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FINAL

SPATIAL COMPUTABLE GENERAL EQUILIBRIUM MODELLING OF CAPACITY EXPANSION AT HEATHROW AIRPORT

Report Prepared for the Department for Transport

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Contents

EXECUTIVE SUMMARY

We model the effects of capacity expansion at Heathrow Airport on economic growth in the UK and its regions. To do this, we draw on data supplied by the Department for Transport (DfT) on the expenditures related to airport capacity expansion, and on its operational effects in terms of passenger movements to and from the UK. This data is then used in a Computable General Equilibrium (CGE) model of the UK, TERM-UK, developed by the Centre of Policy Studies, in Melbourne, Australia.

TERM-UK is a regionally disaggregated CGE model. It enables simulations of the effects of airport capacity expansion, versus a baseline case of no expansion. The model includes a detailed database capturing economic activity in the UK, including inter-regional linkages, and international linkages such as exports and imports. It also includes competitive product and factor market, including markets for labour, optimising behaviours of producers and households, and the government sector. The model is dynamic as it allows to simulate changes over time, by comparing projections under the expansion case to projections under the base case.

The model captures the effects of expenditures on capacity expansion, and the operational effects of increased passenger movements in and out of the UK. Projections regarding expenditures and passenger movements are developed “off-model” i.e. outside the CGE framework. In the case of passenger movements, projections are the result of simulations undertaken by DfT via its Aviation Modelling Suite.

Projected passenger movements are a key determinant of growth, through a variety of channels. First, through changes to spending by inbound visitors and outbound UK residents implied by the changes in passenger movements. Increased spending by inbound visitors can be characterised as an expansion of demand facing the domestic tourism industry; while spending by outbound passengers can be characterised as an increase in demand for tourism imports. Secondly a body of empirical evidence suggests that increased air connectivity, as captured by increases in air passenger numbers, can reduce trade costs between partners, notably by reducing transactions costs associated with the conclusion of contracts. Trade costs are measured in ad valorem terms, that are sector-specific. These ad valorem reductions are imposed on the UK’s external trade. Thirdly, changes to trade – both exports and imports – can induce further effects by increasing productivity, which positively to greater trade openness. We assume a conservative trade openness to productive elasticity of 0.3 i.e. a 1% increase in the sum of export and imports increases productivity by 0.3%

We modelled a core scenario, and three sensitivities. All of these include the same projections regarding expenditures, and passenger numbers supplied by DfT. The main differences are that:

1. The core scenario applies trade cost reductions to the UK's trade with all of its partners, and applies a productivity response as a result of greater trade openness.
2. As with (1) above, but the productivity response is removed.
3. We restrict trade cost reductions to the UK's non-European partners, while maintaining a productivity response to greater trade openness.
4. As above with (3), but the productivity response is removed.

Finally, we model a sensitivity as follows:

5. We use an alternative passenger movement projection supplied by DfT, which assumes a full pass through to passengers via the aero-charge of the costs of capacity expansion.

