengers. The impact of the sensitivity is greatest in the latter half of the period, during which the TEE effect is around a third of the size of the original TEE effect, at around 0.05%.

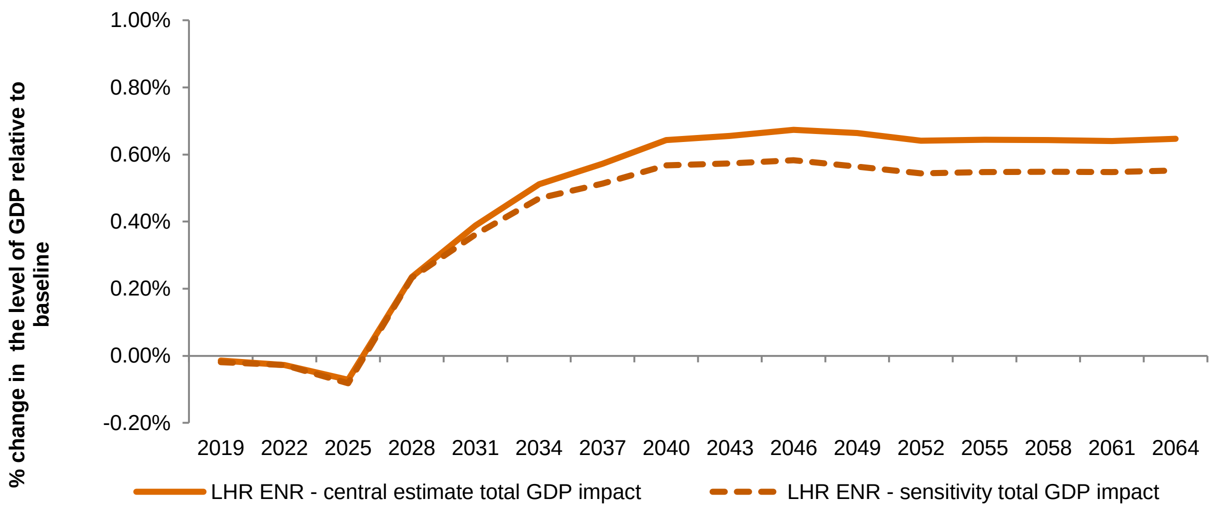
*Figure 102: LHR ENR – Impact of business passenger sensitivity on TEE GDP impact*




*Source: PwC analysis*

Figure 103 below shows the impact of the TEE sensitivity on the overall GDP impact of the LHR ENR scheme. Please note that this sensitivity test excludes the impact of construction. As expected, the reduction in the overall GDP impact is equivalent to the reduction in TEE effect GDP impact (0.1% by the end of the time period), which is now lower as a result of the change in the magnitude of model inputs, which now relate only to business passengers, as opposed to business and leisure passengers. The TEE effect was previously a significant component of the airport scheme's overall GDP impact – 22% by the end of the time period in the original analysis, compared to 9% in the sensitivity.

*Figure 103: LHR ENR – Impact of business passenger sensitivity on overall GDP impact*




*Source: PwC analysis*

Table 61 below displays the PVs of the forecast total real GDP impact for the Assessment of Need scenario by effect. It also shows the PV of the business passenger only TEE sensitivity and the new overall total PV. The PV of the TEE effect is significantly lower in the sensitivity, by £15.5bn.

*Table 61: LHR ENR Present Value of real GDP impacts by effect (£bn, 2014 prices)*

| 60 years (2019-2078) | LHR ENR |
|---|---|

| | |
|---|---|
| **1. Passenger Flows** | 28.3 |
| **2. Productivity** | 61.7 |
| **3. Frequency Benefits** | 5.6 |
| ***4. TEE (original - business and leisure PAX)*** | *22.6* |
| **Total (original: 1+2+3+4)** | **118.2** |
| ***5. TEE (Business PAX only)*** | *7.1* |
| **Total (sensitivity test: 1+2+3+5)** | **102.7** |

*Source: PwC analysis*

Lower airfares represent a decrease in the cost of intermediate inputs for businesses. As a result, the sectors which therefore benefit the most are those which purchase the most from the air passenger transport sector. Excluding travel agents and the air passenger transport sector itself, the three largest beneficiaries are the financial sector, the manufacturing sector, and the information and communication sector. Between them, these sectors represent nearly 50% of air passenger transport intermediate consumption.

### *7.8.5 Testing the effects of alternative labour market assumptions*

Comments raised in relation to an earlier version of this report, published as part of the AC's consultation on "increasing the UK's long-term aviation capacity", made reference to the potential senstivity of the results to the treatment of labour supply. Based on these comments we discussed and agreed with the AC the following two tests:

**Test 1:** creating an assumption where the supply of labour is fixed; and

**Test 2:** testing the assumption where the elasticity that governs the pace at which unemployed workers enter the labour market in response to change in labour market demand and wages.

*How does the S-CGE model treat labour supply?*

In the S-CGE model, the volume of labour supply adjusts in response to changes in the wage level in two main ways:

3) Workers are able to enter and exit the market, known as the **extensive labour supply margin**.
4) Workers are able to increase or decrease their hours, known as the **intensive labour supply margin**.

Allowing the extensive and intensive margins to adjust assumes that the economy is not always operating at a fixed full employment, in that there are both unemployed and underemployed workers who can enter the market in response to an increase in demand, or vice versa.

In the baseline model, the extensive labour supply margin is based on an elasticity that governs the relationship between out of work income and wages This reaction is known technically as the income effect. The elasticity chosen as an input for this function is taken from a comprehensive literature review of labour supply elasticities by Keane (2011)[180] and also the Mirrlees Review (2011), the elasticity is weighted to reflect male, female and household labour supply decisions. It must also be set at a positive value to reflect the nature of the income effect i.e. as the gap between out of work income and in work income increases, people enter the labour market. On this basis, and to reflect data on flows of entry and exit into the labour market observed in the UK in recent years, we set this value at 0.2 i.e. for every 1% increase in wages, the supply of hours from non-working housheolds increases by 0.2%.

180 Keane, M. (2011) "Labour Supply and Taxes: A Survey" Journal of Economic Literature 49:4, 961–1075

However, the model also generates a substitution effect – households gain additional utility from consuming a greater and wider variety of different products and services. But, they also supply “hours” to the labour market, and will experience a disutility from forgoing leisure time. For each additional hour of work supplied an hour of leisure is forgone. The decline in utility associated with forgone leisure is considered alongside the additional utility gained from earning more money and being able to consume more. Economic theory suggests that as incomes rise consumers will have more disposable income and will therefore place greater value on leisure time and may even seek to work less – this is known as the substitution effect.

In the S-CGE model the substitution effect is determined in a separate equation to the income effect. However, the net outcome regarding the income and substitution effect is determined by the households overall utility maximising function, meaning that the net outcome of these two effects is determined simultaneously.

Each household in the model is alsogiven a “stock of leisure”. The model assumes that in the baseline, households spend one-third of their time at work, and two-thirds of their time not at work i.e. engaging in what we have termed leisure activities, but this would also include basis subsistence activities such as sleeping etc.

There is also an intertemporal element to the labour supply decision. In this context intertemporal substitution is reflected in the Frisch elasticity, which represents the willingness of households to postpone leisure in favour of work during periods of anticipated high wages. The Frisch elasticity is also governed by the households preference to smooth consumption – if preferences to smooth consumption are strong then labour supply is less likely to adjust when wages rise. The value of this elasticity is set at 0.4, in line with empirical estimates reviewed by Mirlees (2011).

*Implementing the labour supply tests*

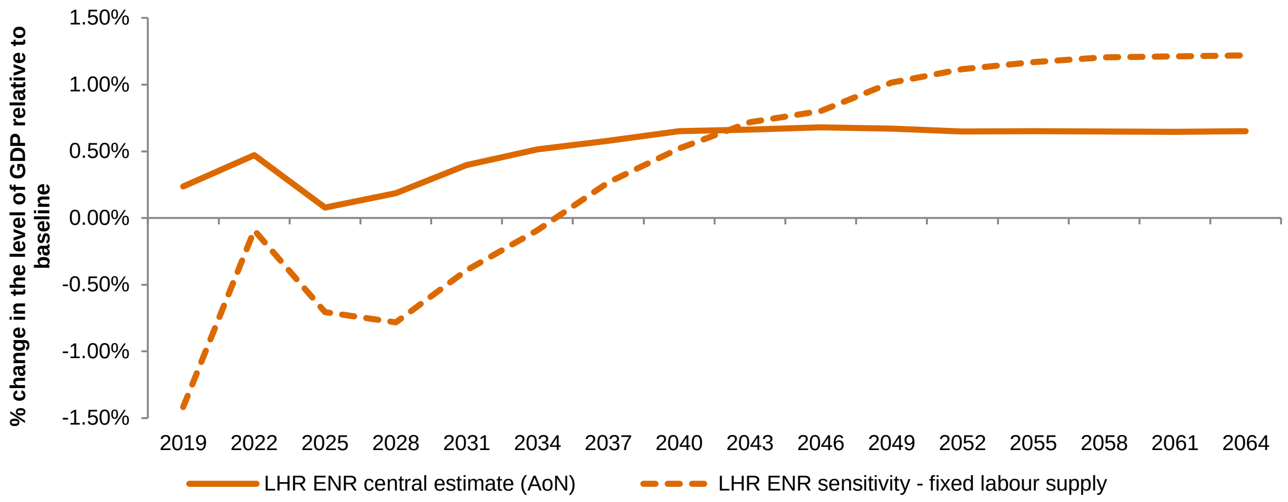
In test 1, which is a test of a fixed labour supply assumption, we change  the extensive margin elasticity from 0.2 to zero and also hold the stock of leisure fixed – this means that those households who are out of work do not enter the labour market. The intensive margin is also fixed and the model is constrained so that households who are in work will not substitute leisure for additional hours of work. The Frisch elasticity is also set to zero, meaning there is no intertemporal substitution in response to wages.The assumption of a fixed labour supply is extreme, and this is highly unlikely to occur in reality, but is implemented to show the magnitude of impact of our assumptions for the labour market.

In test 2 we fix only the extensive margin elasticity. The stock of leisure and the Frish elasticity allow workers to increase hours, but no new households will enter the labour market. The difference in results between tests 1 and 2 shows the effects of varying the extensive margin.

*Test 1: Fixing labour supply*

The result of  the fixed labour supply assumption, in which both the extensive and intensive labour supply margins are fixed (i.e. workers can neither enter the market, nor increase their hours) is shown in Figure 104 below.

*Figure 104: LHR ENR - Overall GDP impact of central estimate and fixed labour supply sensitivity test, Assessment of Need*




*Source: PwC analysis*

The results of this sensitivity test are reflective of how restrictive the assumption is. In the early years of the modelling it can be seen that the level of GDP is substantially below both the baseline and central estimate. This is driven primarily by construction spending, which requires firms in the construction sector to offer a material wage premium to attract workers in order to meet demand.

Due to the fixed labour supply, these workers cannot be taken from unemployment or underemployment, and instead must move from employment in other sectors. This wage premium drives up the cost of labour for firms in all sectors, who need to adjust their own wages in order to retain workers in light of the greater compensation offered by the construction sector. This increase in the cost of labour motivates firms to restrict output, and causes the economy to reach a new, lower-output, equilibrium as seen in Figure 104.

Table 62 below breaks down the impact of the trends described above on jobs, by sector. As discussed above, the fixed labour supply condition means that the overall volume of labour supply is unable to change. Therefore, the overall impact on net job creation is zero throughout the time period, with increases in employment in one sector displaced from other sectors. Table 62 that the airport expansion results in a significant increase in the number of jobs in the air passenger transport sector, which are drawn primarily out of the manufacturing sector. This is because this is the sector with the most closely aligned wages and skillsets. There is also a short-term boost in employment in the construction sector, due to the airport expansion. By 2050, there are 42,000 more jobs in the airport passenger transport sector, and 24,000 less jobs in the manufacturing sector - which should be a key beneficiary of the airport expansion. There is also a significant fall in the number of jobs in the other services sector  in the long-run.

*Table 62: LHR ENR - Breakdown of impact on net job creation by sector relative to baseline for fixed labour supply sensitivity, Assessment of Need scenario (000's of jobs)*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and Mining** | -0.1 | -1.8 | -2.1 | -1.8 | -1.6 |
| **Manufacturing** | -3.9 | -14.7 | -19.7 | -24.0 | -26.4 |
| **Utilities** | -0.4 | -1.6 | 0.1 | 0.4 | 0.4 |
| **Construction** | 5.1 | 0.6 | 0.3 | 0.1 | 0.2 |
| **Retail and wholesale trade** | -0.1 | -0.9 | -2.9 | -2.7 | -2.9 |
| **Air passenger transport** | 1.4 | 32.1 | 41.6 | 42.1 | 45.3 |

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Air freight** | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 |
| **Other freight** | 0.0 | 0.4 | 0.7 | 0.6 | 0.3 |
| **Other passenger transport** | -0.1 | 0.1 | 0.6 | 1.1 | 1.4 |
| **Accommodation and food services** | -0.4 | -3.4 | -4.3 | -5.9 | -3.8 |
| **Other services** | -1.5 | -10.6 | -13.0 | -12.5 | -15.5 |
| **Health, education and public spending** | -0.1 | -0.2 | -1.4 | 2.4 | 2.3 |
| **Total** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

*Source: PwC analysis*

As the modelling period progresses, the difference between the central estimate and the sensitivity reduces, and eventually the impact on the level of GDP is seen to be higher under an assumption of fixed labour supply scenario. This occurs because it is fixed within the model that the ratio between consumption and investment must remain broadly constant in the long-run[181]. This is not an unreasonable assumption, historically in the UK this relationship has shown relative long-run stability. However the rise in labour costs, and the associated fall in profitability, which occurs at the beginning of the period is sufficient to break this relationship in the short-run. The only way to meet the assumption is to therefore assume a substantial increase in investment throughout the second half of the period modelled. This increase drives the greater GDP growth shown in Figure 104.

As this trend is driven purely by the requirements of the model, rather than any real economic effect captured within the inputs, this result should not be interpreted with the same credibility as the previous findings. What the result from the modelling does demonstrate is just how restrictive the assumption of fixed labour supply is. Under this assumption, a demand increase of this size could only be absorbed with a substantial change to long-run economic relationships within the UK. In reality this has not been the experience of UK economic history, where levels of employment have fluctuated in response to short-run changes in demand. This would suggest that completely fixing labour supply is an unrealistic and erroneous sensitivity test, a suggestion which is borne out in the results of the modelling.

*Test 2: Reducing the extensive margin labour supply elasticity to zero*

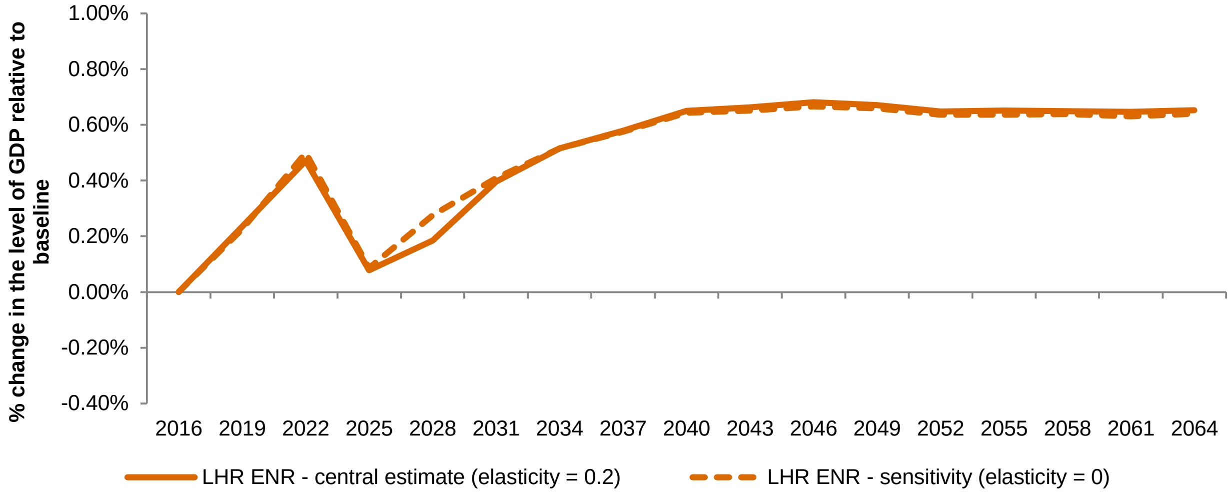
1. Under this assumption, the overall number of workers in the economy remains fixed (i.e. the unemployment rate is fixed). This is done through setting the elasticity of unemployment to real wages to zero. However, the intensive labour supply margin is allowed to adjust, giving workers the ability to move from part- to full-time work, increase their hours, or take additional jobs in response to changes in the wage rate.

The results of this sensitivity test show that the impact on GDP of either change in assumption is minimal, demonstrating that the GDP impact of the increase in aviation capacity is not sensitive to the number of individuals who can be attracted out of unemployment. Specifically under the fixed extensive labour supply margin, it is shown that the increased demand for labour associated with the expansion in aviation capacity can be handled without expanding the number of workers in the labour force.

These results show that the precise labour supply assumption regarding the extensive margin applied in the central estimate does not have a material impact on the estimated GDP impact. Only an overly-restrictive assumption, such as completely fixed labour supply, causes a substantial change in this estimate.

[181] This type of fixed long-term relationship within the model is known as a 'terminal condition'

*Figure 105: LHR ENR - Comparison of the overall GDP impact across different intensive labour supply elasticities, Assessment of Need*




*Source: PwC analysis*

## 7.8.6 Testing the imperfect competition assumption

So far in the analysis, we have assumed imperfectly competitive markets (the marginal benefits of increasing output, measured by price, are above marginal costs). Thus, an output expansion brought about by reduced costs gives rise to an additional welfare benefit over and above what would be seen in a perfectly competitive framework. In this way, the S-CGE model allows us to depart from the conventional assumption in scheme appraisal of perfect competition, and to capture the real world implications of how most markets in the economy are characterised by effective but imperfect competition. This sensitivity is particularly relevant for the construction phase of the project, and construction effects are included within the analysis.

So direct cost savings associated with, for example, the production process becoming more efficient would be present in a model of perfect competition and are captured in conventional transport appraisal. However, where the market is imperfectly competitive, there are further effects. We therefore re-run the model assumption to test the model results under similar assumptions to those used in conventional welfare analysis. This assumption has been tested each of the three proposed airport schemes, under the Assessment of Need scenario, for all effects (construction, passenger flows, productivity, frequency benefits and TEE).

Under the original assumption of imperfect competition, some of the effects modelled give rise to multiple equilibria in the S-CGE model (an upper and a lower case). This phenomenon, described in detail in Chapter 2 and Appendix B, depends on the nature of competition in markets and the agglomeration effects.

Note that the baseline for this sensitivity (i.e. the projected GDP growth in the absence of new airport capacity) is different from that of the central estimate; the baseline for the sensitivity would reflect a counterfactual with perfect competition and constant returns to scale (CRTS), whereas the baseline for the central estimate would reflect a counterfactual with imperfect competition and increasing returns to scale (IRTS).

Under the central estimate, industries are imperfectly competitive with IRTS. Under this assumption, firms will restrict output below the level of market demand in order to drive up prices and in turn generate a mark-up on their sales, i.e. Cournot competition. Mark-ups are determined by the firms perceived elasticity of demand – these are inversely related, the lower firms perceive the elasticity of demand for their products, the higher mark-ups will be. The market structure suffers from inefficiencies in the short run which may delay the potential benefits from improved access to transport (for example, firms may choose not to pass on the lower costs to consumers in the short run).

However, the short-run effects under this market structure can also facilitate agglomeration. For example, if firms in a particular sector/region decide to raise prices in order to capture additional mark-ups in response to improved transport links, then, in the model a concentration of new firms emerges in this sector/region facilitated by the forward and backward linkages inherent in the economy and the rise in economic activity associated with the new transport links.

In contrast, under perfect competition, firms face CRTS and therefore, individual firms do not have any market power. Any benefits to firms due to improved transport links are quickly passed on to consumers, and the benefits to the economy accrue immediately. The pass-through of benefits implies that the economic gains associated with improved transport links are likely to be higher under perfect competition.

However, as discussed in Section A.2, there would be no agglomeration with perfect competition. This is because under perfect competition and the presence of transport costs, firms in a sector would spread out in order to minimise the costs of supplying consumers in different location. There would a large number of small production units, each supplying their local customers. The benefits, therefore, are likely to be spread out more evenly across sectors.

The difference between the two scenarios depends on the balance between the delay of benefits of reduced transport costs due to imperfect competition and agglomeration effects. Under perfect competition, if the transport costs gains are outweighed by the loss in agglomeration effects, then the overall impact on GDP is lower. On the other hand, if the transport costs gains are larger than the loss in agglomeration effects, then the overall impact on GDP is higher.

It is not possible to predict in advance which equilibrium will prevail (i.e. whether prices will be higher or lower, or whether the impact will be larger or smaller than the agglomeration benefits under imperfect competition). This is because the impact on the economy, i.e. the equilibrium outcome, will vary based on which sector/region becomes the focal point for convergence. It is difficult to predict which sector/region is likely to emerge as the focal point for convergence, and therefore, it is difficult to predict which equilibrium will prevail (i.e. whether prices will be higher or lower, or whether the spatial effects will aid agglomeration or dispersion), hence the need to consider each of the potential equilibria.

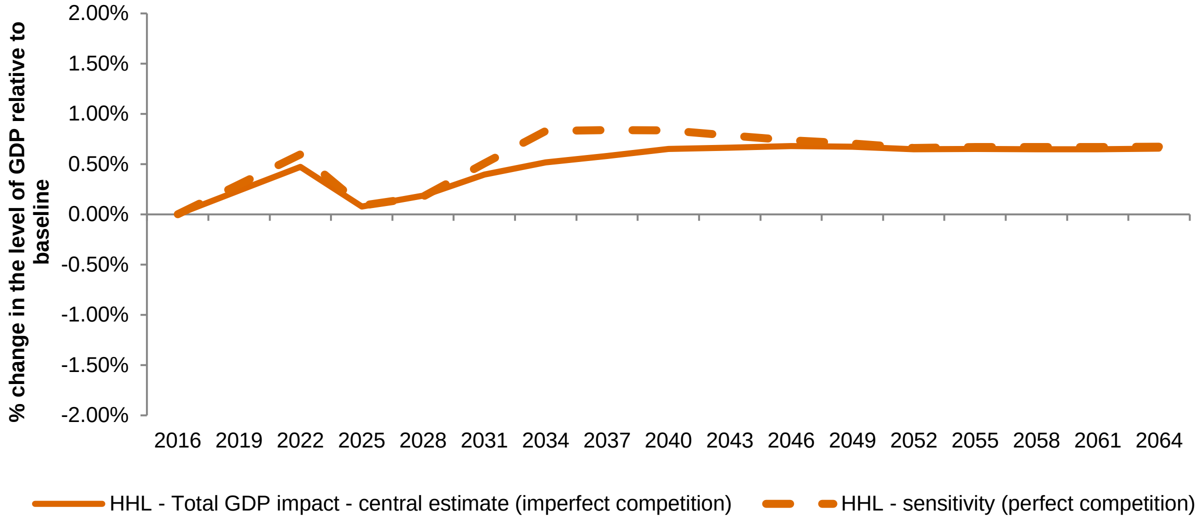
To be consistent with the central estimates presented in the rest of this report, Figure [x] shows the results corresponding to the higher results in terms of GDP effects. This is in line with Aghion *et al*[182] who use firm-level panel data for the UK and find that entry has led to greater innovation and faster total factor productivity growth, and to aggregate productivity growth.

Figure 106 below demonstrates the impact of the perfect competition sensitivity test, on the overall change in the level of GDP for the Assessment of Need scenario. This shows that the change in the level of GDP is greater when perfect competition is assumed. As described above, the implication of this finding is that the transport cost gains are greater than the loss in agglomeration effects. The impact of the different assumption is most significant towards the beginning of the period studied, 2030 to 2040. This occurs as the increased efficiency of the market under perfect competition facilitates the flow of benefits from reduced transport costs more quickly throughout the economy. In addition, the agglomeration benefits which occur under imperfect competition are most substantial towards the end of the time period studied. As a result, the positive impact of perfect competition and CRTS diminishes beyond 2040.

[182] Aghion, P., Blundell, R., Griffith, R., Howitt, P., & Prantl, S. (2004). Entry and productivity growth: Evidence from microlevel panel data. Journal of the European Economic Association, 2(2-3), 265-276.

By exploiting a firm-level panel dataset, and using policy reforms that changed entry conditions by opening up the UK economy during the 1980s as natural experiments, Aghion *et al* show that more entry has led to faster total factor productivity growth of domestic incumbent firms and thus to faster aggregate productivity growth.

*Figure 106: LHR ENR - Total GDP impact, under imperfect competition & IRTS and perfect competition & CRTS, Assessment of Need scenario*




*Source: PwC analysis*

The impact of the sensitivity test on GDP is further shown through Table 63 below, which outlines the Present Value (PV) of the GDP impacts over the 60 year appraisal period. This shows that under the assumption of perfect competition and CRTS the PV is nearly £150bn, just over 10% higher than under imperfect competition and IRTS. The majority of this increase is driven by the increase in GDP towards the beginning of the appraisal period. Changes in the level of GDP are particularly material during these years as they are discounted less heavily than changes towards the end of the appraisal period. In the long-run, after 2060, the increase in the level of GDP is only 3% greater under perfect competition and CRTS.

*Table 63: LHR ENR Present Value of Real GDP impacts (£bn, 2014 prices)*

| Scenario | Present Value (£bn) |
|---|---|
| **LHR ENR - central estimate (imperfect competition & IRTS)** | 130.6 |
| **LHR ENR - sensitivity (perfect competition & CRTS)** | 149.1 |

*Source: PwC analysis*

The impact of assuming perfect competition and CRTS, compared with imperfect competition and IRTS can be more substantial at the individual sector level than when looking at GDP as whole. This is because the level of competition in the market, characterised by the existence of mark-ups, varies substantially across sectors. As a result, for the most competitive sectors the assumption can have very little impact, whilst for others the change can be very material. When looking solely at the overall GDP impact these sector differences are aggregated and the effect looks more moderate.

The impact by sector under perfect competition is given in Table 64. This should be compared with Table 42 above, which shows the corresponding data for imperfect competition and CRTS[183]. Comparing these tables shows that the most substantial positive effects of perfect competition and CRTS are seen in agriculture, manufacturing and construction. These are sectors which are typified by relatively higher mark-ups, and therefore have the greatest potential for efficiency improvements under perfect competition and CRTS. By contrast, no change is seen in sectors such as retail and public services which have relatively small mark-ups. The positive impact on air passenger transport is also reduced, although it remains substantially the sector with

[183] For consistency with previous analysis this table excludes the impact of construction and surface access spending

the greatest growth. This is because the increase in aviation capacity causes substantial agglomeration benefits to occur under imperfect competition and IRTS, which are not possible under perfect competition.

*Table 64: LHR ENR - Breakdown of impact on the level of real GDP by sector under perfect competition, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and mining** | -0.3% | 0.9% | 2.4% | 2.4% | 2.3% |
| **Manufacturing** | 0.0% | 1.7% | 2.5% | 2.7% | 2.6% |
| **Utilities** | -0.3% | 0.6% | 1.8% | 1.8% | 1.8% |
| **Construction** | -1.5% | 1.4% | 2.7% | 3.8% | 3.7% |
| **Retail and wholesale trade** | -0.2% | -0.6% | -0.3% | -0.4% | -0.4% |
| **Air passenger transport and freight** | 0.6% | 8.8% | 10.8% | 10.5% | 10.2% |
| **Other freight** | -0.3% | -0.9% | -1.0% | -1.1% | -0.9% |
| **Other passenger transport** | 0.0% | -0.4% | -0.9% | -1.3% | -1.0% |
| **Accommodation and food services** | -0.1% | 1.0% | 1.4% | 1.4% | 1.4% |
| **Other services** | -0.6% | -0.7% | 0.4% | 0.1% | 0.2% |
| **Health, education and public spending** | 0.0% | 0.0% | -0.1% | -0.2% | -0.2% |

*Source: PwC analysis*

Overall, at a macro level the assumption of perfect competition and CRTS does not yield substantially dissimilar results to imperfect competition and IRTS. Where there are differences and the macro level between the impacts of the two assumptions, these are predominantly driven by increases in GDP being brought forward, with only moderate changes in the level of GDP seen in the long-run. However, when looking at sector-specific results far more variation is seen. Understanding the impact of imperfect competition and IRTS at this level gives greater insight as to likely sectoral reactions to the increase in aviation capacity.

### *7.8.7 Testing the carbon capped passenger scenario*

In our primary analysis, we have based the scenarios on the assumption of a "carbon-traded", rather than a "carbon-capped" emissions policy. As described previously, under both policy assumptions, limits are set on the amount of carbon that can be emitted. These limits may be allocated or sold to firms. However, under the carbon-traded scenario, firms can then trade their allocations: firms emitting less than their allocated limits can sell the remainder of their allocations to firms that are likely to emit more than their allocated limits.

Given the uncertainty of future carbon emissions policy, it is appropriate to test the sensitivity of the results to changes in the carbon assumption. In this section we present results for the LHR ENR scheme under a "carbon capped" emissions policy based on the AC's 'demand reduction' carbon capped scenario. For illustrative purposes, results are presented only for the Assessment of Need scenario.

The overall results for the carbon traded scenario are shown in Table 65 below. The total PV values are calculated for the 60 years following the scheme opening in 2026, and are therefore equivalent to the results presented in Table 41 above. Table 65 breaks down the impact into the four different effects. This allows comparison of the different mechanisms through which changing emissions policy would affect the economic impact of increasing aviation capacity.

*Table 65: LHR ENR Present Value of real GDP impacts by carbon emissions policy, Assessment of Need scenario (£bn, 2014 prices)*

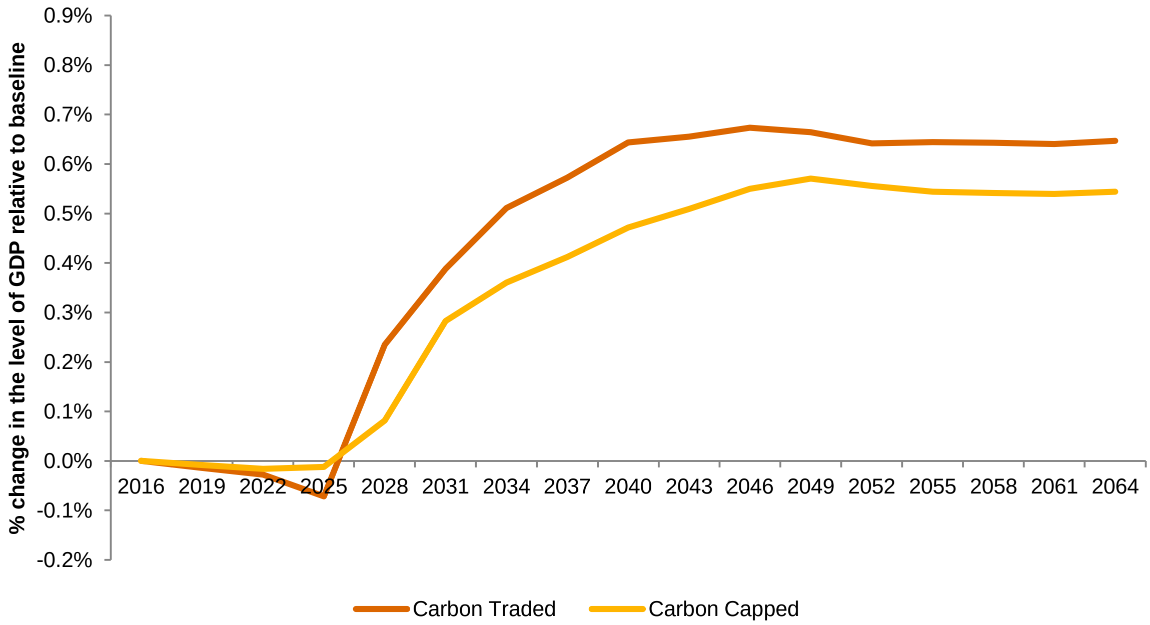
| | Carbon traded emissions policy | Carbon capped emissions policy |
|---|---|---|
| **Passenger Flows** | 31.3 | 25.6 |
| **Productivity** | 67.6 | 57.4 |
| **Frequency Benefits** | 6.5 | 6.0 |
| **TEE** | 25.3 | 13.7 |
| **Total** | **130.6** | **102.6** |

The results of this table demonstrate that the carbon capped emissions policy leads to a reduction in the PV of economic impact by just over 20%, from £131bn to £103bn. Although this is a material reduction, the results of the sensitivity test highlight that the vast majority of the benefit of the LHR ENR scheme is forecast to accrue irrespective of the future climate policy landscape.

All effects lead to smaller economic impact under a carbon capped emissions policy, although the magnitude of the reduction varies by effect. The most substantial fall is seen in the TEE effect, which falls by nearly 50% (£25.3bn to £13.7bn). By comparison the economic impact generated through the productivity effect falls by approximately 15%, from £67.6bn to £57.4bn. This analysis is based on the current inbound/ split, and has not been tested with the alternate inbound/ outbound splits which have been applied in other sensitivity tests. Below we explore the inputs which drive these results in more detail.

Figure 107 provides additional detail by demonstrating how the scale of the GDP impact changes over time as a result of the changing emissions policy scenario. This shows that the carbon capped scenario leads to a lower GDP impact throughout the period studied, with the gap widening most substantially from the early-2030s. The long-run impact on the level of GDP falls by just over 15%, from 0.65% on the level of GDP to 0.54%.

*Figure 107: LHR ENR - Total GDP impact, under a carbon traded and carbon capped emissions policy scenario, Assessment of Need scenario*




The primary difference between the two scenarios, which drives much of the difference between the results, is the change in the number of additional passengers which the expanded capacity enables. The additional number of passengers under each scenario is given in Table 66 below. This demonstrates that the additional number of passengers in the UK system as a result of the LHR ENR scheme (in 2050) falls from 7.5m under a carbon traded emissions policy to 4.6m under a carbon capped scenario. This fall in overall passenger traffic is the reason for the reduction in the magnitude of economic impact found in Figure 107. Please note that Table 66 excludes international transfer passengers, as they are not assumed to have a material impact on the UK economy in this context.

It should be noted that the reduction in economic impact between the carbon policy scenarios (21%) is much smaller in magnitude than the fall in passengers (39%). This is a result of the nature of the passenger mix under each scenario, with the carbon capped scenario leading to a disproportionately high number of additional long-haul passengers. This can be seen in Table 66 with only moderate falls in the number of passengers flying to/from East Asia and North America under the carbon capped scenario, compared to larger falls to/from Europe.

The econometric results presented in Appendix C demonstrated that long-haul flights have a larger impact on UK productivity than flights to Europe. As a result, the passenger mix which occurs under the carbon capped scenario is more likely to stimulate a positive productive response within the UK economy, than the mix seen under the carbon traded scenario. This change in mix explains that while overall passenger flows are substantially lower under the carbon capped scenario, the fall in economic activity generated through the productivity effect is more moderate.

*Table 66: LHR ENR, Additional UK-wide passengers in 2050 relative to the Do Minimum, by carbon emissions policy*

| Region of destination/ origin | Carbon traded emissions policy | Carbon capped emissions policy |
|---|---|---|
| **Africa** | 0.4m | 0.3m |
| **Central & South America** | 0.1m | 0.0m |
| **East Asia** | 0.5m | 0.4m |
| **Europe & Channel Islands** | 5.6m | 3.1m |
| **Middle East** | 0.1m | 0.1m |
| **North America** | 0.4m | 0.3m |
| **Oceania** | 0.1m | 0.1m |
| **UK** | 0.3m | 0.3m |
| **Total** | **7.5m** | **4.6m** |

The change in passenger mix is also the reason why the passenger flow effect leads to similar economic impact in the carbon capped and carbon traded emissions policy scenarios. Under the carbon capped scenario, a similar number of passengers pass through the London airport system (which continues to operate at close to full capacity), but fewer passengers pass through the UK regional airports. Passengers at these airports are more likely to be outbound than London passengers (i.e. UK passengers flying abroad) and hence have a less positive, or even negative impact on the UK economy. As a result, the reduction in passenger traffic of this type under the carbon capped scenario does not substantially lower the overall economic impact.

By comparison, the TEE effect captures the degree to which surplus is transferred from consumers to producers. This is primarily driven by the number of additional passengers which the airport capacity enables, and not materially impacted by the change in passenger mix. As a result, the difference between the carbon policies in the total economic impact is much greater for the TEE effect, and not substantially different to the overall change in passenger numbers.

Finally, Table 67 captures the regional distribution of the economic impact of the LHR ENR scheme, under both the carbon traded and carbon capped policy scenarios. Despite the larger share of passengers which flow through the London airport system under the carbon capped scenario, the London & the South East share of benefits is marginally smaller (39% compared with 40%). This effect the benefit even of air traffic going through the London system is largely national in nature, i.e. businesses all over the country feel the benefit of increased connectivity and openness, and a substantial share of passengers' expenditure is outside of London & the South East. As a result, benefits continue to be well distributed across the country.

*Table 67: LHR ENR Present Value of regional real GDP impacts by carbon policy, Assessment of Need scenario (£bn, 2014 prices)*

| Region of destination/ origin | Carbon traded emissions policy | Carbon capped emissions policy |
|---|---|---|
| **London & the South East** | 51.8 | 40.8 |
| **Rest of England** | 57.7 | 45.6 |
| **Rest of UK** | 21.1 | 16.1 |
| **Total** | **130.6** | **105.1** |

## *7.8.8 Testing the results using the AC's welfare -based productivity assessment*

As a further sensitivity, the AC instructed us to model the outputs from its conventional welfare -based welfare analysis to see how they would play out in an S-CGE framework. This sensitivity has been undertaken to better understand the interactions in the economy that might occur in a welfare assessment (this is done for the Assessment of Need scenario only).

The AC's welfare -based analysis focusses on the following wider impacts:

- Increasing productivity through trade;
- Increasing productivity through the formation of new business agglomerations and strengthening existing business agglomerations;
- Impact on government's tax revenue from increases in wages associated with the rise in GDP observed in response to airport expansion; and
- Increasing output by exposing domestic firms to more competition.

Table 68 describes these effects in further detail and explains how we have incorporated them into the S-CGE framework. Table 69 shows the PV of the inputs provided by the Airports Commission.

*Table 68: AC welfare impacts*

| Impact | Description[184] | Incorporation into the S-CGE framework |
|---|---|---|
| **Increasing productivity through trade** | According to the AC, "airport expansion provides increased connectivity in the form of better access to foreign markets and thus, facilitates trade between the UK and the rest of the world. This impact on trade is exclusive to aviation and thus, is not covered in standard transport guidance. Exports to other countries encourage knowledge and technology transfers from international firms and also allows British firms to exploit economies of scale by selling to larger international markets. In addition to the | The AC has provided us with estimates of the productivity increases as a result of higher trade. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |

[184] Descriptions have been taken from the Airports Commission's *Wider Economic Impact Note* shared with PwC on 18 April 2015.

| | | |
|---|---|---|
| | knowledge transfers, imports from other countries also increase the level of competition in the market and leads to the removal of inefficient firms and a more efficient use of resources. These effects result in an increase in the overall level of productivity in trade-related sectors of the economy, which has been captured in the trade benefits". | |
| **Increasing productivity through formation agglomerations and strengthening existing agglomerations** | According to the AC, "the change in connectivity offered by airport expansion attracts businesses which benefit from the better international links as well as their supply chains to cluster around the airports. This leads to the creation of agglomerations around the airports, leading to productivity increases in these sectors through knowledge and technology spillovers as well as access to and developing larger input markets and labour markets. These changes in productivity have been captured in the agglomeration effects". | The AC has provided us with estimates of the productivity increases as a result of agglomeration effects. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |
| **Impact on government's tax revenue from people moving to better suited and higher paid jobs** | According to the AC, "the changes in productivity arising from the agglomeration effects in particular sectors increases the returns to labour in these sectors and thus, attracts some workers to move to better suited more productive jobs in the clusters surrounding the airports. The increase in productivity of the workers translates into higher wages in a competitive market and thereby increases the taxes paid by these workers. These impact on the government's tax revenue" | The AC has provided us with estimates of the impact on government's tax revenues from people moving jobs. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |
| **Increasing output by exposing domestic firms to more competition** | According to the AC, "the expansion also results to a reduction in the cost of production for firms that use air transport as an input and thus, allows them to profitably increase the level of output they produce. These benefits for firms that operate in perfectly competitive markets are captured in the direct benefits to business users. However, since the calculations for direct benefits assumes perfect competition, similar effects for firms in imperfectly competitive markets are missed out. These impacts of increase in output in imperfectly competitive markets are captured here". | The AC has provided us with estimates of the impact on firms' outputs in imperfectly competitive markets. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |

*Source: Airports Commission and PwC analysis*

*Table 69: LHR ENR Present Value of real GDP impacts by effect (£bn, 2014 prices)*

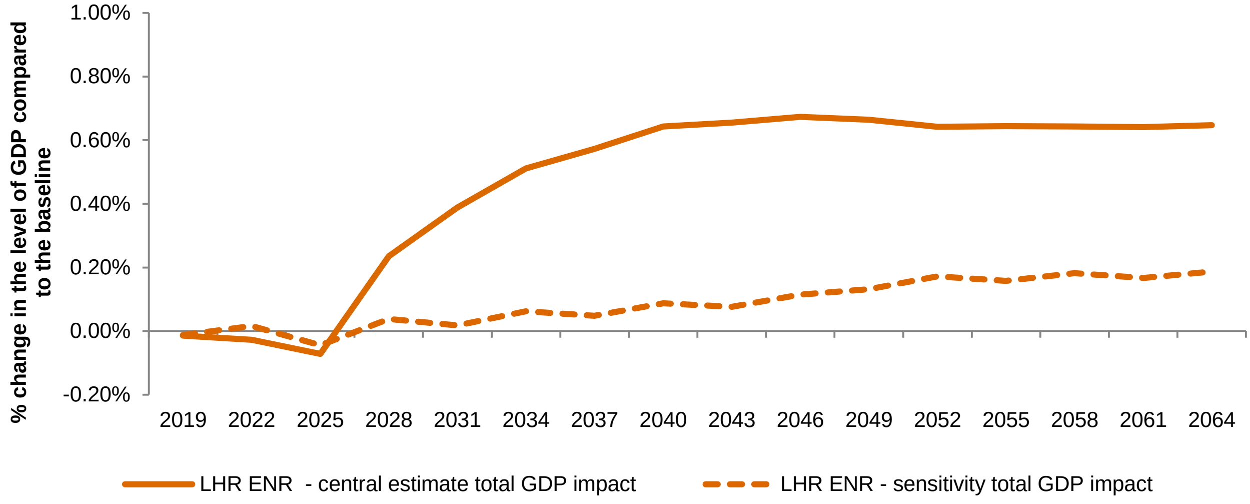
| | **Assessment of Need** |
|---|---|
| Increasing productivity through trade | 6.3 |
| Increasing productivity through formation agglomerations and strengthening existing agglomerations | 1.5 |
| Impact on government's tax revenue from people moving to better suited and higher paid jobs | 1.0 |
| Increasing output by exposing domestic firms to more competition | 1.2 |
| **Total** | **10.0** |

*Source: Airports Commission*

The results of this sensitivity when welfare inputs are used as inputs to the S-CGE model are presented in Figure 109. The graph shows the combined GDP effects of all of the impacts described in Table 68 and compares the results to the central estimates presented above.

Under this alternative set of inputs, the GDP impacts are modest between the opening of the scheme and the mid-2040s. This reflects the underlying inputs provided by the AC. Under this sensitivity, the long run effect is to increase GDP by around 0.3%. The broad patterns are similar when the welfare inputs are used, with the impacts increasing gradually as aviation flows rise. The key difference between this sensitivity and the central estimate is the overall scale of the effect. The scale of the estimate using the welfare inputs is approximately one third of the central estimate. The smaller scale is to be expected for a number of reasons. Firstly, the welfare analysis abstracts from important effects that have been taken into account in the central estimate, notably TEE and passenger flow impacts. Secondly, the AC approach to estimating the productivity effects of trade uses elasticity evidence which is *partial equilibrium* in nature. In contrast, the central estimate captures the relationship between trade and GDP in *general equilibrium*. Please note that this analysis is entirely separate to the previous modelling undertaken on this effect, and should be seen as complementary rather than additional.

*Figure 108: LHR ENR – Impact of welfare -based productivity assessment on overall GDP*



# 8 Heathrow Airport Northwest Runway results

This chapter presents the results of our analysis of the LHR NWR scheme and describes the underlying transmission mechanisms through which the various effects described in previous chapters are forecast to impact on the economy. The chapter proceeds as follows:

- Section 8.1 provides a summary of the results;
- Section 8.2 presents the total GDP impacts;
- Section 8.3 sets out the Present Values of the GDP impacts;
- Section 8.4 explains the drivers of the GDP impacts;
- Section 8.5 sets out the impacts by region;
- Section 8.6 presents the construction impacts;
- Section 8.7 provides the results for other economic impacts; and
- Section 8.8 describes a number of sensitivities.

## 8.1 Summary of results

This section provides an overview of some of the key results emerging from the S-CGE framework for the LHR NWR scheme and describes, at a high-level, the underlying economic mechanisms that drive the results. Depending on the scenario, by 2050, the level of GDP is forecast to be 0.5% to 1.0% higher than in the baseline scenario (as discussed in Chapter 5, the economy is assumed to grow at 2.75% in per annum in the baseline scenario, which is consistent with HM Treasury's long-term growth assumptions). This is a result of higher net inbound passenger flows[185], increased net trade, and higher consumption and investment. In the Assessment of Need scenario, the scheme is forecast to create approximately 180,000 new jobs by 2050 (of which, approximately 30% are at the airport itself). Each of the regions of the UK considered in this analysis (London & South East, the Rest of England and the Rest of the UK) are expected to experience increases in GDP as a result of the scheme, the extent of the gain depending on the passenger flow scenario considered.

### 8.1.1 Phases of impacts

The forecast impacts of the LHR NWR scheme are experienced in two phases:

1. The **construction phase**, during which the economic impacts are principally associated with the building activities of the scheme; and
2. The **operational phase**, during which the construction impacts fade but other economic impacts – notably passenger flow, productivity, frequency benefits and TEE (Transport Economic Efficiency) effects – are felt.

[185] More of the additional passenger journeys associated with the scheme originate outside the UK than within the UK.

For the LHR NWR scheme, the construction and operational phases are very distinct. The construction phase takes place between 2019 and 2026, and the operational phase commences immediately upon project completion.

In order to provide a summary of the overall progression of the LHR NWR scheme over time and its forecast wider economic impacts we consider the impacts in the construction as well as the operational phase of the scheme. In later sections of this chapter, the main emphasis is on the forecast impacts of the scheme excluding construction since we are primarily interested in the long-term effects of the enhanced aviation linkages created (although we reintroduce construction impacts towards the end of the chapter for completeness).

### *8.1.2 Construction phase effects*

The first forecast impact of the scheme occurs as a direct result of the construction activities. Clearly the construction impacts do not, in themselves, provide reasons for undertaking the scheme. However, the S-CGE model suggests that diverting[186] available resources of the economy towards constructing the airport may have significant economic impacts in its own right.

We have agreed with the AC to assume that the scheme itself is funded wholly by the domestic private sector (although surface access improvements are assumed to be funded by government for the purposes of this report, see below). Therefore, whilst the construction sector expands, this will be offset by reductions in activity elsewhere in the economy. Higher investment returns than those in other parts of the UK economy would be needed in order to attract investment to the scheme which: (i) would encourage households to increase their saving (at the expense of consumption) and (ii) would draw in funds that would otherwise be invested in other projects (although past experience, on which the model is based, suggests that the impact on investment in other projects should be modest).

Airport investment boosts the overall demand for construction. There is a positive multiplier effect that is associated with this expansion[187]. However, there will also be an reduction in both consumption and other forms of investment as the investment funding has to be found from elsewhere in the economy offsetting the previous effects, as described above. This generates an offsetting negative multiplier effect. In addition to this, in the long-term, borrowers would also have to pay back this money in the future which also generates a negative multiplier.

The overall or “net” effect of shifting the economy towards construction depends on the strengths of the two opposing effects described in the preceding paragraph. The model, and the evidence on which the multipliers are based, suggests that the net impact is to increase GDP, since the positive effects of expanding the construction sector outweigh the negative effects of contractions elsewhere. Our modelling suggests that re-orientating the economy towards building the LHR NWR airport scheme might increase GDP by around 0.5% in 2022.

The construction multiplier implied by the ONS UK Supply Use Tables, which are the basis for the S-CGE model, is higher than those for other sectors – this is because the import content of construction is relatively low, and construction has strong inter-linkages with some high value added sectors. The forecast construction impacts of the LHR NWR scheme are effectively the same across the different passenger flow scenarios, since the assumptions for construction costs and phasing are invariant with respect to these scenarios.

The PV of the GDP impact is forecast to be £12.6bn over the 60 year appraisal period (the figure for construction is very similar across the scenarios), compared to costs of £27.1bn[188]. This implies that for every £1

[186] We use the phrase ‘diverting’ to emphasise that resources for construction of the scheme must come from elsewhere in the economy in the S-CGE framework.

[187] It should be noted that not all of the investment taking place comes from the construction sector. Other sectors will invest too. This is because the economy assumes ‘perfect foresight’ and rational expectations. This means that agents will make an expectation of the future benefits of the new airport. The S-CGE model tends to front load this investment in the results (as it would be rational to capitalise on the gains associated with the expanded runway as early as possible). However, in reality agents may not operate with perfect foresight and rational expectations so we might expect this effect to be more muted and spread out over a longer period of time.

[188] As set out elsewhere in this report, this assumes a 60 year appraisal period with discount rate of 3.5% for the first 30 years and 3.0% for the remaining 30 years.

of construction expenditure on the LHR NWR scheme, GDP is forecast to increase by around £0.5 on a present value (PV) basis.

### *8.1.3 Operational phase effects*

The operational phase for LHR NWR is scheduled to commence immediately after scheme completion in 2026, and it is in this phase that the long-term economic impacts associated with passenger flows, productivity, frequency benefits and TEE are first felt.

At the outset of the operational phase, there is a very small forecast reduction in GDP of up to 0.1% (depending on the scenario), relative to the baseline scenario. This occurs because households in the model are assumed to be "rational" (make decisions that maximise their welfare) and "forward-looking" (consider their future wellbeing as well as current). In particular, households foresee that the airport expansion will have a positive effect on whole economy GDP once the scheme becomes fully functional. They therefore anticipate increased returns in the future. In order to capitalise on these higher investment returns across the economy, households reduce their consumption in the short-term in order to increase savings, which results in a temporary (and modest) contraction in output.

It is difficult to be sure whether the effect will materialise in reality and it is possible that the effect will be less pronounced than that implied by the model. However, the assumption of "forward looking" households has been thoroughly investigated within the academic literature and has sound theoretical underpinnings, and in any case is relatively small and transitory.

We now turn to the operational phase effects (passenger flows, productivity, frequency benefits and TEE), and consider the mechanisms through which they may have on impact on GDP, and set out the high-level forecasts implied by the model.

*Passenger flow effects*

One of the most palpable effects expected once the scheme becomes operational is an increase in both UK passenger expenditure outside of the UK and foreign passenger expenditure in the UK. Increased passenger flow expenditures are **direct demand-side effects** that have an impact on GDP – they result in changes in spending by visitors to and from the UK that "flow through" the economy[189]. UK passenger expenditure outside of the UK and foreign passenger expenditure in the UK have opposing impacts on GDP:

- UK passenger expenditure outside of the UK represents foregone consumption in the UK. UK passenger expenditure outside of the UK therefore represents a "leakage" from the UK economy, which reduces UK GDP. The S-CGE model suggests that domestic GDP is relatively sensitive to outbound passenger expenditure – the "**UK passenger expenditure outside of the UK multiplier**" is relatively large. This is because the consumption foregone in the UK – for example, a household appliance which is not bought in the UK as the UK resident instead spends the money on meals and accommodation abroad – has strong supply chain linkages into the domestic economy; and

- Foreign passenger expenditure in the UK increases GDP since it increases UK aggregate demand. However, the S-CGE model suggests that domestic GDP is less sensitive to inbound expenditure – the **"foreign passenger expenditure in the UK multiplier"** is relatively small. This is because the inbound expenditure – spending, for example, on accommodation and restaurants in the UK – has weaker linkages into the wider UK economy.

These expenditures also have important "diffusion" effects which dampen the impacts described in the bullet points above. For example, the foreign passenger expenditure in the UK increases prices in the UK, for instance, for accommodation and other goods and services used by visitors and domestic residents, which reins in the overall level of demand.

[189] We refer to the passenger flow effects as "demand-side" impacts from international movements of visitors, since they are not associated directly with changes in the productivity of firms (except to the extent that changes in demand may increase or reduce scale economies, generate incentives to invest or otherwise endogenously affect productivity).

While the inbound passenger expenditure multiplier is relatively small, inbound passenger spending still provides a boost to the UK economy. It is an important source of foreign exchange and is equivalent to an exported good or service in this sense. This effect occurs on the demand-side of the economy: inbound passengers spend money on a range of goods and services in the UK economy (e.g. hotels, restaurants, retail sector etc.) Increased flows of "exports" can have important supply-side effects. The sectors of the economy associated with inbound passengers will expand as a result of the increase in spending and these sectors will need to hire more workers and invest more to support any expansion. Sectors which service inbound passenger demands are important for the UK economy as they provide a range of low-skilled and school leaver jobs and can facilitate working on a part-time basis. These types of jobs are often taken up by the long-term unemployed. If sectors which service inbound passenger demand expand, this can also have positive upstream effects for those sectors that supply goods and services to these sectors (e.g. the manufacturing or agriculture sectors). Overall the model suggests a small, but permanent increase in productivity resulting from the supply-side expansion associated with inbound passenger demand.

During the first 15 years of operations, the AC estimates that passenger flows associated with the LHR NWR scheme will increase substantially (24.7m additional passengers are forecast to use the UK system by 2040 in the Assessment of Need scenario). The increase in foreign passenger expenditure in the UK (£5.6bn per annum compared to the baseline scenario in 2040 in the Assessment of Need scenario) is forecast to be significantly larger than the increase in UK passenger expenditure outside of the UK (which is forecast to increase by around £0.7bn per annum on a comparable basis). A full description of the underlying reasons is provided later in this chapter.

Even though the UK passenger expenditure outside of the UK multiplier is greater than the foreign passenger expenditure in the UK multiplier, foreign expenditure to the UK is so much larger than the UK expenditure abroad such that the net impact on UK GDP is forecast to be positive, leading to a 0.07% to 0.16% increase in the level of GDP in 2050, depending on the scenario. The model suggests that for every additional £1 of net passenger flow expenditure, GDP increases by £0.75 in 2050, in the Assessment of Need scenario. The reason that the ultimate impact on GDP is less than the original increase in expenditure is the diffusion effect described above as prices respond to the changes in demand.

The PV of the passenger flow impact for LHR NWR is forecast to be between £16.7bn and £32.8bn over the 60 year appraisal period, depending on the scenario. The PV is highest in the Assessment of Need scenario, and lowest in the Relative Decline of Europe scenario. These results are driven by the number and type (e.g. inbound or outbound, short-haul or long-haul etc) of passenger

### *Productivity effects*

Improved aviation linkages can improve firms' productivity in a number of ways. For example, better aviation linkages may enable firms to access larger markets, allowing them to exploit scale economies. Less tangibly, but also importantly, by being able to access foreign markets more readily, aviation linkages could allow firms to "learn" from customers and competitors in other countries, helping them to exploit technologies and adopt more efficient "ways of working" (these effects form the basis of the so-called "endogenous growth" literature which has revolutionised the way economists think about how economies grow). Similarly, by facilitating international trade, aviation linkages can allow firms to increase their productivity by importing more efficient equipment and technology from abroad.

An increase in productivity has a direct positive impact on GDP: firms can produce more output for a given amount of resources used as inputs. At the "microeconomic" level (i.e. at the level of individual firms) higher productivity means that it becomes profitable for firms to produce output that was previously unprofitable, so that firms increase the amount they produce. This productivity improvement may be experienced across the economy, and not just by firms in the immediate vicinity of the airport.

In a "partial equilibrium" framework, the effects would end here. In the S-CGE model, however, a number of indirect impacts also come in to play. On the supply-side, firms pass on their increased efficiency to consumers and other producers in the form of lower prices. In addition, increased productivity places upward pressure on wages since workers become more efficient (and hence more valuable to firms), which in turn attracts people into work and reduces unemployment. Both of these effects place further upward pressure on real GDP. On the demand-side, the higher output produced by firms increases demand for intermediate inputs, which also increases GDP.

As with the passenger flow effect, there are also diffusion impacts – effects which limit the net impact on GDP due to use of scarce resources. The increases in GDP results in higher aggregate demand which places upward pressure on prices. This dampens the size of aggregate demand increases and it is this increase in prices that ultimately keeps the economy "in check" and prevents economic activity from spiralling ever-upwards.

Turning to the results, our model forecasts that the productivity effect associated with the LHR NWR scheme may develop relatively slowly, since the effects are cumulative and it takes time for them to permeate the economy. Ultimately, however, the productivity effect is forecast to be the largest of all of the effects considered in our analysis for the LHR NWR scheme. In 2035, the productivity effect is forecast to add between 0.2% and 0.3% to the level of UK GDP, increasing to around 0.3% to 0.5% by 2050 (depending on the scenario).The model suggests that for every additional £1 incorporated into the model as increased productivity, GDP increases by £0.60 in 2050, in the Assessment of Need scenario. The primary reason for the "multiplier" being less than one is that the diffusion impacts of price increases suppresses demand and GDP.

The PV of the productivity impact is forecast to be between £41.8bn and £79.7bn over the 60 year appraisal period. The PV is highest in the Global Growth scenario, and lowest in the Relative Decline of Europe scenario, reflecting the differing magnitude of passenger flows between the two scenarios (which drives the size of the productivity impact, see Chapter 4).

### *Frequency benefits*

Greater frequency of services can increase firms' productivity, for example by enabling travel at more efficient and/or convenient times, thus reducing the effective travel time. We only consider frequency benefits accruing to businesses – frequency benefits to leisure travellers have been excluded from our analysis since it is unclear whether they will impact directly on GDP. Frequency benefits are an additional, albeit relatively modest, source of economic gains associated with the LHR NWR scheme[190].

Since frequency benefits increase business productivity, the transmission of the effect through the economy is very similar to that described above for the productivity effect. In particular, there is a direct impact as firms are able to increase the amount they produce for a given level of inputs, but there are also indirect effects as the economy responds dynamically (for example as wages increase, as described above). As with the productivity effect described above, diffusion effects ultimately mean that prices rise and keep the economy in check.

The results of the S-CGE model suggest that the frequency benefit effect to businesses associated with the LHR NWR scheme may add between 0.03% and 0.06% to the level of UK GDP by 2050, depending on the scenario. The model suggests that for every additional £1 incorporated into the model as frequency benefits, GDP increases by £1.30 in 2050, in the Assessment of Need scenario.

The PV of the frequency benefits impact is estimated to be between £4.5bn and £10.6bn over the 60 year appraisal period. The PV is highest in the Low Cost is King scenario, and lowest in the Global Fragmentation scenario, reflecting the differing magnitude of passenger flows between the two scenarios.

### *Transport Economic Efficiency effects*

TEE is the final effect examined in the analysis. Input data provided by the AC assumes that the relaxation of the capacity constraint in the UK aviation sector means that airlines are able to extract less "economic rent" associated with the scarcity of available airline capacity, implying that fares fall, benefiting customers but with an offsetting effect on airline shareholders. The net impact on real GDP is captured in the TEE effect.

Consumers benefit from the assumed fall in prices (the benefits to consumers of a fall in prices are captured by means of a change in "consumer surplus"). For modelling purposes, we interpret the reduction in price as an increase in households' real incomes or "purchasing power"[191]. This results in increased demand for air travel,

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[190] The econometric estimation period used to inform the productivity effect did not include any step-changes in frequency benefits. Therefore, frequency benefits were captured in the coefficients estimated as part of the econometric analysis. This point is considered in more detail in Chapter 4.

[191] For technical reasons, the price impact on consumers is modelled as a change in productivity. See Chapter 4 for details of this.

and potentially other goods and services in the economy as households' savings from lower fares can be spent elsewhere (this is called the "income effect" of a price change). This increased demand places direct upward pressure on GDP: consumers are willing to pay more for goods and services, meaning that firms are able to produce output profitably that was previously unprofitable, so that output expands. In turn, this has multiplier impacts through the supply chain as firms increase their demand for inputs. As GDP and aggregate demand increase, upward pressure is placed on prices – this, again, is the diffusion effect. This dampens the ultimate impact of the effect of the real increase in consumer incomes.[192]

Conversely, airlines are able to extract less economic rent as a result of the reduction in capacity constraints and experience a reduction in profitability as a result of the price fall (a reduction in "producer surplus"). Airlines pay lower dividends to households – the ultimate owners of firms in the model – which places additional downward pressure on GDP. As with the consumer gain, diffusion effects (diffusion tends to *decrease* prices in this case) dampen the ultimate impact on GDP.

The overall impact of the TEE effect depends on:

1. The relative sizes of the gains to consumers and losses to producers; and

2. The relative strength of the multiplier linkages of the gains to consumers and losses to producers.

The sizes of the forecast gains to consumers and losses to airlines have been provided for use in our modelling by the AC. In the Assessment of Need scenario in 2050, the gains to consumers are £8.2bn, compared to the losses to producers of £6.1bn. The S-CGE model suggests that in the same year and scenario, for every £1 of consumer gain, the increase in GDP is £0.60, whilst for every £1 of airline loss the fall in GDP is £0.20. The reason that the GDP loss associated with a £1 reduction in producer surplus is larger (in absolute terms) than the GDP gain associated with a £1 increase in consumer surplus is as follows. The reduced producer surplus results in lower returns to airline shareholders. In the S-CGE model these shareholders are households. However, the households most affected by the reduction in airline profits are amongst the most affluent in the economy, and their consumption does not reduce at the same rate as the boost to consumption associated with the increased consumer surplus since these wealthier households have a higher propensity to save (consumer surplus accrues to a broader set of households, being those who use airlines). For both the consumer gain and the airline loss, the final impact on GDP is less than the original input, reflecting the diffusion effects described above.

On the basis of this information, the results of our analysis suggest that the TEE effect might increase GDP by between 0.1% and 0.5% in 2050, depending on the scenario. The PV of the TEE impact is estimated to be between £21.6bn and £73.6bn over the 60 year appraisal period. The PV is highest in Low Cost is King scenario, and lowest in the Assessment of Need scenario.

### *8.1.4 Overall impact*

The level of GDP in 2050 is forecast to be around 0.5% to 1.0% higher than it would have been in the absence of the LHR NWR scheme, depending on the scenario. When all of the effects are taken together, the PV of the GDP impacts of the LHR NWR scheme is forecast to be between £95.2bn and £184.5bn, excluding construction impacts (depending on the scenario). This rises to £107.8bn to £197.1bn when construction impacts are included. The ratio of the PV of the GDP impacts to the PV of the inputs to the S-CGE model (i.e. the total PV of the net passenger expenditure, productivity, frequency benefits, and TEE inputs) for the LHR NWR scheme is 0.61. This ratio provides an indication of the magnitude of the GDP impact implied by the model, relative to the magnitude of the inputs to the model. The fact that this ratio is less than one is largely a result of diffusion effects of price rises described above. This illustrates the point made in the introduction that the S-CGE framework does not allow a "free lunch", and many of the impacts we describe are offset by effects working in the opposite direction. The increase in GDP by 2050 is underpinned by increased:

[192] There could be a of an overlap when considering only business passengers, between these benefits and the productivity effects outlined above, as the potential increase in trade could be a reason for business travellers demanding air transport. However, this issue does not occur within our analysis as the econometric relationship has not been estimated over a period where there is a step-change in seat capacity, and therefore does not capture the reverse impact of changes in capacity on demand (please see Section 4 in Appendix C for a full exposition of this).

- Net inbound and passenger spending (UK passenger expenditure outside of the UK is forecast to be 0.1% to 0.2% higher than they otherwise would be and foreign passenger expenditure in the UK is forecast to be 0.2% to 0.5% higher);
- Net trade (net trade is forecast to be around 0.1% lower than it otherwise would be)[193] while the trade deficit increases the additional flows of imports and exports have facilitated a substantial productivity gain; and;
- Consumption (which is forecast to be 0.5% to 0.9% higher); and
- Investment (which is forecast to be between 0.0% and 0.4% higher, see below).

Among the sectors of the economy, the air passenger transport and freight industry is forecast to experience the largest percentage growth, being a forecast 15.4% higher in GDP terms in 2050 in the Assessment of Need scenario, compared to the baseline scenario. The sector is forecast to grow by more than the increase in passenger numbers in proportional terms, owing to the projected shift towards more high-value and long-haul services. Due to their strong international linkages, the manufacturing and agriculture sectors are also expected to be important beneficiaries: in 2050 manufacturing is forecast to expand by 2.0% relative to the baseline scenario, with agriculture expanding by 1.5% in the same period. The construction sector is also forecast to benefit, with output increasing by 33.1% in 2020 compared to the baseline as a result of airport construction, and by 2.7% in 2050, principally as a result of ongoing maintenance activities at the airport.

The model suggests that the LHR NWR scheme could create 180,000 new jobs (both at the airport itself and indirectly in the wider economy), many of which would be in the aviation and manufacturing sectors. The number of firms in the economy is not expected to change in the long run (an analysis by sector is provided later in this chapter).

The LHR NWR scheme would also be expected to have important regional impacts. The model suggests that the benefits would be somewhat concentrated in London & South East, which is forecast to gain by between £35.8bn and £70.5bn in PV terms (excluding construction). Over time, prices in London & South East would be expected to rise relative to other regions as a result of the increased activity. With projected increases in GDP of £42.4bn to £78.1bn and £16.7bn to £36.5bn in PV terms respectively by 2050 the Rest of England and the Rest of the UK also stand to benefit by a significant amount from the schemes. The reason is that productivity impacts are experienced nationally (for example, even firms which do not use the aviation linkages directly may still benefit, since they may be able to “learn” from firms which do seek to increase their productivity by exploiting the improved aviation linkages), and the frequency and TEE benefits would be expected to accrue to all airport users, a large proportion of whom reside outside of London & South East.

The estimated impact of the LHR NWR scheme is in line with the findings from previous studies. For example, analysis of potential airport sites in Sydney found that a new airport carrying up to 54 million passengers in 2060 could increase the level of real GDP in Australia by 1-1.2%[194]. Given the greater increase in passenger flows enabled by the new airport in Sydney, relative to the LHR NWR scheme, one would expect it to have a greater impact on GDP. In addition, the smaller size of the Australian economy, relative to the UK, would ensure that additional passenger flows have a relatively larger impact.

Whilst some of the impacts are less certain than others (see Chapter 5) and the figures are different under alternative scenarios, this illustrates the extent of forecast GDP benefits associated with the LHR NWR scheme.

## *8.2 Total GDP impacts*

This section examines the forecast GDP impacts of the LHR NWR scheme by scenario at a national level. In this analysis we look only at the effects produced during the operational phase of the expanded airport, since we are primarily interested in the effects of improved aviation linkages rather than construction impacts.

Figure 109 shows the forecast overall impact on the level of real GDP of the operations of the LHR NWR scheme. In all scenarios, operational phase impacts would be expected to increase relatively gradually, reflecting the

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[193] It should be emphasised that this represents the *net* change in trade (excluding tourism/passenger flow impacts). This is underpinned by significant increases in both imports and exports, which have an offsetting effect.

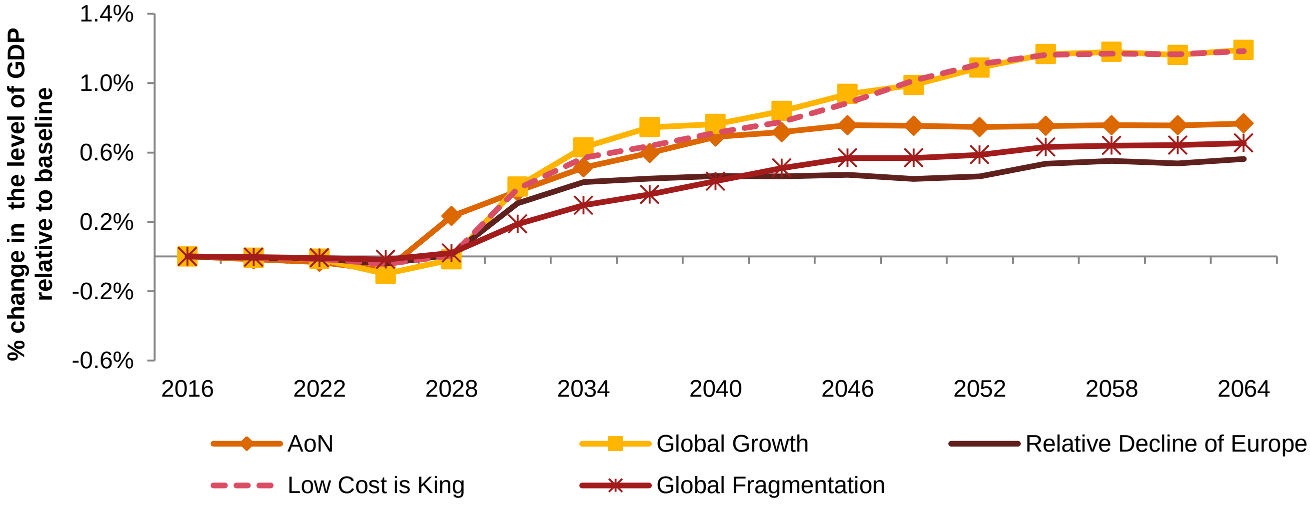
[194] Ernst & Young (2012). *Economic and social analysis of potential airport sites: Sydney Aviation Capacity Study*. Report for the Australian Government Department of Infrastructure and Transport.

underlying assumptions embodied in the passenger flow figures supplied to us by the AC. The overall effect of passenger spending itself is positive in GDP terms and the increase in runway capacity is expected to increase connectivity and bring with it new business travellers. The increase in business travel would be associated with increased international trade, FDI and inflows of skilled migrant labour. UK businesses can also communicate with international clients more effectively allowing them to build up stronger business relationships (Chapter 2 provides the associated evidence and a more detailed discussion on this topic). By the mid-2030s, the model predicts that the Heathrow LHR NWR scheme will lead to an increase in real GDP compared to the baseline of 0.3% - 0.6%.The overall impact on GDP is forecast to increase to around 0.5% - 0.8% by the mid-2040s. From the mid-2030s the estimated effects begin to diverge across the scenarios. The Global Growth and Low Cost is King scenarios produce greater effects compared to the Global Fragmentation and Relative Decline of Europe scenarios. By the mid-2050s, the Heathrow LHR NWR scheme's impacts are forecast to settle at between 0.5% and 1.2% of GDP. The modelling suggests that any increase in real GDP represents an upward shift in the level of GDP, rather than a permanent effect on the growth rate. The drivers of these GDP effects are: passenger flows; productivity; frequency benefits; and TEE, and are discussed in more detail below.

At the outset of the operational phase, there is a modest reduction in GDP of around 0.1%, relative to its steady-state growth trajectory. This occurs because households in the model are "forward-looking". In particular, households foresee that the airport will have a positive effect on GDP once the scheme becomes fully functional. They therefore anticipate increased returns to expenditure in the future, through relatively price decreases driven by productivity improvements. In order to capitalise on these higher returns, households reduce their consumption in the short-term in order to increase savings, which results in a temporary contraction in output.

It is difficult to be sure whether this effect will materialise in reality and it is possible that the effect will be less pronounced than that implied by the model. However, the assumption of "forward looking" households has been thoroughly investigated within the academic literature and has sound theoretical underpinnings. It is therefore important to be aware of the possibility of such an effect, although the timing and magnitude is unclear.

*Figure 109: LHR NWR GDP impacts on the level of real GDP, by scenario*




*Source: PwC analysis*

## 8.3 Present value of GDP impacts

Table 70 below displays the PVs of the forecast total real GDP impact for each of the scenarios. All PVs are calculated on the basis of a 60 year appraisal period (2019 to 2078) using a 3.5% discount rate for the first 30 years and a 3.0% rate for the remaining years (following HM Treasury Green Book guidance).

The tables show, based on our S-CGE modelling and the inputs supplied to us by the AC, that the economic impact of a third runway at Heathrow is forecast to be considerable across all scenarios. If all the effects, which are modelled are realised, the PV of the GDP impacts could be in excess of £100bn. The variation in forecast PVs across the scenarios is significant. The Relative Decline of Europe and Global Fragmentation scenarios have similar PVs, which are lower than those seen in other scenarios. PVs associated with the Global Growth and Low Cost is King scenarios are considerably higher.

In most cases, the analysis below considers all five of the passenger flow scenarios, in order to show how impacts differ across the different assumptions for passenger flows in the AC's alternative scenarios for the development of the aviation sector. In the interest of brevity, and where the choice of passenger scenario is unlikely to alter the findings materially, we occasionally present detailed analysis for only one of the scenarios. In this case, the Assessment of Need scenario is used as the example. Table 70 demonstrates that this scenario has a moderate overall GDP impact relative to the other four scenarios.

Table 70 also demonstrates the degree to which **the findings from the analysis are driven by the underlying input assumptions provided by the AC**. Changing the underlying assumptions on passenger flow growth is sufficient almost to double the modelled economic impact which the additional capacity generates.

*Table 70: LHR NWR Present Value of real GDP impacts, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Total** | 131.8 | 184.5 | 95.2 | 183.2 | 103.0 |

*Source: PwC analysis*

In addition, the AC have asked us to display the PVs of the forecast total real GDP impact for each of the scenarios for a 60 year appraisal period starting from the opening date of the scheme, in 2026. These are displayed in Table 71 below.

*Table 71: LHR NWR Present Value of real GDP impacts, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Total** | 147.2 | 211.4 | 111.7 | 209.6 | 118.3 |

*Source: PwC analysis*

## 8.4 Drivers of GDP impact

The previous section demonstrates the range of GDP impacts provided by the LHR NWR scheme under the five passenger scenarios. In this section, we describe the key drivers of these impacts and the underlying economic mechanisms that lead to the results.

### 8.4.1 Impact by GDP component

*GDP components and transmission mechanisms*

We begin by breaking down the change in GDP into its constituent parts. One way to measure GDP is on an "expenditure basis", which means accounting for the expenditure by households and businesses in the UK. The expenditure measure is made up of a number of components according to the "National Accounting Identity" (NAI). This can be expressed as follows:

$$\begin{aligned} Real\ GDP = {} & Real\ Consumption + Real\ Investment + Real\ Government\ Consumption\ and\ Investment \\ & + Real\ Net\ Trade + Real\ Passenger\ Flow\ Exports - Real\ Passenger\ Flow\ Imports \end{aligned}$$

Usually, trade and passenger flow impacts are accounted for together in expressing the NAI. This is because passenger flow impacts form part of trade (in particular, additional passenger spending within the UK is regarded as an export and additional passenger spending outside the UK is regarded as an import). However, since passenger flow impacts are such an important part of this research, we have separated passenger flow effects from trade. This means that Real Net Trade in the equation above is net of passenger flow impacts.

Figure 110 below breaks down the forecast GDP impacts into their component parts for the Heathrow LHR NWR scheme (using the Assessment of Need scenario to illustrate). The impacts can be summarised as follows:

- **Real consumption.** The most substantial forecast impact of the LHR NWR scheme is seen in consumption. In the initial phase, before the runway is open, consumption falls marginally. This occurs because agents anticipate future improvements in productivity and therefore substitute away from current economic activity to additional activity in future. However, this drop is insignificant in the context of the overall impact of the LHR NWR scheme and in the long-term real consumption is forecast to increase well beyond the level that it would have been in the absence of the LHR NWR scheme. This is because the higher productivity generated by the increase in capacity is expected to increase household income, and therefore allows higher consumer spending.
- **Real investment.** The overall impact of the operational phase of the LHR NWR scheme on real investment is forecast to be limited, with the majority of the investment occurring during the construction phase. A small dip in investment is seen in the early years of operation, but this is reversed towards the end of the period with the total change being roughly neutral. There are two key drivers underlying this effect: firstly, the removal of the capacity constraint is expected to generate a large transfer from the airline sector to consumers, as the potential to charge economic rents on landing slots is reduced (see section 8.4.3.4). This reduces the incentive to invest in the airline sector following the opening of the new runway. Secondly, as agents in the model are rational and forward-looking, they predict that a greater return on investment will be possible towards the end of the period as the airport reaches capacity and the full productivity benefits materialise – this is known in the model as a *confidence effect* (see below). This incentivises them to defer investment from the early operational phases to the end of the period studied, giving rise to the small, temporary fall in investment.

| | |
|---|---|
| **Confidence effect** | A key feature of the model is that economic agents (consumers and firms) are "forward-looking", in the sense that they form expectations of future economic variables (such as interest rates, the price level and output) and adjust their behaviour accordingly. Specifically, the model assumes that agents form "rational expectations" (Muth, 1961)[195], meaning that the firms and households within the model assume that the predictions generated by the model are correct. In forward-looking models like this one, "confidence effects" can be important. In the context of airport expansion, the confidence effect means that agents foresee that airport improvements will have a positive impact on profits and output. |

The forecast increased level of investment later in the period consists of a mix of both domestic and foreign direct investment (FDI). The increased level of economic activity associated with the LHR NWR scheme incentivises other sectors of the economy, as well as the aviation sector, to invest. Our model results suggest that investment will rise in the majority of the business sectors captured in the S-CGE model. However, the precise mix of domestic and foreign investment is too difficult to predict as appropriate data are not available at the regional level. The forecast long-term increase in investment is also partly driven by ongoing maintenance activities at the enhanced airport facilities.

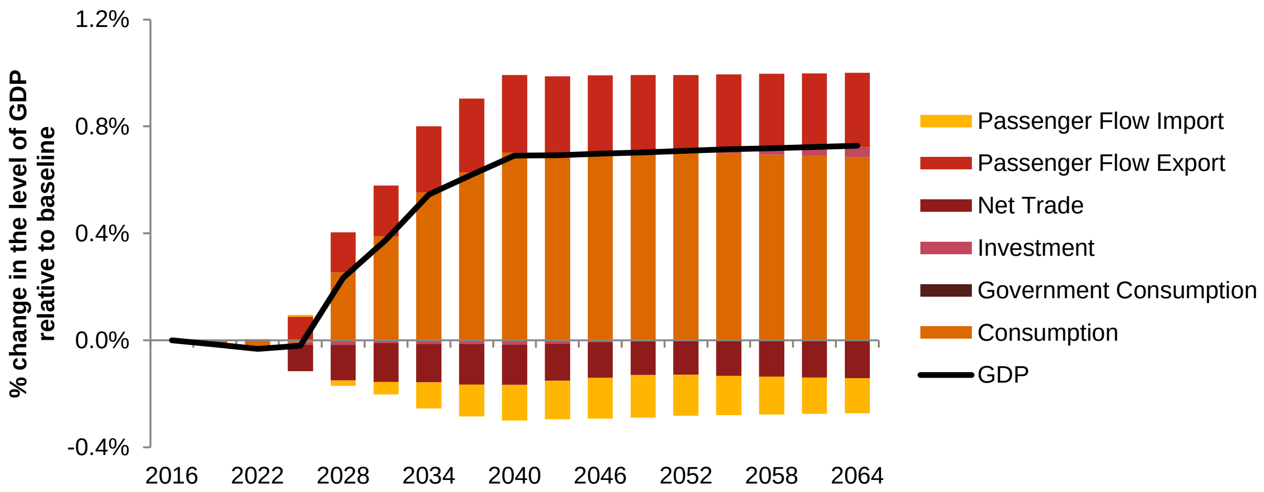
- **Real government consumption and investment.** In the operational phase, government consumption is unchanged relative to the baseline. This is due to the assumed "Harberger closure rule" (described in detail in Appendix B), which states that net government expenditure remains constant i.e. any government receipts (outgoings) are transferred to (from) consumers. Overall the level of taxes paid rises in the model (see Section 7.7 for more detailed fiscal results), this increase being attributable to the higher levels of economic output. Despite not directly contributing to an increase in the level of GDP, this has a positive impact through the *government expenditure effect* explained below.

| | |
|---|---|
| **Government expenditure effect** | The expansion of the aviation sector generates receipts to government in the model via Air Passenger Duties. Moreover, higher levels of GDP raise government revenues from general taxation. Under the "Harberger closure rule" adopted for this work (see Appendix B), these increased tax receipts are "handed back" to consumers via lump-sum transfers. As consumption increases as a result, this places further upward pressure on aggregate demand and GDP. |

[195] Muth, J.F., (1961). Rational Expectations and the Theory of Price Movements, *Econometrica*, Vol. 29, No. 3, pp. 315-335.

- **Real net trade.** Figure 110 demonstrates that the overall impact of the increase in airport capacity is a fall in net trade, excluding the impact of changing passenger spending patterns. Although UK firms experience an improvement in international competitiveness and exports increase substantially, this generates wealth, part of which will be spent by households on increasing their consumption. The increase in household consumption within the UK is forecast to lead to an increase in imported consumer goods. Businesses also use imports, in the case of the manufacturing sector, they are processed and turned into exports, if businesses are able to produce and source imports more efficiently, this will be better for their overall productivity.
  Overall the UK's terms of trade improves. This is because the price level in the UK is forecast to fall as the increased productivity associated with UK aviation sector expansion allows goods and services produced in the UK to be sold more cheaply. Exports therefore expand. An improvement in the terms of trade could in turn signal a reduction in imports. However, part of the boost to productivity is associated with UK businesses being better able to source production inputs from overseas – greater air connectivity allows businesses to link with a wider range of suppliers and get better quality products and improved deals. The impact of openness on domestic productivity is established within the econometric analysis. Also, the underlying expansion in output in the UK economy means that more imports will be required for consumption in the domestic market (household incomes rise, so demand rises).
- **Real passenger flow imports and exports.** Due to the importance of changing passenger flows in our analysis, Figure 110 also shows separately the contribution of passenger flow imports (spending by UK residents abroad) and passenger flow exports (spending by foreign visitors within the UK) to overall GDP. In conventional National Accounting treatments these effects would be captured within changes in net trade. The passenger flow impacts are explained in full below. At a high level, the overall impact of passenger flows on GDP is determined by the net impact of these two different effects. Figure 110 shows that both are forecast to have substantial impacts on overall GDP, although the net impact is considerably smaller.

*Figure 110: LHR NWR breakdown of real GDP impacts, Assessment of Need scenario*




*Source: PwC analysis*

## *8.4.2 Impact by sector*

Table 72 shows the forecast change in sectoral real GDP as a result of the increase in aviation capacity associated with a third runway at Heathrow, over the period 2020-2060. These figures are based on the Assessment of Need passenger flow scenario, and show the percentage difference in each year from the corresponding baseline scenario figure. The relative sizes of these sectors is given in Section 3.4.

*Table 72: LHR NWR Breakdown of impact on the level of real GDP by sector, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and mining** | 0.5% | 0.7% | 1.4% | 1.5% | 1.5% |
| **Manufacturing** | -0.1% | 1.5% | 2.1% | 2.0% | 1.9% |
| **Utilities** | 0.5% | 0.6% | 1.3% | 1.4% | 1.3% |
| **Construction** | 0.7% | 0.8% | 2.0% | 2.2% | 2.1% |
| **Retail and wholesale trade** | 0.1% | -0.6% | -0.5% | -0.5% | -0.4% |
| **Air passenger transport and freight** | 1.5% | 8.3% | 13.0% | 15.4% | 12.9% |
| **Other freight** | -0.2% | -1.1% | -1.2% | -1.4% | -1.2% |
| **Other passenger transport** | -0.4% | -0.6% | -1.1% | -1.6% | -1.2% |
| **Accommodation and food services** | 0.1% | 0.9% | 1.3% | 1.3% | 1.3% |
| **Other services** | 0.9% | -0.7% | 0.1% | 0.2% | 0.3% |
| **Health, education and public spending** | 0.2% | 0.0% | -0.1% | -0.1% | -0.1% |

*Source: PwC analysis*

The most significant change is seen in the air passenger transport and freight sector, which is forecast to be more than 13.0% larger than in the baseline scenario by the end of the period. This is unsurprising given the direct boost to this sector which the reduction in the capacity constraint allows.

Sectoral growth elsewhere is relatively small, with the magnitude of change being no greater than +/- 2.6% of sector size in the baseline by the end of the period.

Of the remaining sectors, those with strong international linkages, most notably agriculture and manufacturing, are forecast to grow relatively more substantially than others as a result of the increase in capacity. This is due to a decline in the cost of air transport, leading to sector-specific increases in productivity and international competitiveness, and subsequently an increase in output. Accommodation and food services are also forecast to grow significantly, due to the increase in demand generated through the increase in passenger flows. The efficiency benefits for non-aviation sectors are expected to be magnified through the *reorganisation effect*, whereby they shift their production processes towards air transport.

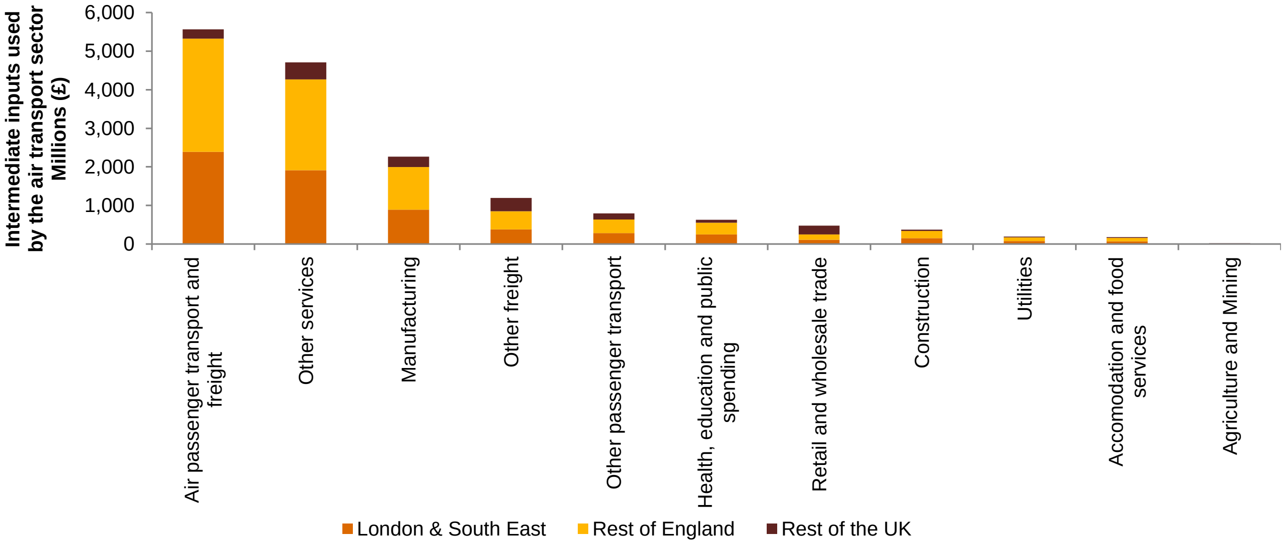
| | |
|---|---|
| **Reorganisation effect** | SACTRA identifies a "reorganisation effect" as input substitution within the production system and logistics of the firm to take advantage of lower transport costs. Although transport costs are not modelled explicitly in the S-CGE framework, a key strength of the S-CGE model is that firms will automatically reorganise their production processes in response to changes in input prices (be they wages, rental on capital or the prices of intermediate inputs). This means, for example, that as prices of intermediate inputs fall (for instance as a result of the firms becoming more efficient as a result of the productivity effect discussed below), firms will be able to reorganise their activities to make efficient use of the cheaper inputs, thereby increasing GDP. |

The two sectors which are forecast to contract the most are other freight and other passenger transport, which between them represent all non-air transportation and storage. This is because these sectors are substitutes for air transportation, and therefore see a fall in demand as the cost of air transportation falls. It should be noted that these results are the average impacts, and so do not capture sub-sectoral variation. For example, it is likely that freight forwarders who rely on air freight may benefit from an increase in capacity, while over longer distances the two sectors may be stronger substitutes.

Retail and wholesale trade GDP is also forecast to shrink marginally. This is due to declining transport margins increasing competition and subsequently reducing profitability. This leads to a negative price effect which more than offsets the reduction in input costs generated by cheaper air transport, leading to a decline in the GDP of the sector. A final small reduction is also forecast for the public sector, as a small proportion of workers move to the private sector as a result of higher wages.

Figure 111 below demonstrates the distribution of spending by the air transport sector in 2010, by sector. This helps to explain some of the findings above, particularly in the forecast growth of manufacturing, which features prominently in the supply chain of the air transport sector, and will therefore experience an increase in demand as the sector expands, in addition to the benefits from international linkages previously explained. The wholesale and retail trade sector is a material receiver of expenditure from air transport, although this is still relatively modest in relation to the size of that sector, and therefore is not sufficient to reverse the contraction explained above. The second largest receiver of expenditure is the Other Services sector, although given the size of this sector (which includes financial, professional and business services), this is a reasonably moderate effect in relative terms.

*Figure 111: Distribution of intermediate inputs used by the air transport sector in 2010*




*Source: PwC analysis*

GDP in the freight sector is forecast to be impacted by up to 2.6% in 2030, going up to 5.1% in 2060. This implies that the impact on the freight sector is larger compared to the impact on other sectors, but lower than the impact on the air passenger transport sector. This relatively large impact is due to the strong linkage between the air freight and air passenger transport sector in the supply chain and labour market. This ensures that positive effects within the air transport sector have a disproportionately large impact on air freight.

Please refer to Box 7 below for a more detailed discussion of the air freight sector.

*Table 73: LHR NWR Breakdown of impact on the level of real GDP of the air freight sector, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Impact on air freight GDP (%)** | 0.00% | 2.59% | 3.28% | 3.81% | 5.09% |

*Source: PwC analysis*

**Box 7: The air freight sector**

*Air freight*

The air freight, or air cargo, sector refers to goods transported by aircraft, whether by dedicated freighters or in the belly-hold of passenger aircraft.

The GVA of the UK air freight sector is currently £87m, or less than 0.01% of total the economy's total GVA. In 2011, £116bn worth of goods were transported by air freight between the UK and non-EU countries, around 35% of the UK's extra-EU trade by value, and in total air freight was one fifth of all trade by value. These are large proportions considering that air freight represents a very small proportion of tonnage of all freight, and is due to the nature of goods and produce usually transported by air freight, which tend to be high value and low volume, such as the jewellery or high-tech sectors. Industries that are time-sensitive are also large users of air freight, such as pharmaceutical products. Air freight is currently estimated to provide approximately 39,000 jobs in the UK.

*Market outlook*

Boeing's 2013 forecast reported that world air cargo traffic has slowed since 2004, having only grown 2.0% per year on average since then, relative to the historical trend of 6.7% between 1981 and 2004. According to Boeing, this slowdown was mainly down to the global economic downturn and the rising price of fuel, but within this time period there has been volatility; a 12.50% fall in traffic between mid-2008 and mid-2009 was followed by an 18.5% surge in 2010, followed by another contraction in 2011.

Despite this deceleration in growth, Boeing forecasts that world air cargo traffic will double by 2031 and grow at a rate of 5.2% per annum over the next 20 years, and that air freight will average 5.3% annual growth, measured in real revenue tonne-kilometres. Asia will lead the industry in terms of highest average annual growth rates, whereas the mature Northern American and European markets will be reflected in slower and lower rates.

Boeing also estimates that the number of aircraft in the worldwide freighter fleet will increase by more than 80% during the next 20 years, in reaction to the growth in demand for air cargo services. It is envisaged that large freighters will play an increasing role and represent 36% of this enlarged fleet today compared to 22% a decade ago; large freighters can take advantage of greater capability and efficiency that they offer to manage the increase in demand without proportionally increasing the number of aircraft. Globally, cargo revenue represents around 15% of total air transport revenue. However, some airlines earn nearly 40% of their revenue from freight.

*Inclusion in the model and potential impacts*

In the S-CGE model, air freight is split out from the Transportation and Storage Sector in order to more accurately estimate the impact of the change in airport capacity on specific subsets of the aviation sector. The split has been created primarily using data from the Annual Business Survey published by the Office for National Statistics (ONS), giving the sub-sectoral breakdown across a number of areas, including number of employees, GVA and intermediate consumption.

We would expect an airport expansion in the model to feed through via wider economic impacts and affect the air freight sector in a positive way. Expansion at Heathrow or Gatwick would initially affect belly-hold cargo; belly-hold accounts for the majority of air freight in the UK, but new options would also be opened up for dedicated freighters.

In the S-CGE model, increased connectivity at an airport fosters the flow of passengers, which includes business passengers, resulting in an increase in trade. New long-haul routes in particular have the potential to open up new export markets. Demand for freight is pro-cyclical and likely to track movements in trade as local businesses become better connected to global markets. On the supply-side, air freight and passenger flows are inextricably linked as much air freight travels in the belly-hold of passenger aircrafts; this is particularly relevant for new markets where demand is not yet predictable or established. Airport expansion would enable the increase in passenger flows that is forecast until 2050 and therefore would also imply more capacity for belly-hold freight, which may in turn even lower the cost of exporting goods.

For dedicated air freighters, a key issue is to maintain the express delivery industry, which they dominate. The express industry is supported primarily by the availability of night flights, the regime of which may be affected by an expansion. The DfT concluded in July 2014 that it would not make any significant changes to the current restrictions on the night flight regime at Gatwick, Heathrow or Stansted before the AC publishes its final report. The express industry was estimated to contribute £2.3bn to UK GDP and 82,000 jobs in 2010. Research undertaken by Oxford Economics has suggested that restricting night flights could have a negative employment impact, and removing the availability of next-day delivery services in the UK could reduce GDP by £3bn.

At present, the majority of air freight infrastructure resides at Heathrow airport, which handles 86% of all UK belly-hold passenger cargo, and many freight operators are based there. An increase in demand for air freight, facilitated by additional airport capacity, would raise the question of whether any activity would be substituted away from Heathrow to Gatwick, and whether Gatwick would be required to invest in freight infrastructure in order to take on some of the increase in demand.

### *8.4.3 Impact by effect*

To further understand the impacts, we now examine in detail the four key effects associated with the operation of the LHR NWR scheme which we modelled as set out above:

1. Passenger flows;
2. Productivity;
3. Frequency benefits; and
4. TEE.

The PV of each of these effects[196], for each passenger scenario, can be seen in Table 74 below. The table demonstrates that the greatest impact is forecast to be through the productivity and TEE effects. The inputs which drive each of these forecast effects and how they impact on overall GDP are explored in greater detail below.

The PV estimations below are heavily influenced by the time trend of the inputs, which determine whether the majority of the benefit is experienced at the beginning or the end of the period studied. This motivates households to shift their economic activity towards the time periods where they get the greatest return on their expenditure. While this doesn't affect the long-run impact on the level of GDP, it has important implications for the PV estimations as benefits experienced in later time periods are heavily discounted relative to earlier ones.

[196] Please note that the “passenger flows” effect here refers to the overall GDP impact of changes in passenger flows. This captures a broader range of effects on GDP which result from changes in passenger flows than the direct spending impact as outlined in Table 74.

*Table 74: LHR NWR Present Value of real GDP impacts, by effect and scenario (£bn, 2014 prices)*

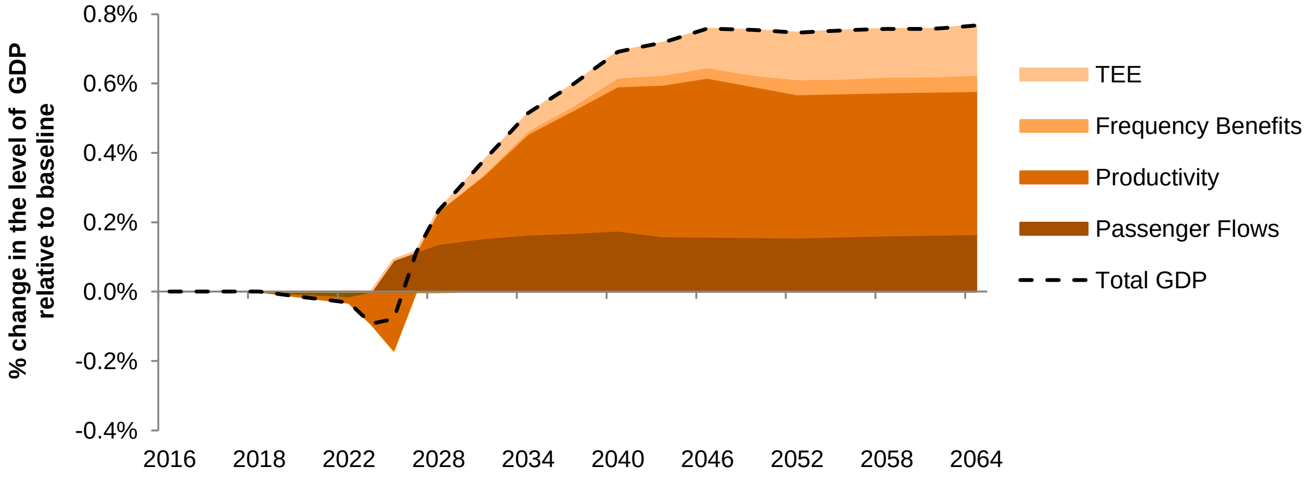
| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Passenger Flows** | 32.8 | 24.7 | 16.7 | 25.9 | 21.1 |
| **Productivity** | 70.9 | 79.7 | 41.8 | 73.1 | 54.5 |
| **Frequency Benefits** | 6.5 | 8.5 | 8.9 | 10.6 | 4.5 |
| **TEE** | 21.6 | 71.6 | 27.8 | 73.6 | 23.0 |
| **Total** | **131.8** | **184.5** | **95.2** | **183.2** | **103.0** |

*Source: PwC analysis*

Figure 112 below splits out the forecast real GDP impacts into these components over time. We show the results for the Assessment of Need scenario in order to illustrate these impacts; Table 74 demonstrates that the direction and relative magnitude of **each** effect are reasonably consistent across all passenger scenarios.

The early years of the operational phase of the LHR NWR scheme are dominated by the productivity effect. This initially sees a slight contraction in GDP as rational, forward-looking agents delay economic activity until the runway opens, before increasing in magnitude steadily. The effect of passenger flows can also be seen in the early stages as demand for capacity starts to be met with the opening of the new runway. From the mid-2030s, as the scheme becomes operational, the productivity and TEE impacts grow rapidly. The TEE effect becomes positive and significant, eventually contributing roughly one-quarter of the overall GDP impact. Passenger flow impacts remain at around one quarter of the effect from the operational phase until the end of our analysis period. Frequency benefits also begin to have an impact in the early 2030s, but the magnitude of this impact is moderate. By 2064, around 55% of the GDP benefits are associated with productivity effects, approximately 20% arise from TEE, and 20% from increased passenger flows. Finally, frequency benefits are also forecast to have an impact, but the magnitude of this impact is relatively small.

*Figure 112: LHR NWR effect-by-effect impacts on the level of real GDP, Assessment of Need scenario*




*Source: PwC analysis*

We now examine the passenger flow, productivity, frequency benefits and TEE impacts in detail, considering each in turn.

### 8.4.3.1 Effect 1: Passenger flows

*Inputs*

The passenger flow data are taken from the AC's demand forecasts produced using a version of the DfT's aviation forecasting model. More information on the model and approach is contained in the consultation document forecasts reports[197], and technical appendix 3 to the Interim Report[198].

In this section, we briefly describe the estimated passenger flows under each of the AC's passenger flow scenarios, which act as direct inputs into the S-CGE model and also inform our analysis of productivity effects (i.e. Effect 2). Passenger flows affect the results of the S-CGE analysis by determining:

- The size of the aviation sector;
- Changes in productivity; and
- The level and nature of additional passenger spending, inside and outside of the UK.

*Data input description*

Table 75 summarises the total forecast UK passenger flows across the five scenarios in 2050 for the Do Minimum baseline scenario and the LHR NWR scheme. There is a wide range in the number of additional passengers in the UK system as a whole which the additional capacity enables, ranging from 17m (418m to 435m in the Relative Decline of Europe scenario) to as much as 39m (457m to 496m in the Global Growth scenario).

*Table 75: LHR NWR and Do Minimum Total UK passenger flows in 2050, by scenario (millions of passengers)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Do Minimum** | 405.6m | 456.7m | 418.4m | 458.0m | 396.6m |
| **LHR NWR** | 430.2m | 495.5m | 435.1m | 494.1m | 419.8m |
| **Increase** | 24.6m | 38.8m | 16.7m | 36.1m | 23.2m |

*Source: PwC analysis*

In addition to the total UK passenger numbers, the characteristics of these passengers and their associated spending patterns are important in determining the impact on real GDP. The AC did not provide forecasts of the split between inbound and outbound passengers in the future. For the purpose of this analysis we have agreed in conjunction with the AC to assume that the balance of inbound and outbound passengers and their associated spending patterns remain at their existing levels in the event of airport expansion. Any difference from this assumption in reality would have an impact on the magnitude of the estimated impact on GDP.

The ONS Travel Trends publication contains information on the number of inbound and outbound trips made through Heathrow in 2011[199]. This demonstrates that, through Heathrow, 9.8m passengers made outbound trips from the UK (22% of UK total), and 9m passengers made inbound trips to the UK (40% of UK total). Differences in spending patterns mean that, despite facilitating more outbound than inbound trips, passengers travelling through Heathrow spent more within the UK than outside it. Using data from the Tourism Satellite Account[200], it can be estimated that these trips through Heathrow led to £6.8bn additional expenditure by UK passengers outside the UK, and £7.3bn additional expenditure in the UK by passengers from abroad. In addition, UK passengers travelling abroad spent an estimated £5.2bn in the UK on their outbound trip. Overall

[197] See: Department for Transport (DfT) (2013) *UK Aviation Forecasts 2013*. London: Department for Transport.

[198] See: Department for Transport (DfT) (2014) *Appendix 3: Technical Appendix to the Airports Commissions Interim Report*. London: Department for Transport.

[199] Office for National Statistics (ONS) (2011) *UK Travel Trends, 2011*. Available at: http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-269632

[200] Office for National Statistics (ONS) (2013) *Tourism Satellite Accounts 2010*. http://www.ons.gov.uk/ons/rel/tourism/tourism-satellite-account/index.html

therefore, spending due to passenger flows through Heathrow in 2011 was associated with approximately £12.5bn of expenditure in the UK compared to £6.8bn outside the UK.

However, only £7.3bn of the expenditure in the UK (that which relates to passengers travelling from abroad) could be seen as additional demand. The remaining £5.2bn is likely to largely displace household consumption in the UK which would have otherwise occurred in the absence of air transport through Heathrow. This displacement of domestic consumption means that the net GDP impact of passenger spending associated with Heathrow in 2011 is likely to have been less positive than the difference between expenditure within and outside the UK. This pattern will have important implications for the GDP impact of additional passenger flows resulting from the LHR NWR scheme.

*Nature of passenger flow change*

This sub-section looks in more detail at two specific elements of the passenger flow input data:

- The time profile of the increases in passenger flows forecast by the AC; and
- How the increase in passenger flow is expected by the AC to vary by type of passenger.

Table 76 below summarises the first of these elements by showing the forecast change in passenger numbers over time from 2011-2050. There is a large increase in the total number of UK passengers across all passenger scenarios relative to 2011, with overall increases of between 98% and 127%, between 2011 and 2050. The growth in passenger flows is relatively consistent over time, but there is an extra ramp up between 2020 and 2030 when the new capacity is first available. It should be borne in mind that the additional capacity created by a third runway at Heathrow would be in the region of 40-45m passengers per year by 2050, and that under all passenger scenarios this capacity would be highly utilised by this date. The information in Table 75 above shows that the size of the increase in total UK passenger flows relative to the Do Minimum is often below this, highlighting that a substantial share of the additional demand at Heathrow is forecast to be redirected from existing UK airports. This would also have important implications for the net impact of additional passenger spending, as any additional inbound expenditure due to increased passenger flows through Heathrow would partly be offset through falling expenditure associated with other airports. The same effect would apply to additional expenditure outside the UK due to an increase in the number of outbound trips.

*Table 76: LHR NWR Total UK passenger flows from 2011 to 2050, by scenario (millions of passengers)*

| | 2011 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| **Assessment of Need** | 217.8 | 256.8 | 327.3 | 382.5 | 430.2 |
| **Global Growth** | 217.8 | 267.9 | 355.5 | 426.6 | 495.5 |
| **Relative Decline of Europe** | 217.8 | 259.6 | 328.6 | 379.8 | 435.1 |
| **Low Cost is King** | 217.8 | 267.9 | 352.6 | 423.1 | 494.1 |
| **Global Fragmentation** | 217.8 | 250.1 | 311.7 | 366.1 | 419.8 |

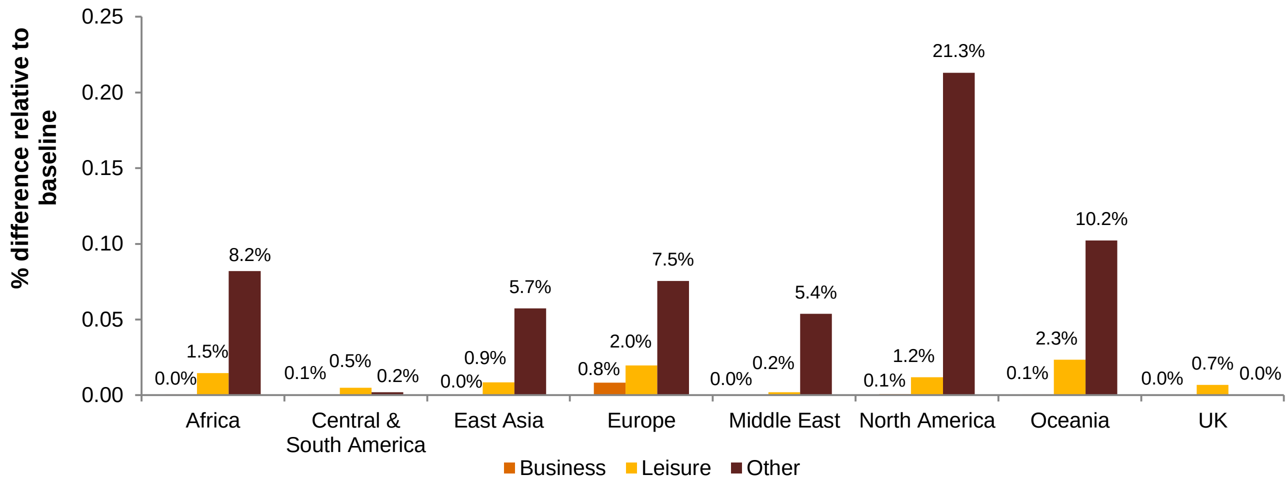
*Source: AC demand forecast*

Figure 113 below demonstrates how passenger flows have been forecast by the AC to change by type of passenger (business, leisure, or other - which primarily comprises international transfer passengers), and destination region. Changes in the forecast passenger mix will have an important impact on the level of connectivity generated.

This figure demonstrates that there is some growth across all passenger types as a result of the LHR NWR scheme. The majority of the increases in passenger flows forecast by the AC for the LHR NWR scheme, relative to the Do Minimum, are for international transfer and leisure passengers. The largest relative increases can be seen in journeys to and from North America, although there is growth across all regions. There are also significant increases in trips to other global destinations such as Africa, Oceania and East Asia.

The AC's forecasts suggest that new capacity will result in an increase in international transfers, which might also improve the feasibility of long-haul routes (e.g. by providing a "critical mass" of traffic which in turn might result in high frequency, long-haul flights being provided to a greater range of destinations in a cost effective manner). This would have important implications for the UK's international connectivity. The productivity benefits of additional long-haul traffic are captured through the econometric analysis in the modelling of Effect 2.

*Figure 113: LHR NWR change in PAX in 2050 relative to Do Minimum, by passenger type and region, Assessment of Need scenario*




*Source: PwC analysis*

**Box 8: Multipliers on inbound and outbound passenger flows**

To understand the passenger flow impacts, it is helpful to illustrate the different types of 'multipliers' observed in the S-CGE model associated with passenger spending patterns. There are four different multipliers relating to the decision to travel and the decision to trade (Bond, 2008; Vellas, 2011):

1. UK exports: positive multiplier through UK-based supply chain;
2. UK imports: negative multiplier as displaces domestic consumption;
3. Foreign inbound tourists: positive multiplier from additional passenger spending; and
4. UK outbound tourists: negative multiplier as displaces consumption.

When a UK resident travels on a holiday overseas, they will spend money in the foreign country which will be a positive gain for that country. However, this money will be taken out of the UK and not spent on UK goods and services, so this implies a negative multiplier for the UK economy.

A key finding of the model is that the positive multiplier generated by foreign passenger flow spending is smaller than the cost to the UK economy of an additional UK resident travelling overseas. This is because of the strong downstream linkages that the purchase of domestic non-passenger-related products has in the UK economy versus the weaker linkages of foreign passenger consumption. This finding is consistent with that of other studies. For example, the Scottish government for Scotland, Hermannssonn (2011) for Northern Ireland and California Economic Strategy Panel (2009) for the US state all suggest that passenger expenditure multipliers tend to be lower than the economy-wide average.

*Impact on GDP*

To understand the passenger flow impacts, it is helpful to illustrate the different "multipliers" observed in the S-CGE model associated with passenger spending patterns. These are discussed in Box 8 above. The process through which the direct impact of this effect is multiplied throughout the economy, as with other inputs captured within the model, is called a *multiplier effect*.

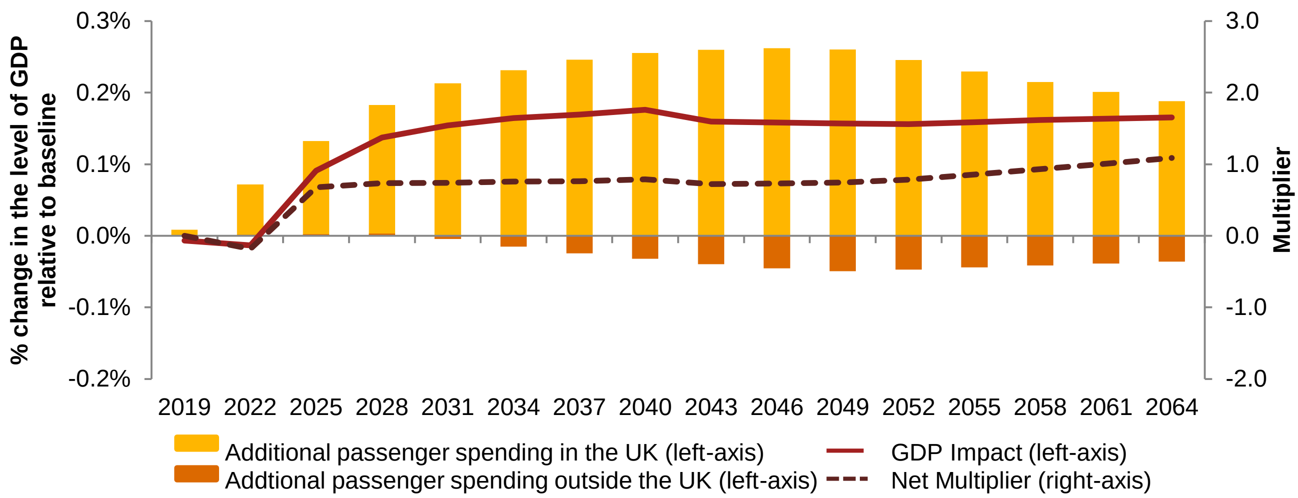
| | |
|---|---|
| **Multiplier effect** | The increase in output in both the airline sector and the wider economy will mean that across the whole economy there will be more demand for inputs from suppliers. This positively affects the downstream supply chain. This means that the positive aggregate demand effects are multiplied. This will be combined with a further knock-on impact on aggregate demand as workers employed will spend more on goods and services in the UK economy. |

With an understanding of the passenger flow changes summarised in Box 8 above, it is straightforward to appreciate the GDP impacts of these passenger flows. Figure 114 demonstrates the GDP impacts from the passenger flow effects, along with the passenger expenditure inputs. For brevity, we present only the Assessment of Need scenario.

During the first 15 years of the scheme, the AC estimate that passenger flows under the LHR NWR scheme will increase rapidly (25m additional passengers are estimated to use the UK system by 2040). The increase in additional passenger expenditure in the UK (£5.6bn per annum compared to the baseline scenario in 2040 in the Assessment of Need scenario) is estimated to be significantly larger than the increase in passenger expenditure outside the UK (passenger expenditure outside the UK is estimated to increase by around £0.7bn per annum on a comparable basis). This net increase in expenditure within the UK reflects Heathrow's status as supporting a relatively large proportion of inbound visitors compared to other UK airports, and the relatively high amount they are expected to spend in the UK relative to the leakage of spending associated with outbound passengers.

Even though the passenger expenditure multiplier outside the UK is greater than the multiplier inside the UK, additional expenditure in the UK is so much larger than the outbound expenditure under the LHR NWR scheme that the net impact on UK GDP is estimated to be positive, leading to a 0.2% increase in the level of GDP by 2050. The reason that the ultimate impact on GDP is less than the original increase in expenditure is the diffusion effect described above, as prices respond to the changes in demand.

*Figure 114: LHR NWR Passenger Flows input, real GDP impact and implied multiplier, Assessment of Need scenario*




*Source: PwC analysis*

Inbound passenger flows are an important source of foreign exchange and is equivalent to exported goods or services in this sense. This effect occurs on the demand-side of the economy: inbound passengers will spend money on a range of goods and services in the UK economy (e.g. hotels, restaurants, the retail sector etc.) Increased flows of "exports" can have important supply-side effects. The sectors of the economy associated with passenger flows will expand as a result of the increase in passenger spending and these sectors will need to hire more workers and invest more to support any expansion. The labour market associated with passenger expenditure is important for the UK economy as it provides a range of low-skilled and school leaver jobs and can facilitate working on a part-time basis. These types of jobs are often taken up by the long-term unemployed. If the number of inbound passengers increases, this can also have positive upstream effects for those sectors that supply goods and services to relevant sectors for servicing these additional passengers (e.g. the manufacturing or agriculture sectors). Overall the model suggests a small, but permanent increase in productivity resulting from the supply-side expansion associated with inbound passenger flows.

There are also spending benefits for the UK economy associated with UK residents travelling overseas. Before travelling, UK residents purchase items from UK businesses e.g. airline tickets, clothes etc. The ONS TSA data suggests about one-third of all expenditure from UK outbound tourists is spent in the UK rather than overseas. This geographic distribution is reflected with the S-CGE modelling.

#### *8.4.3.2 Effect 2: Productivity*

As discussed previously, the construction of an airport scheme can stimulate an external positive supply-side effect in the economy. This is because an airport scheme can lead to improved transport connectivity which in turn provides a benefit to those businesses that use air transport. The drivers of these benefits are productivity effects associated with the improved connectivity. No specific data inputs are presented in this section because, as explained below, the productivity effects are driven by the same forecast passenger flows provided to us by the AC as described in the previous section.

*Econometric analysis*

To evaluate how forecast changes in passenger flows might result in increased productivity and hence economic activity, we used econometric analysis to estimate the link between international trade and passenger numbers. This relationship is used in the S-CGE framework to proxy productivity effects. As explained in Chapter 4, the key results are that a 10% increase in passenger numbers is associated with a:

- 2.37%-2.93% increase in exports of goods;
- 5.81%-6.12% increase in imports of services; and
- 2.48%-2.97% increase in exports of services.

We were not able to establish a significant econometric relationship between passenger numbers and UK goods imports.

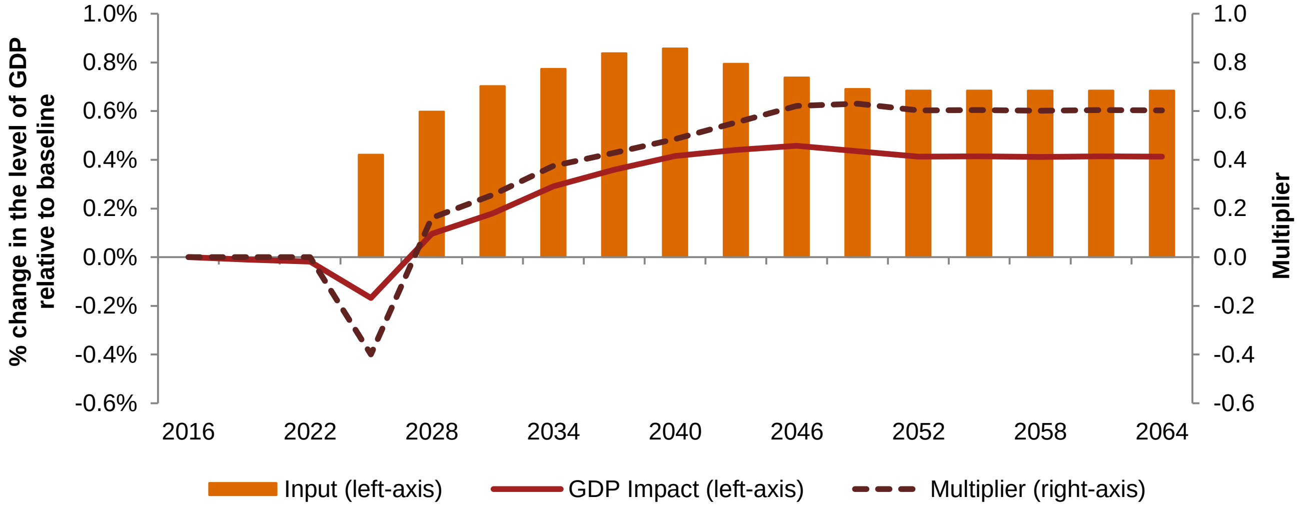
*GDP impact*

Figure 115 below summarises the productivity inputs estimated through the relationships identified above, and the impact on GDP which these are forecast to have. The figure demonstrates that the magnitude of the productivity improvement is forecast to increase steadily throughout the first half of the operational phase, before flattening out as the airport reaches capacity. After an initial dip, the forecast real GDP impact follows this trend reasonably closely, eventually leading to an increase in GDP of around 0.4% in 2050, relative to the baseline scenario. Although the productivity effect develops relatively slowly, ultimately it is the largest of all the effects considered in the analysis for LHR NWR.

Also evident is that the magnitude of the GDP impact is less than the value of the input. This is representative of some “crowding out” in the economy, as more productive sectors expand at the expense of less productive ones. The sectors that use the highest proportion of air transport experience the greatest productivity gains. Wages rise in these sectors as they seek to attract new workers to enable them to expand. Similarly, they also need to raise the returns they offer to capital investors to attract new investment funding. Increases in both wages and the cost of investment capital contribute to a diffusion of the initial productivity gains associated with the expansion in air transport.

In addition, the marginal propensity of firms and households to consume goods and services from outside of the UK ensures that a share of the GDP benefit leaks out of the economy. These diffusion and leakage effects are reflected in the multiplier, which is shown on the right-hand axis to remain less than one. The multiplier increases throughout the period as the sustained productivity benefits lead to capital accumulation which further increases productivity. As a result, the GDP impacts at the end of the period are greater, relative to the size of the input, than at the beginning.

*Figure 115: LHR NWR Productivity input, real GDP impact and implied multiplier, Assessment of Need scenario*




*Source: PwC analysis*

### *8.4.3.3 Effect 3: Frequency benefits*

In order to limit our analysis to those inputs which have a measurable economic impact, our modelling has reflected only the frequency benefits which accrue to business passengers, and which therefore can be interpreted as being likely to have positive productivity effects. In reality, the time savings experienced by some leisure passengers could lead to a productivity increase, but this is unlikely to represent a substantial share of these benefits and they have not been included in our modelling.

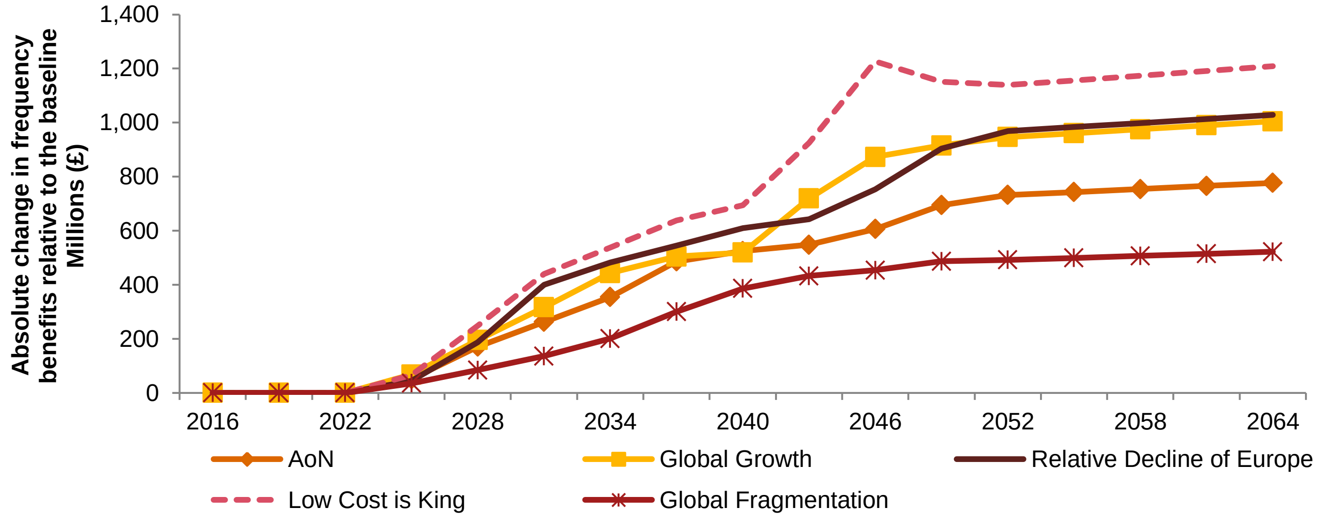
*Inputs*

The AC has provided us with estimates of frequency benefits to be used as inputs to the S-CGE model. These inputs have been taken from the AC demand forecasts, and are estimated by combining estimates of the value of time with the time benefits from increased frequency. The effects shown in the figure below refer to businesses only. Frequency benefits contribute to increased connectivity for business and can facilitate improvements in productivity. This in turn can lead to increases in profitability and in additional investment in the long-term.

Figure 116 below shows the cash value of frequency benefits for the five scenarios. This demonstrates that there are significant differences across scenarios. These differences tend to be correlated with differences in the passenger flows as discussed above.

As shown in Figure 116, the AC's forecast frequency benefits are highest under the Low Cost is King scenario, which peak in 2049. At its largest in the 2060s, the difference in frequency benefits between the scenario with the largest and smallest values is in excess of £0.6bn per annum.

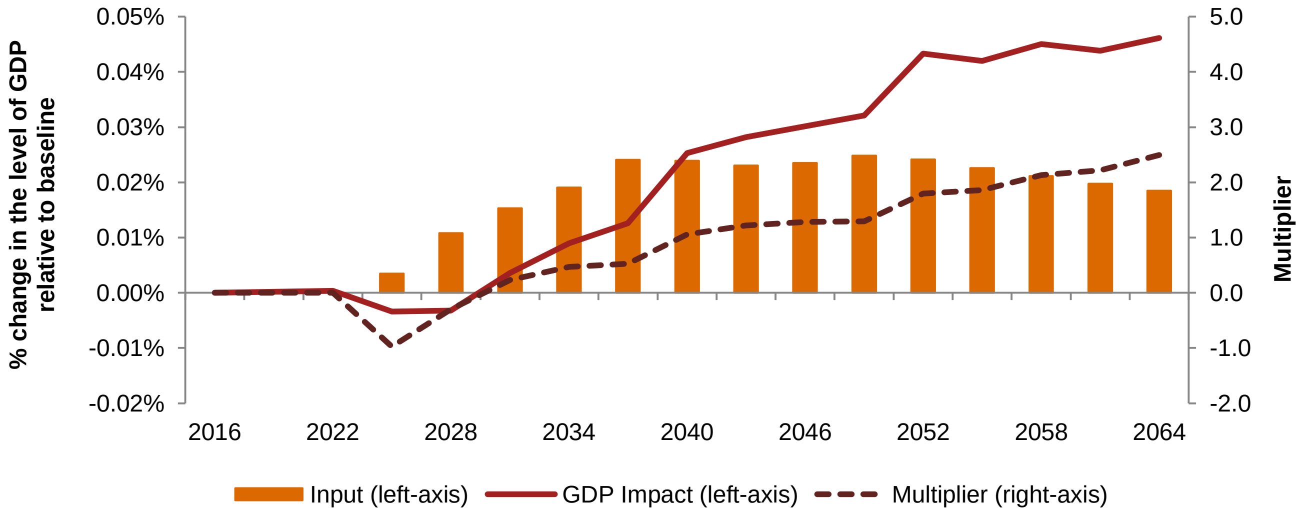
*Figure 116: LHR NWR Frequency Benefits, by scenario*




*Source: Airports Commission*

Compared to the previous effects described above, the frequency benefits are modest in magnitude, reflecting the underlying inputs provided by the AC. As a result, the estimated GDP impact of these inputs is also modest, at no more than 0.05% of GDP under the Assessment of Need passenger flow scenario. The multiplier on the frequency benefit inputs is greater than one by the end of the period. This occurs because the forecast improvements in efficiency experienced by producers in the early periods of operation incentivise higher levels of investment. This in turn leads to further productivity increases and a long-run impact on GDP which is greater than the value of the input.

*Figure 117: LHR NWR Frequency Benefits input, GDP impact and multiplier effect, Assessment of Need scenario*




*Source: PwC analysis*

### 8.4.3.4 Effect 4: TEE

*Inputs*

Chapter 4 outlined how the AC have provided estimates of the TEE impacts, which capture the impact of the expansion in airport capacity on air fares. Specifically, the AC TEE impacts show that the cost of travel falls once new capacity is introduced, and this results in a transfer of money from producers (airlines) to consumers (air passengers). Scarcity rents which producers could charge for use of the airport when it was capacity constrained are reduced, leading to benefits for consumers (through lower air fares)[201]. It should be emphasised that the estimated changes in consumer and producer surplus are relative to the level of consumer and producer surplus that would be expected in the absence of capacity expansion (rather than being compared to today's levels of producer and consumer surpluses).

Table 77 below summarises the AC's forecast undiscounted consumer and producer surplus elements[202] of the TEE benefits, under the five passenger flow scenarios[203]. It is evident from the tables that much of the estimated increase in consumer surplus is a transfer from producers and that where there are forecast to be larger consumer surplus gains these are typically accompanied by higher producer surplus losses across and scenarios. As a result, the net impact of these two effects is small in comparison to the absolute consumer and producer surplus changes. The absolute magnitude of the individual impacts are £2-7.5bn in 2050, which is substantially larger than the frequency benefit effects outlined in above, which are between £0.5-1.2bn at the same date. The overall magnitudes of consumer and producer surplus changes are lower in the Assessment of Needs, Relative Decline of Europe and Global Fragmentation scenarios than in the Global Growth and Low Cost is King scenarios. This is consistent with the passenger flow forecasts described above.

*Table 77: LHR NWR Consumer and Producer Surplus impacts relative to the Do Minimum, by scenario*

| | | Change in Consumer Surplus (£m) | Change in Producer Surplus (£m) | TEE net welfare change (£m) |
|---|---|---|---|---|
| **Assessment of Need** | **2030** | 629 | -594 | 34 |
| | **2050** | 2,699 | -2,011 | 688 |
| **Global Growth** | **2030** | 995 | -928 | 68 |
| | **2050** | 7306 | -5,718 | 1,588 |
| **Relative Decline of Europe** | **2030** | 549 | -501 | 48 |
| | **2050** | 2,969 | -2,525 | 443 |
| **Low Cost is King** | **2030** | 937 | -822 | 115 |
| | **2050** | 7,457 | -5,992 | 1,464 |
| **Global Fragmentation** | **2030** | 414 | -411 | 3 |
| | **2050** | 2,439 | -2,187 | 252 |

*Source: PwC analysis*

### *Impact on GDP*

Figure 118 to Figure 120 below show the impact of these two effects, separately and then combined. The absolute magnitudes and time profiles of the two inputs are relatively similar, with the consumer surplus effect being only marginally larger. However, after an initial dip, the projected GDP impact becomes substantially positive towards the end of the period, as the multiplier effect of the change in consumer surplus increases.

These figures show the size of the input and the GDP impact of these consumer and producer surplus changes for the Assessment of Need scenario, which is again selected for illustrative purposes. Also presented is the implied multiplier for each effect, which captures the ratio between the size of the input and the forecast impact.

Looking first at consumer surplus only in Figure 118, the GDP impact of the change in consumer surplus is shown to be reasonably modest until the mid-2040s, then becoming increasingly significant towards the end of

[201] A more detailed explanation of these effects is provided in the Transport Economic Efficiency Technical Appendix, available on the Airports Commission website.

[202] Please note that in the interest of internal consistency, Table 77 presents the undiscounted inputs to the S-CGE model in two illustrative years. For a full outline of the TEE inputs, please see the Transport Economic Efficiency Technical Appendix, available on the Airports Commission website.

[203] It is also important that the taxation impacts are captured in the modelling framework. The S-CGE model has a full description of taxation structures in the UK, and therefore it is important that inputs to the model are **gross** of tax impacts. We have, therefore, incorporated producer and consumer surplus changes **prior** to the levy of taxes.

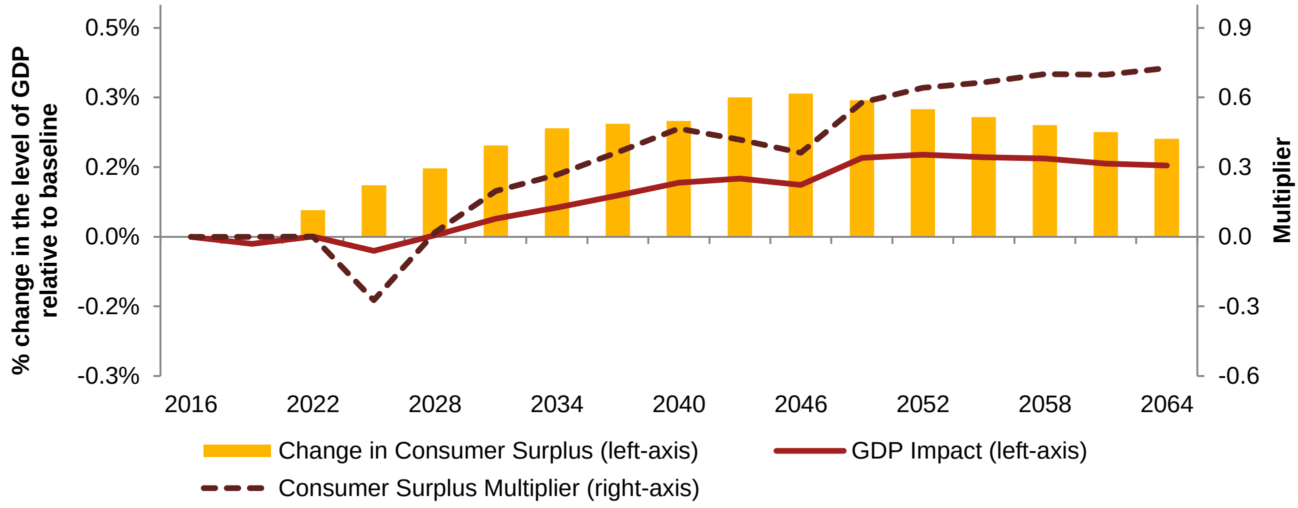
the period. This occurs as consecutive periods of positive impact lead to re-investment of economic gains and increased capital accumulation. This generates a sustained increase in the level of GDP through a persistent positive impact on productivity, even as the relative magnitude of the impact begins to diminish from the early 2050s. For the final few periods analysed, this is a forecast increase of nearly 0.2% of GDP, representing a multiplier of 0.6 – 0.7 on the value of the input. The fact that this multiplier is less than one (i.e. the positive impact on GDP is less than the value of the input) demonstrates that some of the increase in consumer demand is crowded out through a rise in the price level – the *price rebound effect*. This result is typical when using a general (relative to partial) equilibrium approach.

| | |
|---|---|
| **Price rebound/diffusion effect** | As real GDP and aggregate demand increase, upward pressure is exerted on prices. As prices rise there is a nominal, positive inflation effect. As noted above, inflation effects could be particularly strong in the aviation sector. The price rebound effect is important in ensuring that the economy ultimately reaches a new, stable equilibrium. In particular, there are a number of positive "cumulative" forces at play in the S-CGE framework (e.g. the confidence effect described above). The effect of increasing prices keeps the economy "in check" and prevents economic activity from spiralling ever-upwards. |

Figure 119 shows the equivalent pattern for the producer surplus input and impact. The time trend of the input is similar, with a rise through to the mid-2040s as the airport reaches capacity, followed by a relative decline. However, there are two distinct differences in the nature of the forecast GDP impacts. Firstly, unlike the consumer surplus effect, the reduction in GDP closely tracks the time profile of the input, with an initial decline which gradually reduces in magnitude from the early 2050s. This occurs as the reduction in surplus represents the removal of excess profits generated through scarcity rents in the airline sector. As this does not substantially alter the national level of savings and investment, there is no significant change in the long-run productive potential of the economy, and subsequently the negative GDP impact diminishes with the magnitude of the negative input.

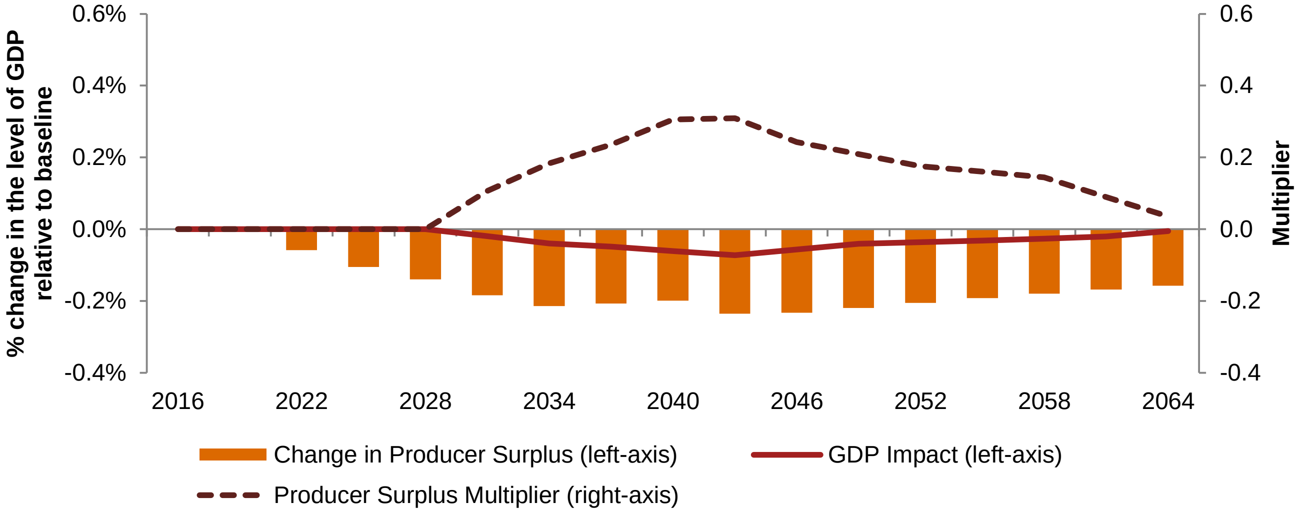
Secondly, the impact on the level of GDP by the end of the period is substantially lower in absolute terms than the consumer surplus impact, despite the level of input being similar. By the end of the period, the forecast reduction in the level of GDP associated with this effect is below 0.1%, and less than half the size of the forecast increase generated by the consumer surplus effect.

*Figure 118: LHR NWR Consumer surplus input, GDP impact and implied multiplier, Assessment of Need scenario*




*Source: PwC analysis*

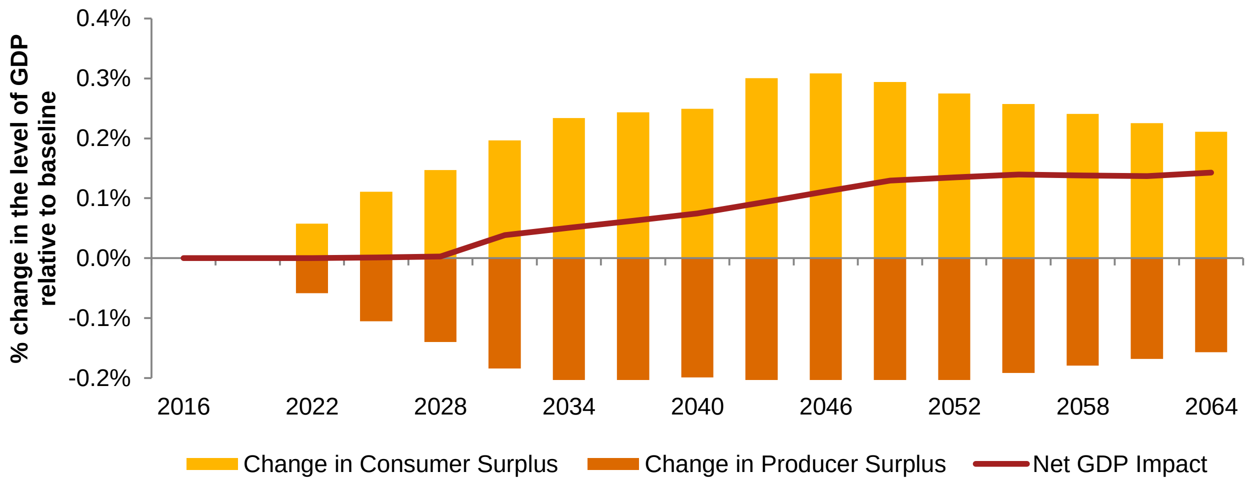
*Figure 119: LHR NWR Producer surplus input, GDP impact and implied multiplier, Assessment of Need scenario*




*Source: PwC analysis*

These two trends lead to the net impact seen in Figure 120, which shows the combined forecast GDP impact of these two effects, along with the two inputs. This reiterates that the absolute magnitudes and time trends of the two inputs are relatively similar, with the consumer surplus effect being only marginally larger. The GDP impact becomes substantially larger towards the end of the period, as the multiplier effect of the change in consumer surplus increases. The intuitive explanation for this is that the reduced producer surplus results in lower returns to airline shareholders. In the S-CGE model these shareholders are households. However, the households most affected by the reduction in airline profits are amongst the most affluent in the economy, and their consumption does not reduce at the same rate as the boost to consumption associated with the increased consumer surplus (which accrues to a broader set of households, being those who use airlines).

*Figure 120: LHR NWR combined TEE inputs and net GDP impact, Assessment of Need scenario*



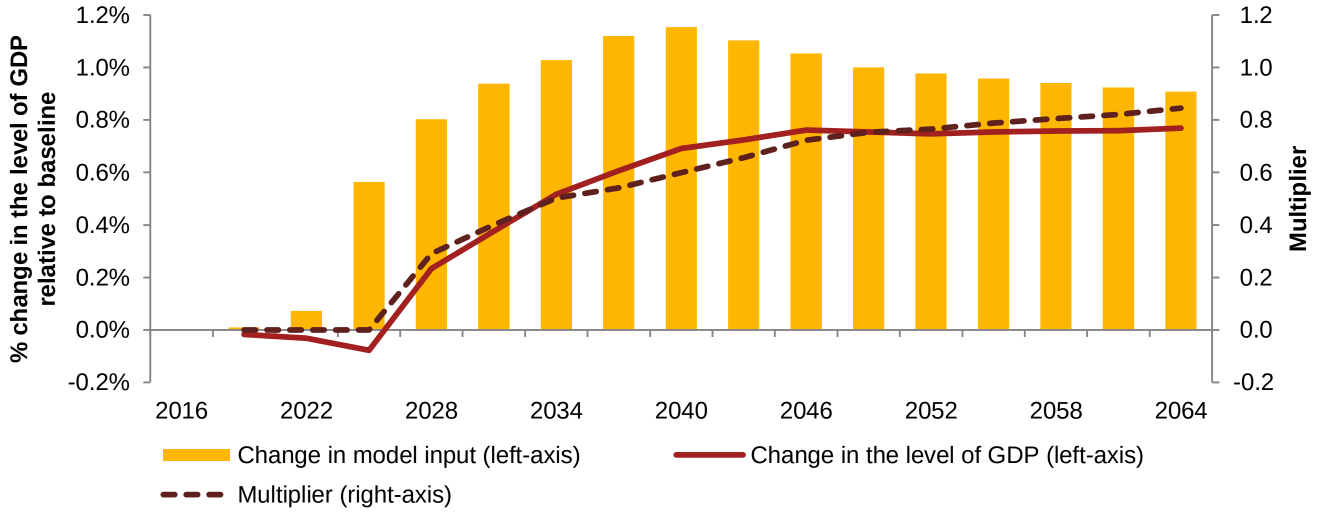

*Source: PwC analysis*

### 8.4.3.5 Combined inputs and GDP impact

Each of the effects outlined above contributes to the projected overall impact of the LHR NWR scheme on the level of GDP. Combining the inputs and GDP impacts of each effect gives an estimate of the overall GDP multiplier of the model inputs – this is shown in Figure 121 below. This shows that the value of the inputs peaks in the early 2040s before gradually declining, while the impact on the level of GDP gradually rises before levelling off in the late 2040s. This leads to the multiplier rising from 0.3 in 2030 to 0.8 in 2060.

The rise in the multiplier over the period demonstrates that the full GDP impact of an input will not exclusively be felt in the years in which they have a direct effect. For example, increases in household spending or productivity in the early years of the analysis are expected to result in an increase in investment. This investment is expected to lead to long-run productivity gains which increase the level of GDP in all future years. In addition, agents within the model recognise that the increase in capacity will yield positive demand (through increased household and passenger spending) and supply (through increased productivity) effects. This motivates them to delay economic activity until later years, thus dampening the GDP impact in the early years of the analysis and accentuating it in the later years.

*Figure 121: LHR NWR combined model inputs and GDP impact, Assessment of Need scenario*




*Source: PwC analysis*

There are two important considerations that should be noted alongside this multiplier effect:

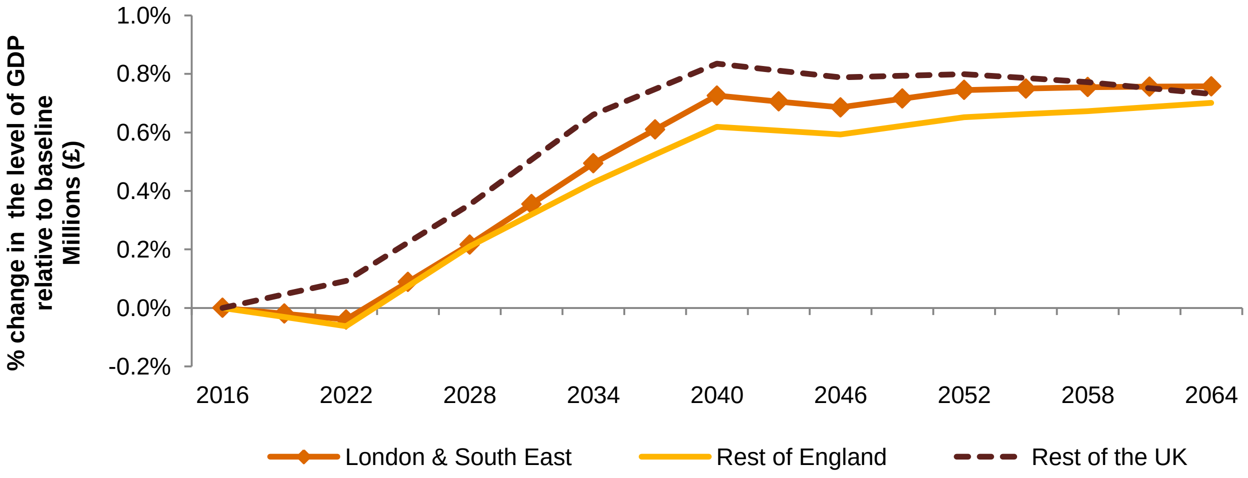
- The S-CGE model captures a wider range of impacts (such as price effects and feedback loops to non-aviation users, and the wider benefits of wage and skill growth) which increase the scope of our estimates beyond what would normally be captured using other techniques that do not fully account for changes in economic behaviour (e.g. input-output analysis). Therefore, while the magnitude of some the effects generated by the S-CGE model (e.g. passenger spending), may be smaller than comparable estimates that take limited or no account of diffusion, the S-CGE model will pick up a broader range of effects which may or may not lead to a larger overall impact.
- These multipliers are "net" in the sense that they capture both displacement of economic activity from sectors of the economy that do not have strong direct or indirect linkages with the aviation sector and, as described above, also include the costs of airline expansion. Our study for the AC (3. Local Economy: Literature Review) illustrated a range of multiplier estimates relating to airport impact assessments, the majority of which were larger than 1 – this is because they are "gross" multipliers and do not fully factor in the range of effects described above.

## *8.5 Impact by region*

Figure 122 provides the forecast GDP impacts over time, by region. For brevity, the information provided is only for the Assessment of Need scenario. Figure 122 shows the PVs of the schemes by region, for each of the five scenarios. As stated above, the regions are defined as:

- London & South East, which is made up of the London and South East NUTS 1 regions (or "Government Office Regions");
- The Rest of England, which is made up of all other NUTS 1 regions in England (East of England, East Midlands, North East, North West, South West, West Midlands, Yorkshire and the Humber); and
- The Rest of the UK, which is made up of Northern Ireland, Scotland and Wales.

*Figure 122: LHR NWR regional GDP impacts, Assessment of Need scenario*




*Source: PwC analysis*

*Table 78: LHR NWR Present Value of regional real GDP impacts, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **London & South East** | 52.5 | 70.5 | 35.8 | 70.7 | 40.2 |
| **Rest of England** | 57.7 | 78.1 | 42.4 | 76.1 | 46.1 |
| **Rest of the UK** | 21.6 | 35.9 | 16.9 | 36.5 | 16.7 |

*Source: PwC analysis*

Table 78 demonstrates that all three regions are forecast to experience positive GDP impacts across all five passenger flow scenarios as a result of the LHR NWR scheme. Given the scheme's location, it is not surprising that London & South East generally enjoys an increase in GDP from the scheme. However, Figure 122 demonstrates that in percentage terms the largest increase in the Assessment of Need scenario is actually seen in Rest of the UK, despite this region experiencing the smallest benefit in PV terms.

There are a number of reasons why benefits are modelled as dispersing across all regions of the economy. Primarily, the majority of impacts are national effects and therefore benefit all regions, such as productivity improvements brought by cheaper imports and better access to export markets, as well as the reduction in the cost of air travel due to the assumed fall in air fares. Although passengers who land at Heathrow and Gatwick spend disproportionately in London & South East, the model captures the degree to which the spending by these passengers is dispersed across the other parts of the UK. Further, the increase in air transport capacity in London & South East will diffuse to the other UK regions through inter-regional trade. For example, London & South East exports insurance and financial services to the other UK regions whereas it imports manufacturing products from the other UK regions. As the London & South East economy expands due to the increase in air capacity, London will begin to import more manufacturing from the other UK regions. This will have a positive impact on GDP in the other UK regions, which will, in turn, lead to an increase in demand for imports from London & South East in sectors such as financial services, which will have a positive impact on GDP in London & South East. Also, any rise in activity within London & South East which is not mirrored in other regions, causes an increase in the price level in that region. This could crowd out other activity, tending to cause it to relocate to other regions.

Finally, while many of the positive effects are distributed evenly across regions, the negative impact of the decline in producer surplus is expected to affect London & South East disproportionately due to the relatively high share of the aviation sector which is headquartered there. Although the economic impact may be dispersed across all regions, the majority of the reduction in gross operating surplus resulting from this effect would be experienced in London. This would occur because a greater number of airlines are registered in London than any other region for accounting reasons, and this region therefore receives an above-average share of profits from the industry.

In addition to direct effects, the regional distribution of impacts can be explained by “agglomeration” and “cumulative causation” forces identified in the New Economic Geography literature. These effects are outlined in Box 9 below.

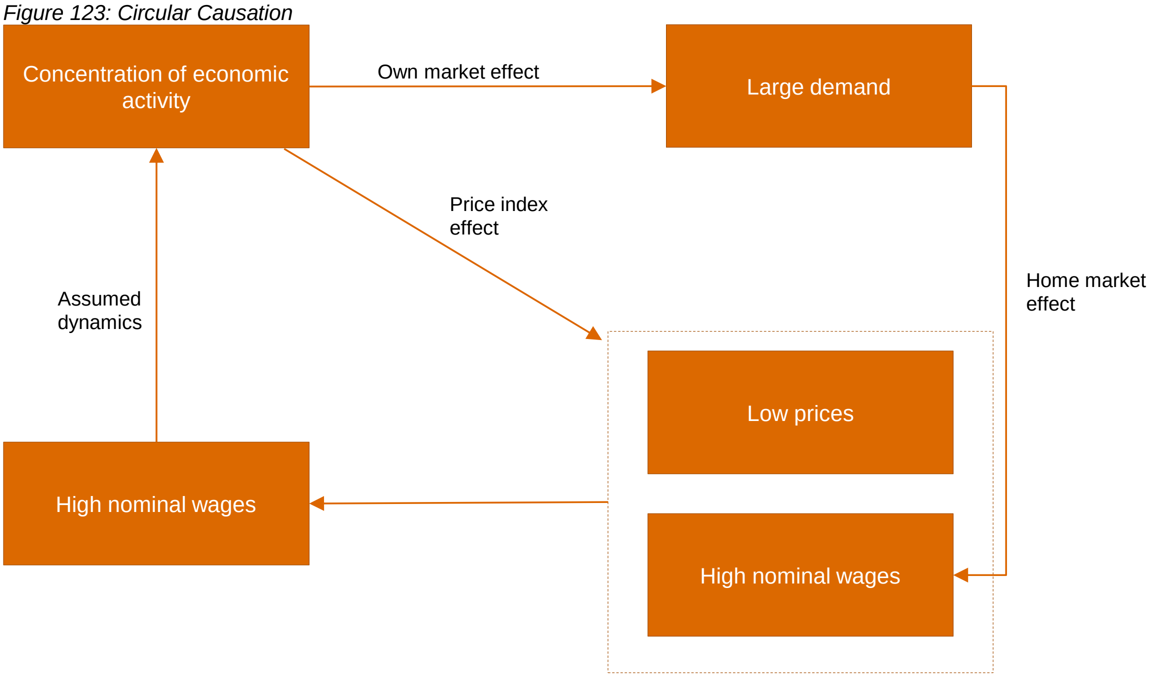
**Box 9: Agglomeration and cumulative causation**

As described in Chapter 2, the S-CGE framework has a regional structure with imperfect competition, meaning that agglomeration will be an inherent or 'endogenous' feature of the model that can follow from any of the modelled effects described above. These key agglomeration impacts are considered in detail in Chapter 2 and Appendix A. In particular, the model implies the following effects (these are explained in general terms later in this chapter):

- **Own Market Effect.** The expanded aviation sector in London & South East generates demand, which makes London & South East a more attractive place for businesses to locate;
- **The Home Market Effect.** The expanded airport facilities lead to increases in employment in London & South East (as described above). This increases nominal wages in London & South East, which makes the region more attractive as a place to work; and
- **The Price Index Effect.** Prices may be lower in regions with denser economic activity because distances between consumers and suppliers are lower on average, resulting in lower transport costs. Whilst this precise effect is not present in the S-CGE framework, an analogous effect – which has the same implication – does exist. In particular, higher economic activity in London & South East which may come about as a result of the airport could give rise to increased competition between firms, which reduces profit margins and prices. These lower prices make London & South East more attractive to consumers and firms.

Between them, these effects generate a process of what Myrdal (1957) calls 'circular causation': the presence of the expanded airport in London & South East generates demand (own market effect) which, by the home market effect, increases local wages. At the same time, the price index effect means that prices on average are lower in this region. These arguments combined imply that real wages in the region are relatively high. Since workers in the S-CGE model are attracted to regions where they can command higher real wages, workers move to London & South East. This reinforces the prominence of the region and so the cycle repeats itself. Figure 123 below illustrates the process.

*Figure 123: Circular Causation*



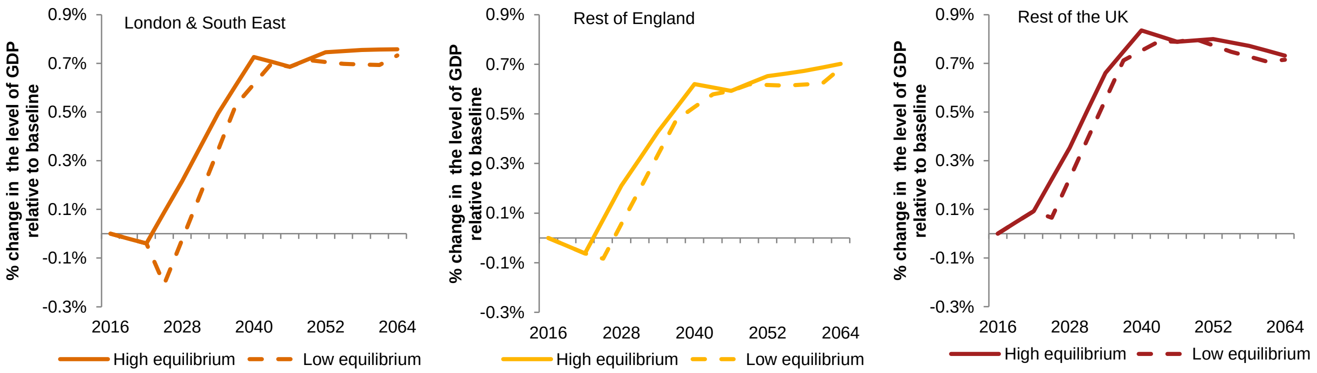

*Source: PwC analysis*

## 8.5.1 *Factors affecting the regional distribution*

As noted in Chapter 2, models based on imperfect competition can give rise to multiple equilibria. The results from the S-CGE model suggest two different equilibrium outcomes for the LHR NWR scheme (a "high scenario" outcome and a "low scenario" outcome). Both are consistent with profit maximising behaviour. In addition to the discussion in Chapter 2, Appendix A highlights the key economic theory in relation to multiple equilibria. The multiple equilibria produced by the model are largely borne out of the functional forms in the model used to capture imperfect competition and regional trade.

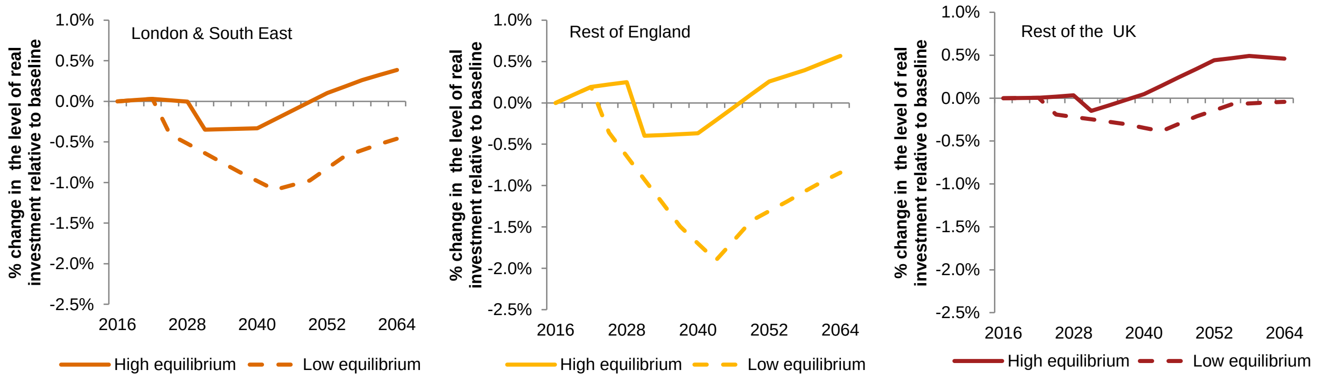
In the "high scenario" outcome for LHR NWR, there is more GDP and investment in each region of the UK than in the low outcome – about 0.1 percentage points in extra GDP is observed in the high outcome relative to the low outcome. However, neither of these outcomes implies a "lock-in" of economic growth in London & South East at the expense of other UK regions. The results for both outcomes suggest a long-term change in the level of real GDP across all regions, with this growth eventually flattening out as the LHR NWR scheme reaches full capacity. The GDP effects are relatively small, but the effects are more pronounced on the different components of GDP, Figure 125 illustrates this from an investment perspective.

*Figure 124: LHR NWR effect of expansion on the level of real regional GDP in London & South East, Rest of England and Rest of the UK – multiple equilibria, high and low scenarios*




*Source: PwC analysis*

*Figure 125: LHR NWR effect of expansion on the level of real regional GDP in London & South East, Rest of England and Rest of the UK – multiple equilibria, high and low scenarios*




*Source: PwC analysis*

The extent to which economic gains are realised by each region is dictated by the pricing behaviour of airlines. In the S-CGE model, each firm has a perception of the consumers' income elasticity of demand for the products that it sells. This perception varies with the level of economic activity. As has been shown in the previous sections, following the introduction of a new airport scheme the S-CGE model has estimated that economic activity will be higher, and as a result entrepreneurs may perceive this as a good time to enter the market. The reasoning behind this is that customers may be finding it hard to find suppliers for the products they wish to purchase. This may lead to consumers' income elasticity of demand falling (i.e. becoming more inelastic). If the income elasticity of demand falls, firms can charge higher mark-ups and make more profits per unit of output sold.

However, when mark-ups rise the threat of new market entrants will be greater for businesses already operating in the market. This may lead to them to lower their mark-ups to make it less attractive for potential new entrants to enter the market. This effect can potentially offset the factors that might entice firms to enter the market described above and the overall effect on mark-ups could potentially be zero (Carlin and Soskice, 2006)[204] or they could even fall if firms felt that total profits (as opposed to profits per unit of output) could increase.

If businesses are more sensitive to the threat of entry than to existing competition then the perceived income elasticity of demand could be procyclical: this would imply higher margins when the level of economic activity is at a relatively low point (and hence the perceived threat of entry is low, reducing the perceived income elasticity of demand, and encouraging incumbent firms to raise prices and margins) and lower margins when the level of economic activity is at a relatively high point. If businesses are more sensitive to the threat of internal competition from the existing market then their perceived elasticity of demand will be countercyclical. Margins will be lower when output is at a relatively high level and vice versa. Carlin and Soskice note that in the latter case there will be a unique equilibrium. However, in the case where there is a greater sensitivity to the threat of entry there is a possibility that multiple equilibria will occur.

This latter effect is what we observe in the S-CGE model in the high outcome. Firms within the airline sector are willing to accept lower mark-ups to act as a deterrent to new entrants. Overall they make more profits, because the UK aviation market has expanded, but profit per passenger falls.

This reaction is in part triggered by the reduction in producer surplus described in relation to the TEE effects. In the TEE framework, the increase in airport capacity has opened up competition in the UK aviation sector and driven down prices. This has the knock-on effect of driving up demand from households and businesses wishing to travel by air. In the high scenario, incumbent airline firms accept the lower mark-ups that come with the threat of increased competition and as passenger demand rises, they do not seek to increase mark-ups in response. This has a dual effect – new entrants are deterred, and some incumbents will exit the market as they view operating in a market with low mark-ups as not viable or attractive. So the outcome is that there are fewer airlines in operation in the UK market, but the remaining airlines fly to more destinations and at lower prices.

Figure 126 demonstrates this by showing results from the S-CGE model for the number of firms in the air passenger transport sector (in the left-hand chart), and all other sectors (in the right hand chart). Please note that the scales for these charts are intentionally different due to the substantially different scales of the impact.

The S-CGE model suggests that in the "high scenario", there is substantial consolidation in the air passenger transport sector, with the number of firms falling by nearly 2.5%. In this scenario the lower prices and mark-ups in the aviation sector benefit other business users, which in turn can reduce their costs and increase their profits. This leads to more firms entering the non-aviation sectors to contest the higher mark-ups there associated with the increased levels of business and consumer activity.

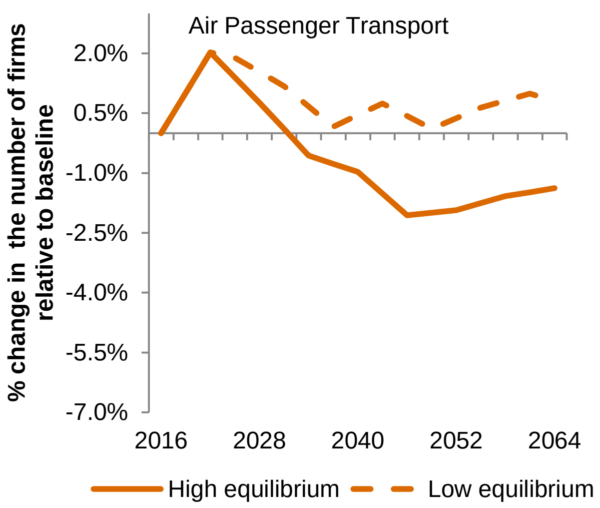
In the "low scenario" the pricing behaviour of airlines is the opposite of that observed in the "high scenario". Air fares initially fall in response to the increase in airport capacity, but in the longer-term they rise in response to increases in demand. This implies that there will be new entrants into the UK aviation sector who will seek to compete away any new potential higher mark-ups back down to the levels before new airport capacity was built. Overall in this scenario there are more firms in the UK aviation market (between 0.5 and 1% more), but prices are higher and there is less benefit passed on to consumers in the form of lower fares. This means that the overall impact of this scenario on GDP is smaller.

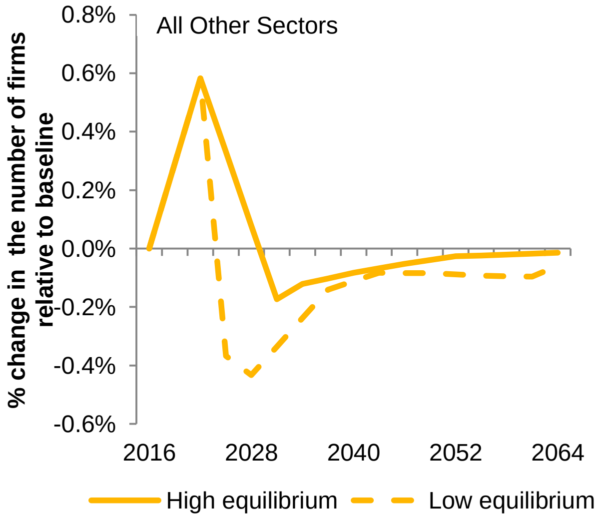
The higher fares in the "low scenario" effectively deter some passengers from using the newly expanded Heathrow airport. This means that the magnitude of the GDP gains observed in the "high scenario" is reduced. In the "low scenario", the negative economic multiplier associated with UK residents flying overseas offsets a

[204] Carlin, W. & Soskice, D. (2004) Marcoeconomics: Imperfections, institutions & polices, Oxford, Oxford University Press

greater share of the other positive wider economic effects. However the gains, even in this low outcome, are substantial, not only in London & South East, but also for the rest of the UK economy.

*Figure 126: LHR NWR change in number of firms, relative to Do Minimum, for Air Passenger Transport (APT) and all other sectors by high and low equilibrium, Assessment of Need scenario*




*Source: PwC analysis*

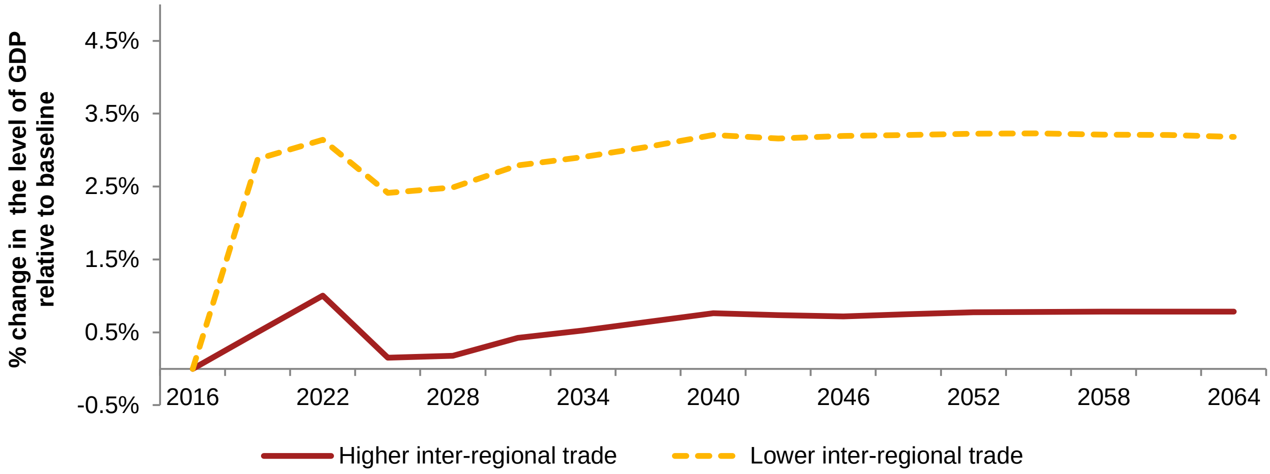
The results above illustrate that the overall level of UK GDP can differ between the multiple equilibria in the S-CGE model, but the impacts on its relative regional distribution are more limited. Given this, we tested the model to identify those factors that would affect the regional distribution of GDP. We found that the regional distribution of the impact relies heavily on the extent of inter-regional trade linkages specified in the model. As set out in Chapter 4, these linkages have been estimated using standard techniques. Nonetheless, the data on which they have been estimated still present a source of uncertainty in our modelling, not in terms of the overall scale of the impact, but in terms of which regions will gain relative to others.

Our modelling results presented in suggested that the Rest of England region would be expected to gain more than London & South East in absolute terms, while the Rest of the UK region would also be expected to gain significantly. A sensitivity analysis of the results suggests that by lowering the flows of inter-regional trade linkages by 20.0% (in terms of both regional imports and exports) the pattern of results can be reversed. The results of this exercise are shown in Figure 127 to Figure 130.

The results suggest that when a lower estimate of UK inter-regional trade linkages is compared to a central estimate the impact on London & South East is 2.4 percentage points higher while the impact on the rest of England is 2 percentage points lower, and the Rest of the UK is 0.1 percentage points lower. The overall impact on the UK economy as a whole is unchanged. This result is important for two reasons. Firstly it highlights the key determinant of the regional results: the stronger the trade linkages between the different regions of the UK economy, the more likely it is that the benefits of new airport capacity at Heathrow will benefit regions other than London & South East. Secondly it illustrates that, depending on the strength of inter-regional trade linkages, that airport expansion in London & South East could have some negative effects on other UK regions.

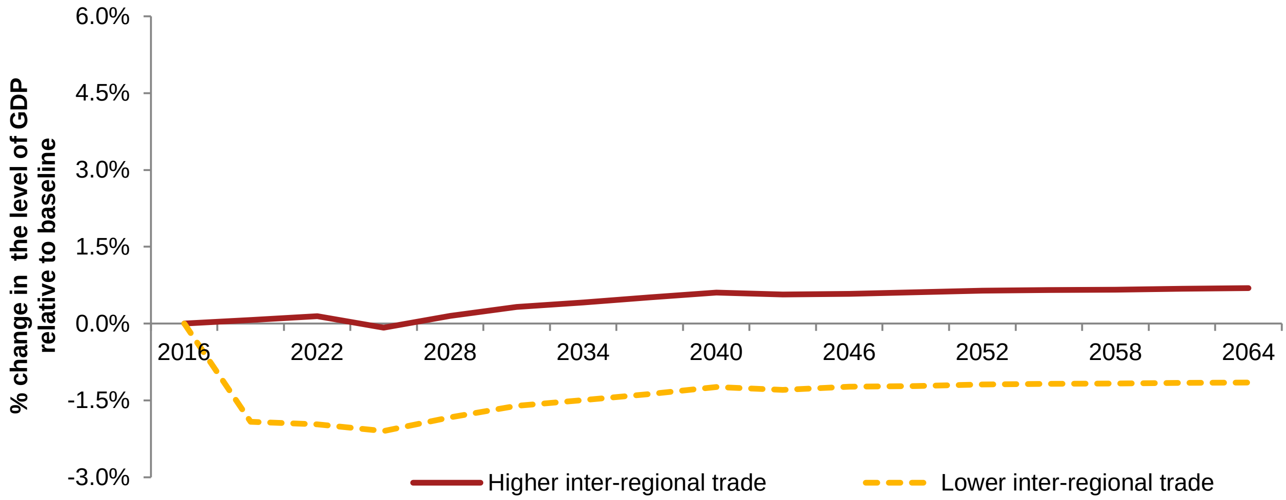
Our central estimate implies that the scale of inter-regional UK trade linkages is broadly 150% of international trade linkages and it is difficult to say whether this is realistic or not. However, as outlined above it has been estimated in line with international best practice and has been discussed with various UK Government Departments. At the time of writing this report, as far as we are aware, there is no better estimate of inter-regional trade flows in the UK.

*Figure 127: LHR NWR impact on the level of real GDP in London & South East by level of inter-regional trade, Assessment of Need scenario*



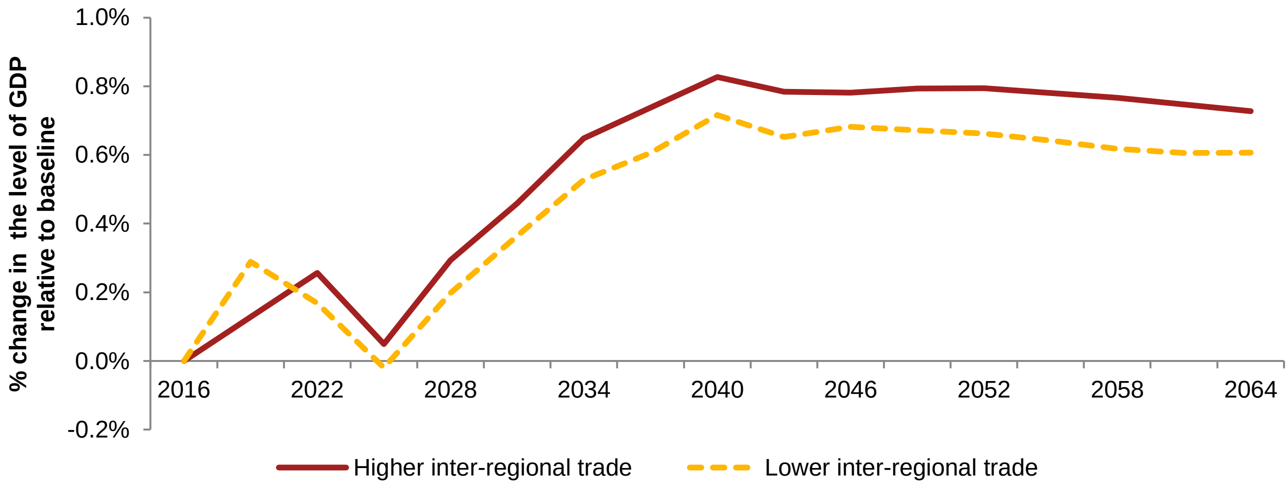

*Source: PwC analysis*

*Figure 128: LHR NWR impact on the level of real GDP in Rest of England by level of inter-regional trade, Assessment of Need scenario*



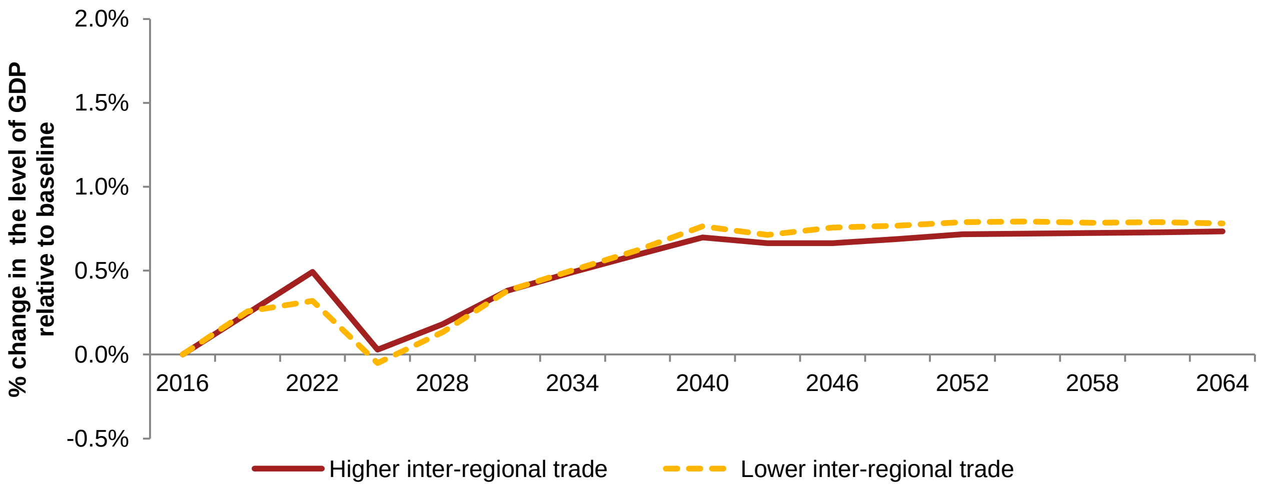

*Source: PwC analysis*

*Figure 129: LHR NWR impact on the level of real GDP in Rest of the UK by level of inter-regional trade, Assessment of Need scenario*




*Source: PwC analysis*

*Figure 130: LHR NWR impact on the level of real GDP in the UK by level of inter-regional trade, Assessment of Need scenario*




*Source: PwC analysis*

## *8.6 Impact of construction*

### *Construction phase inputs*

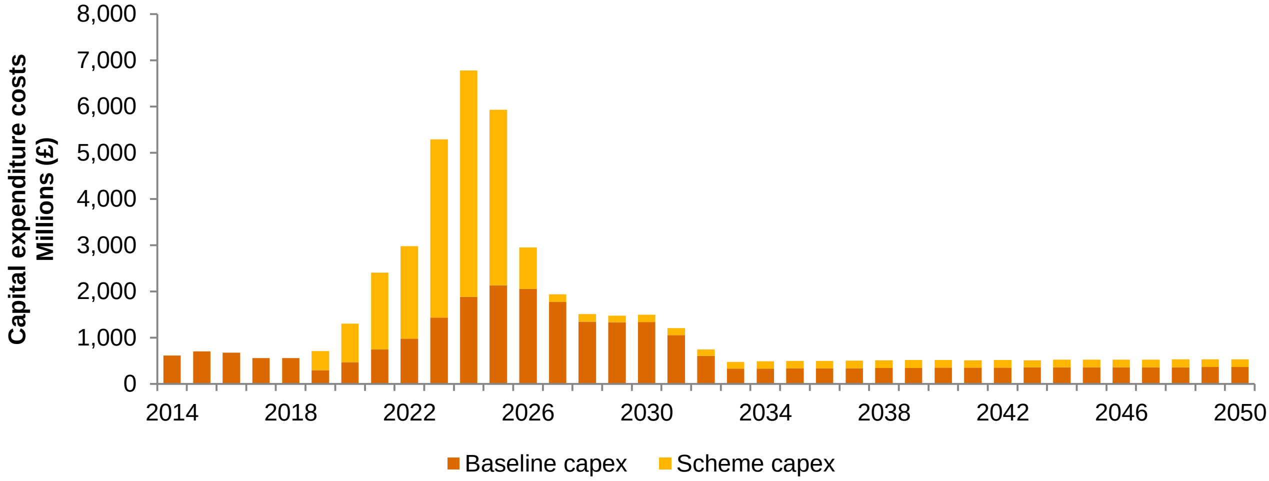
Figure 131 reflects a single, large capital injection between 2019 and 2026, after which there is expected to be a small amount of ongoing capex to cover asset replacement. The largest expense relates to terminal buildings and land. Table 79 shows the incremental construction costs required for the LHR NWR scheme, which comprise expenditure on airport infrastructure and facilities and the associated surface access.

*Table 79: LHR NWR Incremental construction capex costs (£mn, undiscounted and not adjusted for inflation)*

| 2015-2050 | Airport scheme capex | Surface access capex | Total |
|---|---|---|---|
| **LHR NWR** | 22,180 | 4,934 | **27,114** |

*Source: LeighFisher analysis*

*Figure 131: LHR NWR airport capital expenditure costs*




*Source: LeighFisher Analysis*

Around 80% of the capital expenditure for the LHR NWR scheme relates to road expenditure, with the requirement to place the M25 into a tunnel being a significant component. Further investment in strategic roads and reconfigurations of local roads are required. It is assumed that all of this investment would be required prior to the scheme's opening date in 2026.

*Table 80: LHR NWR Surface access capex costs by type (£mn, undiscounted and not adjusted for inflation)*

| 2015-2050 | Road | Rail | Risk & Optimism Bias | Total |
|---|---|---|---|---|
| **LHR NWR** | 2,812 | 533 | 1,589 | **4,934** |

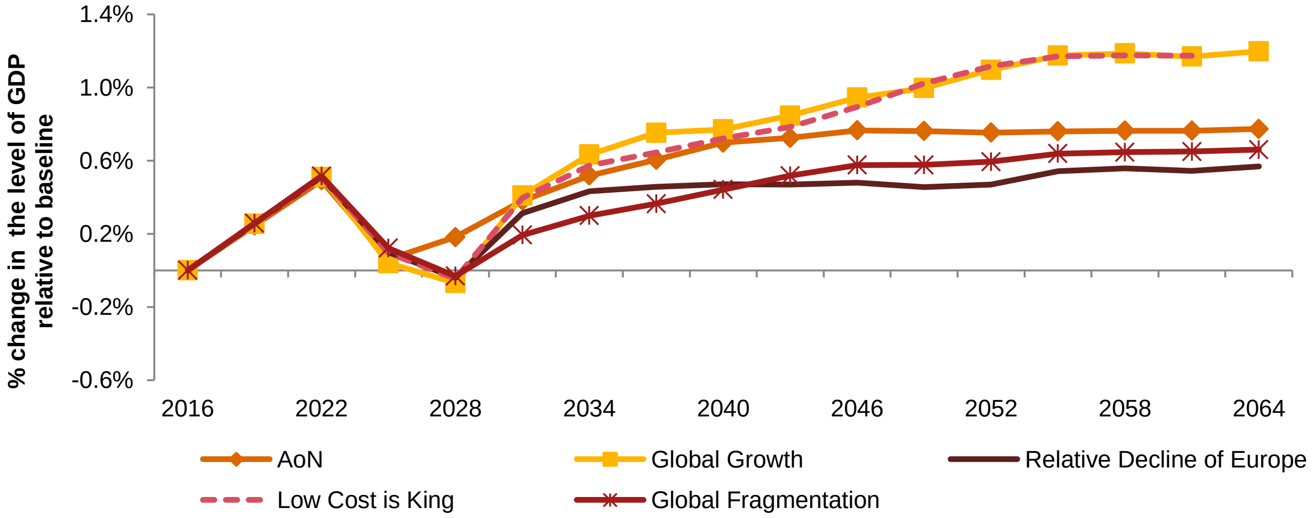
*Source: LeighFisher Analysis*

## *Construction phase impacts*

Our modelling suggests that despite our assumption that the economy is at near full employment in the baseline scenario and every £1 spent on the LHR NWR scheme must be funded by a reduction of £1 in other parts of the domestic economy (most notably private consumption), the LHR NWR construction activities themselves are likely to have significant GDP impacts. This is because at a high level, shifting economic activity towards construction is estimated to have a net positive impact on economic output because of the strong linkages between construction and the other sectors of the economy. As a result, the positive multiplier impacts from expanding the construction industry outweigh the negative multiplier impacts from the contraction of other sectors as a result of (primarily) reduced consumption to fund investment. The implication is that shifting economic activity away from consumption towards construction raises overall GDP in net terms.

Figure 132 shows the projected real GDP impacts including construction of the LHR NWR scheme for the different passenger flow scenarios. The profiles of the impact of the five scenarios remain the same, except that there is an initial spike relating to construction activities, which results in a forecast real GDP impact of 0.5% compared to the baseline scenario.

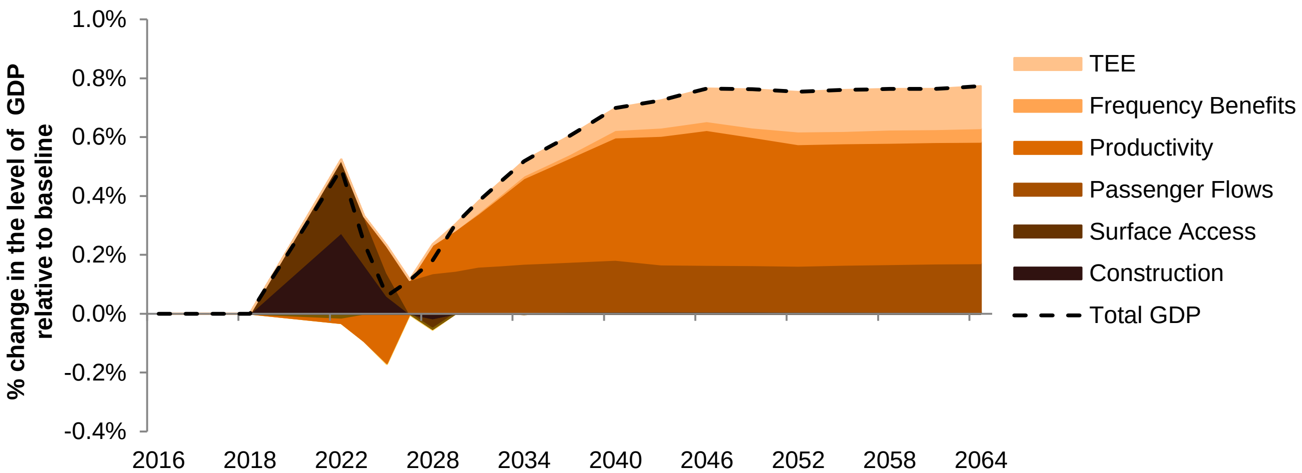
*Figure 132: LHR NWR GDP impacts on the level of real GDP including construction, by scenario*




*Source: PwC analysis*

In order to more clearly isolate the impact of construction on GDP, Figure 133 shows the total projected GDP impact of the Assessment of Need scenario, with the impact of construction and surface access effects included. The impact of construction is clearly distinguishable from other effects and relatively short-term; after 2030 there are no direct effects realised from construction activities.

*Figure 133: LHR NWR effect-by-effect impacts on the level of real GDP including construction, Assessment of Need scenario*

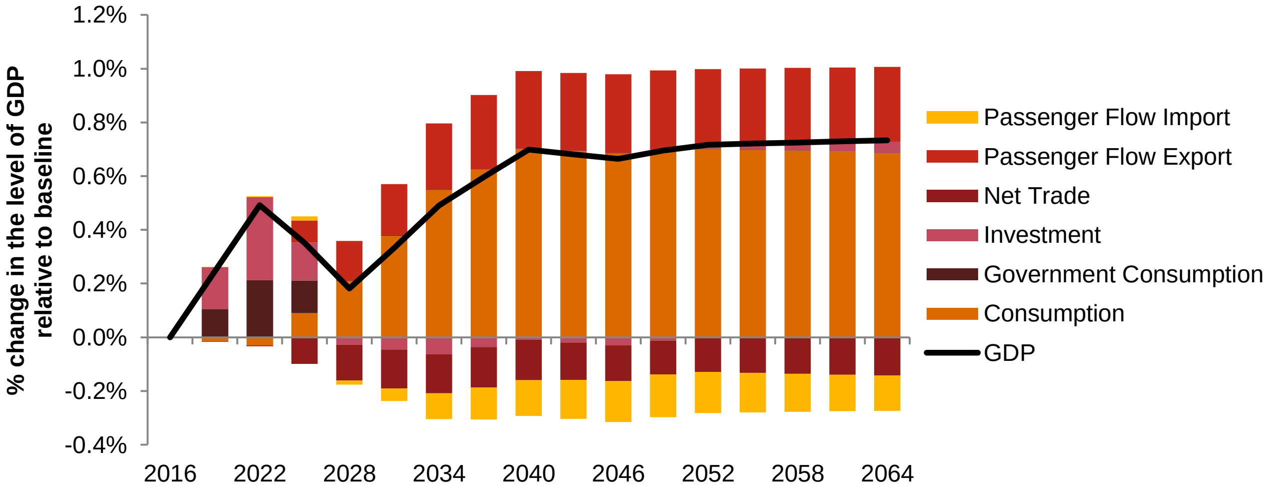



*Source: PwC analysis*

Figure 134 demonstrates how the different components of GDP contribute to the overall change, once construction and surface access effects are included. Unsurprisingly, the positive increases in GDP resulting from construction can be seen through increased investment (the *investment effect*), with a few periods of increased government consumption to reflect surface access expenditure. Despite the positive construction impact, total GDP is largely unchanged due to a concurrent reduction in consumption. The majority of this is due to forward-looking agents postponing economic activity until the capacity constraint is lifted, although some is driven by a shift from consumption to savings in order to finance the investment.

| | |
|---|---|
| **Investment effect** | The investment effect is at its greatest during the construction phases of the scheme. As noted above, even in the long-term, investment remains important and continues to place upward pressure on GDP as a result of continued maintenance and renewals of the enhanced infrastructure, together with the greater level of investment generated from higher confidence and the expectation of increased economic output amongst businesses (see *confidence effect* in section 7.4.1). |

*Figure 134: LHR NWR breakdown of real GDP impacts including construction, Assessment of Need scenario*




*Source: PwC analysis*

As Figure 133 demonstrates, once the airport is in operation the impact of additional construction phases is modest. To enable a more detailed comparison of the relative magnitudes of each effect, Table 81 summarises the PV of each effect for each passenger scenario. As we have assumed that the required level of construction and maintenance expenditure does not vary by passenger scenario, the construction and surface access impacts are constant. This shows that under the five passenger scenarios, the modelled combined impact of construction and surface access are no more than 7-13% of the total increase in the level of GDP, and have the smallest impacts of the effects analysed.

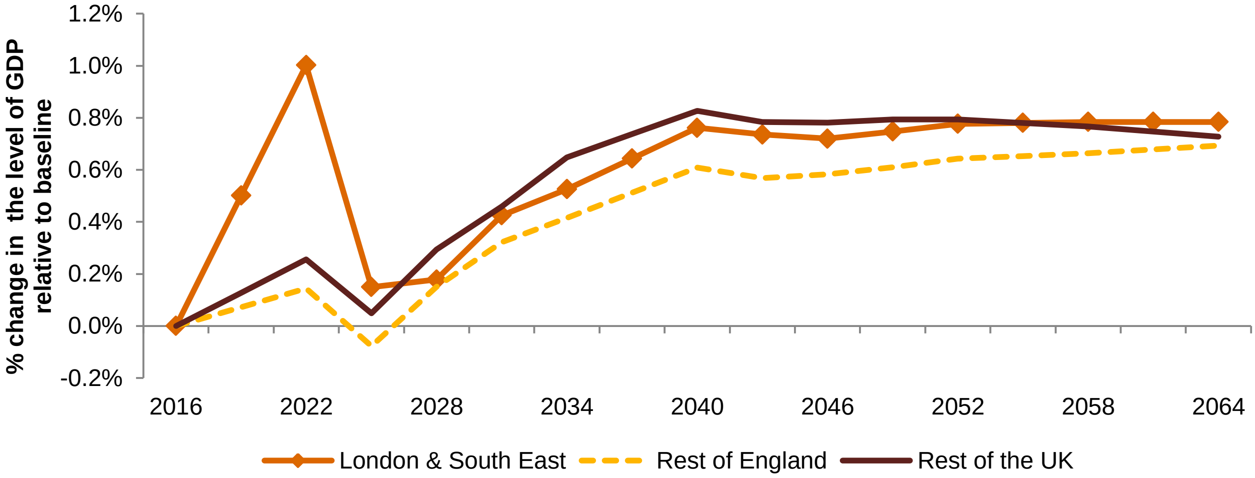
*Table 81: LHR NWR Present Value of GDP impacts including construction, by effect and scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **Construction** | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 |
| **Surface Access** | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 |
| **Passenger Flows** | 32.8 | 24.7 | 16.7 | 25.9 | 21.1 |
| **Productivity** | 70.9 | 79.7 | 41.8 | 73.1 | 54.5 |
| **Frequency Benefits** | 6.5 | 8.5 | 8.9 | 10.6 | 4.5 |
| **TEE** | 21.6 | 71.6 | 27.8 | 73.6 | 23.0 |
| **Total** | **144.4** | **197.1** | **107.8** | **195.8** | **115.6** |

*Source: PwC analysis*

Finally, Figure 135 investigates how the regional distribution of GDP impacts change with the addition of construction and surface access effects. In comparison with Figure 122 London & South East can be seen to gain substantially, and on this basis experiences the greatest increase in the level of GDP throughout the 2020s. To a lesser extent, the Rest of England and the Rest of the UK also gain slightly as a result of the construction phase, as the beneficial effects of the additional construction flow throughout the national economy through inter-regional trade.

*Figure 135: LHR NWR regional GDP impacts including construction, Assessment of Need scenario*




*Source: PwC analysis*

*Table 82: LHR NWR Present Value of regional real GDP impacts including construction, by scenario (£bn, 2014 prices)*

| | Assessment of Need | Global Growth | Relative Decline of Europe | Low Cost is King | Global Fragmentation |
|---|---|---|---|---|---|
| **London & South East** | 64.6 | 83.6 | 48.1 | 84.2 | 51.6 |
| **Rest of England** | 58.1 | 77.9 | 42.8 | 75.7 | 47.1 |
| **Rest of the UK** | 21.6 | 35.6 | 16.9 | 36.0 | 16.9 |

*Source: PwC analysis*

As agreed with the AC, our results are based on the assumption that construction costs are funded "wholly by the domestic private sector". Box 10 below discusses how the results might have varied if we had made an assumption regarding partial or full foreign investment.

**Box 10: Financing runway expansion schemes - the potential use of foreign investment**

As described in Section 4.7.3.1 we made the assumption in our economic modelling that the construction cost of the three airports schemes was funded "wholly by the domestic private sector". This assumption was discussed and agreed with the AC and its external advisors. However, it is also possible to assume in the S-CGE model that the airport schemes are fully or partly funded by foreign investors. In this box, we discuss how the results might have varied if we had made an assumption regarding partial or full foreign investment.

The S-CGE model requires the user to identify the source of each airport scheme's financing – new financing will be sourced from additional investment. In the models baseline, investment markets are assumed to be in equilibrium, investors are assumed to have balanced portfolios and there is no excess supply of capital.[205] So for new investment to be created, rates of return for capital must rise.

[205] The model is capable of proxying the effects of either excess supply or demand in capital markets. For instance, investors may have capital they want to invest, but do not have appropriate opportunities available to them. If this is the case, the rate of return that businesses need offer to investors will be lower. The model can therefore be set up with lower

The investment needed to build each airport must be supplied by either domestic or foreign investors. As we have seen in Figure 75, if the investment for each scheme is sourced from within the UK then the additional investment required will be sourced from either households (who consume less in response to being offered higher rates of return on their investments) or at the expense of other investment projects (again higher rates of return will need to be offered to attract investment into the airport sector).

The transmission mechanism associated with airport construction is given in Figure 176 in Appendix D of this report. As we note in that figure, if foreign investment is used to finance an airport scheme either as an alternative or complement to domestic investment and it could be competed away from another UK project as there will be international competition for foreign investment.

If foreign investment is used as a direct alternative to domestic investment, then the reduction in household consumption that is observed in our results would not occur. Similarly, it would be less likely that the airport sector would compete domestic investment away from other sectors of the economy.

However, the degree to which foreign investment displaces domestic investment is difficult to calculate and we are only able to make a qualitative assessment. Overall we think the level of displacement would be small for the following reasons:

- The UK is an attractive hub for foreign investment. According to UNCTAD[206], the UK is the number one country for inward FDI stock in Europe, and only the second in the world after the USA. Given the UK's attractiveness foreign investment hub, we think it would be unlikely that
- The implied rate of return for inward investment[207] into the UK decreased to 5% in 2012 from 6% in 2011 and was still lower than the value reported in 2007 (7%). However, overall flows are rising.

These findings can be interpreted in two ways. Firstly, it could be that the UK will remain a well-liked destination for FDI, falling returns could imply that the UK can offer less favourable terms to investors because of its popularity as an investment destination. This means that the UK airport schemes could find it easy to attract foreign investors. Alternatively, the foreign investment community could infer that the UK is a saturated market and that in order to balance their global portfolios they are better off placing their investments in other countries. The scale of FDI is ultimately linked to the rate of return offered to bond holders by each airport scheme.

According to ONS surveys,[208] the main beneficiaries of FDI are the power and utilities sectors, communications, financial services and the manufacturing sector. So if displacement were to occur, it is likely that these sectors would be most affected.

One negative consequence that would be associated with foreign investment can be described as follows. The scale of investment required for each airport scheme will require the body corporate associated with each airport scheme to sell bonds in order to raise capital. This process will be facilitated through investor roadshows and the wider financial sector. If foreign capital is required, international investor roadshows will need to be held and this will require the support of international (rather than UK banks). This could lead to a small leakage in activity from the UK financial sector. But relative to the overall results, this effect would be minimal.

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capital returns in different sectors or across the whole economy. Similarly a shortage of investment supply means that businesses need to raise rates of return to attract scarce capital, so the model could be set up with higher capital returns.

However, it is not clear whether capital markets are generating long-term deviations in investment supply or demand. There were clearly liquidity shortages following the financial crises, but these have now eased. Further, markets will tend to look at capital infrastructure projects on a case by case basis. Airports represent long-term investment opportunities, and so are likely to be resilient to deviations in investment supply or demand. On this basis we make no special assumption about capital market disequilibrium.

[206] https://www.gov.uk/government/publications/ukti-inward-investment-report-2013-2014/ukti-inward-investment-report-2013-2014--2

[207] Sourced from UK Office for National Statistics, rate of return is calculated as dividends divided by positions.

[208] http://www.ons.gov.uk/ons/dcp171778_351956.pdf

Overall, the assumption made regarding the degree of domestic investment has been designed to be deliberately cautious. If FDI is the primary source of airport finance, the dampening effects of lower household consumption and displacement of domestic investment from other sectors would be less likely to occur and the overall results presented for the construction effect in our report would be larger.

## 8.7 Other economic indicators

### 8.7.1 Impact on welfare

Some of the welfare gains associated with transport improvements do not impact directly on GDP. For example, environmental benefits and time savings to *leisure* travellers are not usually thought to have a direct impact on economic output, despite being clearly valued by consumers and being likely to form part of any measure of economic welfare. Other effects influence GDP, but do not directly impact welfare. For instance, a person joining the labour market will produce output and therefore increase GDP, but the welfare impact to the individual may be lower than the GDP impact since that person has to spend time commuting.

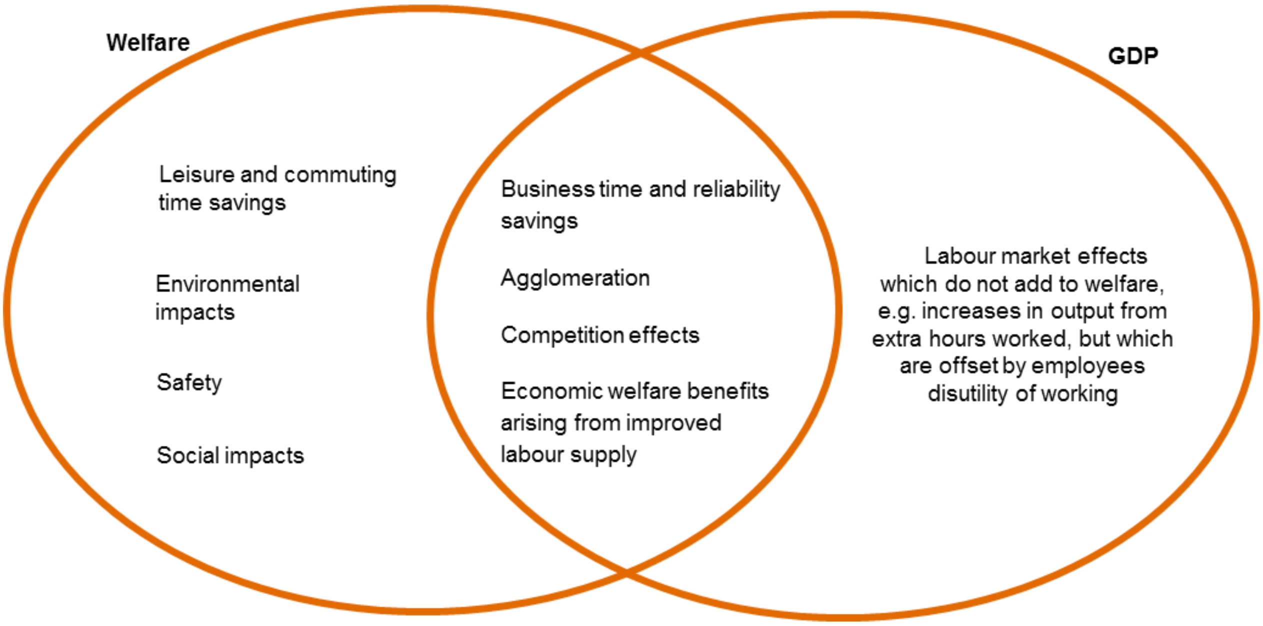
The relationship between welfare and GDP is set out in Box 11 below. Box 11 also emphasises that the welfare effects considered as part of this work are not comparable with the concept of welfare emerging from conventional transport appraisal.

**Box 11: Relationship between welfare and GDP**

*Welfare in transport appraisal*

The Venn diagram below summarises the relationship between GDP and economic welfare at a general level, and characterises how welfare is usually regarded in conventional transport appraisal. This is taken from the DfT's *Transport, Wider Economic Benefits, and Impacts on GDP* report of 2005.

*Figure 136: Relationship between GDP and economic welfare*




*Source: PwC analysis*

In this framework, factors such as safety improvements and social impacts form part of economic welfare since they are implicitly assumed to enter households' "utility" functions. Extensive empirical evidence - summarised in WebTAG - supports the idea that households value these factors and there are well-established estimates of agents' "willingness to pay" for improvements in these variables.

*Welfare in the S-CGE framework*

In general, it is possible to incorporate these factors into a CGE framework by generalising households' utility functions to capture these effects. For the purposes of this study, however, we have not included these factors in households' utility functions. The reasons for this are to simplify the analysis and allow focus on the purely economic effects. However, this should not be taken to mean that we consider these issues to be less important.

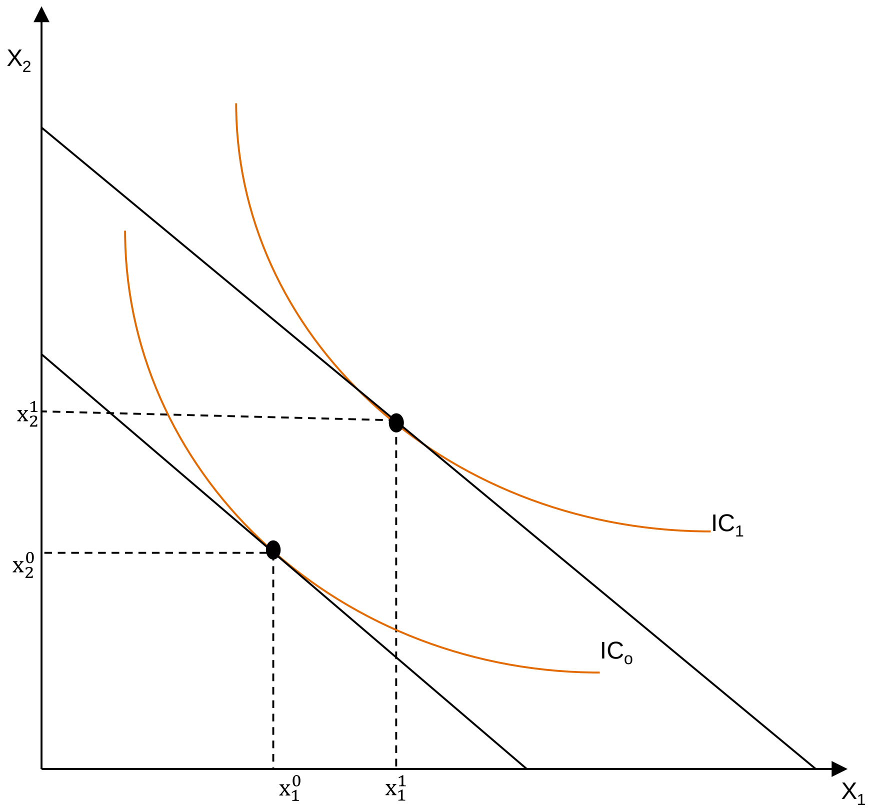
Overall therefore, rather than capturing the welfare effects described in the Venn diagram, welfare effects in the S-CGE framework are associated with consumption of goods/services and leisure (in particular the goods and services produced by the sectors described in Chapter 4).

Welfare is measured in monetary terms in the S-CGE framework using the so-called "Equivalent Variation" (EV), a concept due originally to Hicks (1939). The EV is most easily explained by means of an example. Suppose that the aviation intervention results in a fall in the price of a good. This clearly gives rise to a welfare improvement to consumers. The EV is a measure of how much a consumer would be willing to pay for the welfare improvement of the price change, based on the original set of prices. We use the EV (rather than the "Compensating Variation" or CV which uses the post-expansion set of prices), because the EV is calculated using the original set of prices, which are the same across the passenger flow scenarios. Using the EV therefore provides a like-for-like comparison. If we were to use the CV, any comparison across scenarios would be distorted by the use of different prices.

The EV is illustrated diagrammatically below. As described in Appendix B households' utility is defined as a function of both goods/services consumed and leisure time. Utility can be represented by indifference curves, which show the combinations of goods/services and leisure which deliver the same level of utility. The S-CGE model contains many goods, but to illustrate the interpretation of the EV we use just two goods, $x_1$ and $x_2$. The original level of utility (i.e. before airport expansion) is represented by $IC_0$, and point A represents the original level of consumption on the original budget constraint (which is determined by the original set of prices and income). After the effects have fed through the model, airport expansion and the resulting impacts on the economy allow households to consume more of the two goods and thus attain a higher level of utility, on $IC_1$.

The EV is calculated by taking the original set of prices (we use the original prices in order to ensure that the post-expansion results across the scenarios can be directly compared, as described above), and establishing how much more income households would need in order to increase utility to the post-airport expansion level: $EV = m_1 - m_0 = (p_1 x_1^1 + p_2 x_2^1) - (p_1 x_1^0 + p_2 x_2^0) = p_1(x_1^1 - x_1^0) + p_2(x_2^1 - x_2^0)$, where $m_0$ is the value of the consumer's consumption before airport expansion, $m_1$ is the value of the consumer's consumption after airport expansion, $p_1$ is the price of $x_1$ and $p_2$ is the price of $x_2$. This means that the welfare effect or EV can be interpreted as the change in the value of consumption as a result of the airport expansion, based on the original prices.

Figure 137: Welfare in the S-CGE framework




Source: PwC analysis

*Key issues in comparing welfare across different sources*

It is clear from the preceding discussion that the concept of welfare used in this work is different to the concept used in conventional transport appraisal. Key differences include, but are not limited to, the following:

1. We use the concept of EV to measure the change in consumer welfare, whereas many welfare analyses (e.g. that based on WebTAG) tend to use the change in consumer surplus (in general, these measures will not be the same);

2. We have adopted certain functional form assumptions (for example CES utility, which is widely used in CGE analyses) which may be different to those used in transport appraisal (for example the WebTAG analysis used to derive the TEE effects described above assumes linear demand, and therefore quadratic utility); and

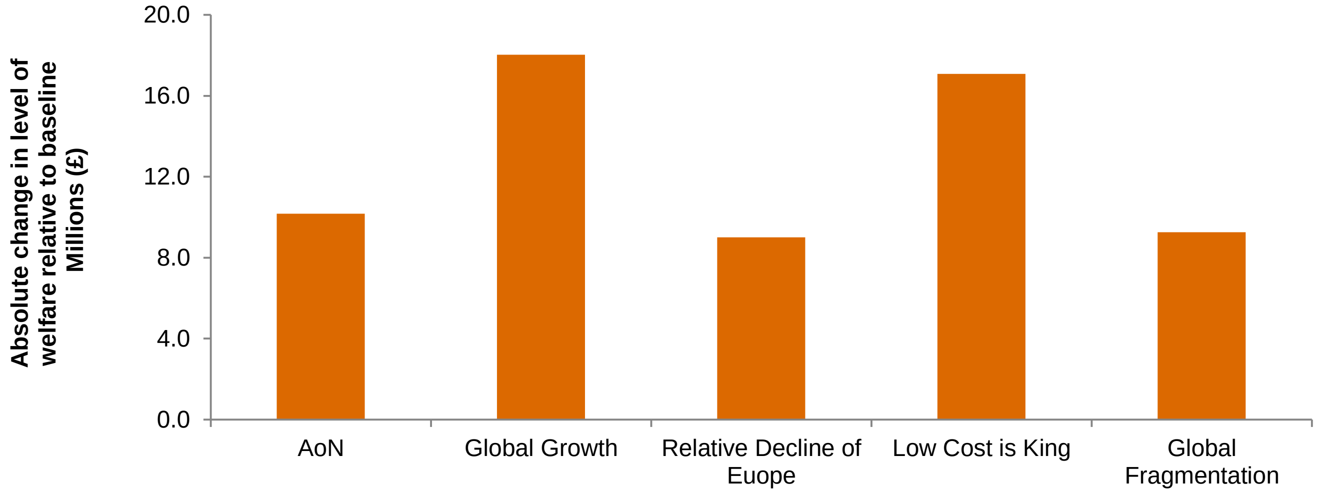
3. We capture "producer surplus" indirectly in our analysis (since households are assumed to own firms), rather than directly (the approach used in conventional transport appraisal).

As such, the welfare outputs described here should not be compared to outputs of conventional transport appraisal.

Whilst these points should be borne in mind, the results of the model to which we now turn are likely to provide a useful indication of the consumer welfare impacts of the airport schemes. Figure 138 shows the change in annualised welfare relative to the baseline across the scenarios.

For the LHR NWR scheme, the largest forecast increase in consumer welfare is observed in the Global Growth scenario. The Low Cost is King scenario is also associated with large consumer welfare impacts, significantly ahead of the impacts experienced in the remaining scenarios, which have similar impacts. This ordering reflects the underlying assumptions about passenger flows, frequency benefits and TEE effects under these scenarios, together with the implied productivity impact. The range of consumer welfare impacts across passenger scenarios reflects the degree to which the additional capacity is modelled as enabling an increase in consumption.

*Figure 138: LHR NWR change in economic welfare (EV) relative to baseline, by scenario*




*Source: PwC analysis*

## *8.7.2 Impact on Employment*

The S-CGE model measures the net impact on job creation resulting from an airport scheme. Figures on the “direct” job creation at each airport scheme have been supplied to us by the AC and have been produced as part of the Local Economic Impact Assessment

In the model baseline, UK employment grows by 0.8% per annum in line with long-run ONS population growth estimates. The labour force rises from around 28 million in 2010 to round 37 million in 2060. More details relating to this are provided in Chapter 3. Projected changes in job figures as a result of the LHR NWR are net in the sense that some sectors expand at the expense of others, since as demand for different goods and services increases/falls, different sectors will be able to pay more/less wages, and this entices workers to either enter the labour market or move jobs. Other key features of the labour market in the model are:

- Workers can move between sectors and regions as these expand or contract depending on the level of economic activity. If wages rise in London & South East retail for example, then conceivably a worker from the government sector outside of this region may move into this region and industry to gain from this wage rise;
- If workers move between sectors, it is assumed they need to retrain (e.g. an investment banker cannot become a chef overnight). The model assumes a temporary loss in productivity as people retrain and consequently their wages fall during this period. This decline in wages approximates a degree of labour market rigidity in the model;
- Current patterns of migration flows limit the flow of workers between regions; and
- The wage sensitivity of migration flows is governed by a separate elasticity parameter.

Results are given in Table 83 below and are again based on the AC's Assessment of Need scenario. The results show that LHR NWR is forecast to generate approximately 190,000 net additional jobs by 2060. A large proportion of jobs are forecast to arise in the air passenger transport and freight sector. These are largely direct jobs on or around the airport site and have been estimated in line with the AC's own assessment. The modelled overall net increase in employment associated with the LHR NWR scheme can be explained by the *employment effect* explained below:

| | |
|---|---|
| **Employment effect** | Increased productivity and profitability among UK businesses as a result of the scheme will increase demand for labour and capital, which in turn increases the returns to labour and capital. Higher wages will attract more workers into employment and unemployment will fall (with analogous effects for capital). The strength of this effect will be governed by the availability of potential workers. |

The key results from our modelling suggest that:

- There is a temporary short-term boost in construction jobs;
- The largest modelled overall net gains are observed in the manufacturing and other services sectors. These sectors are the largest in our model, and are relatively more trade intensive and are therefore forecast to gain more as a result of improved aviation links leading to increased trade. The "other services" sector includes key sectors such as financial services, telecommunications and business services. These sub-sectors are all expected gain due to increased access to air transport and enabling their overall trade volumes to increase;
- Accommodation and food services are also forecast to experience a significant increase as a result of increased domestic and foreign passenger demand;
- Other freight employment is expected to decline as there is shift towards air freight, but these reductions are marginal;
- Public sector job effects are largely forecast to be neutral, but in the long-term the overall proportion of jobs in this sector contracts as workers are assumed to leave for higher wages in other sectors; and
- Although better trade links would drive productivity increases in the retail sector, this effect is forecast to be offset by reductions in mark-ups and profits in the industry. This is forecast to lead to a reduction in the number of jobs, although this effect is small in comparison to the size of the overall sector.

*Table 83: LHR NWR Breakdown of impact on net job creation by sector relative to baseline, Assessment of Need scenario (000's of jobs)*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and Mining** | 1.0 | 2.0 | 5.0 | 6.3 | 4.9 |
| **Manufacturing** | 22.5 | 34.2 | 58.5 | 94.9 | 91.6 |
| **Utilities** | 3.9 | 3.4 | -0.2 | -1.6 | -1.3 |
| **Construction** | 19.4 | -1.4 | -0.8 | -0.3 | -0.6 |
| **Retail and wholesale trade** | 4.7 | -2.0 | -7.0 | -14.8 | -8.8 |
| **Air passenger transport** | 1.5 | 38.1 | 53.6 | 54.1 | 52.3 |
| **Air freight** | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 |
| **Other freight** | 0.2 | -0.9 | -1.6 | -2.0 | -0.8 |
| **Other passenger transport** | 0.5 | -2.3 | -4.1 | -9.1 | -4.3 |
| **Accommodation and food services** | 4.1 | 7.2 | 10.1 | 15.6 | 15.4 |
| **Other services** | 13.5 | 22.6 | 31.1 | 44.9 | 46.7 |
| **Health, education and public spending** | 0.6 | 0.5 | -3.3 | -8.4 | -7.0 |
| **Total** | **72.1** | **101.6** | **141.5** | **179.8** | **188.6** |

*Source: PwC analysis*

### *8.7.3 Impact on the number of firms*

Table 84 shows the modelled change in the number of firms by sector, as a result of the LHR NWR scheme. The S-CGE model is based on the assumption of imperfect competition, and consumers have a preference for variety in the products they purchase. Through these mechanisms, an increase in potential profits within a sector acts as a signal for new firms to enter and compete these profits away. Therefore the change in the number of firms participating within a sector can be seen as a proxy for the change in available profits as a result of the increase in capacity.

Overall it can be seen that the total number of firms is forecast to remain largely unchanged. This is indicative of the fact that while the whole economy is modelled as gaining from the productivity increases and demand boosts modelled, consumers receive a disproportionate share of the gains due to the substantial increase in consumer surplus, at the expense of producer surplus. This can be specifically seen in Table 84 where the air passenger transport and freight sector, which absorbs the producer surplus reduction, is the only sector to see an expected substantial fall in the number of firms. The majority of other sectors, which experience the productivity benefits of cheaper air passenger transport, are expected to exhibit higher total profits which encourage new entrants into the market. The results presented in Table 84 demonstrate that firms in the air passenger transport sector are expected to respond to the reduction in available operating surplus through consolidation in order to retain the economies of scale required to remain competitive and achieve an appropriate margin. Section 7.5.1 outlines an alternative possible equilibrium whereby firms do not consolidate, but instead maintain margins through reductions in investment, therefore leading to long-term relative price increases. The loss of efficiency implied by this alternative behaviour means that this is a lower long-term growth scenario at a national level. The scale of the effect is best seen by comparing with the size of the sector in Section 3.4.

*Table 84:LHR NWR Change in number of firms by sector relative to baseline, Assessment of Need Scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and Mining** | 0.3% | 0.1% | 0.4% | 0.5% | 0.5% |
| **Manufacturing** | 0.6% | 0.5% | 0.8% | 0.8% | 0.8% |
| **Utilities** | 0.2% | 0.0% | 0.4% | 0.4% | 0.5% |
| **Construction** | 4.1% | -1.8% | -0.1% | 0.0% | 0.0% |
| **Retail and wholesale trade** | 0.1% | -0.3% | -0.3% | -0.3% | -0.3% |
| **Air passenger transport and freight** | 2.0% | 0.3% | -1.0% | -2.0% | -1.5% |
| **Other freight** | -0.1% | -0.2% | -0.3% | -0.2% | -0.3% |
| **Other passenger transport** | -0.1% | 0.0% | -0.1% | -0.1% | -0.1% |
| **Accommodation and food services** | 0.0% | 0.2% | 0.4% | 0.4% | 0.4% |
| **Other services** | 0.2% | -0.4% | -0.3% | -0.2% | -0.1% |
| **Health, education and public spending** | 0.2% | 0.0% | -0.2% | -0.3% | -0.3% |
| **Total** | **0.6%** | **-0.3%** | **-0.1%** | **0.0%** | **0.0%** |

*Source: PwC analysis*

## 8.7.4 Impact on house prices

Table 85 shows the projected house price impacts for the LHR NWR scheme. During the construction phases, there is expected to be a very small increase in house prices – mainly in London& South East – as a result of higher demand, for example from construction workers. By the end of the period, the model suggests a reduction in house prices, relative to the baseline scenario. However, across the three regions, the reduction is so small as to be negligible (much less than 1% in all regions). This is due to a diversion of investment activities by households – instead of investing in homes in the rental market, a larger proportion of their investment portfolio will be invested in UK businesses as returns to business investment rise following the expansion in GDP. This puts a small amount of downward pressure on house prices.

*Table 85: LHR NWR Real house price impact relative to baseline, Assessment of Need scenario (baseline = 100)*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **London & South East** | 100.15 | 99.94 | 99.83 | 99.83 | 99.84 |
| **Rest of England** | 100.10 | 99.96 | 99.84 | 99.81 | 99.85 |
| **Rest of the UK** | 99.84 | 99.89 | 99.93 | 99.94 | 99.96 |

*Source: PwC analysis*

## 8.7.5 Impact on net taxes

Table 86 shows the net tax impacts for LHR NWR scheme. During the construction phases, there is a small but significant increase in net taxes as a result of higher incomes, for example from construction workers and firms.

The initial impact, during the construction phase, is large, at £6.5bn in 2020 (0.24% of baseline net taxes). There is a decline in the impact, in relative terms, in the operational phase. The change in net tax in 2030 is £5.6bn in 2030 (0.15% of baseline net tax) and this increases to £10.5bn in 2060 (but is still only 0.12% of baseline net tax).

*Table 86: LHR NWR Change in net taxes relative to the baseline, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Total UK impact (£ mn)** | 6,530 | 5,604 | 6,395 | 7,655 | 10,520 |
| **UK impact (% of net tax in baseline)** | 0.24% | 0.15% | 0.13% | 0.12% | 0.12% |

*Source: PwC analysis*

## 8.8 Testing the results – sensitivity analysis

### 8.8.1 Systematic sensitivity analysis

The S-CGE model is based on assumptions for a range of elasticities. Systematic Sensitivity Analysis (SSA) is a method of testing the influence of the model elasticities on the results. This is carried out using Monte Carlo analysis, the steps of which are outlined in Box 12 below.

The results of the Systematic Sensitivity Analysis are shown in Figure 139 below. The average difference between the central estimate and each of the upper and lower bound estimates is between 0.05 and 0.1% of GDP. This range defines the confidence interval for the degree to which different modelling assumptions could generate different results. Any variation outside of this could only be driven by changes in the model inputs. This range remains reasonably constant throughout the period studied, demonstrating that the time profile of the impacts is determined primarily by the time profile of the inputs, rather than assumptions made during the modelling.

**Box 12: Systematic Sensitivity Analysis**

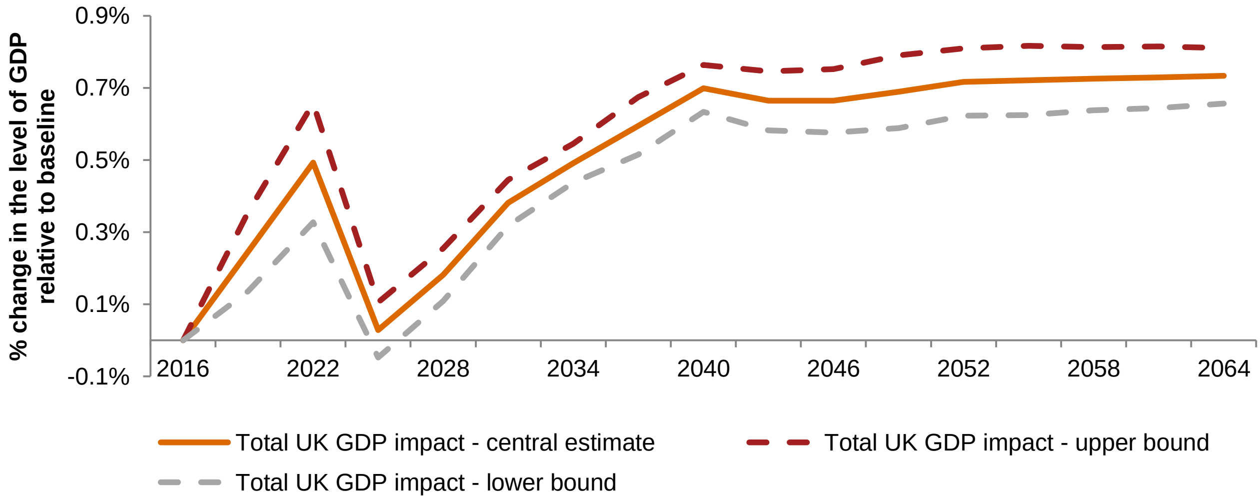
- First, we specify a range for each of the elasticities in the model. These ranges are based on the estimated values in academic literature. These are shown in Table 87;
- We then generate a value for each elasticity by randomly sampling from within the corresponding specified ranges. We assume that each elasticity is uniformly distributed within the specified range, i.e. any value within the range is equally likely to be selected;
- We then solve the model for each combination of elasticities, and calculate the impact on the UK economy. This is repeated for 100 randomly generated combinations of elasticities; and
- Finally, the model results are then aggregated for all 100 combinations, and these are then expressed in the form of *95% confidence intervals*, i.e. the upper- and lower-bounds within which the result can be expected to lie 95 times out of 100.

*Table 87: Specified ranges for elasticities varied in the SSA*

| Parameter | Description | Central Range | Para |
|---|---|---|---|
| **Price elasticity of inbound passenger flows** | Change in inbound passenger expenditure with a change in domestic price levels in all regions | 1.1897 (+/- 0.3) | Price |
| **Price elasticity of outbound passenger flows** | Change in outbound passenger expenditure with a change in domestic price levels in all regions | 1.3825 (+/- .77) | Price |
| **Elasticity in the main passenger flows nest** | Change in passenger expenditure across products with a change in relative prices | 0.5 (+/- 0.25) | Elast |
| **Elasticity in day visits nest – between regions** | Change in inbound day-visit passenger expenditure between regions with a change in price levels between regions | 1 (+/- 0.25) | Elast |
| **Elasticity in domestic passenger nest – between regions** | Change in total inbound passenger expenditure between regions with a change in price levels between regions | 1 (+/- 0.25) | Elast regio |
| **Elasticity in overseas passenger nest – between modes** | Change in outbound day-visit passenger expenditure between regions with a change in price levels between regions | 1 (+/- 0.25) | Elast mode |
| **Inter-temporal elasticity of substitution** | Change in consumption and saving patterns over time with a change in interest rates | 0.2 (+/- 0.05) | Inter- |
| **Elasticity between labour and leisure** | Change in labour supply with a change in wages | 0.5 (+/- 0.125) | Elast |
| **Elasticity between products in utility** | Change in the composition of households consumption basket with a change in relative prices | 1 (+/- 0.05) | Elast |
| **Elasticity of unemployment to real wages** | Change in unemployment rates with a change in real wages | 0.2 (+/- 0.4) | Elast |

The results of the Systematic Sensitivity Analysis are shown in Figure 139 below.

*Figure 139: LHR NWR – Systematic Sensitivity Analysis results, Assessment of Need scenario*



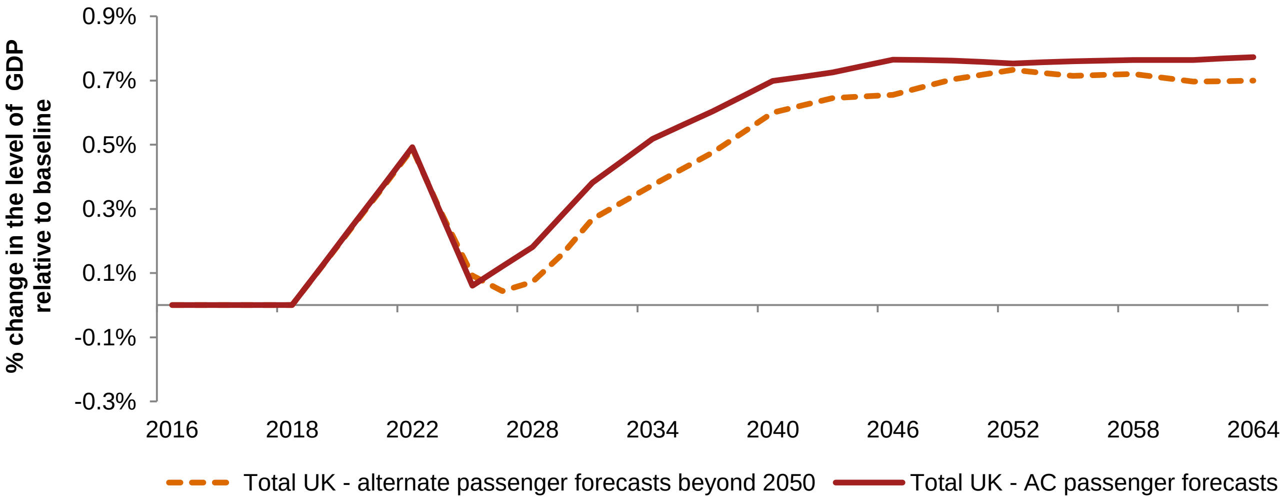

*Source: PwC analysis*

## *8.8.2 Testing the effect of alternative passenger numbers forecasts beyond 2050*

The AC demand forecasts provide passenger numbers estimates beyond 2050 based on an extrapolation of underlying trends in the previous years. We test the impact of this assumption by using alternate passenger number estimates beyond 2050, i.e. where we assume that passenger numbers beyond 2050 grow at the same rate as the baseline, i.e. the "do minimum" scenario.

Figure 140 below presents the results based on the two different model assumptions. The average difference in the GDP impact in the 14 year period from 2050 to 2064 between the original forecasted GDP impact and the GDP impact estimated with the alternate passenger numbers is 0.2%. Note that this difference begins to manifest in 2040, when the passenger numbers begin to differ only in 2050. This is because the forward-looking agents in the model begin to make adjustments in their spending and investment patterns ahead of any change in passenger numbers, and therefore in this alternate scenario, the lower passenger numbers from 2050 onwards has a lower impact on GDP in the previous years. Please note that this sensitivity test includes the construction effect.

*Figure 140: LHR NWR –Testing the effect of alternate passenger numbers forecasts beyond 2050, Assessment of Need scenario*




*Source: PwC analysis*

## *8.8.3 Testing passenger additional spending assumptions*

In this section, we consider the sensitivity of the results of our analysis to changes in the following assumptions:

- the split between inbound and outbound passenger flows; and
- expenditure per passenger per visit.

These assumptions impact on the results of the modelling (particularly GDP) through Effect 1: Passenger flow expenditure. The other three effects do not change in response to changes in these assumptions[209].

The next sub-section sets out the original assumptions in respect of the inbound-outbound passenger flow split and the revised assumptions made for the purposes of the sensitivity analysis. We then consider the original assumptions on expenditure per passenger and the revised assumptions made for the sensitivity analysis. We present the results of the sensitivity analysis.

All assumptions tested in this section relate to changes to the inputs to the S-CGE model that have been provided by the Airports Commission, rather than any changes to the S-CGE model itself.

*Inbound-outbound passenger flow split*

The passenger flow expenditure effect in the S-CGE model is driven by, amongst other things, the relative size of the spending of UK residents abroad (which reduces UK GDP) and foreign residents' spending in the UK (which increases GDP in the UK). In turn, inbound expenditure is driven by inbound passenger flow numbers and outbound expenditure is driven by outbound passenger flows.

The AC  provided us with total passenger flow data under different airport expansion options and scenarios, but did not provide a forecast into whether these passengers are inbound or outbound. In order to assess the passenger flow expenditure effects, it is therefore necessary to make assumptions about the balance between inbound and outbound passenger flows.

For our main analysis we agreed with the AC that the growth of inbound and outbound passengers (and their associated spending) for each scheme should be assumed to be proportional to the existing inbound-outbound split for the relevant airport (specifically the levels in 2011). For example, if the inbound-outbound split at the relevant airport was 60%-40% in 2011, and that passenger numbers were forecast to grow by 10m, inbound passenger growth would be assumed to be 6m and outbound growth would be assumed to be 4m. Mathematically, this means that growth across the UK airports system in inbound passenger numbers is assumed to be:

$$inbound_t = (H_t - H_0)h_0 + (G_t - G_0)g_0 + (R_t - R_0)r_0$$

where $H_t$ is total passenger numbers at Heathrow in period $t$, $h_0$ is the inbound passenger share at Heathrow in the base year, $G_t$ is total passenger numbers at Gatwick in period $t$, $g_0$ the inbound passenger share at Gatwick in the base year, $R_t$ is total passenger numbers at all other UK airports in period $t$, and $r_0$ is the inbound passenger share at all other UK airports in the base year. The subscript *0* represents the base year in all cases. Outbound passenger numbers are simply the difference between total and inbound passenger numbers. Data from the CAA and the International Passenger Survey was used to calculate the current inbound-outbound split at UK airports.

Alternative assumptions could be made to capture, for example, a more even distribution of growth between inbound and outbound passengers across airports (rather than relying on the current split at each airport). Therefore, the AC asked us to perform a sensitivity test in which each UK airport's inbound-outbound split is

[209] Note, in particular, that Effect 2: Productivity is not affected by these sensitivity tests under the modelling approach we have adopted. This is because, as noted in Chapter 3, the econometric relationship which underpins the productivity effect is based on the relationship between total passenger numbers (as opposed to inbound or outbound flows) and international trade volumes. We consider that it is appropriate that the econometric relationship is estimated on the basis of total passenger numbers since productivity effects are likely to be experienced as a result of both UK residents travelling abroad (for example, UK residents may learn from suppliers, customers, and/or competitors when outside of the UK) and foreign residents travelling to the UK (for example, foreign residents may share knowledge and/or technology with UK individuals and firms during visits to the UK).

proportional to the inbound-outbound split of London-system airports taken together. The AC have asked us to test this assumption in order to see how results might change as a result, it is not based on any evidence or forecasts which suggests that this might be likely in the future. Specifically, this asked us to look at the effects of assuming that the growth of inbound and outbound passengers (and their associated spending) at all airports is proportional to the existing inbound-outbound split across Heathrow, Gatwick and Stansted airports combined, the largest three London airports[210]. Mathematically, this means that growth across the UK airports system in inbound passenger numbers is assumed to be,

$$inbound_t = \{(H_t - H_0) + (G_t - G_0) + (R_t - R_0)\}a_0 = (A_t - A_0)a_0$$

where $A_t$ is total passenger numbers across the UK airport system and $a_0$ is the inbound-outbound split across Heathrow, Gatwick and Stansted airports.

The inbound share $a_0$ is based on International Passenger Survey data and is estimated to be 42%. This means that it is assumed that inbound passenger growth at all airports individually (and across the system as a whole) is 42% of forecast total passenger growth.

This sensitivity analysis is designed to test how the results change with different assumptions – it is not suggested that this is a realistic scenario for future development. The results of the S-CGE modelling using this alternative assumption are set out in the results sub-section below.

*Passenger spending assumptions*

Another key determinant of the passenger flow expenditure effect in the S-CGE model is expenditure per passenger per visit (both inbound and outbound). Expenditure per passenger per visit has been estimated on the basis of ONS/TSA data, presented in the tables below.

For the original analysis presented in the main document, it was agreed that expenditure per passenger per visit would be calculated for each world region (Europe, Asia, North America and Others) as follows:

- take spend per visitor per day across all regions (i.e. a single global average); and
- multiply by the average length of visit (in days) for each region.

This exercise was undertaken in respect of inbound and outbound trips separately. Under this approach, differences in spending by passengers from different world regions are captured by how their lengths of stay differ. Importantly, this approach was applied in respect of *each* expenditure category[211] allowing us to model *where* in the economy the expenditure of inbound visitors takes place. This is in keeping with the S-CGE framework, which recognises that 'where' expenditure takes place in the economy matters, as well as the overall level of expenditure (the model recognises this by acknowledging that different sectors interact with other parts of the economy through backward linkages in different ways). This approach allows us to preserve detail of the TSA/ONS data and avoid losing the nuances contained within it. We felt this to be the most appropriate approach after careful consideration of the TSA data.

Another approach is to calculate expenditure per passenger per visit for each world region such that it also reflects differences in average expenditure *per day* across different geographies. At the request of the AC, we have therefore run a sensitivity test in which expenditure per passenger is calculated for each world region as follows:

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[210] We have used the share across Heathrow, Gatwick and Stansted since data is only available for these airports (data is unavailable for London Luton and London City airports). These three airports account for more than 90% of London-system and therefore likely provide a reasonable representation of the London-system split.

[211] The expenditure categories are: agriculture, forestry and fishing; mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply; water supply, sewerage, waste management and remediation activities; construction; wholesale and retail trade, repair of motor vehicles and motorcycles; passenger transport (exc. air passengers); accommodation and food service activities; information and communication; financial and insurance activities; real estate activities; professional, scientific and technical activities; public administration and defence, compulsory social security; education; human health and social work activities; arts, entertainment and recreation; other service activities; activities of households as employers, undifferentiated goods and services; air freight; all other freight; air passenger transport; and overseas expenditure.

- take spend per visitor per day across each region individually (note the difference compared to the original assumption);
- multiply by the average length of visit (in days) for each region; and
- apply the expenditure proportions from the TSA/ONS data.

These tables demonstrates the substantial differences between regions. These are primarily driven by differences in length of visit (with passengers travelling further typically visiting for longer), with some additional variation occurring due to differences in average spend per day. The high spend by visitors from 'Other' countries is largely driven by passengers arriving from the Middle East.

*Table 88: Regional spending - inbound passengers*

| | Europe | Asia | North America | Others |
|---|---|---|---|---|
| **Average spend per visit** | £448.1 | £1,393.4 | £871.6 | £1,367.0 |
| **Average length of visit (days)** | 5.9 | 16.7 | 8.3 | 12.8 |
| **Average spend per day** | £75.8 | £83.7 | £104.8 | £106.5 |

*Source: ONS/TSA, PwC analysis*

*Table 89: Regional spending – outbound passengers*

| | Europe | Asia | North America | Others |
|---|---|---|---|---|
| **Average spend per visit** | £452.7 | £1,008.2 | £1,119.7 | £945.5 |
| **Average length of visit (days)** | 7.9 | 26.3 | 14.0 | 18.0 |
| **Average spend per day** | £57.0 | £38.3 | £80.2 | £52.6 |

*Source: ONS/TSA, PwC analysis*

The key difference, therefore, between this alternative assumption and the original assumption is that:

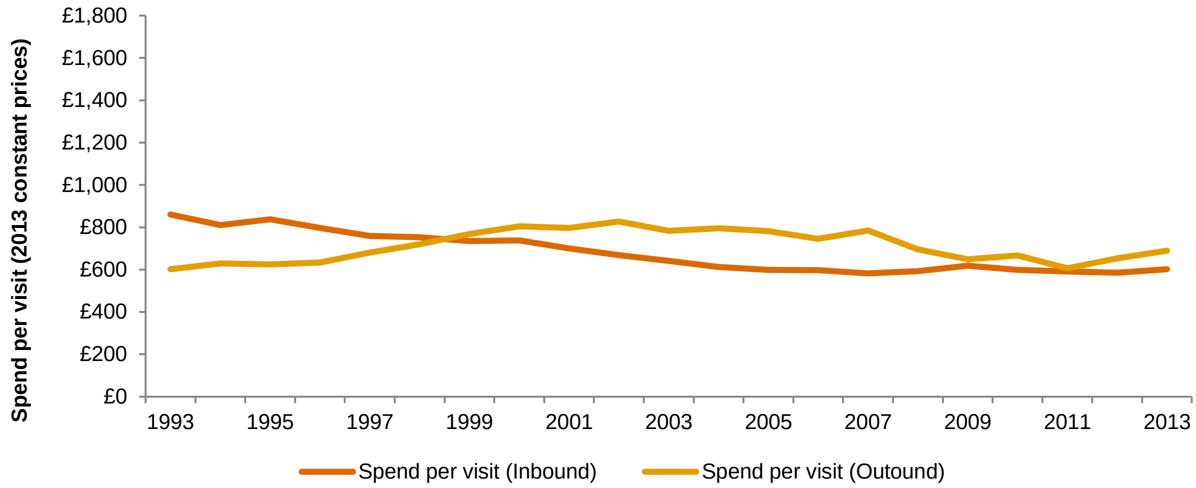
- this alternative approach captures differences in average spend across geographies, but does not fully capture spending differences across product categories; whereas
- the original approach captures differences in average spend across product categories, but does not fully capture differences in average spend across geographies.

Note that these assumptions are strictly alternatives to one another. The results of the S-CGE modelling from adopting this alternative assumption are set out in the results sub-section below. As explained in detail later, the choice of assumption does not have a significant impact on the expenditure inputs that are incorporated into the model, or the resulting GDP impacts.

Finally, we note that the AC has asked us to assume that passenger spend per visit is constant in real terms over the time period under consideration. While it is possible that passenger spend per visit could rise as populations become wealthier, this does not appear to be consistent with the evidence. For example, Figure 141 below shows real inbound and outbound passenger spend per visit since 1993. Between 1993 and 2013, inbound spend per visit actually fell by a third in real terms (despite strong global absolute and per-capita income growth). Outbound spend in 2013 was similar to its 1993 level in real terms (whilst the late 1990s saw moderate growth, the figures subsequently fell back).

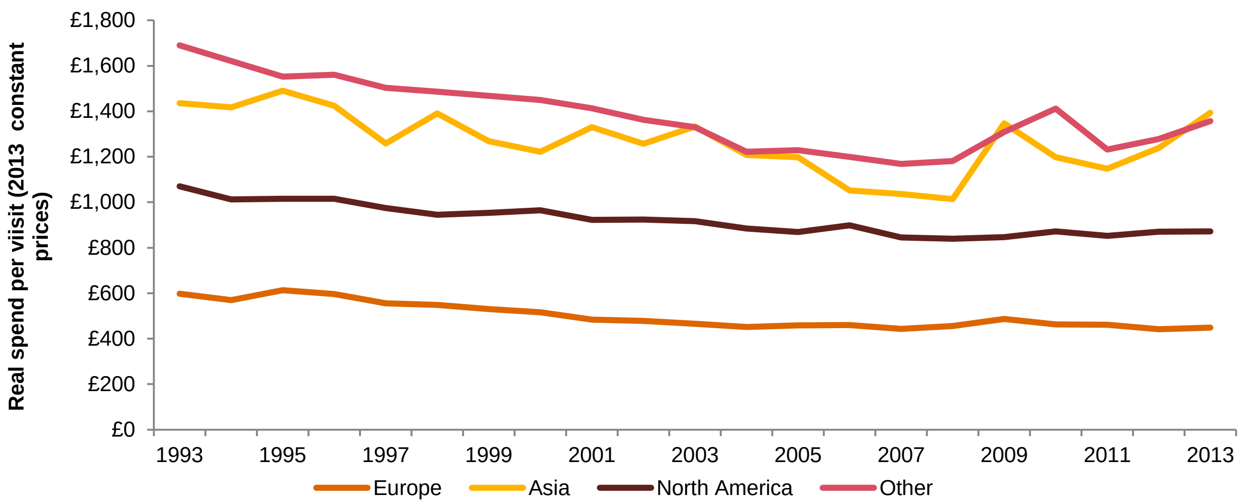
The reasons for the decline in inbound spend per visit could include the growth of low-cost air travel within Europe which may have provoked more frequent, but potentially shorter, trips involving less expenditure. This is borne out by the evidence in Figure 141 which shows a decline in real spend per visit among European inbound passengers. Similarly, lower airfares may have opened opportunities for travel among less affluent passengers, who may spend less during their visits.

*Figure 141: Real spend per visit, inbound and outbound visitors (2013 constant prices)*




*Source: ONS, PwC analysis*

*Figure 142: Real spend per visit by region, inbound visitors (2013 constant prices)*



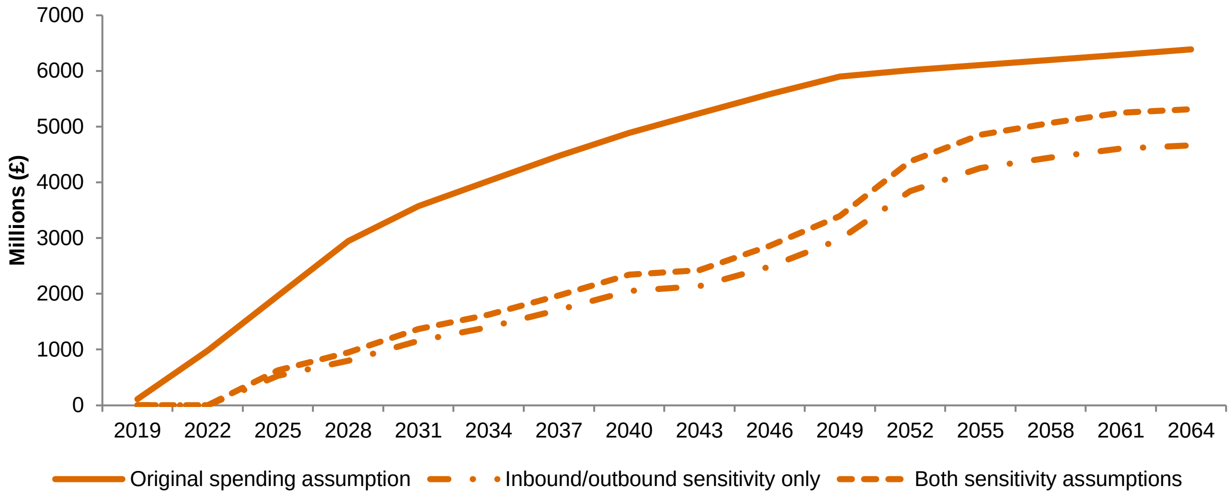

*Source: ONS, PwC analysis*

*Results of the sensitivity*

The charts below demonstrate the impact of the above sensitivity analysis on the overall GDP impact of the LHR NWR scheme, under the Assessment of Need, Low Cost is King and Global Fragmentation scenarios.

*Assessment of Need*

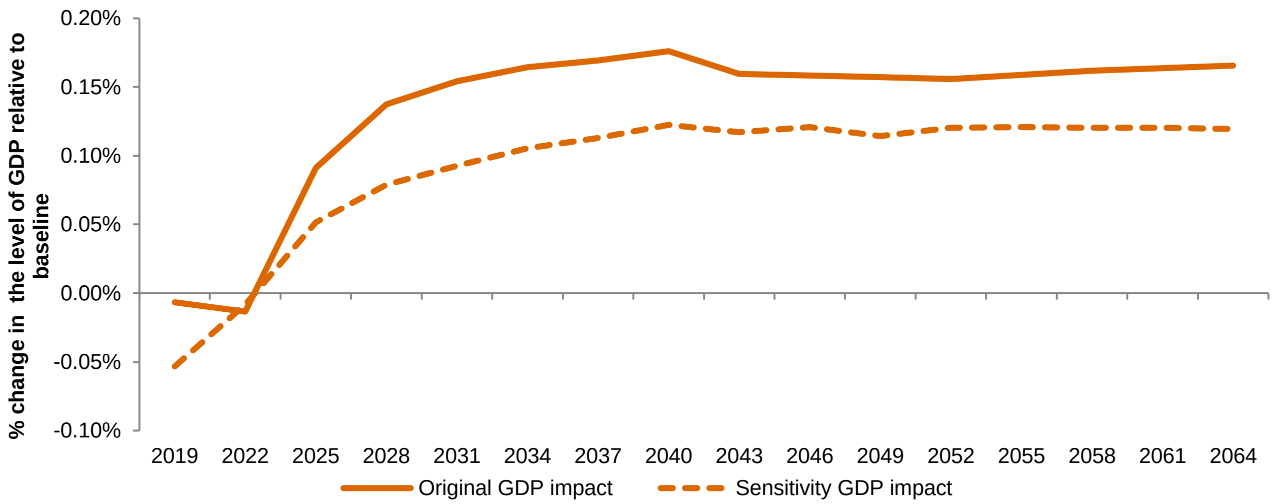
*Figure 143: LHR NWR - Impact of sensitivity assumptions on net additional passenger spending in the UK, Assessment of Need*




*Source: PwC analysis*

Figure 143 shows the impact of the sensitivity assumptions on net passenger spending in the UK for the Assessment of Need scenario. This chart demonstrates a decrease in net additional passenger spending, the majority of which is as a result of the change in assumed inbound/outbound passenger mix.

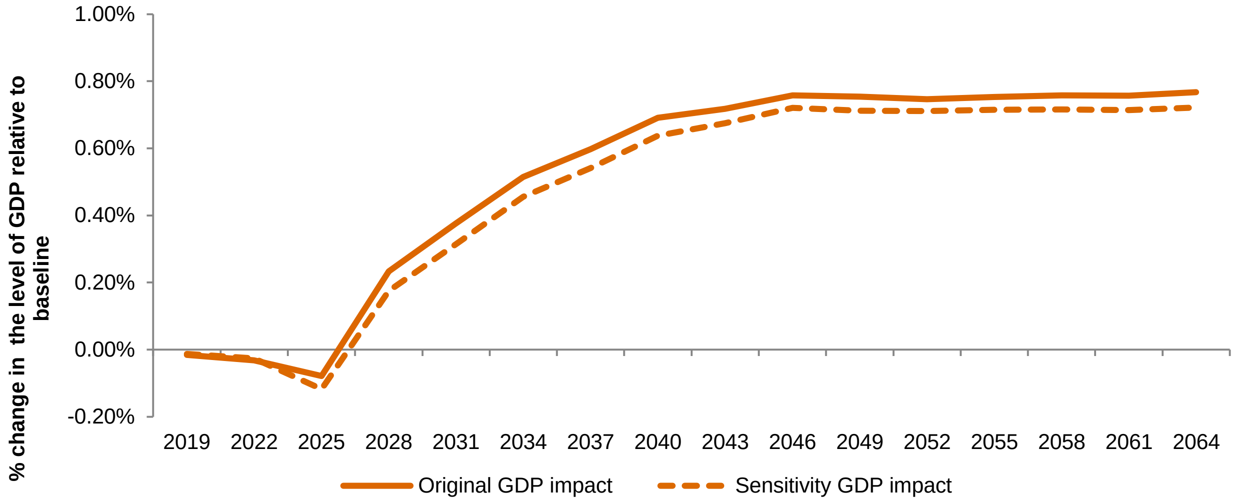
*Figure 144: LHR NWR – Comparing the GDP impact of just the passenger flow effect under different spending assumption, Assessment of Need*




*Source: PwC analysis*

Figure 144 shows how the passenger spend sensitivity affects the GDP impact of the corresponding passenger flow effect (as opposed to the GDP results that combine all effects). The original passenger spending assumptions lead to a positive GDP impact for the majority of the period studied (seeFigure 114 in Section 7.4.3.1 for the original result). The result of the sensitivity analysis is for there to be a lower positive impact on the level GDP. The magnitude of the impact grows throughout most of the period studied, before remaining relatively constant at roughly 0.12% of GDP from 2050. The impact of the sensitivity reflects the sensitivity's fall in the proportion of inbound passengers, who contribute positively to the UK economy (and conversely the increase in outbound passengers).

*Figure 145: LHR NWR – Comparing the overall GDP impact under different spending assumptions, Assessment of Need*

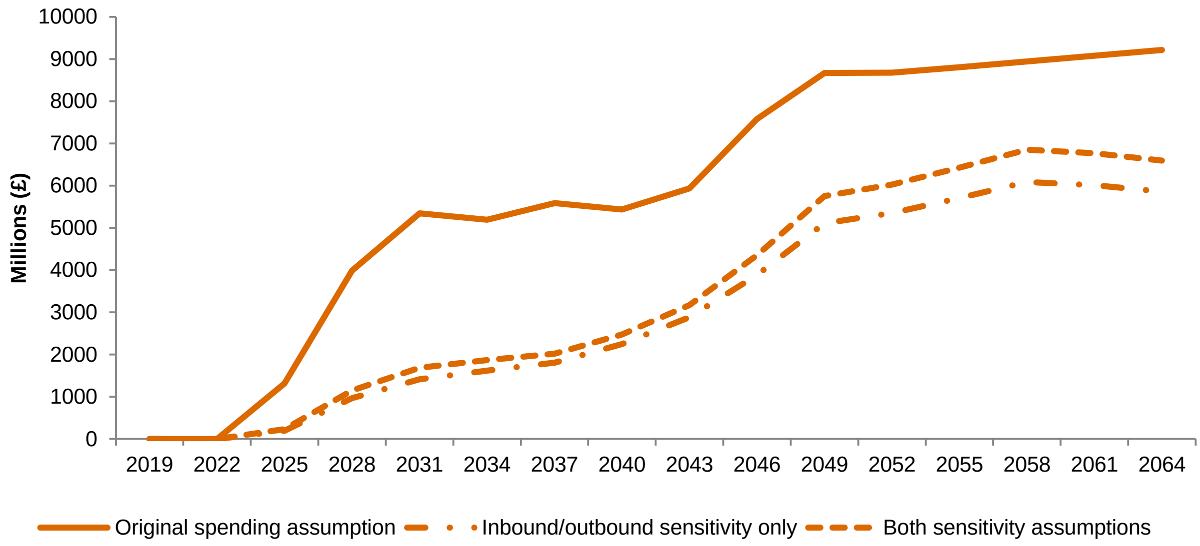



*Source: PwC analysis*

Figure 145 provides the results of this sensitivity test on the overall impact of the LHR NWR scheme, under the Assessment of Need scenario. This impact is relatively insignificant, with the lower GDP impact of the passenger flow effect propotionately affecting the overall GDP impact throughout the time period, by around 0.05%. The sensitivity test does not materially impact on the time profile of the economic impact of the scheme, which rises most substantially between 2040 and 2050 as the expanded airport reaches capacity.

*Low Cost is King*

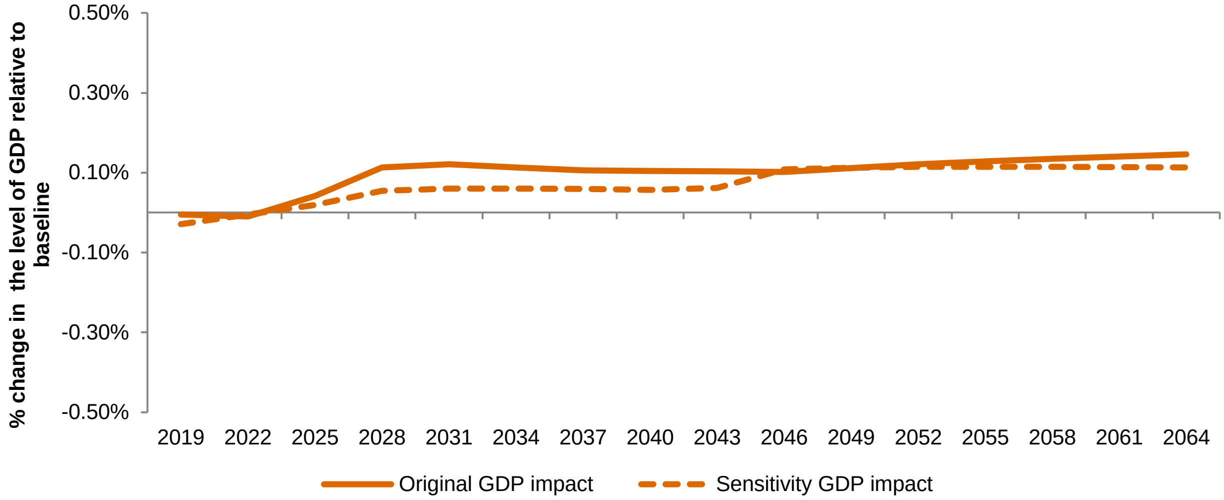
*Figure 146: LHR NWR - Impact of sensitivity assumptions on net additional passenger spending in the UK, Low Cost is King*




*Source: PwC analysis*

We also applied the sensitivity assumptions to the Low Cost is King passenger scenario, the scenario which leads to the greatest increase in passenger flow. Figure 146 shows the impact of the sensitivity assumptions on net passenger spending in the UK. This chart demonstrates that the majority of the decrease in spending is a result of the change to the assumed inbound/outbound passenger mix.

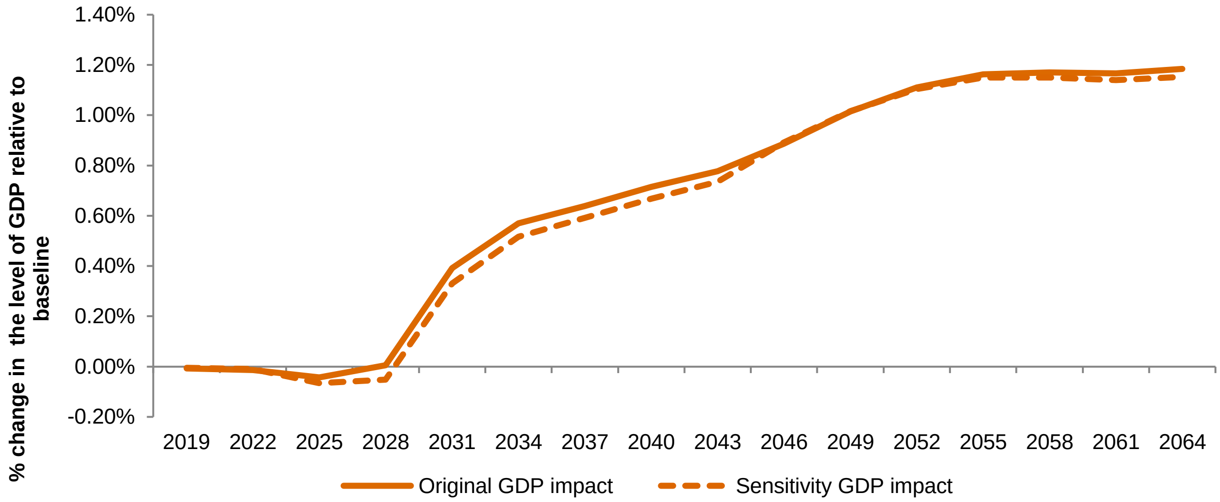
*Figure 147: LHR NWR – Comparing the GDP impact of just the passenger flow effect under different spending assumption, Low Cost is King*




*Source: PwC analysis*

Under this sensitivity, the impact on GDP is positive throughout the period studied. However, the time profile is slightly different in that spending is slightly lower in the first half of the time period, before catching up with the original spending GDP impact in the mid-2040s. This is predominantly driven by the greater number of outbound passengers, before the impact of an incremental increase in long-haul passengers – who spend more – begins to emerge.

*Figure 148: LHR NWR – Comparing the overall GDP impact under different spending assumptions, Low Cost is King*

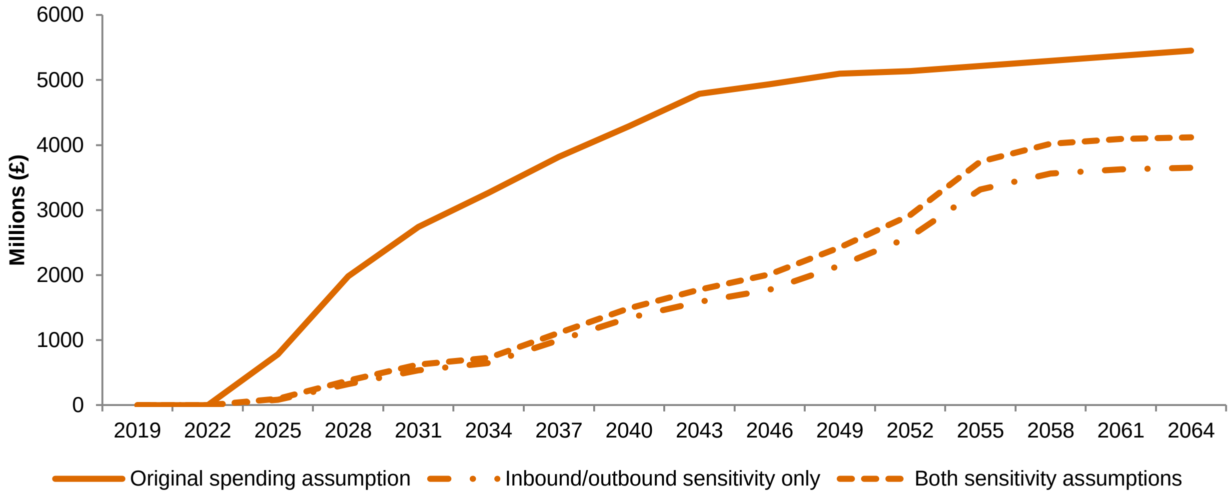



*Source: PwC analysis*

As with the Assessment of Need passenger scenario, the sensitivity does not have a material impact on the economic impact of the additional capacity. Figure 148 shows the effect of the sensitivity on the aggregate GDP result. In the long run, the forecast impact on GDP is around the same as before at 1.15% to 1.18%. Although, it is worth noting that the negative impact on GDP in the 2020s (that was present in the original GDP impact, due to the sudden increase in outbound passengers) is slightly more prolonged.

*Global Fragmentation*

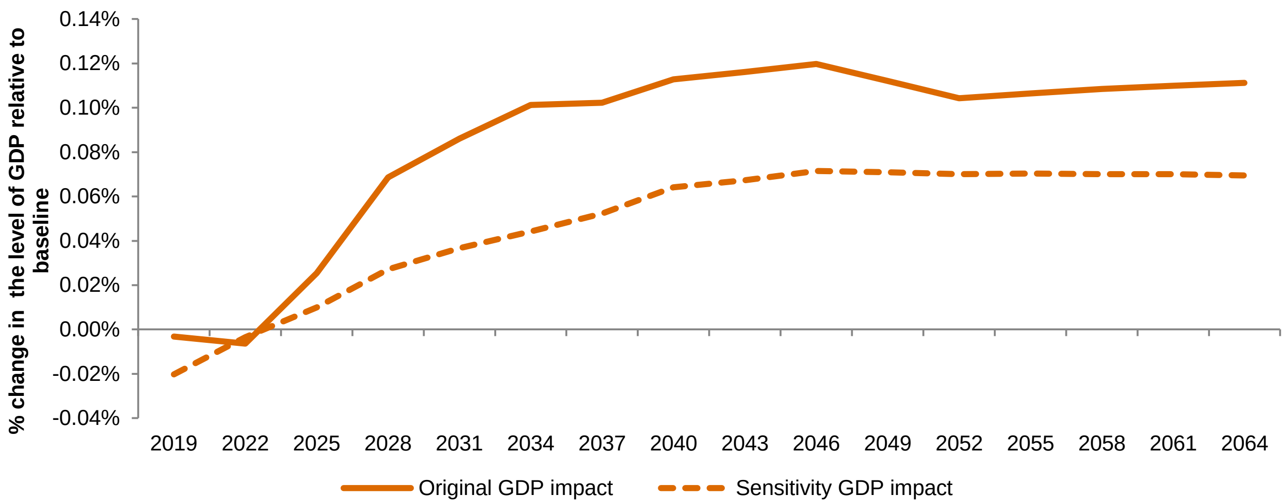
*Figure 149: LHR NWR - Comparing the GDP impact of just the passenger flow effect under different spending assumption, Global Fragmentation*




*Source: PwC analysis*

Figure 149 shows the impact of the sensitivity on net passenger spending in the UK, under the Global Fragmentation passenger flow scenario. As shown in Section 7.4.3.1, the incremental number of passengers under the LHR NWR scheme is lowest under the Global Fragmentation scenario. This chart demonstrates that the majority of the increase in GDP is due to the assumed change in the inbound/outbound passenger mix.

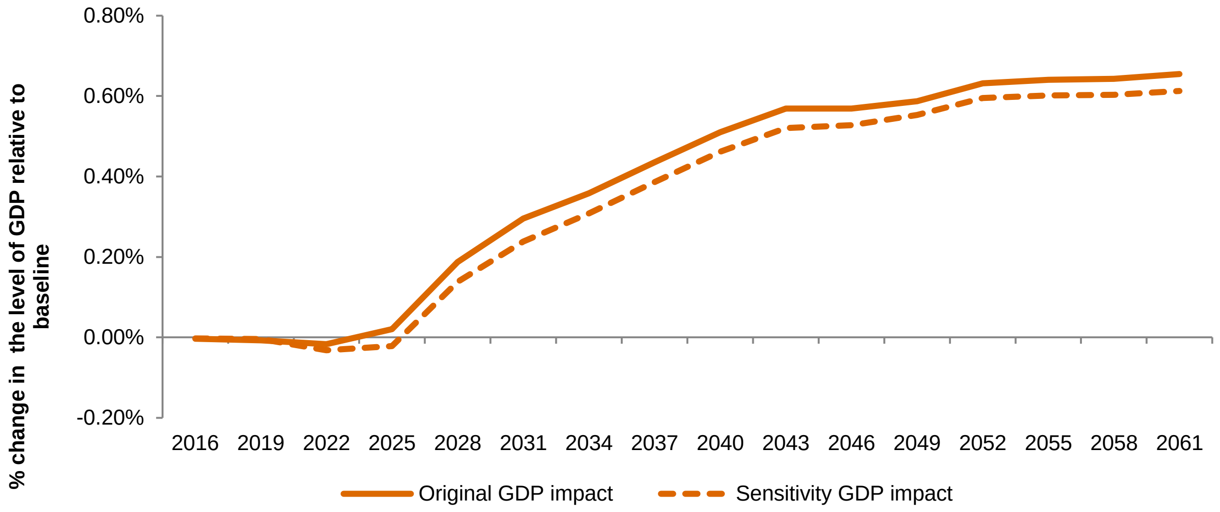
*Figure 150: LHR NWR – Comparing the GDP impact of just the passenger flow effect under different spending assumption, Global Fragmentation*




*Source: PwC analysis*

Figure 150 shows the GDP impact of just the passenger flow effect, under the original and revised sensitivity assumptions. The impact of the sensitivity is similar in magnitude to the Assessment of Need scenario, reducing the level of GDP forecast by around 0.05%. The impact is still positive, with the exception of the initial years, during which there is a sudden increase in outbound passengers.

*Figure 151: LHR NWR – Comparing the overall GDP impact under different spending assumptions, Global Fragmentation*




*Source: PwC analysis*

The sensitivity has a proportionately lower impact on the overall impact of the LHR NWR scheme on GDP. Under the sensitivity, this impact reaches 0.61% of GDP towards the end of the period studied, compared to 0.65% under the original assumptions. These values are calculated based on a 60 year appraisal period starting 2019.

*Table 90: LHR NWR – Present Value of real GDP impacts, by effect and scenario with and without sensitivity (£bn, 2014 prices)*

| | Assessment of Need | Low Cost is King | Global Fragmentation |
|---|---|---|---|
| **Passenger Flows** | 32.8 | 25.9 | 21.1 |
| ***Passenger Flows (Sensitivity)*** | *19.8* | *16.2* | *10.7* |
| **Productivity** | 70.9 | 73.1 | 54.5 |
| **Frequency Benefits** | 6.5 | 10.6 | 4.5 |
| **TEE** | 21.6 | 73.6 | 23.0 |
| **Total** | **131.8** | **183.2** | **103.0** |
| ***Total (Sensitivity)*** | ***118.8*** | ***173.5*** | ***92.6*** |

*Source: PwC analysis*

Table 90 summarises the impact which the sensitivity test has on the PV of the impact of the scheme. This is shown to be significant, and consistent across scenarios, where the PV of the economic impact is reduced by around £10-13bn as a result of the lower passenger spending under the sensitivity. The impact of the sensitivity on PVs is marginally at its largest under the Assessment of Need scenario, as this scenario is associated with the largest passenger flow impact. These results show that the inbound/outbound passenger mix is an important driver in determining the economic impact of the scheme, previously outlined in Section 7.4.3.1.

### *8.8.4 Testing the TEE effect with business passengers only*

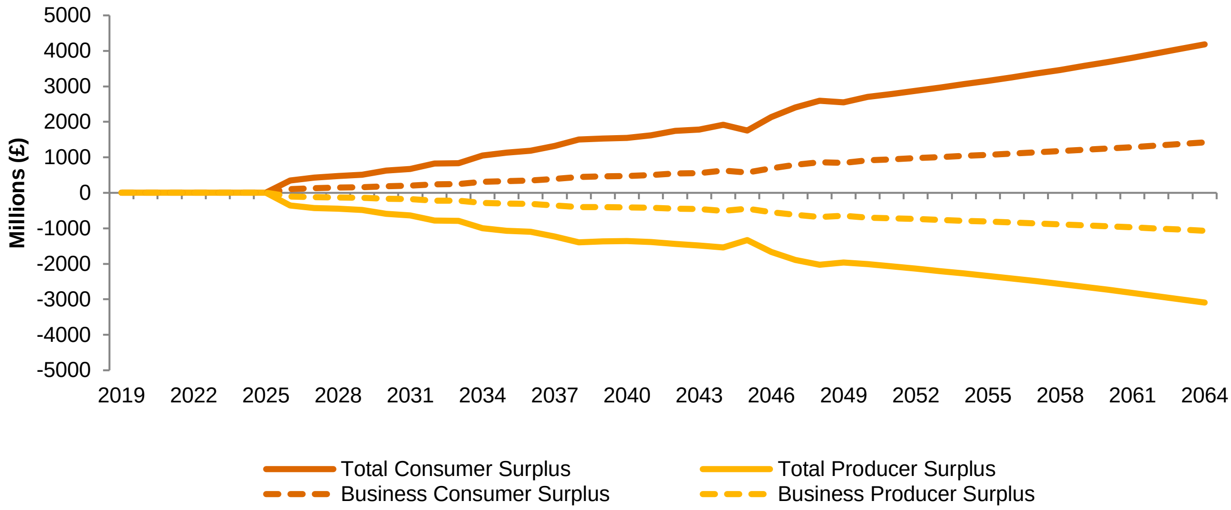
The TEE effect reflects the impact of the expansion in airport capacity on airfares. Specifically, the AC demand forecasts assume that the cost of air travel falls as capacity at Heathrow increases. This results in a transfer of money from producers (airlines) to consumers (air passengers). Scarcity rents, which producers charge for use of the airport when it was capacity constrained are reduced, leading to benefits for consumers through lower costs of travel. For business passengers, the lower airfares result in a productivity boost, which plays through the wider economy through the transmission mechanisms outlined in Appendix D. For leisure passengers, this translates into an income effect i.e. a cash transfer back to households that can be spent or saved.

Previously, we have modelled the impact of changes in producer and consumer surplus for all passengers (passengers travelling for both business and leisure purposes), allowing us to understand the full effect of the transfer from producers to consumers as a result of the increased capacity. We test the impact of this assumption by modelling the impact of changes in producer and consumer surplus relating only to business passengers. This allows us to isolate the direct economic impact on the supply side of the economy. For the Assessment of Need scenario, this section presents:

- the changes in inputs as a result of considering business passengers only;
- the subsequent GDP impact for the TEE effect; and
- the overall GDP impact of LHR NWR scheme (all effects combined).

Figure 152 below summarises the producer and consumer surplus inputs for the TEE effect. The solid lines show the original inputs used, which relate to both business and leisure types of passengers. The dotted line shows the inputs when considering only business passengers. Business passengers represent a smaller proportion of total passengers than leisure passengers. Consequently, by the end of the time period both consumer and producer surplus inputs are around 66% lower.

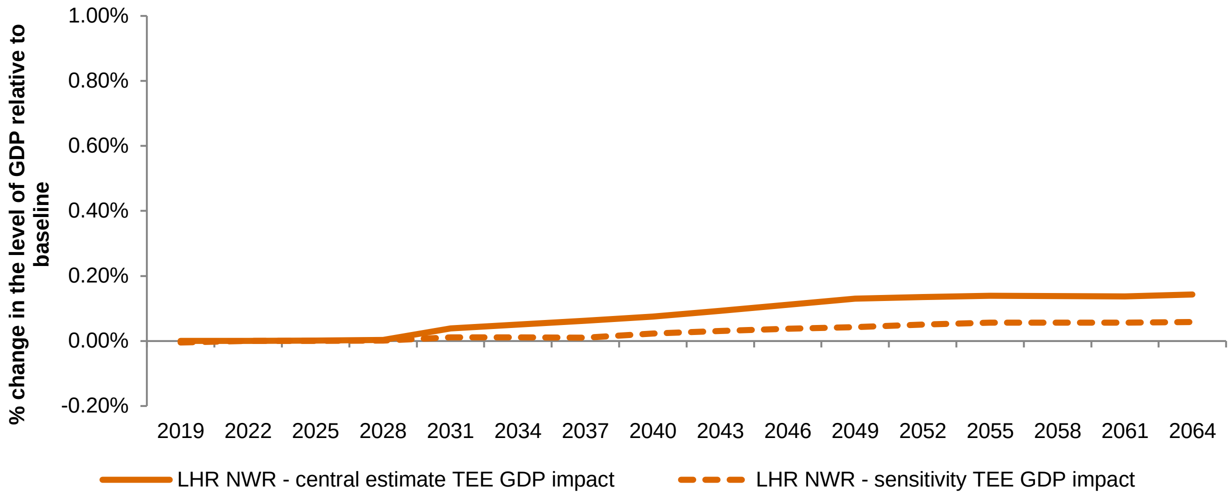
*Figure 152: LHR NWR –TEE inputs for all passengers and for business passengers only, Assessment of Need*




*Source: AC demand forecasts*

As a result of the smaller inputs, the impact of the sensitivity is to reduce the overall magnitude of the TEE effect for both positive and negative periods of GDP impact. Again, the solid line in Figure 153 shows the original GDP impact of the TEE effect, whilst the dotted line shows the impact of the TEE effect when only considering business passengers. The impact of the sensitivity is greatest in the latter half of the period, during which the TEE effect is just under half the size of the original effect, at around 0.06%.

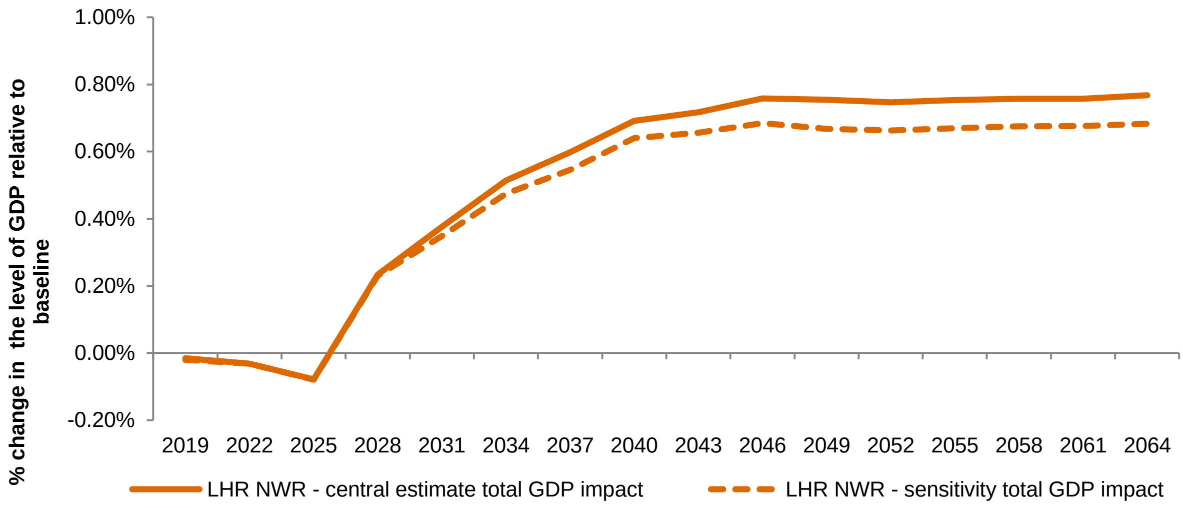
*Figure 153: LHR NWR – Impact of business passenger sensitivity on TEE GDP impact, Assessment of Need*




*Source: PwC analysis*

Figure 154 below shows the impact of the TEE sensitivity on the overall GDP impact of the LHR NWR scheme. Please note that this sensitivity test excludes the impact of construction. As expected, the reduction in the overall GDP impact is equivalent to the reduction in TEE effect GDP impact (0.08% by the end of the time period), which is now lower as a result of the change in the magnitude of model inputs, which now relate only to business passengers, as opposed to business and leisure passengers. The TEE effect was previously a significant component of the airport scheme's overall GDP impact – 19% by the end of the time period in the original analysis, compared to 9% in the sensitivity.

*Figure 154: LHR NWR – Impact of business passenger sensitivity on overall GDP impact, Assessment of Need*




*Source: PwC analysis*

Table 91 below displays the PVs of the forecast total real GDP impact for the Assessment of Need scenario by effect. It also shows the PV of the business passenger only TEE sensitivity and the new overall total PV. The PV of the TEE effect is significantly lower in the sensitivity, by £13.5bn.

*Table 91: LHR NWR Present Value of real GDP impacts by effect (£bn, 2014 prices)*

| 60 years (2019-2078) | LHR NWR |
|---|---|
| **1. Passenger Flows** | 32.8 |
| **2. Productivity** | 70.9 |
| **3. Frequency Benefits** | 6.5 |
| ***4. TEE (original - business and leisure PAX)*** | *21.6* |
| **Total (original: 1+2+3+4)** | **131.8** |
| ***5. TEE (Business PAX only)*** | *8.1* |
| **Total (sensitivity test: 1+2+3+5)** | **118.3** |

*Source: PwC analysis*

Lower airfares represent a decrease in the cost of intermediate inputs for businesses. As a result, the sectors which therefore benefit the most are those which purchase the most from the air passenger transport sector. Excluding travel agents and the air passenger transport sector itself, the three largest beneficiaries are the financial sector, the manufacturing sector, and the information and communication sector. Between them, these sectors represent nearly 50% of air passenger transport intermediate consumption.

## 8.8.5 Testing the effects of alternative labour market assumptions

Comments raised in relation to an earlier version of this report, published as part of the AC's consultation on "increasing the UK's long-term aviation capacity", made reference to the potential senstivity of the results to the treatment of labour supply. Based on these comments we discussed and agreed with the AC the following two tests:

**Test 1:** creating an assumption where the supply of labour is fixed; and

**Test 2:** testing the assumption where the elasticity that governs the pace at which unemployed workers enter the labour market in response to change in labour market demand and wages.

### *How does the S-CGE model treat labour supply?*

In the S-CGE model, the volume of labour supply adjusts in response to changes in the wage level in two main ways:1) Workers are able to enter and exit the market, known as the **extensive labour supply margin**.

2) Workers are able to increase or decrease their hours, known as the **intensive labour supply margin**.

Allowing the extensive and intensive margins to adjust assumes that the economy is not always operating at a fixed full employment, in that there are both unemployed and underemployed workers who can enter the market in response to an increase in demand, or vice versa.

In the baseline model, the extensive labour supply margin is based on an elasticity that governs the relationship between out of work income and wages This reaction is known technically as the income effect. The elasticity chosen as an input for this function is taken from a comprehensive literature review of labour supply elasticities by Keane (2011)[212] and also the Mirrlees Review (2011). The elasticity is weighted to reflect male, female and household labour supply decisions. It must also be set at a positive value to reflect the nature of the income effect i.e. as the gap between out of work income and in work income increases, people enter the labour market. On this basis, and to reflect data on flows of entry and exit into the labour market observed in the UK in recent

212 Keane, M. (2011) "Labour Supply and Taxes: A Survey" Journal of Economic Literature 49:4, 961–1075

years, we set this value at 0.2 i.e. for every 1% increase in wages, the supply of hours from non-working housheolds increases by 0.2%.

However, the model also generates a substitution effect – households gain additional utility from consuming a greater and wider variety of different products and services. But, they also supply "hours" to the labour market, and will experience a disutility from forgoing leisure time. For each additional hour of work supplied an hour of leisure is forgone. The decline in utility associated with forgone leisure is considered alongside the additional utility gained from earning more money and being able to consume more. Economic theory suggests that as incomes rise consumers have more disposable income and therefore place greater value on leisure time and may even seek to work less – this is known as the substitution effect.

In the S-CGE model the substitution effect is determined in a separate equation to the income effect. However, the net outcome regarding the income and substitution effect is determined by the households overall utility maximising function, meaning that the net outcome of these two effects is determined simultaneously.

Each household in the model is alsogiven a "stock of leisure". The model assumes that in the baseline, households spend one-third of their time at work, and two-thirds of their time not at work i.e. engaging in what we have termed leisure activities, but this would also include basis subsistence activities such as sleeping etc.

There is also an intertemporal element to the labour supply decision. In this context intertemporal substitution is reflected in the Frisch elasticity, which represents the willingness of households to postpone leisure in favour of work during periods of anticipated high wages. The Frisch elasticity is also governed by the households preference to smooth consumption – if preferences to smooth consumption are strong then labour supply is less likely to adjust when wages rise. The value of this elasticity is set at 0.4, in line with empirical estimates reviewed by Mirlees (2011).

*Implementing the labour supply tests*

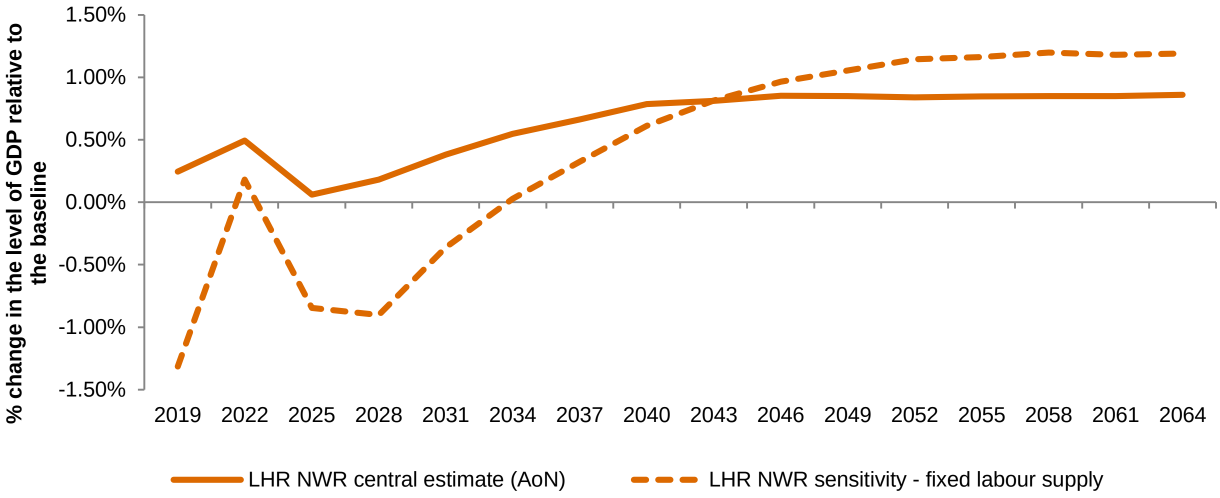
In test 1, which is a test of a fixed labour supply assumption, we change the extensive margin elasticity from 0.2 to zero and also hold the stock of leisure fixed – this means that those households who are out of work do not enter the labour market. The intensive margin is also fixed and the model is constrained so that households who are in work will not substitute leisure for additional hours of work. The Frisch elasticity is also set to zero, meaning there is no intertemporal substitution in response to wages.The assumption of a fixed labour supply is extreme, and is highly unlikely to occur in reality, but it is implemented to show the magnitude of impact our assumptions for the labour market.

In test 2 we fix only the extensive margin elasticity. The stock of leisure and the Frish elasticity allow workers to increase hours, but no new households enter the labour market. The difference in results between tests 1 and 2 shows the effects of varying the extensive margin.

*Test 1: Fixing labour supply*

The result of the fixed labour supply assumption, in which both the extensive and intensive labour supply margins are fixed (i.e. workers can neither enter the market, nor increase their hours) is shown in Figure 155: LHR NWR – Overall GDP impact of central estimate and fixed labour supply sensitivity test, Assessment of Need

*Figure 155: LHR NWR – Overall GDP impact of central estimate and fixed labour supply sensitivity test, Assessment of Need*




*Source: PwC analysis*

The results of this sensitivity test are reflective of how restrictive the assumption is. In the early years of the modelling it can be seen that the level of GDP is substantially below both the baseline and central estimate. This is driven primarily by construction spending, which requires firms in the construction sector to offer a material wage premium to attract workers in order to meet demand.

Due to the fixed labour supply, these workers cannot be taken from unemployment or underemployment, and instead must move from employment in other sectors. This wage premium drives up the cost of labour for firms in all sectors, who need to adjust their own wages in order to retain workers in light of the greater compensation offered by the construction sector. This increase in the cost of labour motivates firms to restrict output, and causes the economy to reach a new, lower-output, equilibrium as seen in Figure 155.

Table 92 below breaks down the impact of the trends described above on jobs, by sector. As discussed above, the fixed labour supply condition means that the overall volume of labour supply is unable to change. Therefore, the overall impact on net job creation is zero throughout the time period, with increases in employment in one sector displaced from other sectors. Table 92 shows that the airport expansion results in a significant increase in the number of jobs in the air passenger transport sector, which are drawn primarily out of the manufacturing sector. This is because this is the sector with the most closely aligned wages and skillsets. There is also a short-term boost in employment in the construction sector, due to the airport expansion. By 2050, there are 51,000 more jobs in the airport passenger transport sector, and 40,000 less jobs in the manufacturing sector. There is also a significant fall in the number of jobs in the other services sector in the long-run.

*Table 92: LHR NWR - Breakdown of impact on net job creation by sector relative to baseline for fixed labour supply sensitivity, Assessment of Need scenario (000's of jobs)*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and Mining** | -0.1 | -1.1 | -2.8 | -2.3 | -1.7 |
| **Manufacturing** | -3.6 | -20.0 | -36.3 | -40.2 | -35.5 |
| **Utilities** | -0.4 | -1.9 | 0.1 | 0.6 | 0.5 |
| **Construction** | 5.1 | 0.8 | 0.5 | 0.1 | 0.2 |
| **Retail and wholesale trade** | -0.5 | 1.1 | 3.9 | 5.4 | 3.1 |
| **Air passenger transport** | 1.3 | 36.4 | 52.4 | 51.1 | 50.9 |

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Air freight** | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 |
| **Other freight** | 0.0 | 0.5 | 0.9 | 0.7 | 0.3 |
| **Other passenger transport** | 0.0 | 1.3 | 2.3 | 3.3 | 1.5 |
| **Accommodation and food services** | -0.4 | -4.1 | -5.6 | -5.7 | -5.4 |
| **Other services** | -1.3 | -12.8 | -17.3 | -16.4 | -16.5 |
| **Health, education and public spending** | -0.1 | -0.3 | 1.8 | 3.1 | 2.5 |
| **Total** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

*Source: PwC analysis*

As the modelling period progresses, the difference between the central estimate and the sensitivity reduces, and eventually the impact on the level of GDP is seen to be higher under an assumption of fixed labour supply scenario. This occurs because it is fixed within the model that the ratio between consumption and investment must remain broadly constant in the long-run[213]. This is not an unreasonable assumption, historically in the UK this relationship has shown relative long-run stability. However the rise in labour costs, and the associated fall in profitability, which occurs at the beginning of the period is sufficient to break this relationship in the short-run. The only way to meet the assumption is by a substantial increase in investment throughout the second half of the period modelled. This increase drives the greater GDP growth shown in Figure 155.

As this trend is driven purely by the requirements of the model, rather than any real economic effect captured within the inputs, this result should not be interpreted with the same credibility as the previous findings. What the result from the modelling does demonstrate is just how restrictive the assumption of fixed labour supply is. Under this assumption, a demand increase of this size could only be absorbed with a substantial change to long-run economic relationships within the UK. In reality this has not been the experience of UK economic history, where levels of employment have fluctuated in response to short-run changes in demand. This would suggest that completely fixing labour supply is an unrealistic and erroneous sensitivity test, a suggestion which is borne out in the results of the modelling.

*Test 2: Reducing the extensive margin labour supply elasticity to zero*

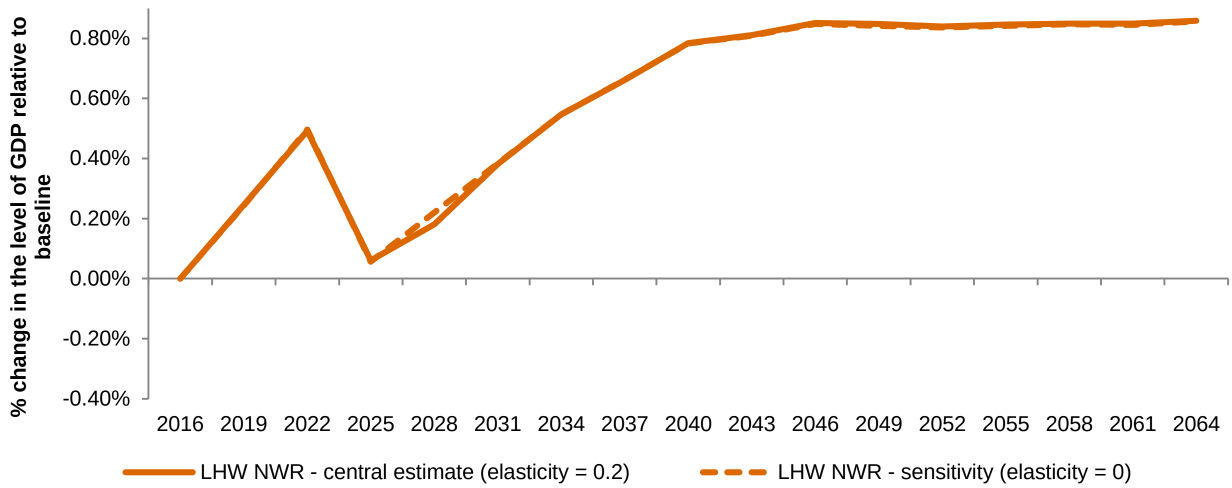
1. Under this assumption, the overall number of workers in the economy remains fixed (i.e. the unemployment rate is fixed). This is done through setting the elasticity of unemployment to real wages to zero. However, the intensive labour supply margin is allowed to adjust, giving workers the ability to move from part- to full-time work, increase their hours, or take additional jobs in response to changes in the wage rate.

The results of this sensitivity test show that the impact on GDP of either change in assumption is minimal, demonstrating that the GDP impact of the increase in aviation capacity is not sensitive to the number of individuals who can be attracted out of unemployment. Specifically under the fixed extensive labour supply margin, it is shown that the increased demand for labour associated with the expansion in aviation capacity can be handled without expanding the number of workers in the labour force.

These results show that the precise labour supply assumption regarding the extensive margin applied in the central estimate does not have a material impact on the estimated GDP impact. Only an overly-restrictive assumption, such as completely fixed labour supply, causes a substantial change in this estimate.

[213] This type of fixed long-term relationship within the model is known as a ‘terminal condition’

*Figure 156: LHR NWR – Comparison of the overall GDP impact across different intensive labour supply elasticities, Assessment of Need*




*Source: PwC analysis*

## *8.8.6 Testing the imperfect competition assumption*

So far in the analysis, we have assumed imperfectly competitive markets (the marginal benefits of increasing output, measured by price, are above marginal costs). Thus, an output expansion brought about by reduced costs gives rise to an additional welfare benefit over and above what would be seen in a perfectly competitive framework. In this way, the S-CGE model allows us to depart from the conventional assumption in scheme appraisal of perfect competition, and to capture the real world implications of how most markets in the economy are characterised by effective but imperfect competition. This sensitivity is particularly relevant for the construction phase of the project, and construction effects are included within the analysis.

So direct cost savings associated with, for example, the production process becoming more efficient would be present in a model of perfect competition and are captured in conventional transport appraisal. However, where the market is imperfectly competitive, there are further effects. We therefore re-run the model assumption to test the model results under similar assumptions to those used in conventional welfare analysis. This assumption has been tested each of the three proposed airport schemes, under the Assessment of Need scenario, for all effects (construction, passenger flows, productivity, frequency benefits and TEE).

Under the original assumption of imperfect competition, some of the effects modelled give rise to multiple equilibria in the S-CGE model (an upper and a lower case). This phenomenon, described in detail in Chapter 2 and Appendix B, depends on the nature of competition in markets and the agglomeration effects.

Note that the baseline for this sensitivity (i.e. the projected GDP growth in the absence of new airport capacity) is different from that of the central estimate; the baseline for the sensitivity would reflect a counterfactual with perfect competition and constant returns to scale (CRTS), whereas the baseline for the central estimate would reflect a counterfactual with imperfect competition and increasing returns to scale (IRTS).

Under the central estimate, industries are imperfectly competitive with IRTS. Under this assumption, firms restrict output below the level of market demand in order to drive up prices and in turn generate a mark-up on their sales, i.e. Cournot competition. Mark-ups are determined by the firms perceived elasticity of demand – these are inversely related, the lower firms perceive the elasticity of demand for their products, the higher mark-ups will be. The market structure suffers from inefficiencies in the short run which may delay the potential benefits from improved access to transport (for example, firms may choose not to pass on the lower costs to consumers in the short run).

However, the short-run effects under this market structure can also facilitate agglomeration. For example, if firms in a particular sector/region decide to raise prices in order to capture additional mark-ups in response to improved transport links, then, in the model a concentration of new firms emerges in this sector/region facilitated by the forward and backward linkages inherent in the economy and the rise in economic activity associated with the new transport links.

In contrast, under perfect competition, firms face CRTS and therefore, individual firms do not have any market power. Any benefits to firms due to improved transport links are quickly passed on to consumers, and the benefits to the economy accrue immediately. The pass-through of benefits implies that the economic gains associated with improved transport links are likely to be higher under perfect competition.

However, as discussed in Section A.2, there would be no agglomeration with perfect competition. This is because under perfect competition and the presence of transport costs, firms in a sector would spread out in order to minimise the costs of supplying consumers in different location. There would a large number of small production units, each supplying their local customers. The benefits, therefore, are likely to be spread out more evenly across sectors.

The difference between the two scenarios depends on the balance between the delay of benefits of reduced transport costs due to imperfect competition and agglomeration effects. Under perfect competition, if the transport costs gains are outweighed by the loss in agglomeration effects, then the overall impact on GDP is lower. On the other hand, if the transport costs gains are larger than the loss in agglomeration effects, then the overall impact on GDP is higher.

It is not possible to predict in advance which equilibrium will prevail (i.e. whether prices will be higher or lower, or whether the impact will be larger or smaller than the agglomeration benefits under imperfect competition). This is because the impact on the economy, i.e. the equilibrium outcome, will vary based on which sector/region becomes the focal point for convergence. It is difficult to predict which sector/region is likely to emerge as the focal point for convergence, and therefore, it is difficult to predict which equilibrium will prevail (i.e. whether prices will be higher or lower, or whether the spatial effects will aid agglomeration or dispersion), hence the need to consider each of the potential equilibria.

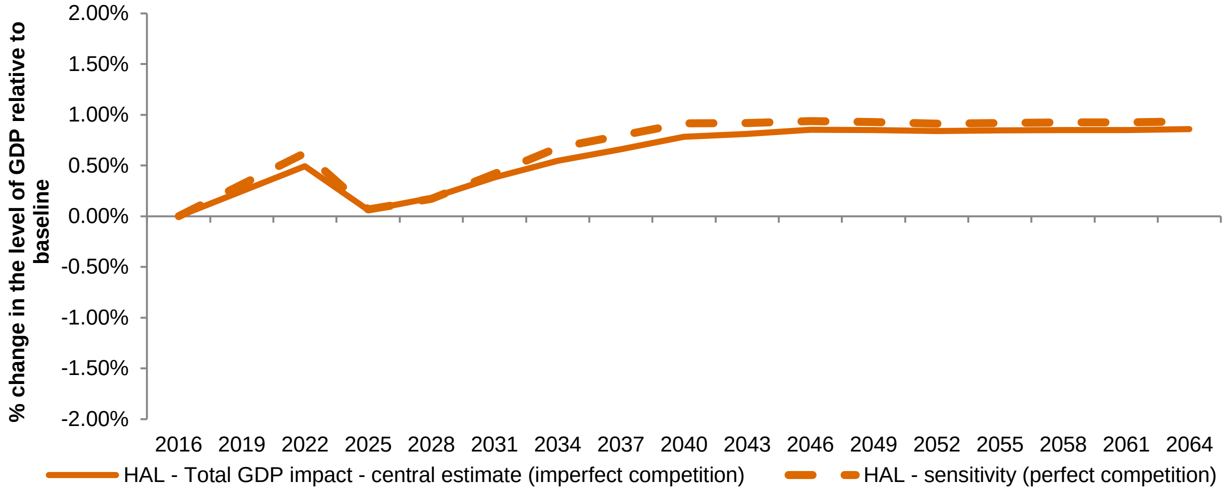
To be consistent with the central estimates presented in the rest of this report, Figure 157 shows the results corresponding to the higher results in terms of GDP effects. This is in line with Aghion *et al (2004)*[214] who use firm-level panel data for the UK and find that entry has led to greater innovation and faster total factor productivity growth, and to aggregate productivity growth.

Figure 157 below demonstrates the impact of the perfect competition sensitivity test, on the overall change in the level of GDP for the Assessment of Need scenario. This shows that the change in the level of GDP is greater when perfect competition is assumed. As described above, the implication of this finding is that the transport cost gains are greater than the loss in agglomeration effects. The impact of the different assumption is most significant towards the beginning of the period studied, 2030 to 2040. This occurs as the increased efficiency of the market under perfect competition facilitates the flow of the benefits from reduced transport costs more quickly throughout the economy. In addition, the agglomeration benefits which occur under imperfect competition are most substantial towards the end of the time period studied. As a result, the positive impact of perfect competition and CRTS diminishes beyond 2040.

[214] Aghion, P., Blundell, R., Griffith, R., Howitt, P., & Prantl, S. (2004). Entry and productivity growth: Evidence from microlevel panel data. Journal of the European Economic Association, 2(2-3), 265-276.

By exploiting a firm-level panel dataset, and using policy reforms that changed entry conditions by opening up the UK economy during the 1980s as natural experiments, Aghion *et al* show that more entry has led to faster total factor productivity growth of domestic incumbent firms and thus to faster aggregate productivity growth.

*Figure 157: LHR NWR - Total GDP impact, under imperfect competition & IRTS and perfect competition & CRTS, Assessment of Need scenario*




*Source: PwC analysis*

The impact of the sensitivity test on GDP is further shown through Table 93 below, which outlines the Present Value (PV) of the GDP impacts over the 60 year appraisal period. This shows that under the assumption of perfect competition and CRTS the PV is over £160bn, just over 10% higher than under imperfect competition and IRTS. The majority of this increase is driven by the increase in GDP towards the beginning of the appraisal period. Changes in the level of GDP are particularly material during these years as they are discounted less heavily than changes towards the end of the appraisal period. In the long-run, after 2060, the increase in the level of GDP is less than 10% greater under perfect competition and CRTS.

*Table 93: LHW NWR Present Value of Real GDP impacts (£bn, 2014 prices)*

| Scenario | Present Value (£bn) |
|---|---|
| **LHR NWR - central estimate (imperfect competition & IRTS)** | 144.4 |
| **LHR NWR - sensitivity (perfect competition & CRTS)** | 161.9 |

*Source: PwC analysis*

The impact of assuming perfect competition and CRTS, compared with imperfect competition and IRTS can be more substantial at individual sector level than when looking at GDP as whole. This is because the level of competition in the market, characterised by the existence of mark-ups, varies substantially across sectors. As a result, for the most competitive sectors the assumption can have very little impact, whilst for others the change can be very material. When looking solely at the overall GDP impact these sector differences are aggregated and the effect looks more moderate.

The impact by sector under perfect competition is given in Table 94. This should be compared with Table 72 above, which shows the corresponding data for imperfect competition and CRTS[215]. Comparing these tables shows that the most substantial positive effects of perfect competition and CRTS are seen in agriculture, manufacturing and construction. These are sectors which are typified by relatively higher mark-ups, and therefore have the greatest potential for efficiency improvements under perfect competition and CRTS. By contrast, no change is seen in sectors such as retail and public services which have relatively small mark-ups. The positive impact on air passenger transport is also reduced, although it remains substantially the sector with

[215] For consistency with previous analysis this table excludes the impact of construction and surface access spending

the greatest growth. This is because the increase in aviation capacity causes substantial agglomeration benefits to occur under imperfect competition and IRTS, which are not possible under perfect competition.

*Table 94: LHR ENR - Breakdown of impact on the level of real GDP by sector under perfect competition, Assessment of Need scenario*

| | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|
| **Agriculture and mining** | -0.1% | 1.0% | 2.5% | 2.3% | 2.2% |
| **Manufacturing** | 0.0% | 1.8% | 2.7% | 2.5% | 2.4% |
| **Utilities** | -0.1% | 0.7% | 2.0% | 1.7% | 1.7% |
| **Construction** | -1.3% | 1.5% | 2.8% | 3.4% | 3.2% |
| **Retail and wholesale trade** | -0.2% | -0.6% | -0.3% | -0.4% | -0.3% |
| **Air passenger transport and freight** | 0.5% | 8.4% | 12.2% | 11.9% | 11.6% |
| **Other freight** | -0.3% | -0.9% | -1.0% | -1.2% | -1.0% |
| **Other passenger transport** | -0.1% | -0.3% | -0.9% | -1.2% | -0.9% |
| **Accommodation and food services** | 0.0% | 1.0% | 1.7% | 1.6% | 1.6% |
| **Other services** | -0.3% | -0.7% | 0.3% | 0.1% | 0.3% |
| **Health, education and public spending** | 0.0% | 0.0% | -0.2% | -0.2% | -0.2% |

*Source: PwC analysis*

Overall, at a macro level the assumption of perfect competition and CRTS does not yield substantially dissimilar results to imperfect competition and IRTS. Where there are differences and the macro level between the impacts of the two assumptions, these are predominantly driven by increases in GDP being brought forward, with only moderate changes in the level of GDP seen in the long-run. However, when looking at sector-specific results far more variation is seen. Understanding the impact of imperfect competition and IRTS at this level gives greater insight as to likely sectoral reactions to the increase in aviation capacity.

### *8.8.7 Testing the carbon capped passenger scenario*

In our primary analysis, we have based the scenarios on the assumption of a "carbon-traded", rather than a "carbon-capped" emissions policy. As described previously, under both policy assumptions, limits are set on the amount of carbon that can be emitted. These limits may be allocated or sold to firms. However, under the carbon-traded scenario, firms can then trade their allocations: firms emitting less than their allocated limits can sell the remainder of their allocations to firms that are likely to emit more than their allocated limits.

Given the uncertainty of future carbon emissions policy, it is appropriate to test the sensitivity of the results to changes in the carbon assumption. In this section we present results for the LHR NWR scheme under a "carbon capped" emissions policy, based on the AC's 'demand reduction' carbon capped numbers. For illustrative purposes, results are presented only for the Assessment of Need scenario.

The overall results for the carbon traded scenario are shown in Table 95 below. The total PV values are calculated for the 60 years following the scheme opening in 2026, and are therefore equivalent to the results presented in Table 74 above. Table 95 also breaks down the impact into the four different effects. This allows comparison of the different mechanisms through which changing emissions policy would affect the economic impact of increasing aviation capacity.

*Table 95: LHR NWR Present Value of real GDP impacts by carbon emissions policy, Assessment of Need scenario (£bn, 2014 prices)*

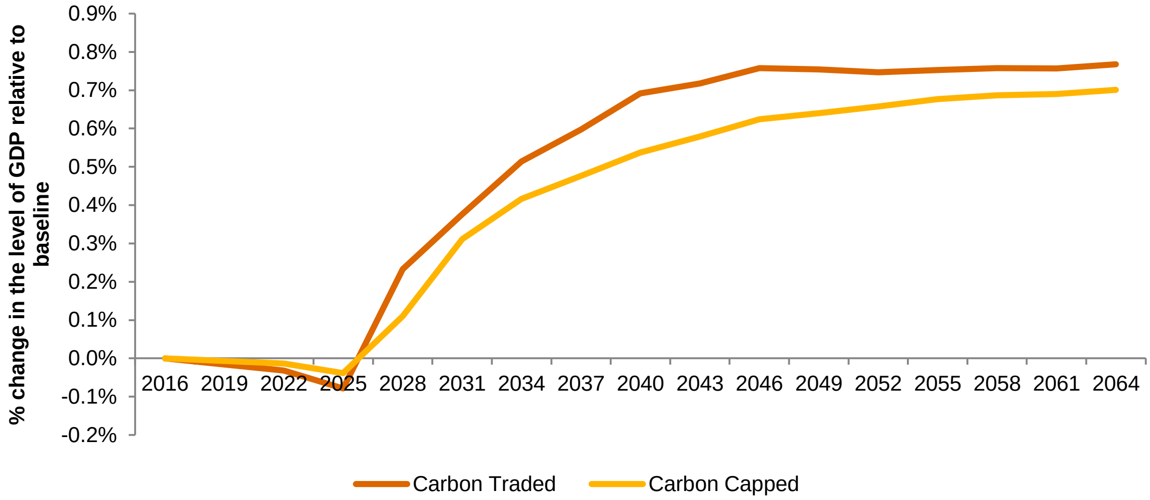
| | Carbon traded emissions policy | Carbon capped emissions policy |
|---|---|---|
| **Passenger Flows** | 36.4 | 34.8 |
| **Productivity** | 78.5 | 70.3 |
| **Frequency Benefits** | 7.7 | 6.9 |
| **TEE** | 24.6 | 16.8 |
| **Total** | **147.2** | **128.9** |

The results of this table demonstrate that the carbon capped emissions policy leads to a reduction in the PV of economic impact by just over 10%, from £147bn to £129bn. Although this is a material reduction, the results of the sensitivity test highlight that the vast majority of the benefit of the LHR NWR scheme is forecast to accrue irrespective of the future climate policy landscape.

All effects lead to smaller economic impact under a carbon capped emissions policy, although the magnitude of the reduction varies by effect. The most substantial proportional fall is seen in the TEE effect, which falls by nearly a third (£24.6bn to £16.8bn). By comparison the economic impact generated through the passenger flow effect falls by less than 5%, from £36.4bn to £34.8bn. This analysis is based on the the current inbound/ split, and has not been tested with the alternate inbound/ outbound splits which have been applied in other sensitivity tests. Below we explore the inputs which drive these results in more detail.

Figure 158 provides additional detail by demonstrating how the scale of the GDP impact changes over time as a result of the changing emissions policy scenario. This shows that the carbon capped scenario leads to a lower GDP impact throughout the period studied, with the gap widening most substantially from the mid-2030s. The long-run impact on the level of GDP falls by roughly 10%, from 0.77% on the level of GDP to 0.7%.

*Figure 158: LHR NWR - Total GDP impact, under a carbon traded and carbon capped emissions policy scenario, Assessment of Need scenario*




The primary difference between the two scenarios, which drives much of the difference between the results, is the change in the number of additional passengers which the expanded capacity enables. The additional number of passengers under each scenario is given in Table 96below. This demonstrates that the additional number of passengers in the UK system as a result of the LHR NWR scheme (in 2050) falls from 8.8m under a carbon traded emissions policy to 6.3m under a carbon capped scenario. This fall in overall passenger traffic is the reason for the reduction in the magnitude of economic impact found in Table 95. Please note that Table 96 excludes international transfer passengers, as they are not assumed to have a material impact on the UK economy in this context.

It should be noted that the reduction in economic impact between the carbon policy scenarios (12%) is much smaller in magnitude than the fall in passengers (28%). This is a result of the nature of the passenger mix under each scenario, with the carbon capped scenario leading to a disproportionately high number of additional long-haul passengers. This can be seen in Table 96, with more passengers flying to/ from North America and Africa under the carbon capped scenario, compared to falls to/from Europe and within the UK.

The econometric results presented in Appendix C demonstrated that long-haul flights have a larger impact on UK productivity than flights to Europe. As a result, the passenger mix which occurs under the carbon capped scenario is more likely to stimulate a positive productive response within the UK economy, than the mix seen under the carbon traded scenario. This change in mix explains that while overall passenger flows are substantially lower under the carbon capped scenario, the fall in economic activity generated through the productivity effect is more moderate.

*Table 96: LHR NWR, Additional UK-wide passengers in 2050 relative to the Do Minimum, by carbon emissions policy*

| Region of destination/ origin | Carbon traded emissions policy | Carbon capped emissions policy |
|---|---|---|
| **Africa** | 0.4m | 0.6m |
| **Central & South America** | 0.1m | 0.0m |
| **East Asia** | 0.5m | 0.4m |
| **Europe & Channel Islands** | 6.6m | 4.0m |
| **Middle East** | 0.1m | 0.1m |
| **North America** | 0.5m | 0.8m |
| **Oceania** | 0.1m | 0.1m |
| **UK** | 0.4m | 0.3m |
| **Total** | **8.8m** | **6.3m** |

The change in passenger mix is also the reason why the passenger flow effect leads to similar economic impact in the carbon capped and carbon traded emissions policy scenarios. Under the carbon capped scenario, a similar number of passengers pass through the London airport system (which continues to operate at close to full capacity), but fewer passengers pass through the UK regional airports. Passengers at these airports are more likely to be outbound than London passengers (i.e. UK passengers flying abroad) and hence have a less positive, or even negative impact on the UK economy. As a result, the reduction in passenger traffic of this type under the carbon capped scenario does not substantially lower the overall economic impact.

By comparison, the TEE effect captures the degree to which surplus is transferred from consumers to producers. This is primarily driven by the number of additional passengers which the airport capacity enables, and not materially impacted by the change in passenger mix. As a result, the difference between the carbon policies in the total economic impact is much greater for the TEE effect, and not substantially different to the overall change in passenger numbers.

Finally, Table 97 captures the regional distribution of the economic impact of the LHR NWR scheme, under both the carbon traded and carbon capped policy scenarios. Due to the larger share of passengers which flow through the London airport system under the carbon capped scenario, the London & the South East share of benefits is marginally bigger (41% compared with 40%). However, this effect is not large as the benefit even of air traffic going through the London system is largely national in nature, i.e. businesses all over the country feel the benefit of increased connectivity and openness, and a substantial share of passengers' expenditure is outside of London & the South East. As a result, benefits continue to be well distributed across the country, if marginally more focussed on London.

*Table 97: LHR NWR Present Value of regional real GDP impacts by carbon policy, Assessment of Need scenario (£bn, 2014 prices)*

| Region of destination/ origin | Carbon traded emissions policy | Carbon capped emissions policy |
|---|---|---|
| **London & the South East** | 58.7 | 52.8 |
| **Rest of England** | 64.5 | 56.7 |
| **Rest of UK** | 24.1 | 19.4 |
| **Total** | **147.2** | **128.9** |

## *8.8.8 Testing the results using the AC's welfare-based productivity assessment*

As a further sensitivity, the AC asked us to run the S-CGE model with the outputs from its conventional welfare based welfare analysis to see how they would play out in an S-CGE framework. This sensitivity has been undertaken to better understand the interactions in the economy that might occur if you input outputs from the partial equilibrium wider economy impacts analysis (this is done for the Assessment of Need scenario only).

The AC's analysis focusses on the following wider impacts:

- Increasing productivity through trade;
- Increasing productivity through the formation of new business agglomerations and strengthening existing business agglomerations;
- Impact on government's tax revenue from increases in wages associated with the rise in GDP observed in response to airport expansion; and
- Increasing output by exposing domestic firms to more competition.

Table 98 describes these effects in further detail and explains how we have incorporated them into the S-CGE framework. Table 99 shows the PV of the inputs provided by the Airports Commission.

*Table 98: AC welfare impacts*

| Impact | Description[216] | Incorporation into the S-CGE framework |
|---|---|---|
| **Increasing productivity through trade** | The AC describe this as, "airport expansion provides increased connectivity in the form of better access to foreign markets and thus, facilitates trade between the UK and the rest of the world. This impact on trade is exclusive to aviation and thus, is not covered in standard transport guidance. Exports to other countries encourage knowledge and technology transfers from international firms and also allows British firms to exploit economies of scale by selling to larger international markets. In addition to the knowledge transfers, imports from other countries also increase the level of competition in the market and leads to the removal of inefficient firms and a more efficient use of resources. These effects result in an increase in the overall | The AC has provided us with estimates of the productivity increases as a result of higher trade. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |

[216] Descriptions have been taken from the Airports Commission's *Wider Economic Impact Note* shared with PwC on 18 April 2015.

| | | |
|---|---|---|
| | level of productivity in trade-related sectors of the economy, which has been captured in the trade benefits". | |
| **Increasing productivity through formation agglomerations and strengthening existing agglomerations** | The AC describe this as, "the change in connectivity offered by airport expansion attracts businesses which benefit from the better international links as well as their supply chains to cluster around the airports. This leads to the creation of agglomerations around the airports, leading to productivity increases in these sectors through knowledge and technology spillovers as well as access to and developing larger input markets and labour markets. These changes in productivity have been captured in the agglomeration effects". | The AC has provided us with estimates of the productivity increases as a result of agglomeration effects. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |
| **Impact on government's tax revenue from people moving to better suited and higher paid jobs** | The AC describe this as, "the changes in productivity arising from the agglomeration effects in particular sectors increases the returns to labour in these sectors and thus, attracts some workers to move to better suited more productive jobs in the clusters surrounding the airports. The increase in productivity of the workers translates into higher wages in a competitive market and thereby increases the taxes paid by these workers. These impact on the government's tax revenue" | The AC has provided us with estimates of the impact on government's tax revenues from people moving jobs. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |
| **Increasing output by exposing domestic firms to more competition** | The AC describe this as, "the expansion also results to a reduction in the cost of production for firms that use air transport as an input and thus, allows them to profitably increase the level of output they produce. These benefits for firms that operate in perfectly competitive markets are captured in the direct benefits to business users. However, since the calculations for direct benefits assumes perfect competition, similar effects for firms in imperfectly competitive markets are missed out. These impacts of increase in output in imperfectly competitive markets are captured here". | The AC has provided us with estimates of the impact on firms' outputs in imperfectly competitive markets. We have incorporated this increase in productivity into the S-CGE framework as a rise in whole-economy total factor productivity. |

*Source: Airports Commission and PwC analysis*

*Table 99: LHR NWR Present Value of real GDP impacts by effect (£bn, 2014 prices)*

| | **Assessment of Need** |
|---|---|
| Increasing productivity through trade | 7.3 |
| Increasing productivity through formation agglomerations and strengthening existing agglomerations | 1.7 |
| Impact on government's tax revenue from people moving to better suited and higher paid jobs | 1.1 |
| Increasing output by exposing domestic firms to more competition | 1.4 |
| **Total** | **11.5** |

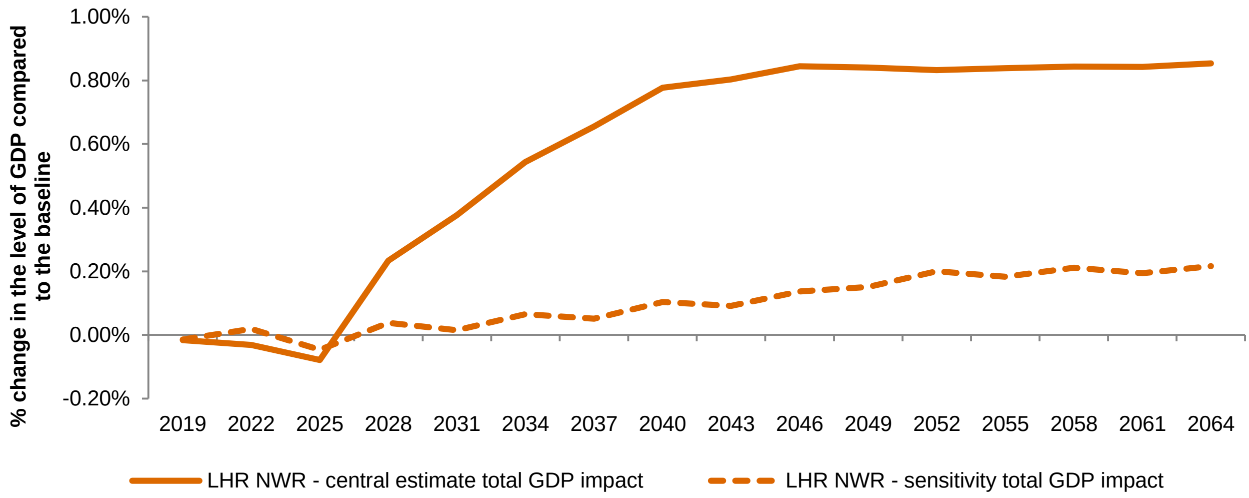
*Source: Airports Commission*

The results of this sensitivity when the AC's wider economic impacts inputs are used as inputs to the S-CGE model are presented in Figure 159. The graph shows the combined GDP effects of all of the impacts described in Table 98 and compares the results to the central estimates presented above.

Under this alternative set of inputs, the GDP impacts are modest between the opening of the scheme and the mid-2040s. This reflects the underlying inputs provided. Under this sensitivity, the long run effect is to increase GDP by around 0.2%.

The broad patterns are similar when the AC's wider economic impacts inputs are used, with the impacts increasing gradually as aviation flows rise. The key difference between this sensitivity and the central estimate is the overall scale of the effect. The scale of the estimate using the welfare-based inputs is approximately one third of the central estimate. The smaller scale is to be expected for a number of reasons. Firstly, the welfare-based analysis abstracts from important effects that have been taken into account in the central estimate, notably TEE and passenger flow impacts. Secondly, the AC approach to estimating the productivity effects of trade uses elasticity evidence which is *partial equilibrium* in nature. In contrast, the central estimate captures the relationship between trade and GDP in *general equilibrium*. Please note that this analysis is entirely separate to the previous modelling undertaken on this effect, and should be seen as complementary rather than additional.

*Figure 159: LHR NWR – Impact of welfare-based productivity assessment on overall GDP*



# Part III - Appendices

# Appendix A: Economic geography and multiple equilibria

## A.1. Motivation and some important ideas

Krugman (1991)[217] suggests that one of the most striking characteristics of the real world economy is the pattern of the location of factors of production in space. He points to examples in the US, where a quarter of the population is crowded into a small area along the east coast, and in Europe where there is a distinct concentration of economic activity with its centre in or near Belgium (see Holmes and Steven (2004) and Combes and Overman (2004) for full descriptions of agglomeration in the US and EU respectively).[218]

These authors suggest that the presence of these concentrations are only partially explained by natural phenomena (e.g. the presence of natural resources): there are other "equally good" locations in terms of their natural characteristics. This suggests that that there may be **"multiple equilibria"** – whilst we happen to observe concentrations in particular locations, the concentrations *could* be sustained just as well in other places, and here the equilibrium outcome could have been different. For many authors, for instance Krugman (1991, JPE)[219] and Fujita *et al.* (2001)[220], the aim of economic geography is to explain such concentrations of population and economic activity. For example, it seeks to account for the distinction between a manufacturing and agricultural belt, for the existence of cities and for the existence of industrial clusters such as Silicon Valley or the City of London.

The literature on the "externalities" that may occur for such co-location goes back to Marshall (1920)[221], who identifies three types of externality – his "trinity" – that give rise to increasing returns to industrial collocation:

- Knowledge spillovers – spillovers between firms can result in clustered firms with improved production conditions relative to isolated producers;
- Thick markets – the concentration of firms in a single location offers a pooled market for workers with an industry-specific skills, ensuring a lower probability of unemployment and a lower probability of labour shortage; and
- Backward and forward linkages – backward linkages describe the process through which a growth industry generates increased demand through the supply chains; and forward linkages describe the process through which a growth industry generates benefits to its customers, for example by exploiting scale economies to drive down price.

## A.2. The importance of increasing returns and imperfect competition

The importance of these issues are widely acknowledged in the so called "new economic geography" literature, for example in Krugman (1991)[222] and Fujita *et al.* (2001)[223]. Such paper have emphasised what Scitovsky

[217] Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy*, 99, 483-99.

[218] Holmes, T.J., & Stevens, J.J. (2004). Spatial distribution of economic activities in North America. *Handbook of regional and urban economics,* 4, 2797-2843.

Combes, P.P., & Overman, H.G. (2004). The spatial distribution of economic activities in the European Union. *Handbook of regional and urban economics, 4*, 2845-2909.

[219] Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy*, 99, 483-99.

[220] Fujita, M., Krugman, P., & Venables, A. J. (2001). *The spatial economy: Cities, regions, and international trade*. MIT press.

[221] Marshall, A. (1920). *Principles of Economics.* 8th edition. London, UK: Macmillan.

[222] Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy*, 99, 483-99.

[223] Fujita, M., Krugman, P., & Venables, A. J. (2001). *The spatial economy: Cities, regions, and international trade*. MIT press.

(1954)[224] calls "pecuniary externalities", that is, benefits of economic interaction that take place through market mechanisms via price mediation (Fujita and Thisse, 1996)[225].

According to Krugman (1991),[226] *"to say anything useful or interesting about the location of economic activity in space, it is necessary to get away from the constant-returns, perfect-competition approach"*. In a world with constant or diminishing returns to scale, the presence of transport costs would imply that industry would spread out in order to minimise the costs of supplying consumers in different locations. There would exist a large number of very small production units, each supplying their local customers (Fujita and Thisse, 1996; Henderson *et al*., 2001; Combes *et al*., 2008; Klarl, 2009).[227] Any sustained differences in economic concentration should, in the words of Venables (2006)[228], *"be rapidly arbitraged away"*. The absence of imperfect competition would imply a **single** "solution" or "equilibrium" in an economic model of space: activity would be evenly spread across possible locations.

## A.3. The Krugman (1991) Core Periphery Model

We now examine the core-periphery model, due initially to Krugman (1991, JPE)[229], and generalised by Fujita, Krugman and Venables (2001)[230]. An important feature of this model is that we do not *assume* some form of externality that gives rise to agglomeration forces. Rather externalities *emerge as a consequence* of increasing returns to scale that are internal to the firm.

### A.3.1. Assumptions

The model makes the following assumptions:

- There are two sectors – a perfectly competitive agricultural sector producing a homogenous good, and a manufacturing sector producing a variety of differentiated products under monopolistic competition. In particular, as in the new trade and endogenous growth literature, and the CGE model used in our work, Krugman employs the Dixit and Stiglitz (1977)[231] model of monopolistic competition;
- Agricultural activities and workers are assumed to be immobile, but manufacturing workers are able to move between locations. If we associate manufacturing workers with skilled workers and farmers with unskilled workers, the empirical evidence tends to support these assumptions (Greenwood, 1997)[232]; and
- Following for example Krugman (1993)[233] and Fujita et al (2001)[234], we impose the ad hoc, but fairly reasonable assumption that workers move towards to those regions where real wages are highest.

### A.3.2. Centripetal and centrifugal forces

The model gives rise to two sets of forces: (a) "centripetal" forces which tend to encourage agglomeration in the "core" and (b) "centrifugal" forces which tend to promote an even spread of economic activity across space.

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[224] Scitovsky, T. (1954). Two concepts of external economies. *Journal of Political Economy, 62*, 143-151.

[225] Fujita, M., & Thisse, J. F. (1996). Economics of agglomeration. *Journal of the Japanese and international economies, 10*(4), 339-378.

[226] Krugman, P. (1991). *Geography and trade*. MIT press.

[227] Fujita, M., & Thisse, J. F. (1996). Economics of agglomeration. *Journal of the Japanese and international economies, 10*(4), 339-378.

Henderson, J. V., Shalizi, Z., & Venables, A. J. (2001). Geography and development. *Journal of Economic Geography, 1*(1), 81-105.

Combes, P.P., Mayer, T., Thisse, J.F. (2008). *Economic Geography. The Integration of Regions and Nations*. Princeton, NJ: Princeton University Press.

Klarl, T. (2009). Modelling the Folk Theorem of Spatial Economics: A Heterogeneous Growth Model. Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1398834

[228] Venables, A.J. (2006). Shifts in economic geography and their causes. Centre for Economic Performance, London School of Economics and Political Science.

[229] Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy*, 99, 483-99.

[230] Fujita, M., Krugman, P., & Venables, A. J. (2001). *The spatial economy: Cities, regions, and international trade*. MIT press.

[231] Dixit, A.K., & Stiglitz, J.E. (1977). Monopolistic competition and optimum product diversity. *The American Economic Review*, 297-308.

[232] Greenwood, J. (1997). *The third industrial revolution: Technology, productivity, and income inequality*. Washington, DC: American Enterprise Institute (AEI) Press.

[233] Krugman, P. (1993). First nature, second nature, and metropolitan location. *Journal of regional science*, 33(2), 129-144.

[234] Fujita, M., Krugman, P., & Venables, A. J. (2001). *The spatial economy: Cities, regions, and international trade*. MIT press.

*Centripetal Forces*

There are three main centripetal forces present:

1. **The Price Index Effect – Forward/Supply Linkages:** suppose there is a movement of manufacturing workers to a region. This means that a smaller proportion of manufactures must be imported from other regions and therefore a smaller proportion bears the transport cost of this. This reduces prices the growing region, making it more attractive. Thus the model exhibits forward linkages (Hirshman, 1958)[235] in that the concentration of industry brings with it low prices;
2. **The Home Market Effect – Backward/Demand Linkages**: a movement of manufacturing to the first region leads to an increase in demand for labour in that region, generating an increase in the nominal wage of that region (and a reduction in the wage of other regions). This is the home market effect, described originally in Krugman (1980)[236]. This relationship corresponds to a backward linkage commonly described in the development literature (see in particular Hirshman (1958)[237]); and
3. **The own market effect:** the own market effect says very simply that the income of the first region is higher the larger is its manufacturing sector. This simply reflects the fact that manufacturing workers themselves demand manufactures. Whilst this idea is somewhat trivial, by implying that the presence of manufacturing in a region generates its own demand, it helps generate the strong circular causation of the core-periphery model.

*Circular causation*

The critical feature of the model is that it generates a process of what Myrdal (1957)[238] calls "circular causation". If one region develops a "large" manufacturing sector for whatever reason, this generates large demand for manufacturing output which, by the home market effect, increases local wages. At the same time, the price index effect means that prices are on average lower in this region since large amounts of goods are produced locally and do not incur transportation costs. These arguments combined imply that real wages in the region are relatively high. Then, given the assumption on dynamics that workers migrate to the region where they command the highest real wage, workers move to this region. This reinforces the prominence of the manufacturing sector and so the cycle repeats itself. Figure 160 illustrates this pattern.

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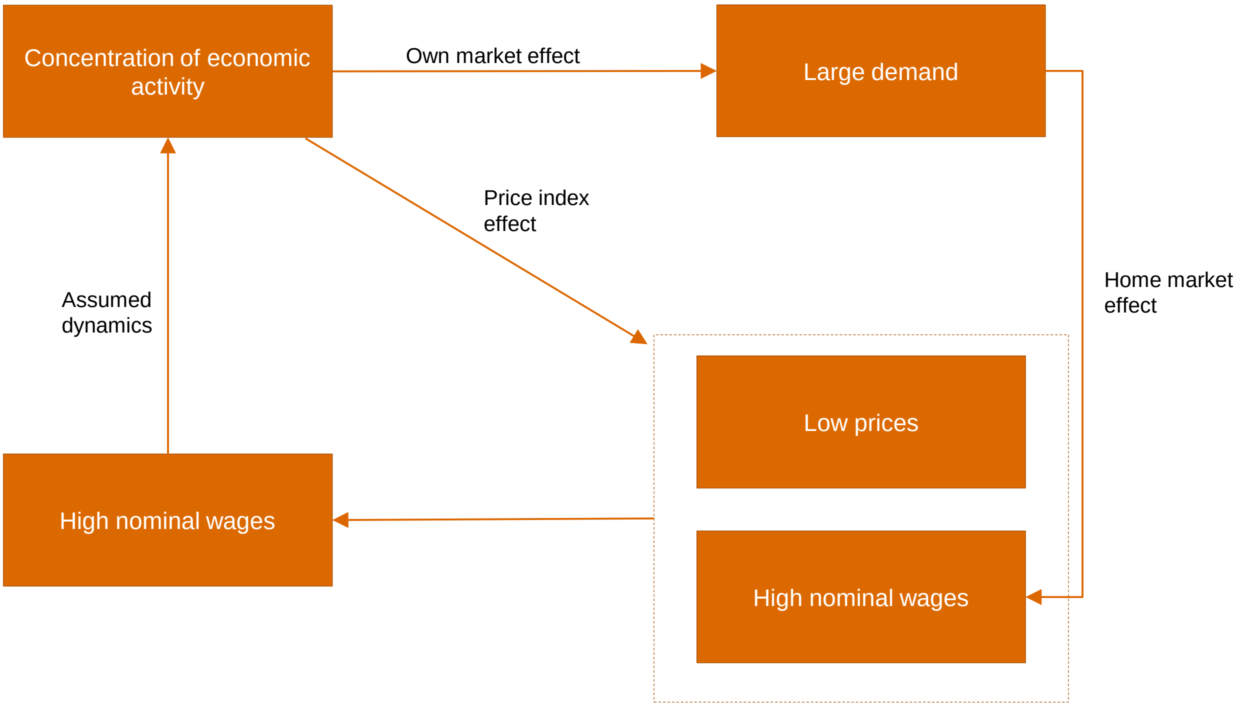
[235] Hirschman, A. (1958). *The Strategy of Economic Development*. New Haven, CT: Yale University Press.

[236] Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. *The American Economic Review,* 950-959.

[237] Hirschman, A. (1958). *The Strategy of Economic Development*. New Haven, CT: Yale University Press.

[238] Myrdal, G. (1957). *Economic Theory and Under-developed Regions*. London, UK: Duckworth.

*Figure 160: Circular Causation*




*Source: PwC analysis*

### *Centrifugal Forces*

The model additionally implies a centrifugal force, which supports stability of the diversified equilibrium. As workers move to the new region, the labour supply is increased, which puts downward pressure on wages (Krugman, 1991)[239].

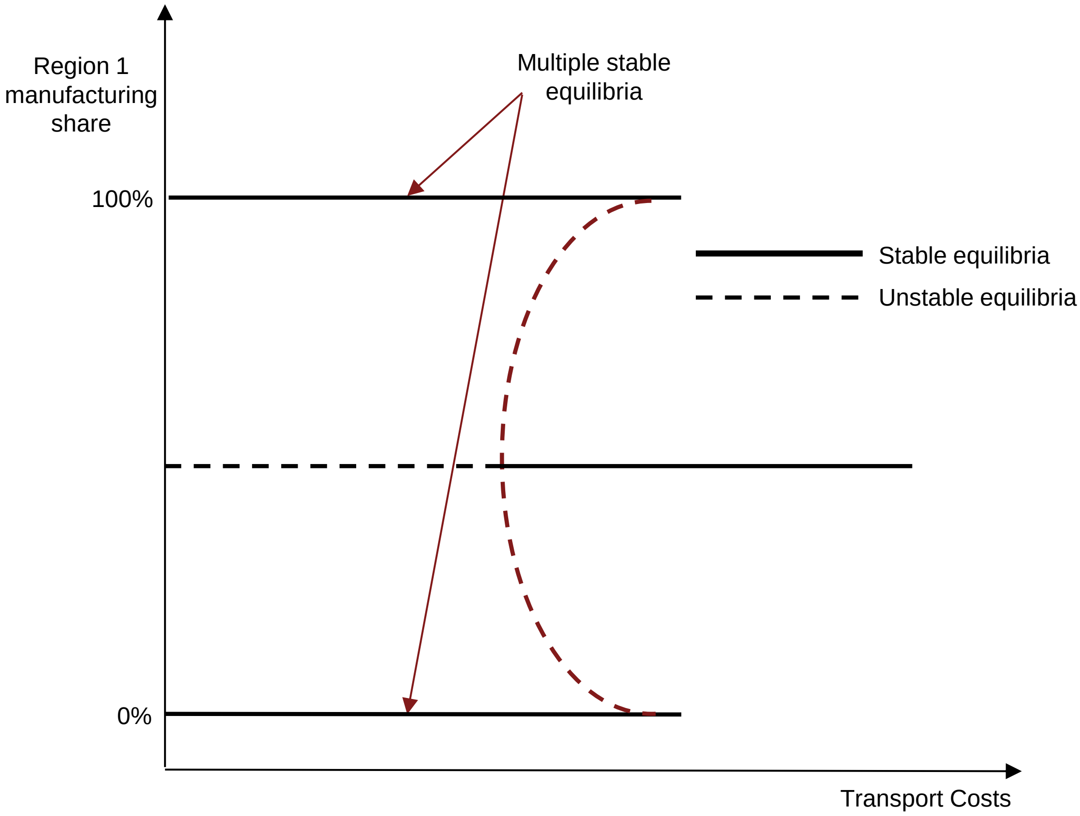
## *A.3.3. The Core-Periphery Model and multiple equilibria*

We now examine the main behaviours of the model, emphasising, in particular, how multiple equilibria emerge. Figure 161 below, summarises the results. Solid lines denote stable equilibria and broken ones unstable equilibria. The pattern described below is sometimes called a "subcritical pitchfork bifurcation" pattern (Pflüger, 2004)[240].

[239] Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy*, 99, 483-99.

[240] Pflüger, M. (2004). A simple, analytically solvable, Chamberlinian agglomeration model. *Regional Science and Urban Economics, 34*(5), 565-573.

*Figure 161: Multiple equilibria in the Krugman model*




*Source: PwC analysis*

### *Case 1 – "High" transport costs*

Suppose first that transport costs are high. In this case, there is a **unique (symmetric and stable) equilibrium** in which no agglomeration takes place. Bearing in mind that there is always residual demand from both regions (i.e. from agricultural workers), when transport costs are very large any benefits from agglomeration are outweighed by excessive costs of getting goods to market. Therefore, if we make the assumptions made in Krugman (1991) and Fujita, Krugman and Venables (2001), the economy always converges to a long-run symmetric equilibrium in which manufacturing is equally divided between the two regions. This equilibrium is unique and stable.

### *Case 2 – "Low" transport costs*

Suppose, instead, that transport costs are low. Suppose that a larger manufacturing sector emerges in one of the regions. The larger manufacturing concentration brings with it lower prices via the price index effect or forward linkages, and higher nominal wages as a result of the home market effect or backward linkages. These agglomeration forces offset the centrifugal effect of the transport cost. The circular causation process described in the diagram above arises and more manufacturing workers move to the region until the manufacturing sector is fully concentrated in that region.

Of course, had the larger manufacturing sector initially emerged in the other region, it is this other region that would have become the "core". That is to say, there are multiple stable equilibria in the model – either region can become the "core", but once the core emerges, it stays at that location.

Note now that an equal division of manufacturing labour between the two regions remains an equilibrium. However, this equilibrium is no longer stable: if one region should have even a slightly larger manufacturing sector for whatever reason, the agglomeration forces mean that there would be a movement of labour towards that region over time. Many authors discard such nonstable equilibrium (Combes *et al.* 2008)[241]. Formally, they

[241] Combes, P.P., Mayer, T., Thisse, J.F. (2008). *Economic Geography. The Integration of Regions and Nations*. Princeton, NJ: Princeton University Press.

are not “trembling hand perfect” (Selten, 1975)[242] – an arbitrarily small error by any individual in the economy implies the unravelling of the equilibrium.

*Case 3 – “Intermediate” transport costs*

In the case of intermediate transport costs, the symmetric equilibrium is now locally stable in that an infinitesimal deviation from the equilibrium in which activity is spread equally between regions will be followed by an adjustment process towards that equilibrium. Moreover, the two equilibria in which all manufacturing is concentrated one of the two regions are also stable. That is to say, for intermediate transport costs, all three equilibria (one in which activity is evenly spread and two in which it is concentrated) are stable. It is also worth noting that there now exist two other unstable equilibria, in which the majority (but not all) of the manufacturing sector, is based in one of the regions.

[242] Selten, R. (1975). Reexamination of the Perfectness Concept for Equilibrium Points in Extensive Games. *International Journal of game Theory, 4*, 22-25.

# Appendix B: Detailed description of the model structure

## B.1. Model structure

This section discusses the basic structure of the CGE model. CGE models are based on the circular flow of income which illustrates how economic agents receive and spend income in the economy. Figure 162 provides a summary of the circular flow in the context of the S-CGE model.

We begin this section with a description of the main blocks in the model, i.e. the production and consumption blocks. We then discuss the role of the government which plays a role in both blocks. We then discuss the other nuances of the model, i.e. the labour market, the dynamic nature of the model, imperfect competition among firms in the model, and international and inter-regional trade.

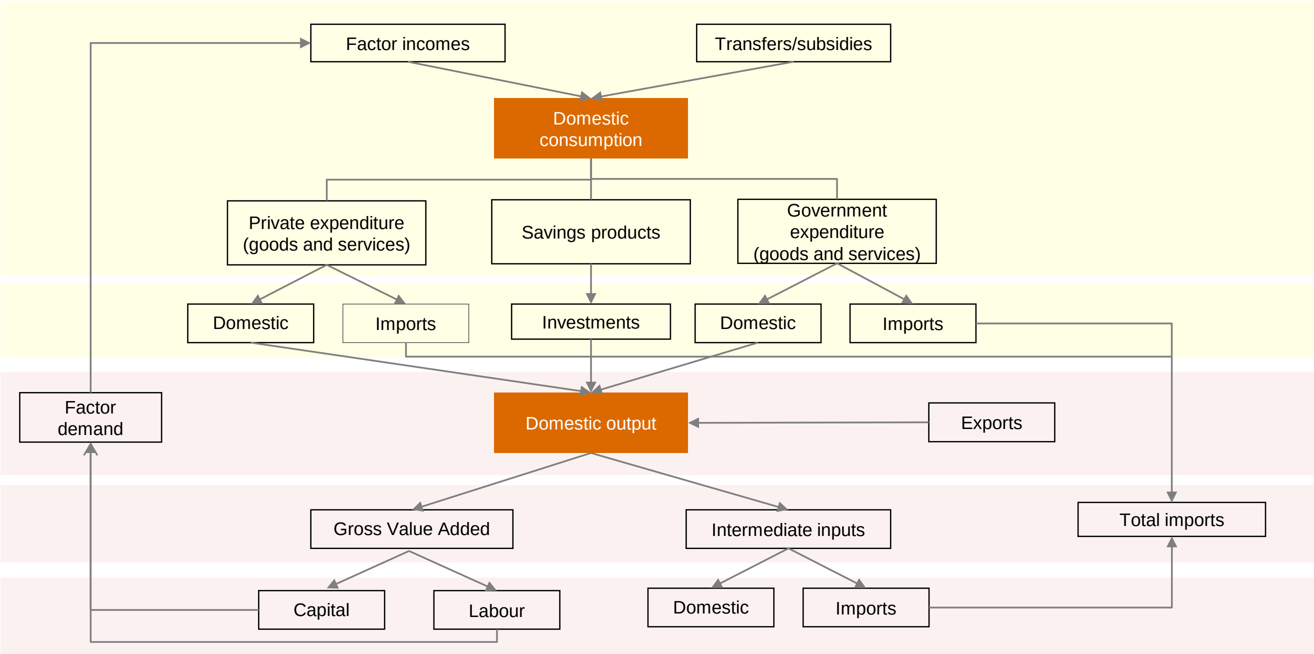
The model is split into two components – or "blocks" as they are often referred to when describing CGE models.

- the production block
- the consumption block.

Each block contains both data and equations that correspond to a key feature of the model e.g. exports or household consumption. The way that we have presented these blocks does not capture all economic linkages in the S-CGE model, they are designed to summarise the key economic interactions in a reasonably intuitive way.

In Figure 162, the rectangular shapes represent blocks of model equations and data. The shaded arrows represent two-way direct, indirect and induced linkages in economic activity. The dotted arrows used in later figures, represent key elasticity parameters and their associated functional forms that govern the interactions of these relationships. These pictorial definitions are used throughout this report.

Figure 162: The circular flow of income

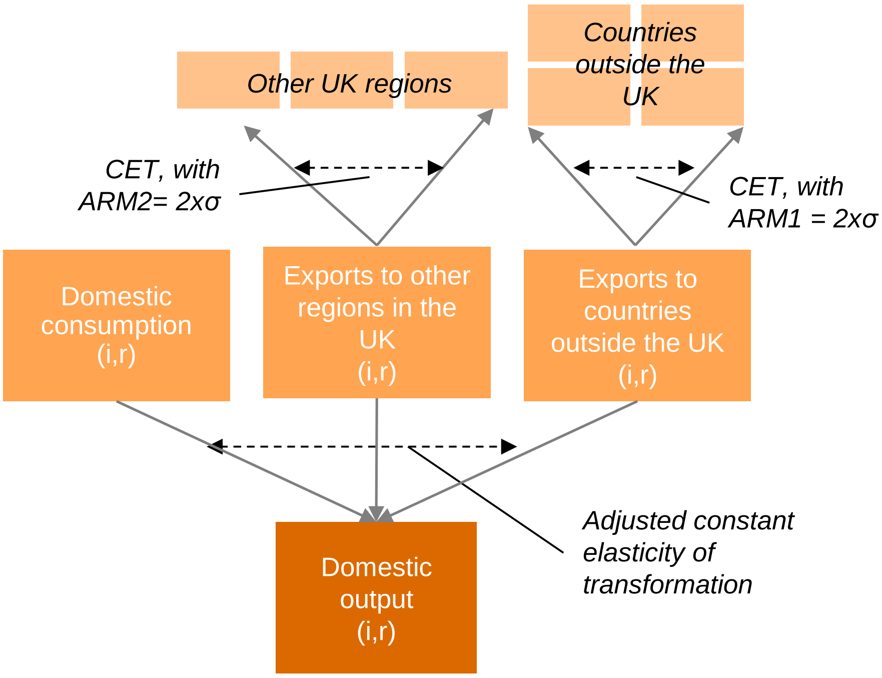



Source: PwC analysis

## B.1.1. The production block

In the S-CGE model, demand from domestic consumption and abroad leads to domestic output being sold to the domestic and export markets. Firms choose the amounts to supply to each market as they cannot switch costlessly from supplying to one market to another (e.g. exported goods need to cater to foreign tastes). These relationships are illustrated in Figure 163 below.

Figure 163: The domestic output nest




Source : PwC analysis

In the S-CGE model, output produced in sector *i* and region *r* can be exported overseas, be exported to another region of the UK or be consumed by households in region *r*. When an economic scenario is imposed on the model, the proportions that are exported and consumed then adjust according to changes in relative export and domestic prices that are determined endogenously by the model. A Constant Elasticity of Transformation

(CET)[243] function governs the rates at which these proportions change. For example, if the CET equals 3, a rise in the relative price of exports outside the UK by 1% causes firms to increase the relative quantity of exports to countries outside the UK by 3%.

Domestic output comprises intermediate inputs used in the production process – both domestically produced and imported – and Gross Value Added (GVA). In the S-CGE model, the Leontief production function[244] is used to represent the technological relationship between the amount of inputs (GVA and intermediate inputs) used and the amount of output that can be produced. Using a Leontief function ensures that the proportion of inputs (GVA and intermediate inputs) is fixed. These relationships are illustrated in the domestic production nest in Figure 164 below.

The domestic production nest determines that when an economic scenario is imposed on the CGE model then:

- GVA will vary by industry *i* and region *r*.
- Intermediate inputs will vary by industry *i*, region *r* and product *j*. Intermediate inputs are sourced from the use matrix and are subject to taxes on production.

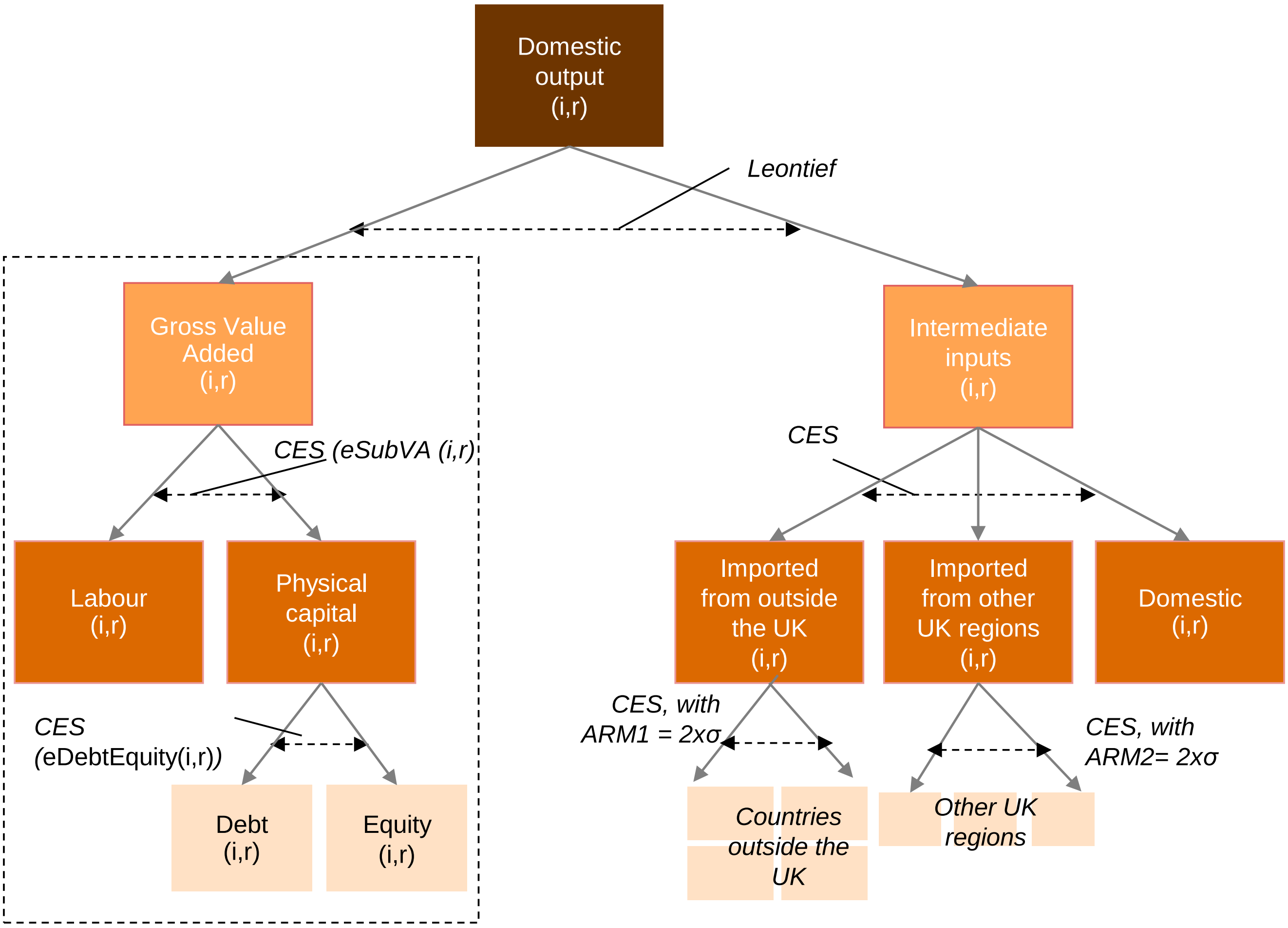
[243] The CET models producers' decisions about how they allocate production to the domestic and export markets. It is the corollary of the constant elasticity of substitution,CES, function. For a more detailed description see Powell & Gruen (1968).

Powell, A.A., & Gruen, F. (1968). The constant elasticity of transformation production frontier and linear supply system. *International Economic Review, 9*(3), 315-328.

[244] The Leontief production function or fixed proportions production function is a production function that implies the factors of production will be used in fixed (technologically pre-determined) proportions, as there is no substitutability between factors. For a more detailed discussion see Allen (1968).

Allen, R.G.D. (1968). Macro-economic Theory: A Mathematical Treatment. London: Macmillan.

*Figure 164: The domestic production nest*




*Source: PwC analysis*

Producers have a choice over using physical capital and labour, and the choice depends on the marginal productivity of these inputs and their relative prices. The size of the Constant Elasticity of Substitution (CES)[245] governs the rate at which the proportions of labour and physical capital change. For example, if CES = 3, then a rise in the relative price of labour of 1% leads to a 3% increase in the relative quantity of physical capital used in production.

When financing capital growth, businesses can choose between debt and equity. This choice is also governed by a CES function. This data is sourced from the FAME datasource[246].

A wide range of intermediate inputs are used in the production of domestic output. These inputs are purchased from the 23 sectors in the model. For example, a manufacturing company may purchase local IT services, which will be recorded as expenditure by the manufacturing company on domestic intermediate inputs.

There is also a regional element of cross-border intermediate purchases which is captured in the inter-regional trade flows, although the data are unable able to distinguish explicitly between final demand and imported intermediates. Inputs are either sourced from domestic producers, or they are imported from other regions in the UK, or from outside the UK. The choice between domestic inputs and imported inputs is determined by a CES function.

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[245] The two factor (Capital, Labor) CES production function introduced by Solow (1956). Solow, R.M. (1956). A contribution to the theory of economic growth. *The quarterly journal of economics*, 65-94.

[246] Fame is Bureau Van Dijk's database on company information. For more information see www.fame.bvdinfo.com.

In this model, a Cobb-Douglas relationship is used to represent the relationship between domestic output and imports. A Cobb-Douglas function with unit elasticity of substitution means that a rise in 1% of the relative domestic price of a product will cause a 1% increase in the relative quantity of imports of the same product.

International trade is governed by an Armington elasticity. This is based on the "rule of two"[247] method which is now commonly adopted in CGE modelling and can be described as follows: suppose a business has made its decision about the amount of capital it will use in its production process. It must then make a choice about how to finance this capital outlay – it could use debt or equity finance. The principle behind the "rule of two" is that the decision about the source of finance is more elastic than the decision to use capital or not. The "rule of two" is used in several instances in the S-CGE model where specific elasticity estimates are not available.

The choice between importing from other regions in the UK and from outside the UK is based on Armington preferences[248]. Armington preferences account for consumers' preference for variety, in terms of the source of their purchases. The choice of different UK regions for imports from other UK regions, and the choice of different regions for imports from the rest of the world are also based on Armington preferences, with the elasticity of substitution being twice that of the higher nest. This is again based on the "Rule of two".

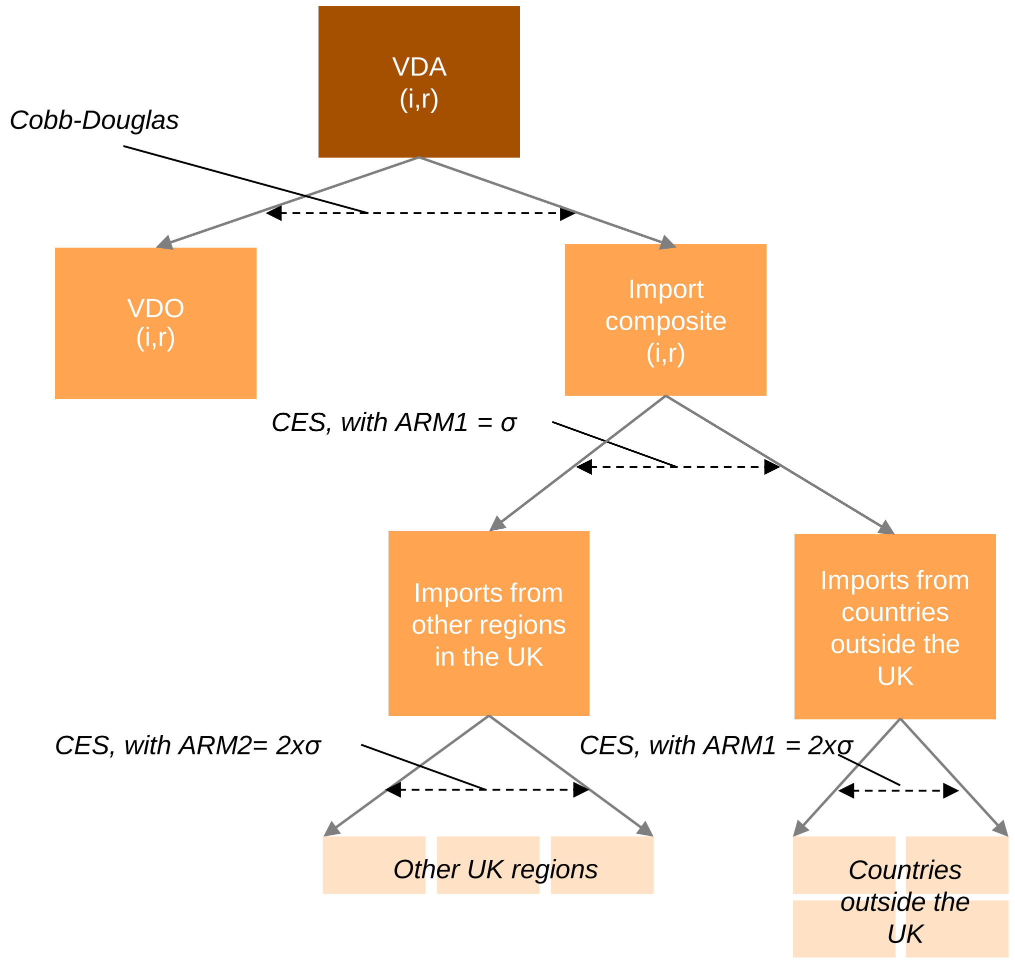
[247] This assumption dates back to the work of Jomini *et al*. (1991) in the context of global CGE modelling. Jomini *et al*. find that most studies focused on estimating the elasticity between domestic and imported goods as a whole, but did not distinguish between imports from different regions. For this reason, they sought a "rule of thumb" linking these two parameters. Using earlier estimates of the elasticity of substitution of domestic and imported goods by Corado and de Melo (1986) as a justification, they adopted the "rule of two". References are as follows:

Corado, C., & De Melo, J. (1986). An ex-ante model for estimating the impact on trade flows of a country's joining a customs union. *Journal of Development Economics, 24*(1), 153-166.

Jomini, P., Zeitsch, J.F., McDougall, R., Welsh, A., Brown, S., Hambley, J., & Kelly, J. (1991). SALTER: a general equilibrium model of the world economy. Model Structure, Database and Parameters. Canberra, Australia: Industry Commission Discussion Paper No. DRD67, World Bank, Washington, DC.

[248] An Armington elasticity represents the elasticity of substitution between products of different countries, and is based on the assumption that products traded internationally are differentiated by country of origin. For a more detailed discussion see: Armington, P.S. (1969). A Theory of Demand for Products Distinguished by Place of Production. *Staff Papers-International Monetary Fund*, 159-178.

*Figure 165: Structure of inter-regional output*



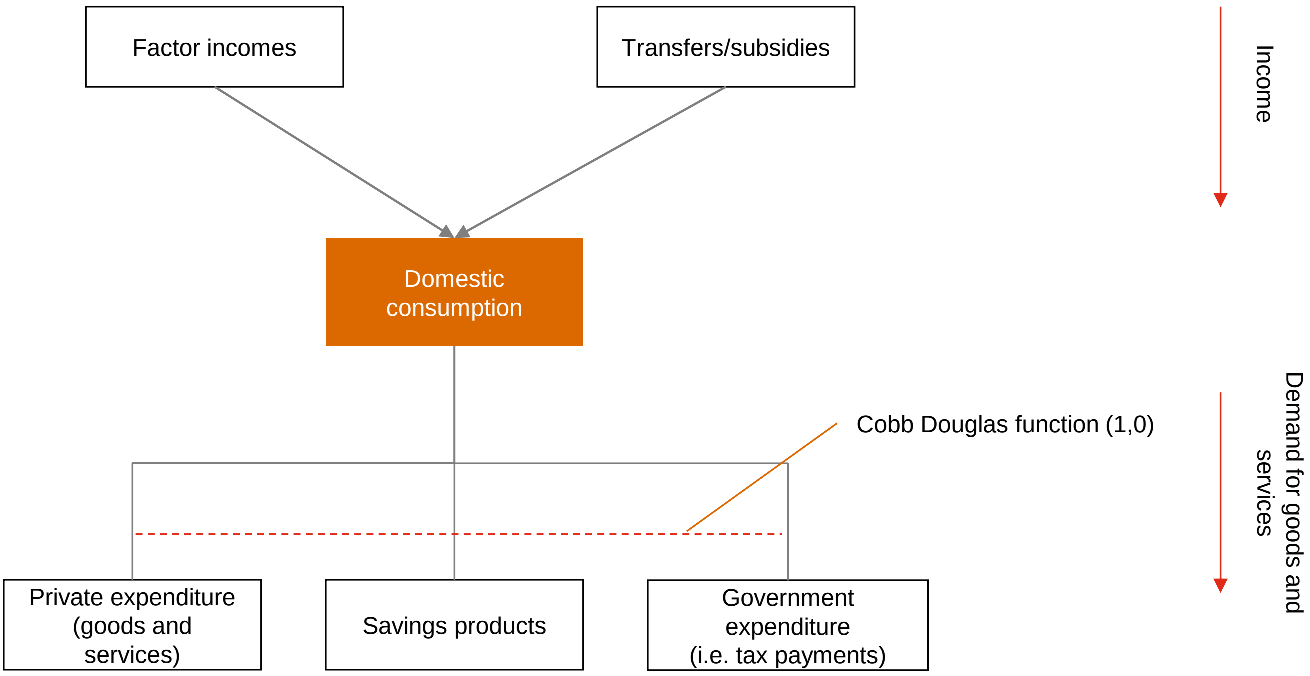

*Source: PwC analysis*

## *B.1.2. The consumption block*

There are two sources of income in the S-CGE model: factor incomes (i.e. wages and gross operating surplus) and government transfers/subsidies from the redistribution of taxes collected by the government. This income is spent in three ways: private expenditure, savings products (also called national savings) and government expenditure. In the S-CGE model, a Cobb Douglas function[249] with unit elasticity determines that a rise of 1% in the relative price of private expenditure, due to a tax increase for example, will initially lead a 1% reduction in the relative quantity of private expenditure. Subsequent behavioural effects and relative price changes are likely to dampen this effect.

[249] The Cobb–Douglas production function is a particular functional form of utility function, widely used to represent the technological relationship between the amounts of two or more inputs, particularly physical capital and labour, and the amount of output that can be produced by those inputs.

*Figure 166: The domestic consumption block*




*Source: PwC analysis*

Private and government expenditure lead to demand for domestic and imported goods, and savings products drive investments in the economy.

In the S-CGE model, Armington preferences are used to allocate demand for domestic and imported goods within the same product category. Such preferences mirror real world trading patterns where countries simultaneously import and produce goods in the same product category.

Spending by households is governed by the Linear Expenditure System (LES). The functional form of the LES requires households to have a minimum level of consumption for subsistence (e.g. housing and food). The scale of these minimum requirements is linked to the income elasticity of demand for these goods. Typically subsistence goods have income elasticity <1, so as income falls, demand falls less than proportionately. The minimum requirements for each good are calibrated so as to achieve certain income elasticities of demand for goods as specified by sourced estimates for the UK from the GTAP (Hertel, 1997)[250] database.

National savings or purchases of savings products drive investments in the economy. Spending by the government is governed by a Cobb Douglas function with unit elasticity to represent spending in each sector as being a constant proportion of total government spending.

Households maximise inter-temporal utility subject to:

- Expected prices of goods and services; and
- Factor earnings

Demand for domestically produced goods and return on investments drive domestic production, which in turn drives the demand for factors of production.

Factor incomes received by households and firms in turn support domestic consumption in a circular loop.

[250] Hertel, T.W. (1997). *Global Trade Analysis: Modelling and Applications*. New York, NY: Cambridge University Press.

### *B.1.3. The Government sector*

Governments perform two functions in the S-CGE model: they collect taxes and spend money. Government expenditure is split into the two main functions used in government accounting: Departmental Expenditure Limits (DEL) and Annually Managed Expenditure (AME).

There is a specific DEL sector in the S-CGE which is a catch-all for the non-capital elements of government department spending (R-DEL). The model also captures capital DEL or (C-DEL) which is government expenditure on capital investment projects, i.e. infrastructure spending. The model estimates the government's capital stock using the assumption that it depreciates at a rate of 5% per annum, so some government investment is necessary, to preserve the level of capital.

AME data is available at the household and regional level from the Department of Work and Pensions (DWP)[251], and is split into tax credits/benefits linked explicitly to hours worked, state pensions, disability benefits and other benefits.

We constructed the model using assumptions about the burden of taxation across households and regions in line with published HMRC statistics[252] about regional tax payments. The S-CGE model accounts for around 95% of all tax payments to the UK exchequer – only taxes paid on a realisation basis (e.g. stamp duty, capital gains tax, dividend taxes and inheritance tax) are not modelled. All other UK taxes are captured in the model.

The government budget balance is dictated by what is known in CGE modelling terms as a closure rule, i.e. the gap between government spending and receipts can be "closed" within the model in different ways. Suppose government DEL spending increases – then there are various options in the model:

- A specific tax head (VAT, corporation tax, income tax etc.) can increase to finance the additional spending (tax closure);
- Spending could be financed through an ad hoc lump sum tax on households (Harberger closure rule)[253]
- The extra spending can be funded by increasing the fiscal deficit (debt closure);and
- Benefits could be cut (household transfer closure).

Correspondingly, if taxes were cut, then in addition to the debt, or household transfer rules being invoked, government spending could be cut to restore balance to the public sector balance sheet (government closure).

The tax closure rule allows the model to investigate revenue neutral tax reform options. For instance, if the government chose to increase income tax to finance a cut in VAT, then this could be specified as a separate closure rule in the model. This allows the economic efficiency of different tax options to be compared. For instance, in the example, if a cut in VAT which is financed by an increase in income tax led to a reduction in GDP, then this would imply that income tax is a less economically efficient tax than VAT. The outcome of this experiment would be dependent on a range of factors, e.g. which bands of income tax were cut, which elements of VAT were increased (the standard or reduced rate), the initial rates of taxation, the surrounding assumptions about the economic environment (i.e. strong consumption outlook or weak labour market outlook). The full plethora of revenue neutral options are not specified in the basic version of the model, but are specified separately depending on the scenario modelled.

Rather than specify any particular taxes to offset each other or to avoid using a specific tax head to close the model when investigating changes in spending or government debt, an alternative closure rule is specified to proxy the effects of an assumed "lump-sum" tax. This tax assumption is taken from Harberger (1962)[254] and is used as a neutral closure assumption. This is the most commonly used closure rule in CGE modelling. The lump sum tax levies an equal tax on each household in response to a change in spending, government debt or other taxes.

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[251] http://data.gov.uk/dataset/gb-regional-benefit-expenditure

[252] http://www.hmrc.gov.uk/statistics/receipts/disagg-method.pdf

[253] Harberger, A.C. (1962). The incidence of the corporation income tax. *The Journal of Political Economy, 3*, 215-240..

[254] Ibid.

The debt closure rule assumes that changes in the budget position are not offset by other policies, but affect the level of national debt. A change in government debt levels leads to a transfer to/from the corporate sector which buys/sells gilt-edged bonds to finance the government debt. The model features an assumption whereby the level of national debt affects the risk premium faced by investors in the economy. Increasing levels of national debt raise the risk premium resulting in lower returns to investors. The model allows this relationship to be strengthened or weakened in sensitivity testing.

The S-CGE model has built in “closure rules” to maintain fiscal balances. For instance, if the government chose to cut the corporate tax rate, then this would need to be financed from government spending, transfer payments, debt, or increases in other taxes. Further, if the corporate tax cut increased the level of activity in the UK, then tax receipts in the Rest of the UK would increase. The model would automatically invoke the Harberger closure rule to bring fiscal positions back into balance.

### *B.1.4. The labour market and migration flows*

The S-CGE model incorporates a direct relationship between employment, wages and levels of economic activity. Underlying the model is a dynamic labour market function. Its core properties are as follows:

- Workers can enter and exit the labour market as wages rise or fall;
- Workers can move between sectors and regions as these expand or contract depending on the level of economic activity. For example, if wages were rise in the Scottish retail sector, then conceivably a worker from the Welsh government sector may wish to move into a new country and industry to gain from this wage rise;
- If workers move between sectors, it is assumed they need to retrain (e.g. an investment banker cannot turn into a chef overnight). The model assumes a temporary loss in productivity as people retrain and consequently their wages fall during this period. This decline in wages approximates a degree of labour market rigidity in the model;
- Current patterns of migration flows limit the flow of workers between regions; and
- The wage sensitivity of migration flows is governed by a separate elasticity parameter.

Data on employee compensation are sourced from ONS GVA data: gross wages are a subcomponent of employee compensation, the other component being benefits in kind (BIKs). BIKs consist of a range of financial and non-financial employee remuneration such as company mobile phones, vehicles, accommodation allowances etc. Employee compensation data are broken down by region and by sector in the model.

### *B.1.5. Model dynamics*

The S-CGE model is dynamic; this means that it makes a forward looking projection of the economy over time. The model assumes perfect foresight and can be run for approximately 54 time periods. The length of time for which the model can be run is dependent on two key factors:

- **The size of the scenario being run:** larger scenarios use more computing power and make the model harder to solve, thus necessitating the need to reduce the number of time periods; and
- **The overall size of the model:** the additional equations relating to the dynamic labour market and imperfect competition increase the size of the model considerably and therefore the required computing power.

Time periods are linked through savings, household utility, and capital accumulation. In each time period capital adjustment is governed by a standard depreciation plus investment function. The model is calibrated so that each time period is equal to 1 year. However, this is approximate and where possible the adjustment processes in the model need to be compared directly to econometric evidence about adjustment speeds to policy changes to refine the model’s accuracy.

Investment in each industry, and by type of capital, is subject to installation costs (Uzawa 1961,[255] Markusen *et al*., 2000)[256] whereby the cost of investment is related to the amount of installed capital. The equations are set-up so that more rapid capital accumulation therefore becomes increasingly costly.

### *B.1.6. Imperfect competition*

Industries are imperfectly competitive with increasing returns to scale. Imperfect competition is based on the Dixit-Stiglitz large-firm Cournot structure[257]. Perceived or real entry by rival firms forces economic profits to zero. Firms set a mark-up depending on their perception of the elasticity of demand for their product. Firms' perception of their elasticity of demand is a function of an index of firms in each industry (this also varies by region) and a conjectural variation parameter. This is used to calibrate firms' market power in both domestic markets, regional markets and overseas export markets for all commodities that they produce.

### *B.1.7. International trade*

The foreign sector is largely governed by the Armington (1969)[258] assumption, whereby domestically produced and imported goods are treated as being qualitatively different. This assumption is used in most trade models. In CGE models, products are often differentiated on the basis of their geographic point of production as well as by their physical characteristics, with "similar" products being close substitutes in demand.

This assumption of product heterogeneity is used to accommodate the statistical phenomenon of cross-hauling (the simultaneous importing and exporting of the same good) in the data used, and to exclude complete specialisation in production as a behavioural response in the model.

### *B.1.8. Inter-regional trade*

Usually when CGE models are built regional trade data is available: examples include Spain (Gillham, 2004)[259] and Australia (Regional version of the ORANI model, which is a general equilibrium model of the Australian economy). There are other models which partially cover the regional trade data; the general equilibrium model for the US, USAGE-51, is built on commodity flow data, but ignores t*ransaction data*. However, as regional trade data for the UK do not exist, we are required to use the existing data available from different sources and estimate regional export and import data for the UK.

However, there are examples of models where regional IO tables are constructed. Most of these come from the US such as IMPLAN (Robinson and Liu, 2006)[260] and Regional Breakdown of GTAP (USAGE-51) Dixon, Rimmer and Wittwer (2012)[261].

While there are several sources for external trade accounts for the UK, there are no readily available relatively up-to-date sources of sectoral inter-regional trade flow accounts. In order to estimate inter-regional trade flows, we use location quotients based on relative employment levels in the sector and region. This approach is based on the approach outlined in Robinson and Liu (1997)[262]. Robinson and Liu use location quotients and export shares (discussed below) to evaluate the role of inter-regional trade in the accuracy of Social Accounting Matrix (SAM) models. We have also used this approach to estimate regional trade data for the HMRC.

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[256] Markusen, J., Rutherford, T.F., & David T. (2000). Foreign Direct Investments in Services and the Domestic Market for Expertise. *NBER Working Papers* 7700. National Bureau of Economic Research.

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[259] Gillham, J. (2004). The economic inter-relationships of tourism: A Computable General Equilibrium Analysis. PhD Thesis, University of Nottingham. Available at: http://etheses.nottingham.ac.uk/1330/1/436728_VOL1.pdf

[260] Robinson, D.P., & Liu, Z. (2006). The effects of interregional trade flow estimating procedures on multiregional social accounting matrix multipliers. Journal of Regional Analysis & Policy, 36(1), 94-114.

[261] Dixon, P.B., Rimmer, M.T., & Wittwer, G. (2012). USAGE-R51, a state-level multi-regional CGE model of the US economy. GTAP Working Paper. Available at: https://www.gtap.agecon.purdue.edu/resources/download/5933.pdf

[262] Robinson, D.P. and Liu, Z. (2006). The Effects of Interregional Trade Flow Estimating Procedures on Multiregional Social Accounting Matrix Multipliers. The Journal of Regional Analysis & Policy, 36(1), 94-114.

# B.2. Adjustments to the core model – Agglomeration

## B.2.1. Benefits from Agglomeration

Previous studies, including Graham (2007)[263], have explored the links between agglomeration, productivity and transport investment. If improvements in transport systems give rise to changes in the mass of economic activity accessible to firms, for instance by reducing travel times or the costs of travel, then they can induce positive benefits via agglomeration economies. Graham concludes addition to user **benefits of agglomeration are significant and typically 10%-20%**. It is therefore important to incorporate these external benefits which are often not included in standard transport appraisals.

## B.2.2. Modelling Agglomeration in S-CGE Models

In S-CGE modelling, there are three common assumptions; one for the industry in the region, one for the market and one for the firm:

- The aggregate industry production function follows a Dixit-Stiglitz functional form;
- Monopolistic competition in markets; and
- Increasing returns to scale at firm level.

These are important assumptions to make for analysing the effects of agglomeration where the number of firms and the number of varieties need to be considered.

### B.2.2.1. Dixit-Stiglitz Industry Production Function

The central principle which the Dixit-Stiglitz function captures is that the more variety that exists and the more elastic that input and products are, the lower per unit production costs and hence higher productivity.

This functional form enables a "love of variety" to be modelled. In the equation below $\alpha$ represents the substitutability between different varieties used in production. An $\alpha$ close to 1 means that varieties in intermediate goods are easily substituted. An $\alpha$ close to 0 means that varieties cannot be easily substituted. If there is increased economic activity, for example as a result of an expansion of an airport, this would attract new firms into the economy hence increasing the number of varieties of intermediate goods. The production process would become more efficient because firms have access to lower price substitutes and an $\alpha$ close to 1 would enhance this effect. This is the agglomeration effect increasing productivity within production.

The following equation represents the total output $Q_j$ from a sector in region $j$.

$$Q_j = \left(\sum\nolimits_{i=1} n_i {Q_{ij}}^{(\alpha-1)/\alpha}\right)^{\alpha/(\alpha-1)}$$

Where $n_i$represents the number of varieties in region $i_j$. $Q_{ij}$ is the quantity of intermediate input from region $i$ to region $j$ required in the production process and $\alpha$ is the elasticity of substitution between varieties.

There are three further assumptions of this functional form applied to our model. Firstly, it is assumed there is symmetry in intermediate inputs, which means the intermediate goods such as legal and cleaning services are of equal production value to the particular industry. Secondly, there is constant elasticity of substitution of the production function of intermediate goods, implying that all commodities used in production have a constant change in factor productions. Finally, it is assumed the output is Leontief, which means that increasing input by a certain amount does not necessarily increase output proportionately.

### B.2.2.2. Monopolistic Competition Market Structure

A monopolistic competition market structure implies that products produced by various firms are differentiated, for example by brand power. This market structure is assumed for each sector in the economy. This means firms have the same degree of differentiation from each other within each sector, but the degree of

[263] Graham, D.J. (2007). Agglomeration, productivity and transport investment. *Journal of transport economics and policy (JTEP), 41*(3), 317-343.

differentiation varies between sectors. They have the same production technology and the same output size. We assume this because there is no statistical data on the production processes of each firm in the industry.

#### B.2.2.3. Increasing Returns to Scale at Firm Level

Production technology exhibits increasing returns to scale for the individual firm. Increasing returns to scale at firm level implies increasing returns at industry level. The cost of production is essentially determined by labour costs. The total amount of labour required by the industry for intermediate goods production, $L(\omega)$, is given by,

$$L(\omega) = f + az(\omega)$$

Fixed labour requirement is represented by $f$ and marginal labour requirement is $az(\omega)$. This exhibits increasing returns to scale since there is a fixed requirement aspect to the labour demand required in production.

### B.2.3. A Firm in the Monopolistic Competition Market

The **profit function,** $\Pi_{i,r}$, of a representative firm in industry ($i$) and region ($r$) is:

$$L = \Pi_{i,r} = p(d_{i,r})d_{i,r} + p(e_i)e_i + p(m_{i,r})m_{i,r} - c_i\left(d_{i,r} + e_i + m_{i,r}\right) - f_i$$

The demand for the firms' products in the domestic region is represented by $d_{i,r}$ and its price is given by $p(d_{i,r})$. The demand in the export market is $e_i$ and its price is given by $p(e_i)$. The demand in a particular region $r$ is given by $m_{i,r}$ with the price being represented by $p(m_{i,r})$. Marginal cost is a function of the total demand, $c_i\left(d_{i,r} + e_i + m_{i,r}\right)$, and fixed costs are given by $f_i$.

Using the profit function as the Lagrangian and solving for the profit maximisation problem, the first order conditions (FOC) below show the relationship between mark-up and price elasticity of demand. Similar to other CGE modelling literature using models with imperfect competition and increasing returns at the firm level, this model employ the Lerner formula to endogenously set the price mark-up.

$$\frac{p\left(d_{i,r}\right) - c_i}{p\left(d_{i,r}\right)} = \frac{1}{\left|\tau_{i,r}\right|},\ \tau_{i,r} < -1$$

$$\frac{p(e_i) - c_i}{p(we_i)} = \frac{1}{|\delta_i|},\quad \delta_i < -1$$

$$\frac{p(m_{i,r}) - c_i}{p(m_{i,r})} = \frac{1}{\left|\eta_{i,r}\right|},\quad \eta_i < -1$$

The price elasticity of domestic demand for a product in industry $i$ and in region $r$ is given by $\tau_{i,r}$. The price elasticity of export demand is represented by $\delta_i$, and price elasticity of a particular region's demand is given by $\eta_i$.

### B.2.4. Analysing the Relationship between Price Mark-Up and Price Elasticity of Demand

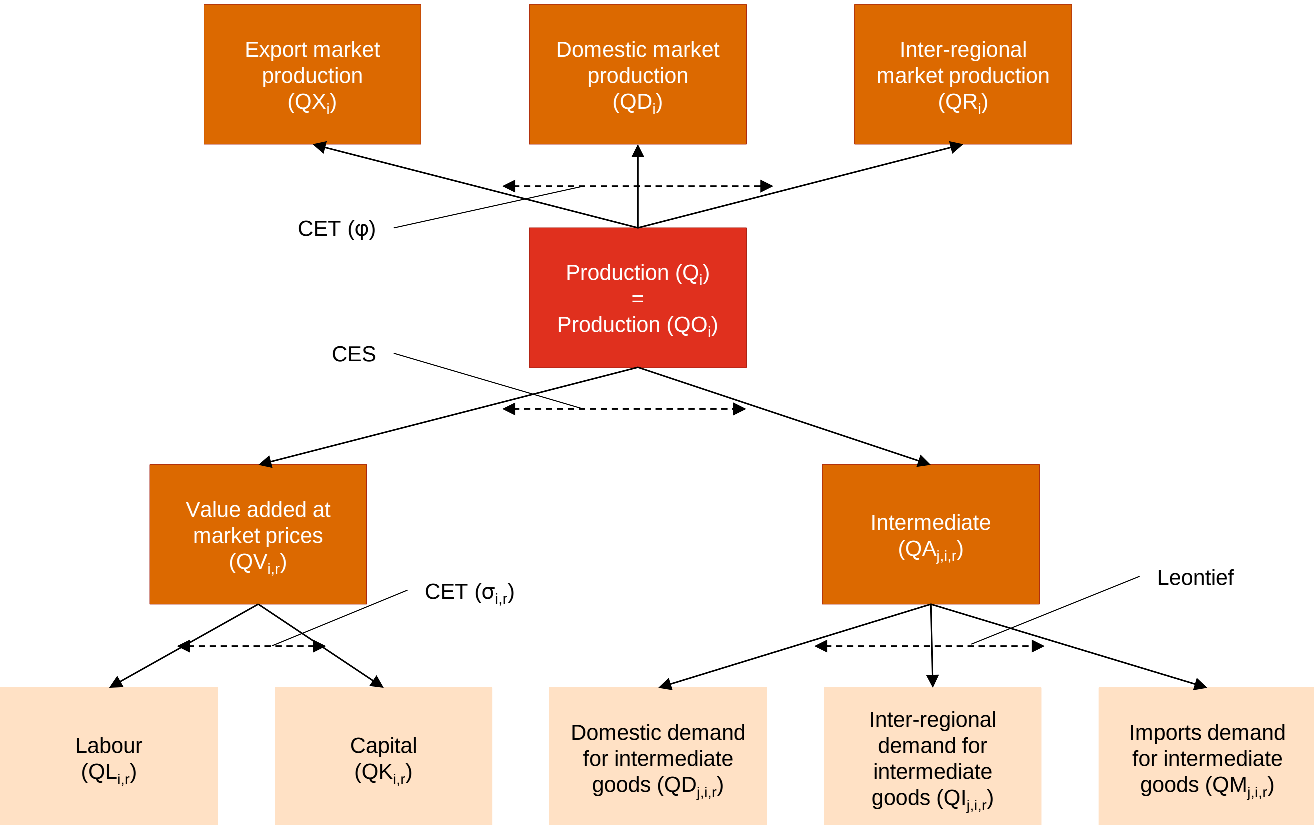
If air transport links improve then the cost of air transport decreases causing a reduction in the cost of production. Lower costs imply marginal cost decreases which implies price mark-up increases. Higher mark-ups incentivise more firms to enter the industry; there is free entry and exit in a monopolistically competitive market. The greater the consumer price inelasticity of demand, the more market power a firm has to raise prices without profit loss which increases the incentive. More firms enter the market if consumers have a stronger preference for variety. Simultaneously, demand for air transport increases and hence the price of air transport rises again. As more firms enter the industry, the positive mark-up is competed away and firms move towards the zero profit condition, where the incentive to enter the industry becomes zero. As a result of the better air transport links, the overall number of firms and varieties have increased. This agglomeration is a spillover effect and increases output and GDP. An increased number of varieties is also welfare improving.

If air transport links worsen, possibly due to increased numbers of road users creating more traffic, then the cost of transport would increase. This would lead to increased costs of production and increased marginal cost causing the price mark-up to decrease. The lower mark-up acts as a disincentive for entrants and if firms move below the zero profit condition, they leave the industry. Again, simultaneously, the demand for transport would decrease causing price to decrease. As the number of firms decreases, the mark-up rises to previous levels. The overall number of firms and varieties have decreased which is welfare worsening.

## *B.2.5. Nested Production Function*

The link between inputs and outputs is represented by this nested production function, a form often used in explaining CGE models. The nest helps illustrate the central principle that demand needs to equal supply, but it also shows the spatial sources of the inputs and outputs. Output is represented by the top half of the nest and the three sources of output are the export market, the domestic market and inter-regional markets. There is constant elasticity of transformation (CET) between the three sources. For example, a CET of 2 means a 1% rise in the price of exports causes the firm's export quantity to increase by 2%.

*Figure 167: Nested production function*



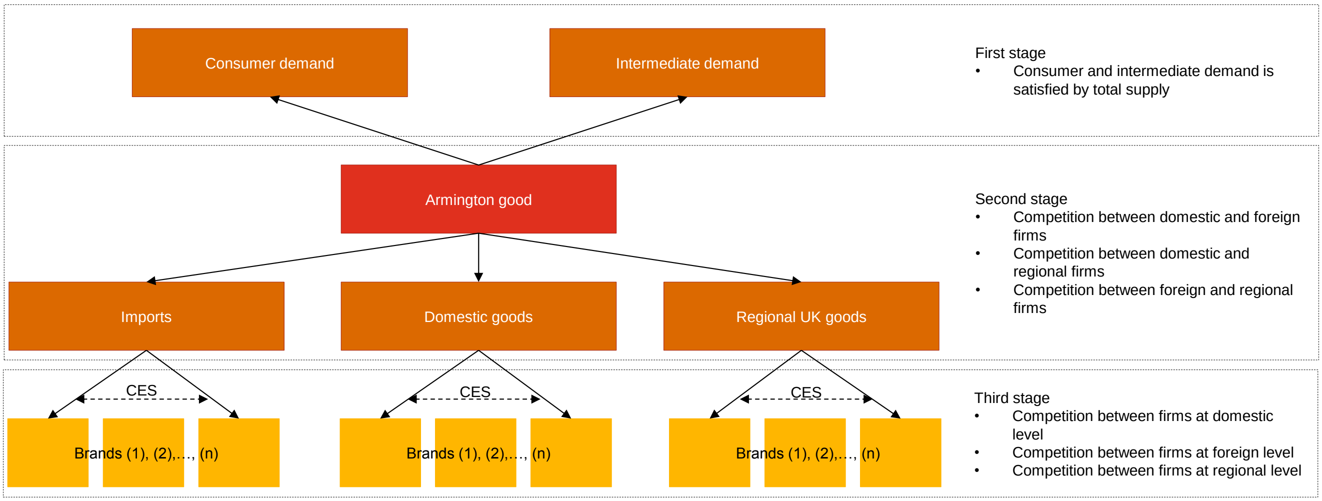

*Source: PwC analysis*

The bottom half of the nest represents the input process in production. There is constant elasticity of substitution (CES) between intermediate goods input and gross value added. Within value added there is also CES between the two factors of production, labour and capital. If the CES equals 2, this means a rise in the relative price of labour inputs by 1% leads to an increase in the relative quantity of capital used in production by 2%. Within intermediate inputs, there is a Leontief relationship between domestic, inter-regional and imported goods.

## *B.2.6. Demand System in Three Stages*

To analyse agglomeration the number of firms and variety needs to be considered which is done via examining demand. Price mark-up is determined by the production process which is simultaneously determined by the intermediate demand. This can be explored further by separating the demand system into three stages (see Figure 168). The three stages are explained in greater detail below:

*Figure 168: Demand in three stages*




*Source: PwC analysis*

## *B.2.6.1. Demand in Three Stages: First Stage*

In the S-CGE model all markets need to clear which means supply needs to equal demand for Walras' Law to hold. This requires the demand from consumers and intermediates to be satisfied by the composite commodity. The following assumptions are made in the first stage demand.

- Relationship between intermediate goods demand and consumer demand, $C_i$, is governed by:

$$C_i = \alpha_i \frac{I}{p_i}$$

- Relationship between consumer and intermediate demand, $X_i$, of industries:

$$X_i = \sum_j a_{ji} Y_i$$

- Equilibrium in the goods market is given by goods consumed and exported which is a function of consumer demand and exports :

$$Q_i = C_i + X_i$$

$\alpha_i$i represents the household budget shares $\sum a_i = 1)$, $p_i$ represents the price vector of the Armington goods, $a_{ji}$ represents the intermediate input-output coefficient, $Y_i$ represents output and $Q_i$ represents the supply of composite commodities.

## *B.2.6.2. Demand in Three Stages: Second Stage*

In the second stage, it is recognized that consumers can distinguish goods by origin. These are called Armington goods. The aggregate demand now consists of a structure where utility is derived from consumption of a variety of goods from a series of origins.

Demand for each good is a function of the share of the Armington good, the price of the good, the Armington price and the elasticity of substitution between the good of interest with the other two types of good.

Expectations that a foreign (domestic) firm has of another domestic (foreign) firm is established at this stage. Expectations that a domestic (regional) firm has of another regional (domestic) firm is also established. Finally, the expectations that a regional (foreign) firm has on a foreign (regional) firm is established at this stage too.

Conjectural variation, which is discussed in more detail later, determines the nature of these interactions.

### *B.2.6.3. Demand in Three Stages: Third Stage*

Having chosen their allocation of domestic, regional and imported goods in the second stage, consumers purchase a variety of each. Due to consumers' "love of variety", competition exists between domestic, regional and imports markets. The third stage examines the competition within each of the second stage categories.

- **Imports demand:** Demand for imports follow a Dixit-Stiglitz functional form to model "love of variety". The more brands there are the greater the consumer welfare. Within this demand function there is an elasticity of substitution between domestic goods and imports and an elasticity between imports and regional. Once total imports demand is determined, output of each foreign brand is derived. Expectations that an overseas firm has of another overseas firm is established in this stage also;
- **Domestic demand (i.e. within a region):** Similarly, demand for domestic goods follow a Dixit-Stiglitz functional form to model "love of variety". Within this demand function there is an elasticity of substitution between domestic goods and imports and an elasticity between domestic and regional. Once total domestic demand is determined, output for each domestic brand can be derived. Expectations that a domestic firm has of another domestic firm is established in this stage; and
- **Regional UK Demand:** Again, demand for regional goods follow a Dixit-Stiglitz functional form to model "love of variety". Within this demand function there is an elasticity of substitution between regional goods and imports and an elasticity between regional and domestic. Once total regional demand is determined, output for each regional brand can be derived. Expectations that a regional firm has of another regional firm is established in this stage.

The total supply of goods and services is then determined as a result of this demand structure.

## *B.2.7. Conjectural Variation*

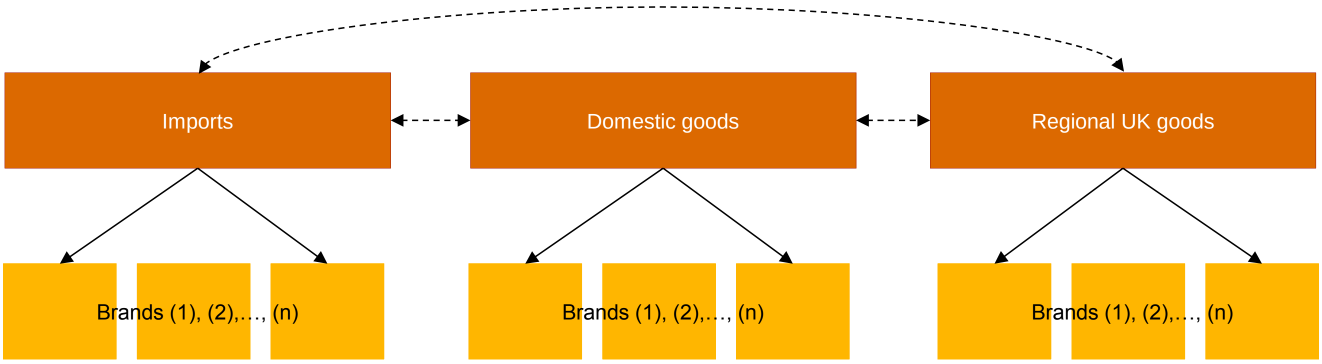
Conjectural variation, with its basis in oligopoly theory, is the belief that one firm has about the way its competitors may react if it varies its output or price. The formation of these beliefs then determines the way firms interact in the market. The nature of this interaction needs to be considered to establish the number of firms in the industry. There are two ways in which firms could react to deter new entrants:

- Existing firms could decide to price out new entrants. They would do this by expanding output to lower prices. New firms would not be able to compete as consumers would buy the incumbent firm's lower priced products. No new firms enter and so there is no increase in the number of varieties; and
- Alternatively, existing firms could improve their product and differentiate their goods to increase sales. The consumer's income elasticity of demand becomes more inelastic and new entrants cannot compete.

Conjectural variation is therefore a determining factor in how many new firms enter the market which then governs the scale of the agglomeration effect.

As seen by the dashed arrows, the relationships to consider are those between foreign firms and domestic firms, between foreign firms and regional firms, and between domestic and regional firms. Within each category there are interactions between firms abroad, firms domestically and firms regionally.

*Figure 169: Interaction between firms*




*Source: PwC analysis*

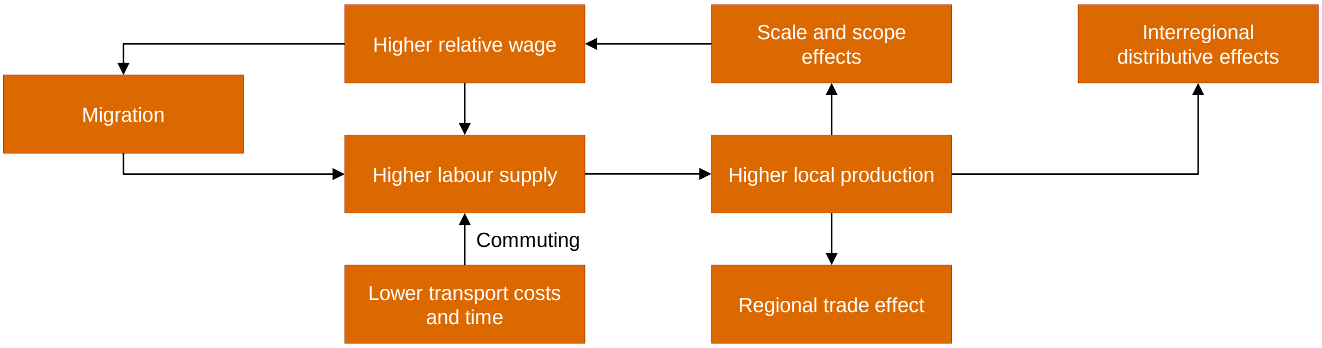
The conjectural variation parameters are endogenously calibrated and are a function of consumer price elasticity of demand. The more price elastic consumer demand is, the more firms that will enter and the greater the agglomeration effect.

## *B.2.8. Labour Market*

As mentioned before labour demand interaction in the production process is an important aspect of determining increasing returns to scale.

There is a further aspect in the labour market which affects the production process job matching. If transport links improve this can lower the cost of transport, time for commuting and hence the overall production costs. In the following figure (Figure 170), it can also be seen that lower transport costs increase labour supply which increases local production. This is because vacancies for jobs will receive better skilled applicants and matching of jobs to workers is more efficient. Higher local production leads to the agglomeration effect as described previously.

*Figure 170: Labour market demand interactions in the production process*

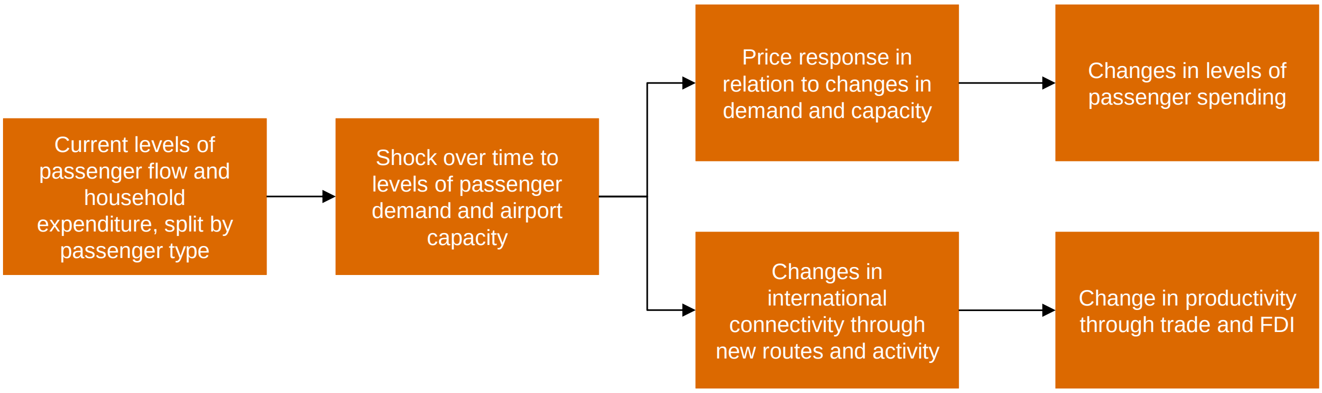



*Source: PwC analysis*

## *B.2.9. Adjustments to the core model – Passenger flow spending*

The final adjustment to the core S-CGE model is the introduction of productivity and expenditure effects through changes in passenger flows. These are captured within the model through two separate mechanisms, a price response leading to a change in levels of passenger spending and a change in productivity due to changes in international connectivity. These are outlined in Figure 171 below. This section will introduce how each of these effects is captured within the S-CGE framework, and the key data inputs used to measure each effect.

*Figure 171: How changes to passenger flows impact on the model*




*Source: PwC analysis*

### *B.2.9.1. Incorporating passenger spending*

In addition to the total UK passenger numbers, the characteristics of these passengers and their associated spending patterns are important in determining the impact on real GDP. The AC weren't able to provide forecasts of the split between inbound and outbound passengers in future. For the purpose of this analysis we have agreed in conjunction with the AC to assume that the balance of inbound and outbound passengers and their associated spending patterns remain constant in the event of airport expansion. Any difference from this assumption in reality would have an impact on the magnitude of the impact on GDP.

The ONS Travel Trends publication contains information on the number of inbound and outbound trips made through Gatwick and Heathrow in 2011[264]. In Gatwick, 7.8m passengers made outbound trips from the UK (17% of UK total), but only 2.9m passengers made inbound trips to the UK (13% of UK total). Overall spending due to passenger flows through Gatwick in 2011 is associated with approximately £6.8bn of expenditure in the UK compared to £5.2bn outside the UK.

In Heathrow 9.8m passengers made outbound trips from the UK (22% of UK total), and 9m passengers made inbound trips to the UK (40% of UK total). Overall spending due to passenger flows through Gatwick in 2011 is associated with approximately £12.5bn of expenditure in the UK compared to £6.8bn outside the UK.

However, only £2.7bn of the expenditure in the UK (that which relates to passengers travelling from abroad) associated with passenger flows through Gatwick and only £7.3bn of the expenditure in the UK associated with passenger flows through Heathrow could be seen as additional demand. The remaining £4.1bn and £5.2bn are likely to largely displace household consumption in the UK which would have otherwise occurred in the absence of air transport through Gatwick. This displacement of domestic consumption means that the net GDP impact of passenger spending associated with Gatwick in 2011 is likely to have been negative and less positive than the difference between expenditure within and outside the UK for Heathrow. This will have important implications for the GDP impact of additional passenger flows resulting from the LGW 2R, LHR NWR and LHR ENR schemes.

Secondly, household expenditure elasticity tables determine the nature of the price response to the change in demand, subject to capacity constraints. These are also split by type of passenger as shown in below:

[264] Office for National Statistics (ONS) (2011) *UK Travel Trends, 2011*. Available at: http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-269632

*Table 100: Estimates of price elasticity of demand based on our review of the literature*

| | Segment | Elasticity |
|---|---|---|
| **UK inbound passenger flows** | Holiday | -1.23 |
| | Visiting family and friends | -0.93 |
| | Other | -0.12 |
| **Domestic passenger flows** | Holiday | -2.62 |
| | Visiting family and friends | -1.84 |
| | Other | -1.95 |
| **UK outbound passenger flows** | Holiday | -0.8 |
| | Visiting family and friends | -2.83 |
| | Other | -1.52 |

*Source: PwC analysis*

This data allows us to make the three following estimates, with regards to the level of household expenditure by passenger type:

- Estimating the spending in the UK from inbound passengers arriving at Heathrow, Gatwick and through other airports and sources of transport. The ONS Travel Trends data-set shows the spending of inbound passengers in 2011 by mode of transport and type of passenger. This shows that 84% of all spending by inbound tourists is from those arriving by air. This data-set also includes the inbound visits by airport of arrival, and shows that 40% of visits from those arriving by air are through Heathrow and 13% through Gatwick. Assuming that the ratio of spending to visits remains constant for those travelling through different airports, we estimate the spending of inbound passengers by type of passenger attributed to travel through Heathrow and Gatwick, using the ONS inbound spending data;

- Estimating the spending in the UK from domestic overnight and day tourists travelling through Heathrow, Gatwick and other airports or sources of transport. For domestic overnight tourists we can obtain the proportion travelling by air from the Great Britain Tourism Survey 2012, which shows that only 2% of domestic overnight tourists travel by air. We can also obtain the equivalent figures for day visits from the GB Day Visits Survey 2011. For day visits only 0.32% travel by air. The CAA UK Airports Statistics 2011 provides the domestic terminal passenger traffic. Assuming that the ratio of spending to visits remains constant across airports and regions, and that the overall airport split of domestic passenger traffic is representative of the split for overnight and day tourists, we can use this and the data above to obtain the spending of domestic overnight and day tourists associated with travel through Heathrow and Gatwick, or other airports and methods of transport; and

- Estimating the spending in the UK from outbound passengers leaving at Heathrow, Gatwick and through other airports and sources of transport. For outbound tourists, ONS Travel Trends 2011 shows the visits abroad of UK residents by method of transport. This shows that 79% of visits abroad are made by air. Likewise the data-set also shows the visits abroad by airport used, showing that 22% of outbound visits abroad are through Heathrow and 17% through Gatwick. Assuming again that the ratio of spending to visits remains constant across airports and modes of transport, we can use this to estimate the spending in the UK from outbound passengers associated with travel through Heathrow, Gatwick and other airports and modes of transport.

### *B.2.10. The choice of closure rules in the S-CGE model*

In order to be able to obtain a solution for a CGE model, the number of equations that need to be solved must equal the number of endogenous variables. If this balance is to be achieved some key variables occurring endogenously in the model must be constrained. In economic terms, this process is more commonly referred to as macroeconomic closure. In order to implement this exogenous constraint, balancing equations need to be added to the model (Ginsburgh and Keyzer, 1997[265]).

There are a number of options available for closure rules and the closure rule chosen can have significant implications for the behaviour of the model. The choice of closure rule is down to the preferences of the modeller and is determined by the issues under consideration (airport capacity expansion in our analysis). The choices made have no influence on the solution to the base simulation but may influence the results for other simulations.

The S-CGE model we have designed for this analysis has four key macro balances that are governed by closure rules. These are:

- the current account closure rule;
- the government closure rule;
- the labour market closure rule; and
- the investment-savings closure rule.

In the sections below, we outline the closure rule choices available and explain our rationale for our choices made in our analysis.

### *B.2.10.1. The current account closure rule*

This closure rule governs the current account deficit, and the associated real exchange rate. The three options typically used in CGE models are:

*Table 101: Current account closure rules commonly used in CGE modelling*

| Current account closure rules | Description |
|---|---|
| **Fixed current account deficit** | Under this specification the real exchange rate is flexible while the current account deficit, which is akin to foreign savings in most models, is fixed. This implies that the net trade balance is also fixed. |
| **Fixed real exchange rate** | Under this specification the real exchange rate is fixed and is indexed to the model numéraire, while foreign savings and hence the trade balance are flexible. |
| **Fixed nominal exchange rate** | Under this specification the nominal exchange rate is fixed and is indexed to the model numéraire, while foreign savings and hence the trade balance are flexible. |
| **Flexible real exchange rate** | In this specification the real exchange rate can vary, so to can the net trade deficit. The volume of exports and imports will be determined by domestic demand and supply and the price of UK goods and services relative to overseas goods. |

In our model, we have used the fouth option, i.e. the “flexible real exchange rate” rule, as this allows us to estimate changes in the volume of of imports and exports in response to increased airport capacity. This is particularly relevant where we have used the econometrically-estimated effects of passenger numbers

### *B.2.10.2. The government closure rule*

This closure rule determines government revenues and government expenditure. There are multiple options available, but the closure rules most often used are:

[265] Ginsburgh, V., & Keyzer, M. (1997). The Structure of Applied General Equilibrium. Changes in Consumption Patterns, 189.

*Table 102: Government closure rules commonly used in CGE modelling*

| Government closure rules | Description |
|---|---|
| **Fixed Revenues** | Government expenditure is flexible and tax rates are fixed. |
| **Flexible revenues (percentage)** | Government expenditure is fixed and tax rates on households adjust to restore equilibrium. This is undertaken by allowing tax rates to adjust endogenously by an equivalent number of percentage points. |
| **Flexible Revenues (scalar)** | Again, government expenditure is fixed and tax rates adjust to restore equilibrium. This is undertaken by scaling the tax rates up or down accordingly. |
| **Harberger closure rule** | Government expenditure is fixed, but instead of changes in tax rates, a lump sum transfer is made from each household. If output shrinks (increases) in the models scenario, the lump sum tax will rise (fall) in order to restore the level of Government consumption. This assumption originates in Harberger (1962)[266] and is used as a neutral closure assumption. This is the most commonly used fiscal closure rule in CGE modelling. |

In our analysis, we have used the Harberger closure rule. Under this closure rule, the lump-sum transfer largely removes any subsequent fiscal effects that might occur within an S-CGE framework. It is important to strip these effects out - it would not be a central policy aim for a government to boost its tax revenues by facilitating airport expansion and we would not expect tax rates or non-airport related government spending to change as a direct result.

### *B.2.10.3. The investment-savings closure rule*

This closure rule governs the quantity of savings and investment in the economy. There are five options available which are:

*Table 103: Savings-investment closure rules commonly used in CGE modelling*

| Investment-Savings closure rules | Description |
|---|---|
| **Fixed investment (percentage)** | Real investment quantities are fixed. The savings of households and institutions are adjusted by the same percentage rate to generate the requisite volume of savings. It is assumed implicitly that the government can implement policy that can generate the required amount of savings. |
| **Fixed investment (scalar)** | Again, real investment quantities are fixed. However, savings are scaled up or down accordingly. |
| **Fixed Savings** | This is the classic savings driven closure. All savings rates are fixed. Savings are scaled up or down at the commodity level to ensure that investment adjusts to meet required savings. |
| **The Loanable Funds closure** | When savings and investment are in equilibrium there is an implicit modelling of financial markets. An alternative approach suggested by Taylor (1991) is to let savings be the supply of loanable funds and investment be the demand for loanable funds, supply and demand are then balanced by the interest rate. |

[266] Harberger, A.C. (1962). The incidence of the corporation income tax. The Journal of Political Economy, 3, 215-240.

In our model, we have used "Loanable funds closure" rule as we believe this is a better approach to fixing or scaling savings or investment ratios. Given the scale of the airport investments we are analysing it is important that interest rates determine the supply and demand of investment and should in turn rise if businesses wish to attract new investment.

#### *B.2.10.4. The labour market closure rule*

The labour market closure rule governs how labour markets are cleared. Early CGE models tended to fix the amount of labour supply, but increasingly flexible labour markets are included in CGE models and many options exist: some CGE models seek to incorporate models of wage bargaining, while others factor in skill accumulation (for a more detailed discussion of the options available see Gillham, 2005).

The main issue that needs to be covered by any analysis of labour markets relates to the extensive and intensive margins of labour supply; these are defined below as follows:

- Extensive margin of labour supply: determines the participation decision (i.e. are workers in the labour market or are they unemployed).
- Intensive margin: determines the number of hours supplied by those already working.

Potentially, CGE models can cover both the extensive and the intensive margins in two sets of separate equations. However, these equations need to be linked to the overall demand for labour and also to the stock of employees available.

| Factor market closure rules | Description |
|---|---|
| **Fixed labour supply** | Early CGE models made the assumptions that the economy is at full employment. This closure rule does allow labour to be mobile across different sectors, but the supply at the whole economy level does not increase. |
| **Flexible labour supply** | The S-CGE models assumes unemployment in labour markets in its three (London & the South East, the rest of England, and the rest of the UK) regions. According to this closure rule, wages (relative to the region numéraire) are specified to be fixed at their baseline rates in all regions whereas their employment levels are determined endogenously to reflect abundant supply of unskilled workers who are willing to offer their services at the prevailing wage rates in these regions. Following the introduction of a scenario, wages and unemployment will adjust to restore the model to a new equilibrium. |

We have not adopted the fixed labour supply closure rule as this does not allow for changes in regional employment patterns due to increased airport capacity in London & the South East. Instead we use the flexible labour supply assumption.

## *B.2.11. Inter-regional trade data*

### *B.2.11.1. The availability of regional trade data*

Usually when CGE models are built, regional trade data are available: examples include Spain (Gillham, 2004)[267] and Australia (Regional version of the ORANI model, which is an S-CGE model of the Australian economy).[268] Not all countries produce these data and in some cases it has been assumed; for instance, the,

[267] Gillham, J. (2004). The economic inter-relationships of tourism: A Computable General Equilibrium Analysis. *PhD Thesis, University of Nottingham*. Available at: http://etheses.nottingham.ac.uk/1330/1/436728_VOL1.pdf

[268] More details on the ORANI model can be found at: http://www.copsmodels.com/oranig.htm

USAGE-51 model[269], is built on commodity flow data for 51 States of the US, but these data are only partial and do not include transactions.

There are several sources of data that describe the trade between the UK and other countries. However, with the exception of Scotland, there are no official government data sources on trade between regions of the UK. The Scottish Government publishes this data as part of the Scottish SUT data. However, it refers only to trade between Scotland and the Rest of the UK – it does not distinguish its trade between the other UK regions. Given this lack of data, we were required to estimate regional export and import data for the UK.

The remainder of this section describes the methodology we used to estimate the regional trade data.

### *B.2.11.2. Building a regional dataset: our approach*

To calculate inter-regional trade flows, we first estimate exports from London & South East, the Rest of England, and the Rest of the UK to each of the other regions. We then compute import estimates by adding up the exports coming into each of the regions i.e. Scotland's exports to Wales are directly equivalent to Wales' imports from Scotland – the net regional trade balance by definition is zero.

Our approach follows the following steps:

- Calculate exports, which consists of the following steps:
  - Calculate location quotients – this is an index used to measure relative levels of economic activity in the UK regions;
  - Calculating location-quotient based export estimates;
  - Comparison of estimates with Scottish data; and
  - Adjustments made for specific sectors.
- Adjustments and rebalancing.

These steps are described in more detail below.

### *B.2.11.3. Exports*

**Calculating location quotients**

In order to estimate inter-regional exports, we use location quotients based on relative employment levels by sector by region. This approach is based on the method outlined by Robinson and Liu (1997)[270]. We define the location quotient of any sector *i* in region *r* ($LQ_i^r$) as:

$$LQ_i^R = \frac{E_i^R / E_T^R}{E_i^B / E_T^B}$$

Where:

- $E_i^R$ is employment in sector *i* in region *R;*
- ETR is the total employment T in all sectors in region R;
- EiB is employment in sector i in the benchmark economy B (all UK in this context); and
- ETB is the total employment T in all sectors in the benchmark economy *B*

[269] More detail on the USAGE_51 model can be found in the following article: Dixon, P.B., Rimmer, M.T., & Wittwer, G. (2012). USAGE-R51, a state-level multi-regional CGE model of the US economy. *GTAP Working Paper*. Available at: https://www.gtap.agecon.purdue.edu/resources/download/5933.pdf

[270] Robinson, D.Dennis P. and Zuomin Liu, Z. (2006). The Effects of Interregional Trade Flow Estimating Procedures on Multiregional Social Accounting Matrix Multipliers, *The Journal of Regional Analysis & Policy*, 36(1) pp 94-114.

A location quotient greater than one indicates that the local economy employs relatively more labour in the sector than the benchmark economy employs in that sector. The implication is that the sector is producing more than the local economy needs, and therefore, it is exporting some proportion of the goods and services produced by the sector.

Alternatively, a location quotient of less than one indicates that the local economy is employing relatively less labour in the sector than the benchmark economy employs in that sector. The implication is that the sector is producing less than the local economy needs, and therefore, it needs to import some of the goods and services consumed by the sector.

We calculate location quotients based on employment data from the ONS Annual Business Survey for the year 2010.

**Calculating location-quotient based export estimates**

An export share[271] for a sector is the proportion of its production that is exported. This is estimated using location quotients calculated previously. For sectors with a location quotient greater than one, the export share of any sector *i* in region *R* ($ES_i^R$) is:

$$ES_i^R = 1 - \frac{1}{LQ_i^R}$$

where: $LQ_i^R$ is the location quotient in sector *i* in region *R*.

The export share, based on location quotients, indicates the portion of a sector's employment that is devoted to producing exports and can be an estimate of the proportion of the sector's production that is exported if the relationship between output and employment is constant for any sector. The export share is then multiplied by the total production in the region to estimate exports within the sub-regions of the area.

**Comparison of estimates with Scottish data**

We calculated the export shares for Scotland specifically and compared the export shares calculated using the methodology described above and compared the results with the direction of trade for Scotland in 2009. The comparison is shown on the table below. The first three columns in the table show

- the actual direction of trade in 2009 based on ONS data;
- the direction of trade estimated using the location quotients approach; and
- whether the direction estimated matches the actual.

To assess the relative importance of the sector in terms of GVA and trade volumes, the table also shows GVA in the sector (as a percentage of total GVA) and the absolute trade volume (exports plus imports) in the sector (as a percentage of total trade volume).

For example, in the agriculture sector, the actual direction of trade is negative while the estimated direction of trade based on the location quotient approach is positive. Therefore, our estimates do not match the actual direction of trade. However, the agriculture sector GVA constitutes only 0.8% of the total GVA in the economy while agricultural trade volume constitutes only 1.8% of total trade volume in the economy.

On the other hand, in the manufacturing sector, the actual direction of trade and the estimated direction of trade are both positive. The manufacturing GVA constitutes 11.5% of the total economy GVA, and manufacturing trade volume accounts for close to 38.5% of the total trade volume in the economy.

The direction of trade calculations matches actual data for Scotland for 11 out of 19 sectors. This covers approximately 61% of GVA and approximately 80% of total trade volumes (export and imports). We make certain adjustments to the location quotients approach for sectors where there is a mismatch which are described in the next section.

### Adjustments made for specific sectors

To account for the lack of consistency in the direction of trade, we use different sector-specific adjustments to our methodology, either in the calculation of export shares, or at the final stage, i.e. when estimating the exports and imports for each region. The adjustments made to each sector are as follows:

- For the financial sector, we think the inconsistency arises because of the influence of large export volumes to the rest of the world. Scottish exports to the rest of the world are around 24% of the total domestic demand (compared to an average of 8% for all sectors). We correct for this by adjusting the location quotient calculations to remove employment devoted to exports to the rest of the world;
- For the accommodation and food services sector, we continue to use location quotients because they are consistent with tourism data;
- For the household activity sector, we use compensation of employees instead of employment to calculate location quotients;
- For the agriculture sector, we continue to use employment based location quotients due to instability in the sector;
- The impact of the public administration, health and education sectors on the economy is small and not material, and so we used the location-quotients based approach to estimate exports; and
- For the arts and entertainment sector, and for the real estate sector, we use the export to GVA ratios along with the total GVA of the sector in the region to obtain the export estimates of the region.

*Table 104: Direction of trade: Comparison between location-quotient based estimates and Scotland data*

| Sector | Direction of trade | | | GVA | Total trade volume |
|---|---|---|---|---|---|
| | Data (2009) | Calculations | Match (✓/×) | % of total (2009) | % of total (2009) |
| Agriculture, forestry and fishing | -ve | +ve | × | 0.80% | 1.77% |
| Mining and quarrying | +ve | +ve | ✓ | 3.06% | 7.68% |
| Manufacturing | -ve | -ve | ✓ | 11.50% | 38.48% |
| Electricity, gas, steam and air-conditioning supply | +ve | +ve | ✓ | 2.52% | 2.61% |
| Water supply; sewerage and waste management | +ve | +ve | ✓ | 1.60% | 0.48% |
| Construction | +ve | +ve | ✓ | 7.59% | 2.94% |
| Wholesale and retail trade; repair of motor vehicles | -ve | -ve | ✓ | 10.06% | 2.02% |
| Transportation and storage | -ve | -ve | ✓ | 4.80% | 4.95% |
| Accommodation and food service activities | -ve | +ve | × | 3.24% | 1.89% |
| Information and communication | -ve | -ve | ✓ | 3.55% | 6.78% |
| Financial and insurance activities | +ve | -ve | × | 9.30% | 14.25% |
| Real estate activities | +ve | -ve | × | 6.26% | 0.68% |
| Professional, scientific and technical activities | -ve | -ve | ✓ | 5.92% | 7.17% |
| Administrative and support service activities | -ve | -ve | ✓ | 3.99% | 6.59% |
| Public administration and defence; compulsory social security | +ve | +ve | ✓ | 5.94% | 0.00% |
| Education | +ve | -ve | × | 6.76% | 0.75% |
| Human health and social work activities | -ve | +ve | × | 10.09% | 0.07% |
| Arts, entertainment and recreation | -ve | +ve | × | 1.56% | 0.63% |
| Other service activities | -ve | -ve | ✓ | 1.19% | 0.21% |
| Activities of households | +ve | n.a. | × | 0.26% | 0.05% |

*Source: Scotland IO tables (Direction of trade and trade volumes, 2009) and ONS (GVA, 2009)*

## *B.2.12. Other adjustments and rebalancing*

Where exports and imports are significantly higher than the GVA share of the sector, and where this high ratio could not be justified, we have adjusted the share of exports (and the converse imports) down based on the export to GVA shares of the region and using other studies. We have also reconciled the estimates with the Scotland Input Output tables, the estimated Welsh Input Output tables and other sector studies. Following these adjustments, further minor adjustments were made to the overall export and import estimates so that the system remains balanced.

We obtain estimates of inter-regional export flows between each pair of regions (i.e. London & South East to the rest of England and the Rest of the UK, etc.).

# Appendix C: Econometric estimation of the link between passenger flows and trade

## C.1. Overview of the appendix

The AC forecast that the operation of new airport capacity in the South East of England is forecast by the AC to increase passenger flows. This, in turn, can be expected to boost economic activity, notably in the form of higher GDP and employment. We are modelling the effect on GDP and employment using our Spatial Computable General Equilibrium (SCGE) model. However, in its standard form, the SCGE model does not fully capture the wider economic benefits associated with the increase in passenger flows. Therefore, we need to change the SCGE model using a change in a variable which is included in the model which can be used as an input to proxy for the wider economic benefits associated with the forecast change in passengers. For the reasons discussed below, we use trade as that variable. This appendix is concerned with the econometric estimation of the link between passenger flows and trade (i.e. exports and imports of goods and services), which we need in order to ensure that the size of our change to trade in the CGE model is appropriate to the size of the forecast change in passengers.

The analysis in this section explores the relationship between passenger numbers on the one hand and UK exports and imports of goods and services on the other.

To conduct our econometric analysis we use a gravity model[272], estimated using an instrumental variable approach, and based on a panel dataset with 112 countries. This is consistent with our analysis during Phase 1 of our work. [273]

To distinguish between the different schemes, we use interacted dummies to estimate how the link between passenger numbers and trade with the UK varies in four world regions. . The trade data underlying the four regions is taken from 112 countries, each country being assigned to a region. The four regions we have modelled are Asia, Europe, North America and the rest of the world.

The concept of interacted dummies and the reasons for our choice of the four world regions are discussed in the model specification section below.

An alternative approach would have been to use trade and passenger numbers at the regional level instead of using a combination of country-level data and interacted dummies for the regions. However, doing so would reduce the size of the dataset to a very small number (4 regions x 10 years = 40 observations). Even if we had used a more granular grouping, say with 12 regions instead of four, we would have 120 observations, which would not be sufficient to draw robust conclusions. Further, by using a country-specific model with 112 countries over a 10 year period from 2001-2010, we are able to account for country-specific observed and unobserved factors and estimate the link between trade and passenger flows in isolation of these country-specific factors.

We estimate the link between passenger numbers and trade using an Instrumental Variable Pseudo-Poisson Maximum Likelihood (IVPPML) estimator. The Pseudo-Poisson Maximum Likelihood (PPML) estimator is

[272] The name “gravity” comes from the fact that in its nonlinear form, the model resembles Newton’s law of gravity. See section 2.3.1 for further details.

[273] PwC (PricewaterhouseCoopers) (2013). Econometric analysis to develop evidence on international business impacts. *PwC report for the Airports Commission and Department of Transport, December*.

widely used in the academic literature to estimate trade models[274]. By using instrumental variables[275], we account for potential endogeneity[276] in our model. There is a risk of the omission of variables and simultaneity bias in the model specification which can cause the estimates to be biased and inconsistent. By testing for endogeneity and using instrumental variables, we mitigate the risk of omitted variables and simultaneity biasing our estimates.

Based on our analysis over a 10-year period, from 2001 to 2010, we find that a 10% increase in passenger numbers is associated with:

- A 2.37%-2.93% increase in exports of goods;
- A 5.81%-6.12% increase in imports of goods; and
- A 2.48%-2.97% increase in exports of services.

We have not been able to establish a significant econometric relationship between passenger numbers and UK services imports.

Our results are largely similar to the estimates used in Phase 1 of our analysis. We discuss the results and the comparison with Phase 1 in the last section of this appendix.

## *C.2. The reason for choosing trade as the channel for productivity effects*

In this section, we discuss our choice of trade as the dependent variable in our econometric analysis, and therefore as the variable changed in our CGE modelling.

As we are most interested in the effect of greater airline passenger flows on economic activity, the ideal approach would be to establish a causal link between passenger flows and GDP. During Phase 1 of our work, we estimated a coefficient that linked seat capacity to GDP. However, the data are not granular enough to distinguish between the three different schemes, i.e. LGW 2R, LHR NWR, and LHR ENR.

To help us distinguish between the different airport schemes, we first explored whether there is a link between GDP and passenger numbers at a more granular level. The AC demand forecast provides data for passenger flows to and from the UK to seven world regions: Asia, Europe, North America, the Middle East, Africa, Central & South America and Oceania. We sought to establish whether there were historic relationships between passenger flows for these regions and UK GDP.

Consistent with the approach in our Phase 1 analysis, we used an error correction model[277] to estimate these relationships. However, we were unable to establish any econometrically significant relationships at the route level. We believe our inability to quantify an econometric relationship between passenger numbers at a regional level and GDP is because passenger numbers at a regional level have only a weak influence on GDP. This is because UK GDP is a national measure of UK economic activity which, as our earlier work showed, is influenced by the totality of aviation activity, and its relationship with passenger flows to and from particular global regions is not necessarily strong. Furthermore, within the world regions data, there may be offsetting effects on different routes – for example, passenger journeys from the UK to holiday destinations in Spain might have a negative impact on UK GDP (because they represent an outflow of cash from the UK), offsetting the positive impact of business flights to another European destination to generate, say, export deals.

As a result, we instead examined the relationship between international trade, i.e. exports and imports, and passenger flows. We considered that this was more likely to yield a significant relationship because we could

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[274] We use a Pseudo-Poisson Maximum Likelihood (PPML) approach because it has a number of desirable properties when estimating gravity models. See section 2.3.3 for further details.

[275] Instrumental variables are 'proxy' variables that are correlated with the endogenous explanatory variables (conditional on other covariates) but not correlated with the error term in the explanatory equation.

[276] In a statistical model, a variable is said to be endogenous when there is a correlation between the variable and the error term in the model. This can arise as a result of measurement error, simultaneity or omitted variables. In our model specification, the key risk is that of simultaneity and omitted variables. The presence of endogenous variables leads to biased and inconsistent estimates (i.e. large standard errors).

[277] Error Correction Models (ECMs) are a category of multiple time series models that directly estimate the speed at which a dependent variable returns to equilibrium after a change in an independent variable.

estimate the link between passenger flows and trade at the regional level to be consistent with the AC's passenger numbers data.

There are alternative approaches that could have been used to estimate the productivity benefits. For example, improved connectivity also has an impact on FDI. FDI can bring in new products to the UK market and also strengthen supply chains into and out of the UK. However, FDI may also reflect other factors (e.g. changes in the ownership of assets), which are not directly linked to airport connectivity. This makes trade a more robust channel for modelling the productivity impact of airport capacity expansion. In addition, using trade **and** FDI would risk double-count in the S-CGE model, since the S-CGE model anyway recognises the relationship between FDI and international trade (i.e. even though we only input the trade effect into the S-CGE framework directly, internal mechanisms within the model mean that we are also capturing the FDI effect).

In addition, given that changes in connectivity have a geographical element, the most direct effect on macroeconomic outcomes will also be on geographic specific outcomes such as trade. Modelling trade therefore gives us a suitable way of linking connectivity and the economy (by contrast GDP, for example, does not have any dimension that would enable us to identify a correlation with different degrees of improved connectivity to different parts of the world).

Again, following the approach we adopted in our Phase 1 analysis, we examined this relationship between the export and the import of goods and services (four dependent variables) on the one hand, and passenger numbers on the other. The analysis is carried out using country-level data. The regional effects are then examined using interacted dummy variables. The use of interacted dummy variables in the model specification is discussed below.

However, in this analysis, we were able to find significant relationships for four world regions, i.e. Asia, Europe, North America and the rest of the world. With four world regions, this gave a total of 16 coefficients. However, we were only able to obtain significant econometric relationships for three of the four components of trade goods exports, services exports and services imports. The modelling approach and model specification, the endogeneity tests and the results are described in the following sections.

## C.3. Model specification

### C.3.1. The Gravity model

To conduct our econometric analysis we use a gravity model based on a panel of 112 countries (UK trading partners) over the period 2001-2010. The name "gravity" comes from the fact that in its nonlinear form, the model resembles Newton's law of gravity. [278]

The gravity model approach considers exports to be directly proportional to the exporting and importing countries' economic "mass" (GDP), and inversely proportional to the distance between them. The gravity model predicts that larger country pairs would tend to trade more, and countries that are further apart would tend to trade less, perhaps because transport costs between them are higher (Arvis and Shepherd, 2013)[279].

According to Leamer *et al.*, (1995)[280] the model has produced some of the clearest and most robust findings in empirical economics. Furthermore, the model has become the "workhorse" of the applied international trade literature (Arvis and Shepherd, 2013)[281]. We discuss some of the potential post-estimation testing issues around the gravity modelling approach in Section C.6.

[278] In Newton's equation, the force of attraction between two objects is directly proportional to the product of their masses and is inversely proportional to the square of the distance between them.

[279] Arvis, J.F., & Shepherd, B. (2013). The Poisson quasi-maximum likelihood estimator: a solution to the 'adding up' problem in gravity models. *Applied Economics Letters, 20*(6), 515-519.

[280] Leamer, E.E., & Levinsohn, J. (1995). International trade theory: the evidence. Handbook of international economics, 3, 1339-1394.

[281] Arvis, J.F., & Shepherd, B. (2013). The Poisson quasi-maximum likelihood estimator: a solution to the 'adding up' problem in gravity models. *Applied Economics Letters, 20*(6), 515-519.

## C.3.2. Model specification[282]

The model specification is similar to the specification used in the gravity model literature, by Melitz (2007)[283], Abedini and Peridy (2008)[284] and Grant and Lambert (2008)[285]. The main difference between our analysis in Phase 1 and the present approach is the use of passenger numbers in our current analysis instead of seat capacity. The model specification can be expressed as:

$\text{Trade}_{it} = f\,(\text{GDP}_{ukt}, \text{GDP}_{it}, \text{Exchange rates}_{it}, \text{Distance}_{i}, \text{Language dummy}_{i}$[286]$, \text{Land-locked}_{i}, \text{Passenger Flows}_{it}$ with "interacted dummies" for each region, income groupings$_i$);

where:

- $\text{Trade}_{it}$: the value of imports/exports in millions of dollars between the UK and country *i* of the 112 countries in our dataset for each year *t* in the period 2001-2010. The trade data is sourced from UNCTAD. This is our dependent variable;
- $GDP_{ukt}$: UK Gross Domestic Product in current prices and billions of dollars for each year *t* in the period 2001-2010;
- $GDP_{it}$: Gross Domestic Product of country *i* in current prices and billions of dollars in year *t* in the period 2001-2010. All GDP data is sourced from the IMF World Economic Outlook (WEO) dataset; and
- $Distance_i$: distance in kilometres between the capital of country *i* and London. The data was collected from CEPII (Centre d'Etudes Prospectives et d'Informations Internationales).

The two GDP figures in our model make up the measures of the countries' mass and together with distance make up the core gravity model. In addition, we included other variables:

- *Exchange rates*$_{it}$: the implied PPP conversion rate between the currency of the trading partner and Sterling. The data was collected from the IMF for year *t* in the period 2001-2010;
- *Language dummy*$_i$*:* a variable indicating whether country *i* uses English as its official language. This data was also collected from CEPII;
- *Land-locked*$_i$: a variable indicating whether country *i* is landlocked; and
- *Passenger Flows*$_{it}$*:* This is the key independent variable in our model, and is the number of passengers travelling from the UK to country *i* in a year *t* in the period 2001-2010.

We then use interacted dummies to examine if the link between passenger numbers and trade varies by the four regions. This is illustrated for two regions, Asia and Europe, in Figure 172 below. An increase in passenger numbers to a country in Asia has a larger effect on UK trade with that Asian country compared the effect of an increase in passenger numbers to a country in Europe on UK trade with that European country.

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[282] The regression is specified at the country-level with 112 countries in the dataset.

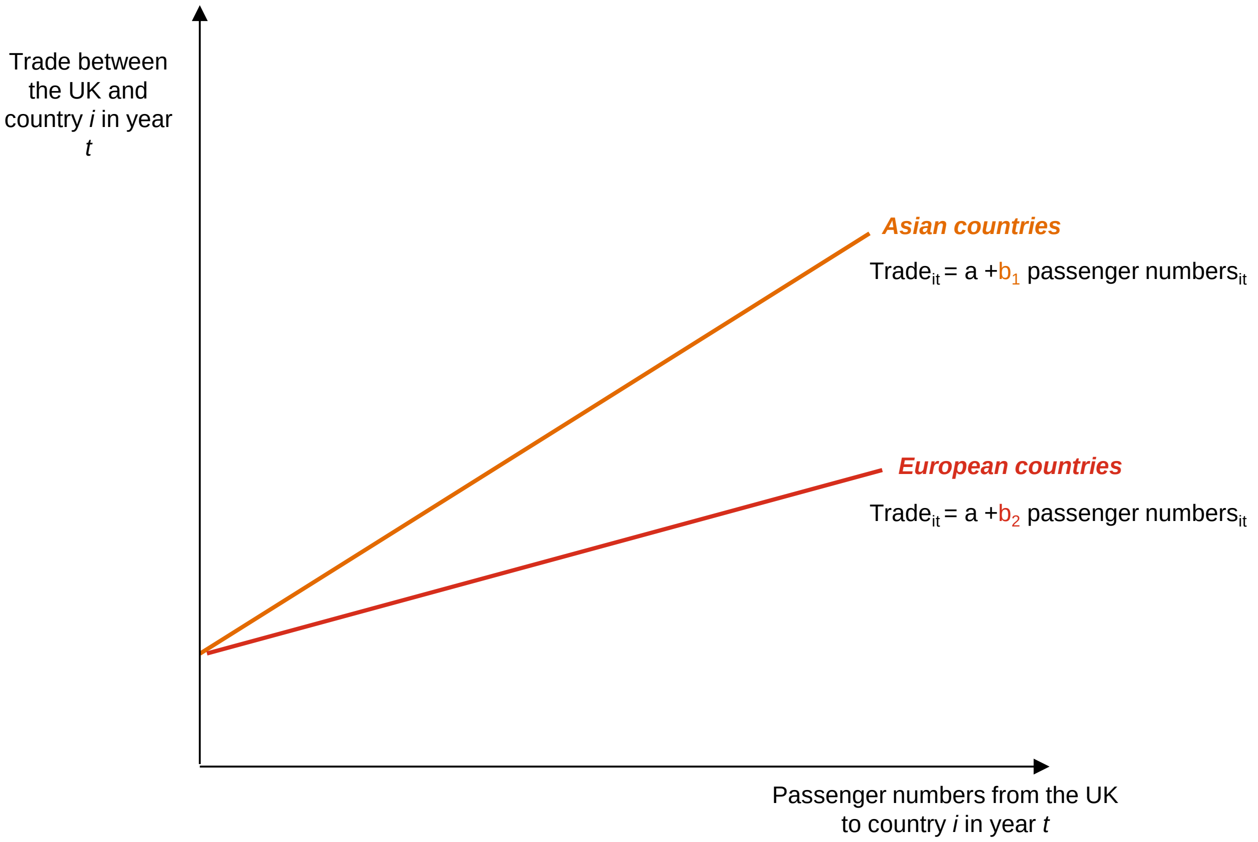
[283] Melitz, J. (2007). North, South and distance in the gravity model. *European Economic Review*, *51*(4), 971-991.

[284] Abedini, J., & Péridy, N. (2008). The Greater Arab Free Trade Area (GAFTA): an estimation of its trade effects. *Journal of Economic Integration*, *23*(4), 848-872.

[285] Grant, J.H., & Lambert, D.M. (2008). Do regional trade agreements increase members' agricultural trade?. *American Journal of Agricultural Economics*,*90*(3), 765-782.

[286] Dummy variables are "proxy" variables for qualitative facts (such as smoker/non-smoker) in a regression model.

*Figure 172: Illustrating the use of interacted dummies*




*Source: PwC analysis*

The country-level annual data is sourced from the SABRE/ADI database. The passenger data obtained from SABRE /ADI captures all passengers whose journey originated in the UK regardless of ultimate destination. The dataset does not therefore consider passengers transiting through the UK where their journey originated outside the UK. The collated dataset considers journeys on a one-way basis.[287]

- *Income groupings$_i$*: We use the World Bank list of economies to group countries into four categories based on their incomes in 2013, i.e. High income (this is composed of OECD countries and non OECD countries), Upper middle income, Lower middle income and Low income.

In our econometric analysis, we also examined other factors pertaining to airline type (e.g. full-service carriers versus low-cost carriers) and first connection point (none, within the UK and outside the UK). However, we were not able to find significant econometric relationships at this level of granularity.

## C.3.3. Modelling approach

We use a Pseudo-Poisson Maximum Likelihood (PPML) approach because it has a number of desirable properties when estimating gravity models. This modelling approach is consistent with the approach in the Phase 1 analysis but has been developed further and tested for this phase of our analysis.

The main advantage of using the PPML over other approaches, such as the pooled Ordinary Least Squared (OLS) models or panel models with random effects (RE), is that the PPML allows us to account for instances where the UK does not export to or import from a particular trading partner in a particular year. This is important, because, for example, in our panel data, zeroes amount to 20% and 22% respectively of UK services

[287] The SABRE dataset also allows us to distinguish between passengers using Heathrow, Gatwick and other airports. However, as we have not included transit passengers in our analysis, the passenger numbers in our dataset are not comparable with the existing DFT figures. The DFT data captures all passengers who have flown to and from the airport (two-way) as well as all transit traffic through that airport originating outside the UK.

exports and imports variables. Santos Silva and Tenreyro (2011)[288] show that the PPML performs well even when the proportion of zeros is very large.

The PPML in its simplest form does not account for fixed effects[289] which would capture unobserved time-invariant country-specific effects. Thus, to account for unobserved country fixed effects in a PPML framework we adopt a similar approach to that used by Fally (2012)[290]. Fally's model considers a large number of countries exporting to and importing from each other, and is able to nest exporter and importer fixed effects. He does this by including two dummies; one if a country is a net exporter and another if the country is a net importer. These nest the country fixed effect elements in the model.

In our panel data, Fally's fixed effects does not apply since each country pair is made up of the UK and its trading partner, with the dependent variable being either UK imports from or UK exports to that country. To generate a set of dummies similar to that of Fally's we use the World Bank list of economies to group countries into four categories based on their incomes in 2013, i.e. High income (this is composed of OECD countries and non OECD countries), Upper middle income, Lower middle income and Low income. These groups will nest the country fixed effects elements thereby allowing our PPML to account for unobserved time invariant country heterogeneity.

Other desirable properties of the PPML are that:

- This approach is robust to the presence of heteroskedasticity[291];
- Tts coefficients are easy to interpret and follow the same pattern as OLS, and the estimation procedure is fairly easy to implement and robust to certain types of misspecifications (Gourieroux, Monfort and Trognon, 1984)[292];
- Santos Silva and Tenreyro (2006)[293] show that the PPML consistently estimates the gravity equation for trade and that it is robust to different patterns of heteroskedasticity and measurement error, which makes it preferable to alternative procedures, such as OLS specified in logs; and
- The PPML also allows us to estimate the gravity model in its non-linear form.

Further, the presence of time-invariant variables, such as distance, lends a fixed-effects element to the model specification.

However, the standard PPML approach does not account for the presence of endogeneity. Following our Phase 1 analysis, we test for the presence of endogenous variables. This allows us to establish which of our explanatory variables are endogenous. We then estimate the gravity model using the Instrumental Variable-PPML (IVPPML) approach, i.e. by using instruments or proxies instead of the endogenous variable. It is not possible to test for omitted variable bias after the IVPPML regression. However, one of the causes for potential endogeneity is the presence of omitted variables. By testing for endogeneity and using instrumental variables, we mitigate the risk of omitted variables biasing our estimates.

## *C.4. Testing for endogeneity*

This section discusses the results of the endogeneity tests.

In our model specification, the GDP variables, exchange rates and passenger numbers can simultaneously influence and be influenced by the amount of trade. For example, an increase in trade could be because of an increase in the trading partner's GDP. However, the causal link may also flow in the opposite direction – an

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[288] Santos Silva, J.M., & Tenreyro, S. (2011). Further simulation evidence on the performance of the Poisson pseudo-maximum likelihood estimator. *Economics Letters*, *112*(2), 220-222.

[289] Fixed effects refer to unobserved time-invariant characteristics of specific to each of the 112 countries, and these characteristics are believed to have an important effect on trade. Econometric models often use fixed effects estimators to account for the presence of these unobserved characteristics.

[290] Fally, T. (2012). Structural gravity and fixed effects. *Unpublished Working Paper, University of Colorado-Boulder*.

[291] A variable is heteroscedastic if there are sub-populations of the data that have different variances from others. The presence of heteroscedasticity can invalidate statistical tests of significance.

[292] Gourieroux, C., Monfort, A., & Trognon, A. (1984). Pseudo maximum likelihood methods: Theory. *Econometrica: Journal of the Econometric Society*, 681-700.

[293] Santos Silva, J.M., & Tenreyro, S. (2006). The log of gravity. *The Review of Economic and Statistics*, *88*, 641-658.

increase in trade may also affect the trading partner's GDP. In this analysis, we seek to quantify the increase in trade because of the increase in passenger numbers relationship. This issue – sometimes called the 'dual causality' or 'simultaneity' problem – is one type of endogeneity[294]. Similarly, the quality of other transport modes may be correlated with the quality of aviation infrastructure. Without appropriate adjustments, if the quality of other infrastructure modes is not explicitly included as a control variable in the regressions, an 'omitted variable bias' (another type of endogeneity) could result.

When testing for endogeneity, we test for simultaneity, i.e. the presence of the opposite causal relationship.

We test the time-varying variables in our model specification, i.e. UK GDP, trading partner GDP, exchange rates and passenger numbers for endogeneity in each of the four equations (export and import of goods and services). The other variables are time-invariant and can be treated as exogenous.

The standard procedure to test for endogeneity is to replace the potentially endogenous variable with appropriate instruments and to test if using instruments instead of the endogenous variable removes any reported endogeneity. We carry out this process in two steps:

2. Test for instrument validity: The test for endogeneity in step 2 relies on using instruments or proxies instead of the potentially endogenous variables. Therefore, before testing for endogeneity, it is necessary to establish whether the instruments used to proxy for the potentially endogenous variables are valid instruments. This is done using the Hansen test[295]. The null hypothesis is that the instruments are valid instruments, i.e., uncorrelated with the error term; and
3. Test for endogeneity: To test for endogeneity, two equations are estimated, one with the potentially endogenous variable and the other with instruments instead of the endogenous variable. The test then compares the two regressions to establish if the suspect endogenous variable can be treated as exogenous.[296] The null hypothesis is that the variable tested for endogeneity can be treated as exogenous.

### 1. Test for instrument validity

We report the p-values[297] for the Hansen test for the instruments used in Table 105 below. Under the null hypothesis for this test, a p-value of greater than 0.05 indicates that the instruments used are valid instruments.

As shown in Table 105, all p-values reported in the table are greater than 0.05, indicating that the instruments used in the endogeneity tests are valid, and therefore, the endogeneity test can be relied upon.

*Table 105: P-values – Hansen test for instrument validity*

| Variable | Imports – goods | Exports – goods | Imports – services | Exports – services |
|---|---|---|---|---|
| **UK GDP** | 0.7652 | 0.5384 | 0.1937 | 0.6408 |
| **Trading partner GDP** | 0.3354 | 0.1819 | 0.4203 | 0.0888 |
| **Exchange rate** | 0.4994 | 0.6140 | 0.5799 | 0.0971 |
| **Passenger flows** | 0.2853 | 0.2603 | 0.8535 | 0.7193 |

[294] Note that endogeneity may also be due to measurement errors or omitted variables.

[295] The Hansen test is a test of overidentifying restrictions. The null hypothesis is that the instruments are valid instruments, and that the excluded instruments are correctly excluded from the estimated equation.

[296] This is tested using the *endog* option as a part of the *ivreg2* regression. The instrumental variable Pseudo-Poisson Maximum Likelihood estimator is a relatively new approach, as such there is currently no way of generating the Sargan or Hansen tests following this procedure. Note that this test is robust to the presence of heteroscedasticity.

[297] P-values indicate the significance, or materiality, of the test result in statistical testing. The p-value is the probability of obtaining a test statistic result close to the one that was actually observed, assuming that the null hypothesis, or the starting hypothesis, of the test is true. The null hypothesis is usually not rejected when the p-value is greater than a pre-determined significance level, often 0.05.

*Source: PwC analysis.*

*Legend: A p-value of greater than 0.05 indicates that the instruments used are valid instruments.*

**2. Test for endogeneity**

We report the p-values of the endogeneity test in Table 106 below. Under the null hypothesis for this test, a p-value of greater than 0.05 indicates the variable suspected of being endogenous can actually be treated as exogenous.

Table 106 shows the presence of potential endogeneity in all four equations. UK GDP is endogenous in the goods imports equation while passenger flows is endogenous in the services exports equation, and trading partner GDP is potentially endogenous in the goods export equation, the services export equation and the services import equation. Therefore, we use instrumental variables instead of the endogenous variables in all four equations.

*Table 106: P-values – endogeneity test*

| Variable | Imports – goods | Exports – goods | Imports – services | Exports – services |
|---|---|---|---|---|
| **UK GDP** | 0.0350 | 0.1229 | 0.1449 | 0.9238 |
| **Trading partner GDP** | 0.8870 | 0.0000 | 0.0301 | 0.0631 |
| **Exchange rate** | 0.2195 | 0.8903 | 0.9069 | 0.8532 |
| **Passenger flows** | 0.2378 | 0.8759 | 0.3599 | 0.0239 |

*Source: PwC analysis.*

*Legend: A p-value of greater than 0.05 indicates the variable suspected of being endogenous can actually be treated as exogenous.*

## C.5. Results of the IVPPML modelling approach

To account for the presence of potential endogeneity – whether it is caused by 'reverse causality' or 'omitted variable bias' – we estimate these equations using instrumental variables in the PPML framework, i.e. Instrumental Variables PPML (IVPPML).

By using instruments, we break the link between the potentially endogenous variable and the error term, avoiding the endogeneity issue, while preserving the link between the dependent variable and the variable of interest. We present the results from our IVPPML models below.

### C.5.1. Gravity model variables

In all equations except for the import of goods, UK GDP is found to have a strong positive relationship. Trading partner GDP, for all equations, also has a strong positive relationship, whereas distance has a strong negative relationship. The signs on the variables are as expected in the gravity model framework.

### C.5.2. Passenger flows

In all equations except the import of goods equation, passenger flows has a strong positive relationship on trade with the corresponding trade component:

- A 10% increase in passenger numbers is associated with a 2.37%-2.93% increase in exports of goods. The effect is 2.37% for passenger numbers, measured at the country-level, to North American countries, and 2.93% for passenger flows, measured at the country-level, to Asian countries;
- A 10% increase in passenger numbers is associated with a 5.81%-6.12% increase in imports of services. The effect is 5.81% for passenger numbers, measured at the country-level, to European countries, and 6.12% for passenger flows, measured at the country-level, to Asian countries;
- A 10% increase in passenger numbers is associated with a 2.48%-2.97% increase in exports of services. The effect is 2.48% for passenger numbers, measured at the country-level, to European countries, and 2.97% for passenger flows, measured at the country-level, to Asian countries; and
- We were not able to establish a significant econometric relationship between passenger flows and the imports of goods.

## C.5.3. Other variables

The language dummy and landlocked dummies are found to play an important role in explaining UK goods trade patterns. Sharing a common language with the UK seems to encourage trade whilst being landlocked discourages trade in goods (see Fally, 2012).

*Table 107: IVPPML estimates*

| Variable[298] | Imports – goods | Exports – goods | Imports – services | Exports – services |
|---|---|---|---|---|
| **UK GDP** | 0.958 | 1.113** | 0.718*** | 0.568 |
| **Destination GDP** | 0.850*** | 0.590*** | 0.384*** | 0.557*** |
| **Distance** | -0.356*** | -0.559*** | -0.198*** | -0.442*** |
| **Exchange rate** | 0.000 | -0.000* | -0.000** | 0.000 |
| Passenger flows | | | | |
| **Asia** | -0.006 | 0.293*** | 0.612*** | 0.297*** |
| **Europe** | 0.034 | 0.256*** | 0.581*** | 0.248*** |
| **North America** | -0.078 | 0.237*** | 0.586*** | 0.257*** |
| **Others** | -0.071 | 0.269*** | 0.601*** | 0.293*** |
| Other variables | | | | |
| **Language** | 1.066*** | 0.973*** | 0.400*** | 1.066*** |
| **Land-locked** | -0.270** | -0.359*** | 0.12 | 0.566*** |
| **High-income** | -0.159 | 0.509*** | 0.337 | 1.329*** |
| **Upper mid-income** | 0.353 | 0.303* | -0.06 | 0.567*** |
| **Lower mid-income** | -0.796*** | -0.272 | -0.202 | 0.123 |
| **Constant** | -10.581 | -12.920*** | -16.383*** | -10.709*** |

*Source: PwC analysis.*

Legend: the stars represent significance levels. * represents 10 % significance level, ** for 5% and *** for 1%. All the variables are in logarithm except for the dummies.The lower the significance level (i.e. the larger the number of stars, the stronger the econometric relationship.

Note that all the coefficients on the income categories (e.g. high income, upper mid-income, lower mid-income) are interpreted relative to the base dummy, low income country group, which is dropped in this case to avoid multicollinearity. The differences in the coefficients by region are small.

## C.5.4. Comparison with Phase 1 results

Our findings are similar to our findings from Phase 1.

Note that the Phase 1 analysis was conducted in order to estimate the link between trade and *seat capacity* as opposed to *passenger numbers* in this phase:

- In this analysis, we found that a 2.37%-2.93% increase in goods exports was associated with a 10% increase in *passenger numbers* in this phase. This is comparable with the 3.3% increase in goods exports associated with a10% increase in *seat capacity* in Phase 1.

[298] We have used the third and fourth lags to proxy for the potentially endogenous variables except the potential endogenous passenger flows variables for which we have used the fifth and sixth lags.

- In this analysis, we also found that a 10% increase in passenger numbers was associated with a 5.81%-6.12% increase in UK imports of service. This is comparable with the 6.6% increase in services imports associated with a 10% increase in *seat capacity* in Phase 1; and
- In this analysis, a 10% increase in passenger numbers is associated with a 2.48-2.97% increase in services exports. This is comparable with the 2.5% increase in exports of services associated with a 10% increase in *seat capacity* in Phase 1.

This UK-specific gravity model is not comparable with most gravity models in the trade literature, which tend to be based on a panel of countries trading with one another. While the gravity model approach is appropriate for our analysis, in our case, our panel data format consists of only the UK trading with its partner countries, and therefore, the coefficients are not directly comparable.

## *C.6. Further analysis in response to critical review*

We commissioned an external academic - a trade theory and econometrics specialist - to review our econometric analysis. The focus of his review was on the model specification and variable construction, and to check the replicability of the main regression tables. The scope of the review also covered a critical evaluation of the various estimation and testing approaches used in this analysis, and checking the accuracy of interpretation and reliability of the claims made in this analysis.

The review concluded that the framework of our analysis, i.e. the gravity model, is the most appropriate empirical tool in this context. The reviewer was able to replicate our main results. The reviewer recommended performing further robustness and sensitivity analyses to ensure that the existing findings are not due to the specific estimation and testing approaches in our study.

We present the results of our analysis in response to his comments in the rest of this document; our analysis shows us that the coefficients do not change materially (the impact of a 1% increase in passenger flows on trade changes by less than 0.1 percentage point) in the context of this study.

We have summarised the main points raised by the reviewer; our analysis in response to his suggestions; and the impact on the results in the table below. Following the analysis below, the reviewer was happy to recommend that the main econometric results can be used to inform the CGE analysis to simulate the economy-wide impact of enhancing airport capacity.

The reviewer classified his comments into four categories:

(i) model specification;

(ii) definition of variables used in our analysis;

(iii) the fixed effects approach; and

(iv) the instrumental variables approach.

| Review comments | Our response |
|---|---|
| *Model specification* | |
| GDP per capita be included in some specifications | We have re-estimated the IV-PPML regressions with GDP per capita included, and this has no material impact on the key coefficients - the impact of a 1% increase in passenger flows on trade changes by 0.03 percentage points at most. |
| A dummy capturing the global financial crisis be included | We have re-estimated the IV-PPML regressions with a global financial crisis dummy included, and this has no material impact on the key coefficients - the impact of a 1% increase in passenger flows on trade changes by 0.02 percentage points at most. |

| | |
|---|---|
| Region/continent specific dummies be included (in addition to the interaction terms) | We have re-estimated the IV-PPML regressions with region/continent specific dummies, and this has no material impact on the key coefficients - the impact of a 1% increase in passenger flows on trade changes by 0.16 percentage points at most. However, we lose the statistically significant relationship between passenger flows to and from North America in the services exports model. |
| *Definition of variables* | |
| Real values be used instead of nominal values | We have re-estimated the IV-PPML regressions using real values for trade and GDP instead of nominal values, and this has no material impact on the key coefficients - the impact of a 1% increase in passenger flows on trade changes by 0.08 percentage points at most. |
| Use stock of passenger numbers or distributed lags instead of a static model to make sure the model allows for dynamic and cumulative adjustment of trade to passengers number. | The static model approach is in line with the existing gravity model literature. Further, the model specification tests tell us that a static model is well-specified. |
| *Fixed effects approach* | |
| Delete the claim of accounting for time invariant country heterogeneity, but agree with the PwC's approach of using group/continent specific dummies | We agree with the reviewer and have deleted the comment. |
| As the PPML does not account for fixed effects, experiment with the fixed effects estimator to test the results for robustness | We note that our comment and the reviewer's comment are both correct. While the PPML does not account for fixed effects by default, the use of country-specific time-invariant factors (language, distance, etc.) makes it equivalent to the suggested Poisson FE estimator. These time-invariant factors, which are key in a gravity model, are dropped when a Poisson FE estimator is used. |
| *Instrumental variables approach* | |
| Use lagged values of potentially endogenous variables with fixed effects as this would mitigate endogeneity concerns resorting to IV estimation | Using the PPML estimator in STATA (see our response on the Poisson FE approach above), we have re-estimated the gravity model using the fifth and sixth lags of the potentially endogenous variables. This has no material impact on the coefficients on passenger flows- the impact of a 1% increase in passenger flows on trade changes by 0.07 percentage points at most. |
| Use a single equation framework to test for endogeneity | We have tested for endogeneity using the single equation framework, and have re-estimated the IV-PPML regressions by instrumenting for all potentially endogenous variables. This has no material impact on the coefficients on passenger flows - the impact of a 1% increase in passenger flows on trade changes by 0.09 percentage points at most. |
| Re-run instrument validity tests using continent-specific passenger flow variables | We have tested for endogeneity using continent-specific passenger flow variables, and have re-estimated the IV-PPML regression by instrumenting for potentially endogenous variables. This has no material impact on the coefficients on passenger flows - the impact of a 1% increase in passenger flows on trade changes by 0.09 percentage points at most. |
| Use Poisson-robust specification tests instead of the tests within a linear regression framework | We had implemented this strategy in consultation with Prof Santos Silva (University of Bristol), who has confirmed that our approach is fully compatible with the Poisson IV estimator. |

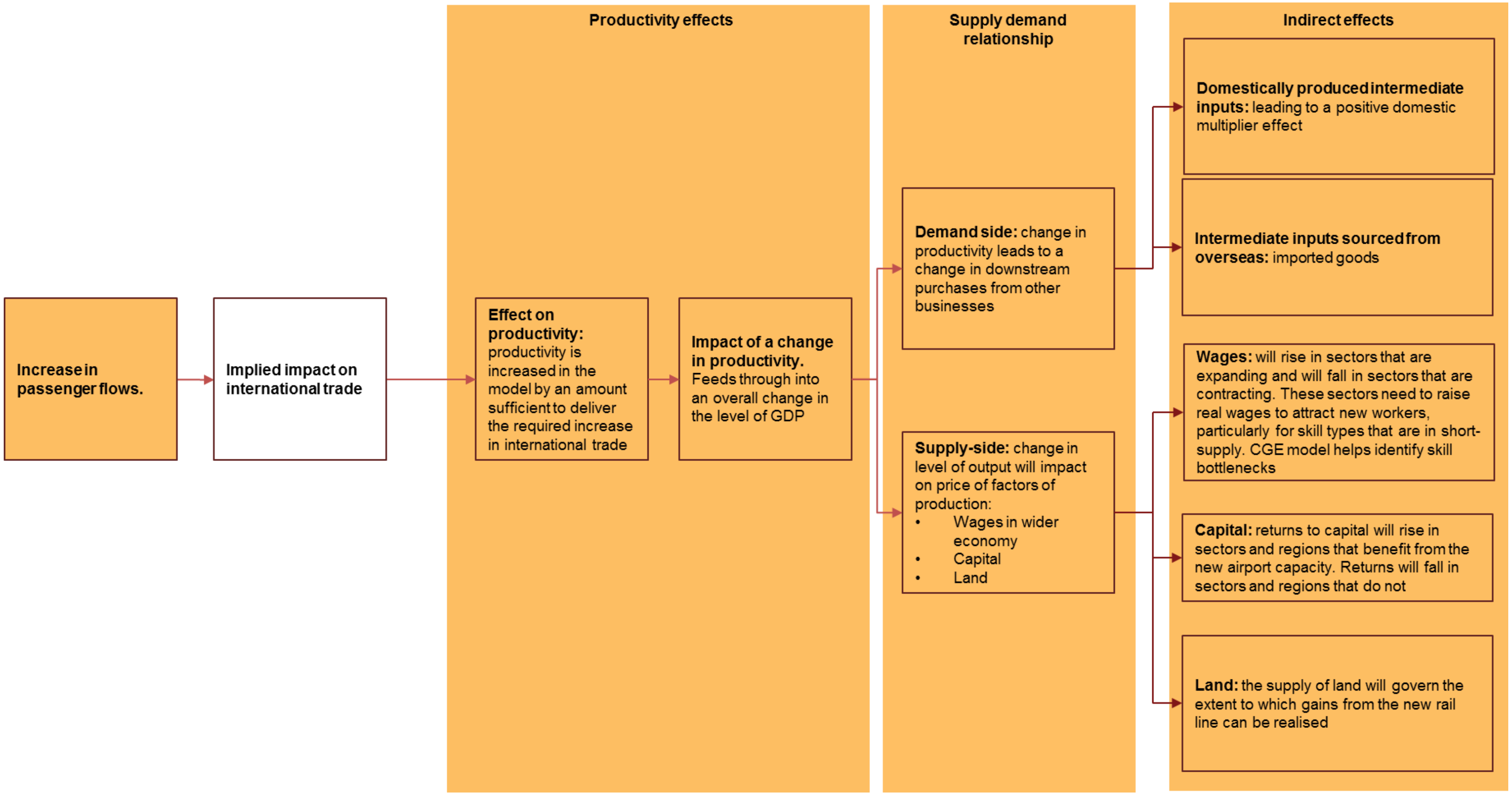
# Appendix D: Transmission mechanisms

## D.1. Overview of the appendix

This Appendix contains key transmission mechanisms which outline how the inputs to the S-CGE model drive GDP impacts. The following four mechanisms are considered:

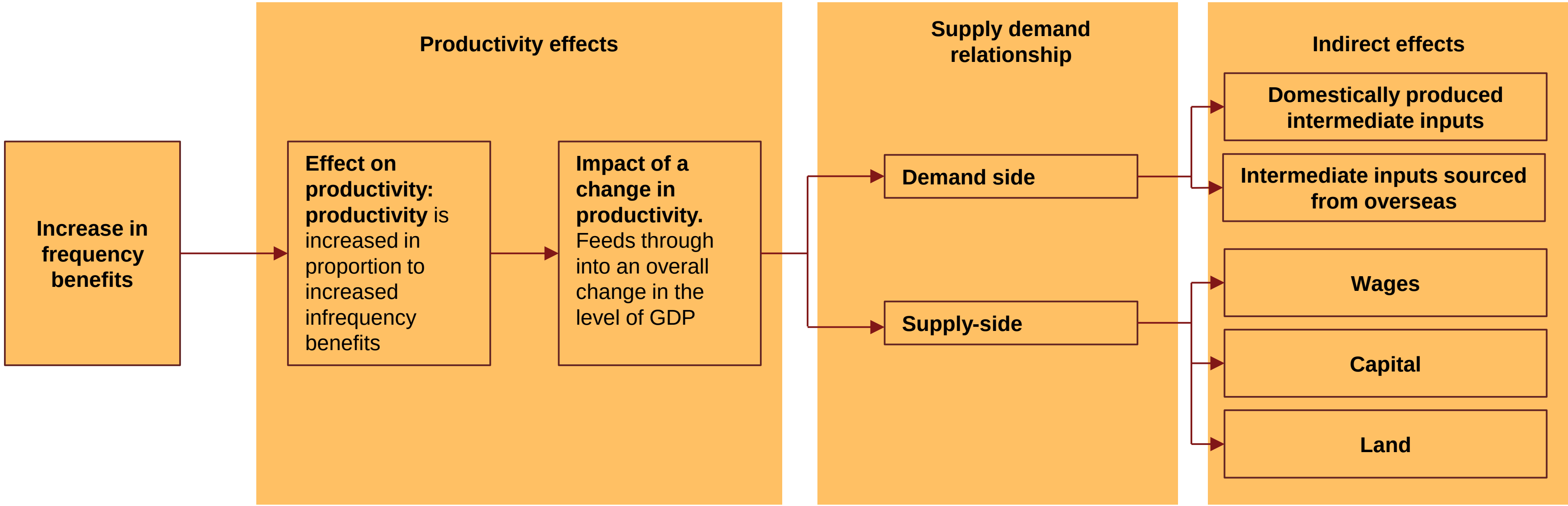
1. Productivity transmission mechanism
2. Frequency benefits transmission mechanism
3. TEE transmission mechanism
4. Construction transmission mechanism

*Figure 173: Productivity transmission mechanism*



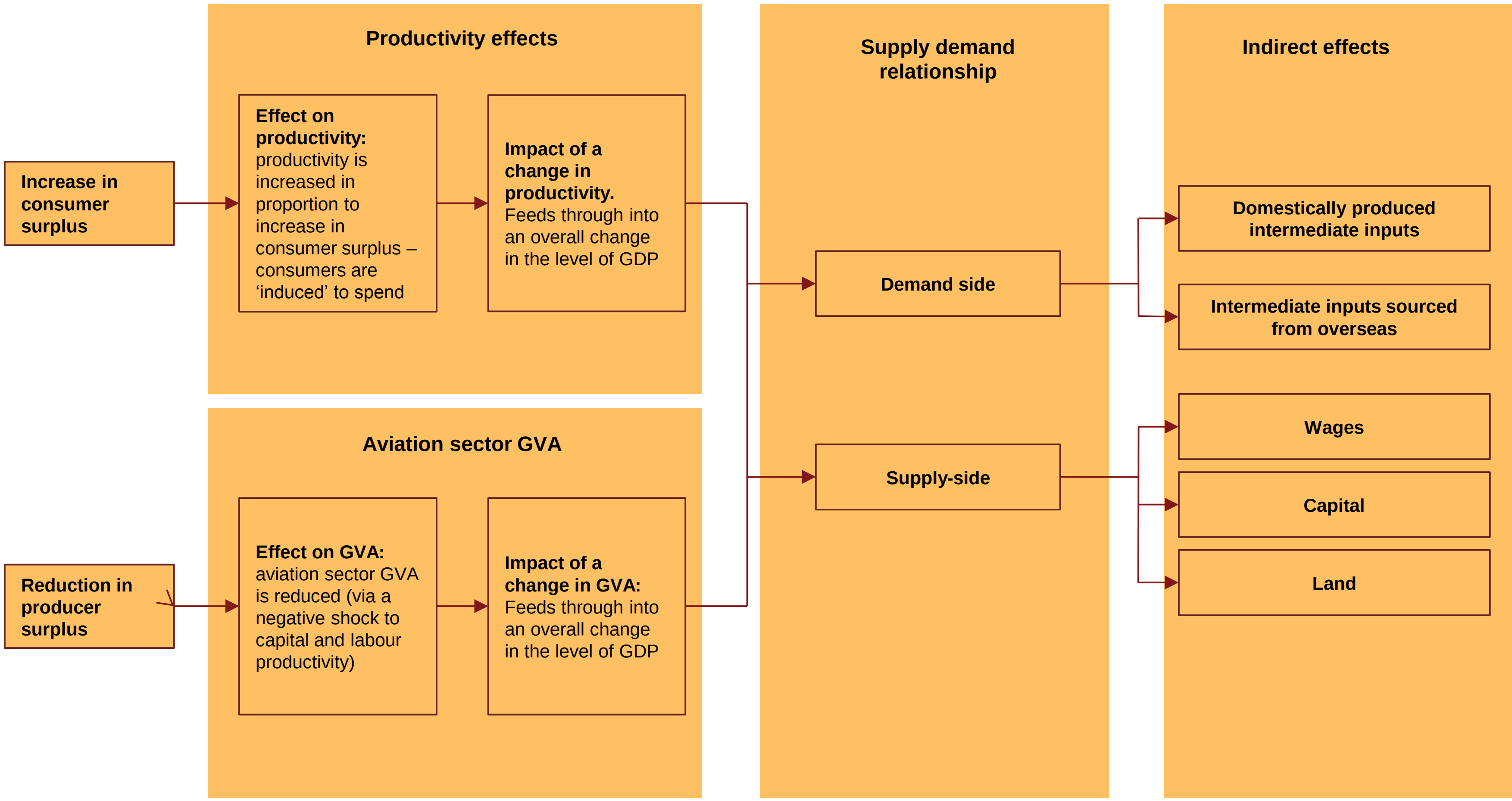

*Source: PwC analysis*

*Figure 174: Frequency benefits transmission mechanism*



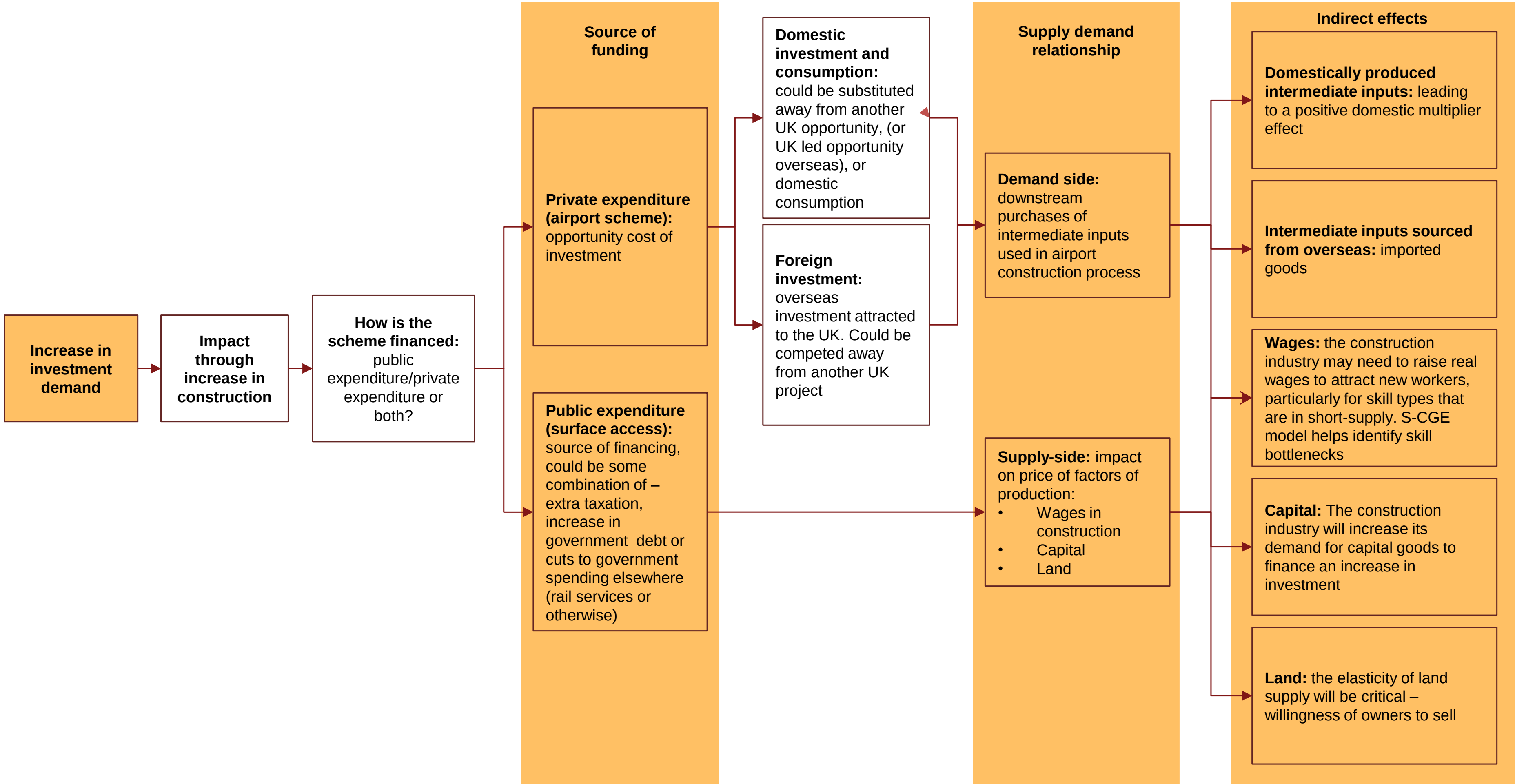

*Source: PwC analysis*

*Figure 175: TEE transmission mechanism*




*Source: PwC analysis*

*Figure 176: Construction transmission mechanism*




*Source: PwC analysis*

# Appendix E: Multiplier analysis

## E.1. Overview of the appendix

This Appendix looks in greater detail at the ratio of the present value (PV) of the model's outputs to the model's inputs (commonly referred to as the multipliers). These values capture the degree to which additional input leads to a positive net impact on national GDP, as opposed to simply displacing or crowding-out existing activity. Examining the multipliers therefore provides greater insight into how the overall GDP impacts we have modelled are driven by the forecasts from AC's demand forecasting model, and how the results from the modelling compare with relevant examples from the literature. Figures displaying the multiplier by year for each scheme, under the Assessment of Need scenario, are included at the back of the Appendix.

One important distinction to be made when interpreting the multipliers in our analysis, is the difference between gross and net impact. The gross impact of a scheme, as typically estimated in input-output or multiplier-based studies, will capture the direct effect and any second-round indirect and induced effects (through the supply chain or employee expenditure). Taking the air transport sector as an example, the gross impact on output would include the value of the additional spend on air transport, as well as the additional output generated through additional spending on suppliers to the air transport industry (and suppliers' suppliers etc.), and additional spending by employees in the air transport industry (and similarly employees throughout the supply chain). The inclusion of these second-round effects on top of the direct impact ensures that the value of the multiplier will always exceed 1, and the value of the multiplier is the ratio of the total impact (direct, indirect and induced) to the direct impact.

The net impact, as estimated in the S-CGE modelling, similarly reflects all the above described direct, indirect and induced effects. However, it also captures the level of displacement and crowding out which are associated with these effects. Returning to the construction example, an increase in demand would require firms to employ more construction workers; this in turn would raise wages and lead to a reduction profits. Similarly, construction firms would need to increase their use of capital, driving up capital costs and further lowering profits. This negative impact would be amplified as the increase the increase in demand for resources form the construction sector could crowd out activity which could otherwise be undertaken by existing firms. The combination of these negative offsetting effects is referred to as the level of diffusion within the model. This diffusion would be present not just as a result of the direct impact, but also through the additional demand created by the induced and indirect impacts described above, and would spread to other sectors that are inter-related to the construction sector. As a result, a net multiplier of less than 1 should be interpreted as the level of diffusion outweighing all of the indirect and induced effects. Similarly, a net multiplier of greater than 1 could still capture substantial diffusion, although it would be less than the value of the indirect and induced impact.

The multiplier values presented below provide greater detail on the values presented in Tables 10, 31 and 52 in the main report. As before, all PVs are calculated on the basis of a 60 year appraisal period (from 2019 to 2078) using a 3.5% discount rate for the first 30 years and a 3.0% rate for the remaining years. This appraisal period allows us to account for the construction period, as well as a period of operation.

The following table summarises the estimated multipliers for each of the three proposed schemes, under the Assessment of Need scenario, and broken down into each of the five main effects. We would not expect the multipliers to differ substantially across scenario. Any change in multiplier will largely be driven by the size of the input, and the Assessment of Need scenario can be seen as moderate in this regard. Subsequently we look at each impact driver in greater detail, providing some commentary as to the key drivers of each multiplier and comparing these values with those in relevant literature, where suitable comparators are available.

*Table 108: Range of real GDP multipliers by driver, Assessment of Need scenario (£bn, 2014 prices)*

| Driver | Multiplier range | Section |
|---|---|---|
| Construction & Surface Access | 0.44 to 0.62 | E.2 |
| Passenger Flows | -0.26 to 0.85 | E.3 |
| Productivity | 0.49 to 0.75 | E.4 |
| Frequency Benefits | 1.67 to 1.93 | |
| TEE Consumer Surplus | 0.5 to 0.59 | E.5 |
| TEE Producer Surplus | 0.07 to 0.15 | |
| **Total** | **0.64 to 0.84** | **E.6** |

## *E.1. Construction and surface access*

Table 108 above demonstrates that the estimated multiplier impacts for the construction and surface access expenditure is reasonably constant across all three schemes, ranging from 0.44 to 0.62. The fact that the multiplier estimate for each of these schemes is substantially below 1 is indicative that, within the model, much of the construction simply offsets activity from elsewhere. The construction and surface access expenditure is relatively large and focused on one region during a relatively short timeframe, so it is likely to place pressure on local resources and employment that is unlikely to be absorbed by existing spare capacity. As a result, it is unsurprising that the majority of the economic activity which the spending generates is diffused within the economy, and hence that the multiplier impact is low.

If the economy were operating at full employment, then the multiplier would be zero (with construction activity relating to the three schemes simply displacing activity from elsewhere). However, there are two mechanisms through which additional construction can have a net positive impact on the economy (and hence a multiplier of greater than zero). Firstly, construction is a highly productive sector of the economy, with strong domestic linkages through the supply chain. This will lead to relatively large indirect and induced effects, relative to the size of the direct effect. Therefore diverting consumption towards the construction sector away from less productive sectors can lead to greater national output. Secondly, the S-CGE model accounts for the availability of local factors of production. Were there to be underutilised capacity (e.g. through unemployment), an increase in demand for construction could utilise this and again generate additional economic activity.

The multiplier estimates for the construction and surface access effect is actually the product of two separate channels within the modelling: the private investment to fund the additional construction and the public expenditure on surface access. The mechanisms for accessing the funding are therefore very different, and as a result the nature and magnitude of the multiplier estimates differ between the channels. Studies in the literature typically find that private investment has a lower multiplier as the national supply of private capital is largely fixed, and therefore any additional investment is likely to displace existing activity. Public investment can be increased through taxation or borrowing, although these channels are also distortive and will lead to some diffusion. The literature is not fully reconciled on the impact of these different mechanisms, but the overall effect on GDP in this instance will be limited. The relative mix of private and public funding (determined by the ratio of construction to surface access spend) does explain some of the difference between the schemes. As described above, the use of public funds by large surface access projects, would lead us to expect them to generate a higher multiplier.

The literature indicates a number of examples where a positive economic impact has been estimated from the construction phase of a project. These are typically based on input-output or multiplier analysis, and hence provide estimates of gross impact which are substantially larger than those outlined above. For example, a report by LEK consulting (2012)[299] using this approach estimated that every additional £1 spent on

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[299] LEK Consulting (2012). *Construction in the UK Economy: The Benefits of Investment*. London: UKCG. Available at < http://www.ukcg.org.uk/fileadmin/clients/UKCG/document/LEK/LEK_May_2012_final.pdf>

construction generates an additional £2.84 in additional economic activity. This gross multiplier is more than five times as large as the net construction and surface access multiplier which is generated through the S-CGE model, highlighting our relatively conservative approach and the importance of fully accounting for diffusion.

The LEK report also re-iterates the relatively large effect which construction has on the UK economy, stating that "construction relies little on imports; hence, investment in construction is more likely than other sectors to generate additional economic activity within the UK". This conclusion supports the finding of net positive multipliers on construction expenditure, and increases the likelihood of expenditure diverted to the construction sector having a net positive impact on UK GDP.

Although much less common, there is also precedent in the literature for using S-CGE modelling to estimate the economic impact of the construction phase of large-scale infrastructure investment. Horridge and Wittwer (2007)[300] from Monash University estimated the impact of 16bn Yuan of investment in the Chongqing rail project between 2010 and 2014[301] using SinoTERM, a 31 region model of the Chinese economy. They found that the short-run impact of this was to increase national GDP by 0.007% during the years of construction. The authors did not convert this into a multiplier, but data from the World Bank suggest that the cash value of this impact would be equivalent to 2.8 – 3.9bn Yuan per year[302]. This would be equivalent to a multiplier of roughly 0.7 to 1 on the annual investment of 4bn Yuan.

## *E.2. Passenger flows*

The magnitude of the multiplier on additional passenger expenditure varies from -0.26 to 0.85 across the three schemes. The input to the passenger flow effect is the net of two opposite effects. On the one hand, an increase in the number of inbound passengers leads to additional expenditure in the UK by foreign visitors, an increase in outbound tourism has a negative impact through UK residents spending money abroad. The input used to calculate the multipliers in  above is the net of these two effects.

The net input varies greatly between the schemes. Two of the schemes (LHR NWR and LHR ENR) are associated with little additional net outbound spending due to relatively large numbers of additional inbound passengers. As a result the GDP impact for these schemes is driven almost entirely by the effect of the additional inbound passenger expenditure. The results for these schemes can be seen in the positive multiplier at the top-end of the range, which largely captures the relationship between additional inbound passenger spending and the additional GDP which it generates.

However, for the remaining scheme (LGW 2R) a larger share of the additional passengers are outbound. This leads to the increase in inbound spending only slightly outstripping the change in outbound spending, and the net input is substantially smaller as a result. A consistent result from the literature is that the positive multiplier generated within the UK from additional foreign passenger flow spending is relatively small, whilst the cost to the UK economy of UK residents travelling overseas is relatively large. This large multiplier on outbound spending means that the small net positive input for this scheme actually has a negative net impact on UK GDP. This negative GDP impact from a positive net input leads to the negative multiplier seen in Table 108. Please note that for each of the schemes we have run a sensitivity test on the mix between inbound and outbound passengers for each of the schemes.

In order to increase their spending abroad, domestic passengers have to reduce their level of domestic expenditure. The strong domestic linkages from this domestic expenditure mean that the indirect and induced impact of this reduction on domestic consumption is large. On the other hand, foreign passenger consumption in the UK has much weaker linkages within the economy, leading to a more muted GDP impact. This difference leads to the greater multiplier on outbound expenditure which is described in the previous paragraph. As outlined in the main body of the report, this finding is consistent with that of other studies. For example, the

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300 Horridge, M. & Wittwer, G., 2008. SinoTERM, a multi-regional CGE model of China. *China Economic Review*, Elsevier, vol. 19(4), 628-634, December.

301 The analysis was limited to the years covered by the construction phase of the project

302 Calculated using data from the World Bank, showing that Chinese GDP rose from 40tn to 56tn Yuan over the period studied. The cash value estimated is based on multiplying these values by 0.007%

Scottish government for Scotland, Hermannssonn (2011)[303] for Northern Ireland and California Economic Strategy Panel (2009)[304] for the US state all suggest that passenger expenditure multipliers tend to be lower than the economy-wide average.

Within the existing literature, multipliers on additional inbound passenger spending (commonly referred to as tourism multipliers) are predominantly estimated using an input-output approach. As discussed in the introduction to this Appendix, this does not account for diffusion within the economy and leads to multiplier estimates which are gross rather than net. Examples of gross tourism multipliers estimated for the UK include Deloitte and Oxford Economics (2013)[305] who developed a bespoke macroeconomic model for 2008 and used this to estimate a tourism multiplier for the UK economy. The study estimated a gross multiplier of 1.8. Similar multipliers for the UK are found elsewhere. For example, Vellas (2011)[306], citing evidence from the World Travel & Tourism Council (WTTC), presents a figure of around 1.9 for the Type II multiplier, whilst the WTTC (2012)[307] themselves suggest that the UK figure could be in excess of 2.5. As these are gross estimates, they cannot be directly compared with the net estimates arising from the S-CGE analysis.

## *E.3. Productivity*

The productivity effect captures the econometrically-estimated relationship between increased connectivity and trade. This is then translated into the model as a productivity shock. The productivity shock is scaled to achieve a level of trade consistent with the passenger flows. For the purpose of calculating multipliers, the value of the input is the cash equivalent value of the productivity improvement which generates this level of trade. Table 108 shows that the multiplier impact of this input is between 0.49 and 0.75, demonstrating again that a sizeable share of the additional productivity gain is lost as it diffuses through the economy. The difference in the implied multipliers is driven by the substantial differences in the productivity impact of the schemes through the mechanisms described in Section E.1. As the size of the productivity input increases, it places greater pressure on the scarce resources employed in existing activity, leading to a lower multiplier.

The literature includes a wide range of examples of econometric or scenario-generated estimates of productivity changes being used as inputs to CGE and S-CGE modelling and the approach is commonplace. We have summarised a few such examples below. However, the methodology is typically applied within contexts quite different to the analysis in this study, often focused specifically on agricultural productivity and predominantly in developing countries. One would expect the underlying multipliers generated from S-CGE analysis to be very different when key factors such as geography and industry are different.  As a result, there is a limit to which the findings from the S-CGE analysis completed in this report can be directly compared with this literature.

One such example is Thurlow and van Seventer (2002)[308], who constructed a CGE model for South Africa using data from the International Food Policy Research Institute. One test which they performed on this model was the impact of a 1% increase in Total Factor Productivity (TFP), under different conditions. They found that the national impact of this was an increase in real GDP of between 0.5% and 1.3%, suggesting multiplier estimates which are similar to, or greater than, those emerging from the S-CGE modelling for this report. They also demonstrated how the impact differed by industry, ranging from 0.2% growth in government services to 3.1% growth in construction[309]. This highlights the degree to which the local economic and sector context will impact affect the magnitude of the GDP impact.

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[303] Hermannsson, K., Lisenkova, K., McGregor, P., & Swales, J. (2010). An HEI disaggreagated input-output table for Northern Ireland.

[304] California Economic Strategy Panel, 2011. *Using Multipliers to Measure Economic Impact.* Available at: <http://www.labor.ca.gov/panel/pdf/Using_Multipliers_to_Measure_Economic_Impacts.pdf>

[305] Visit Britain, Deloitte Oxford Economics (2013). *Tourism jobs and growth: The economic contribution of the tourism economy in the UK*, Available at: <www.VisitBritain.org>

[306] Vellas, F. (2011). The Indirect Impact of Tourism, Third Meeting of T20 Tourism Ministers Paris, 25 October, 2011.

[307] World Travel & Tourism Council (WTTC), 2012. *The Economic Impact of Travel and Tourism*. London: World Travel and Tourism Council.

[308] Thurlow, J. and van Seventer, D. (2002). *A Standard Computable General Equilibrium Model for South Africa*. Washington: IFPRI, Available at: < http://www.ifpri.org/sites/default/files/publications/tmdp100.pdf>

[309] Within the model run under which 'neoclassical constraints' were applied.

Hassine, Robichaud and Décaluwé (2009)[310] econometrically estimate a relationship between trade openness and productivity. They then run an S-CGE model twice to investigate the impact of removing tariffs. The first run takes no account of the productivity impact of the increased trade, and concludes that the net economic impact is negative. However, in a second run of the model they include the relationship estimated above within the model, and find that once productivity effects are appropriately accounted for that the net economic impact of the tariff reform is positive. This analysis is completed based on a model of the Tunisian economy, which again restricts direct comparison with the modelling in this report.

One example of an industry-specific productivity shock, which is an area more typically investigated within the literature, is provided in Wobst (2000)[311], again for the International Food Policy Research Institute. This model tested the impact of an increase in agricultural productivity in Tanzania, and again found the impact to be very material with real GDP in the agricultural sector rising by 4.9% in response to a 5% productivity increase.

## *E.4. Frequency benefits & transport economic efficiency*

The size of the multiplier on the frequency benefit input varies between 1.67 and 1.93 across the three schemes. This is consistently the highest multiplier for any of the effects, although the impact of this on the overall change in the level of GDP is moderate (with frequency benefits representing no more than 2% of all inputs in any of the schemes). The frequency benefit effect has a positive supply-side impact, as opposed to the increased construction or inbound passenger expenditure, which simply reflect an increase in demand. This supply-side shift increases the productive potential of the UK economy, leading to a more substantial increase in GDP. This leads to the additional economic activity generated through the frequency benefits having less of a negative impact on GDP through diffusion than seen in other effects, and subsequently a higher multiplier.

The transport economic efficiency (TEE) effect is comprised of two separate effects: an increase in consumer surplus and a reduction in producer surplus. The greater consumer surplus has the effect of increasing the effective wealth of households, enabling them to increase their saving and consumption in other areas of the economy. The multiplier on this effect is moderate and in line with other drivers, between 0.5 and 0.59 across the three schemes. In contrast, the reduction in producer surplus occurs through a removal of scarcity rents for airlines, as slots would otherwise become increasingly profitable as the airport system's capacity constraint becomes more binding. These scarcity rents are substantial, and hence the magnitude of the impact is large.

The removal of these scarcity rents, whilst important to the sector, would have relatively little impact on the national level of savings and investment compared to their size, and therefore does not have a material impact on UK productivity or GDP. We would expect this effect to have a lower multiplier, as the shareholders who experience the fall in profits are net savers, and the investment multiplier is smaller in magnitude than the consumption multiplier. As a result, the multiplier impact of this effect is substantially smaller than for other drivers which interact more directly with the real economy, ranging from just 0.07 to 0.15.

The impact of transport economic efficiency changes within a CGE model in this manner does not seem to appear in the literature, so we lack comparators against which to sense-check our multipliers.

## *E.5. Overall multiplier and output elasticities*

As discussed above, the overall multipliers for the combined inputs range from 0.64 to 0.84. These values reiterate the degree to which the S-CGE modelling has captured the 'net' impact, with a substantial amount of diffusion evident and overall multiplier values consistently below one. This is as expected, given the magnitude of the inputs and the likely supply-side constraints. These overall multipliers themselves have limited comparability with the existing literature, given the range of inputs and impacts which they entail.

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[310] Hassine, N., Robichaud, V. and Décaluwé, B. (2009). *Agricultural Trade Liberalization, Productivity Gain and Poverty Alleviation: A General Equlibrium Analysis.* Available at: < http://www.erf.org.eg/CMS/uploads/pdf/1254842008_16AC_INT_Belhaj_Veronique.pdf>

[311] Wobst, P. (2000). *Why the Poor Care About Partial Versus General Equilibrium Effects Part I: Methodology and Country Case*. Washington: IFPRI, Available at: < https://www.pep-net.org/sites/pep-net.org/files/typo3doc/pdf/recommended_readings/TDP_60_wobst.pdf>

An alternative method of evaluating the magnitude of the overall impacts is through considering the change in infrastructure which the additional airport capacity represents. Within the literature, the impact of additional infrastructure this is typically measured through output elasticities, which capture the relationship between the level of public infrastructure and economic output. Estimating the implied output elasticity for the increase in aviation capacity allows for a comparison between this, and previous airport investment.

The simplest method to estimating the magnitude of the change in aviation capacity is through the growth in passenger numbers which it leads to. Using the Assessment of Need scenario as an example, the additional capacity could increase passenger numbers by approximately 4-5% in each of the three schemes and lead to long-run increases in GDP in the region of 0.6-0.8%, suggesting an elasticity of roughly 0.15. A large body of literature exists investigating similar elasticities, from Aschauer (1989)[312] who estimated the impact of public infrastructure on total factor productivity to be 0.39, to more recent work by Bom and Ligthart (2009)[313] who place the estimate closer to 0.15. Literature on the topic has found a very wide range of estimates: Guild (1998)[314] summarised thirteen studies with estimates ranging from 0.07 to Aschauer's 0.39. Similarly, Bom and Ligthart (2009) report estimates from -0.175 to 0.917. Other similar studies and estimates exist, one of the more sophisticated studies has been conducted by Calderón et al. (2012)[315] which finds that the long-run elasticity of output with respect to the synthetic infrastructure index ranges between 0.07 and 0.10. These estimates are a useful guide as to the potential impacts of transport infrastructure investments - Calderón et al. seek to take account of private sector contributions Melo et al. are more focused on government investment. Given that each of the airport schemes considered in this study are funded using private sector capital (albeit supported by government funded surface access schemes).

When estimating the impact of the additional capacity it should be considered that the nature of the additional passengers could be very different to the current mix. The analysis presented in this report demonstrates the importance of long-haul passengers for generating trade (Section C.5.3), and inbound passengers for generating additional domestic expenditure. These passenger types, which have the greatest impact on GDP, are disproportionately highly represented in the additional passengers enabled by the expansion in capacity. In addition, the transformational nature of this investment on the UK economy at a time of substantial excess demand (demonstrated by the large TEE effect) suggests that the economic impact could be larger than typically seen. This view is reinforced by the multiplier analysis above, which suggests that the reason for the relatively large GDP increase is the impact of the additional capacity on the model inputs, rather than the modelling approach itself. As a result, we would expect an output elasticity to be greater than found in previous studies. This view is supported by Melo *et al.* (2013)[316] who look specifically at the impact of airport infrastructure on output. They find an average elasticity in 26 previous studies of just 0.027, although the standard deviation of 0.094 around this suggests substantial range.

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[312] Aschauer, D. (1989). "Is Public Expenditure Productive?". Journal of Monetary Economics.

[313] Bom, P. and J. Ligthart. (2009). "How productive is public capital? A meta-regression analysis". Andrew Young School International Studies Program Working Paper 09-12.

[314] Guild, R. (1998). *Infrastructure investment and regional development: theory and evidence*. Department of Planning Working Paper Series. Auckland, New Zealand: Department of Planning, University of Auckland.

[315] Calderón, C., Moral-Benito, E. and Servén, L. "*Is infrastructure capital productive? A dynamic heterogeneous approach"* Washington: The World Bank

[316] Melo, P., Graham, D. and Brage-Ardao, R. (2013). The productivity of transport infrastructure investment: A meta-analysis of empirical evidence. *Regional Science and Urban Economics*. 43(5) 695-706.

*Figure 177: LGW 2R Model input, GDP impact and multiplier, Assessment of Need scenario*

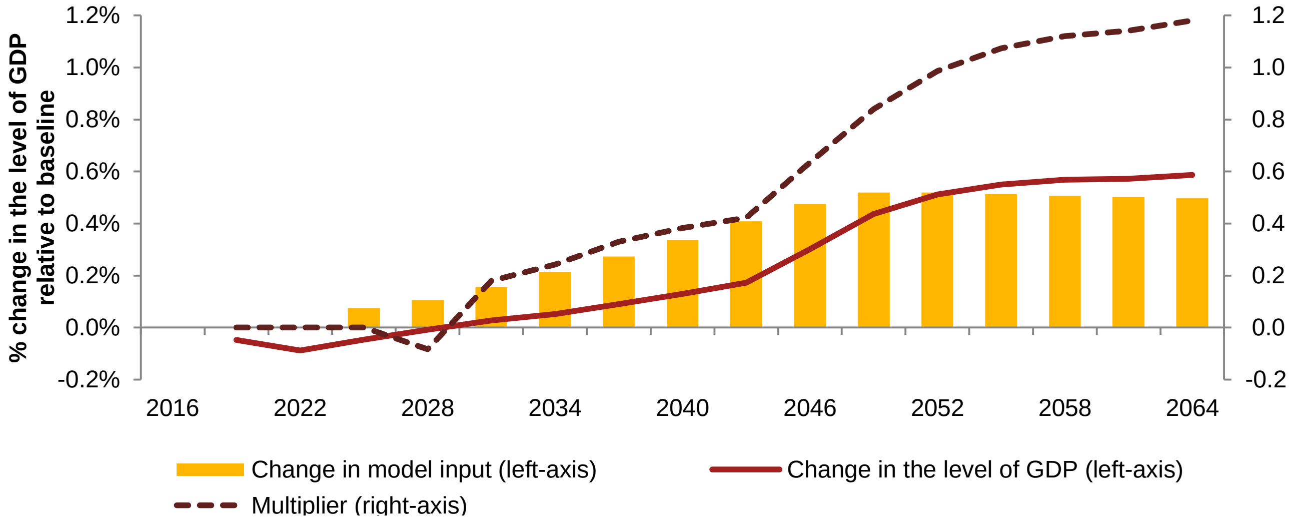


*Figure 178: LHR ENR Model input, GDP impact and multiplier, Assessment of Need scenario*

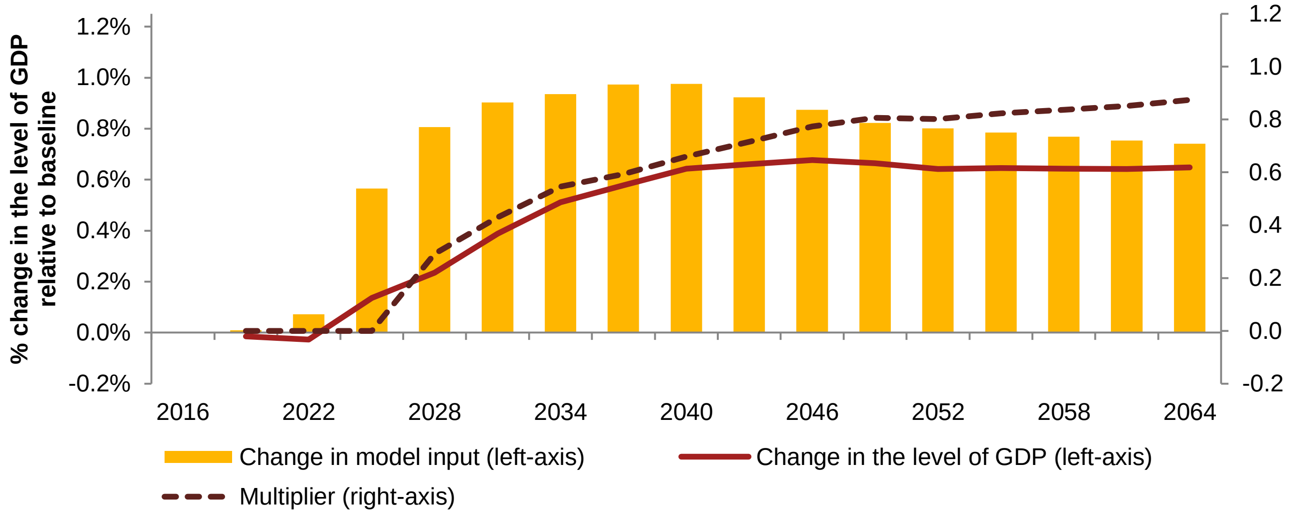


*Figure 179: LHR NWR Model input, GDP impact and multiplier, Assessment of Need scenario*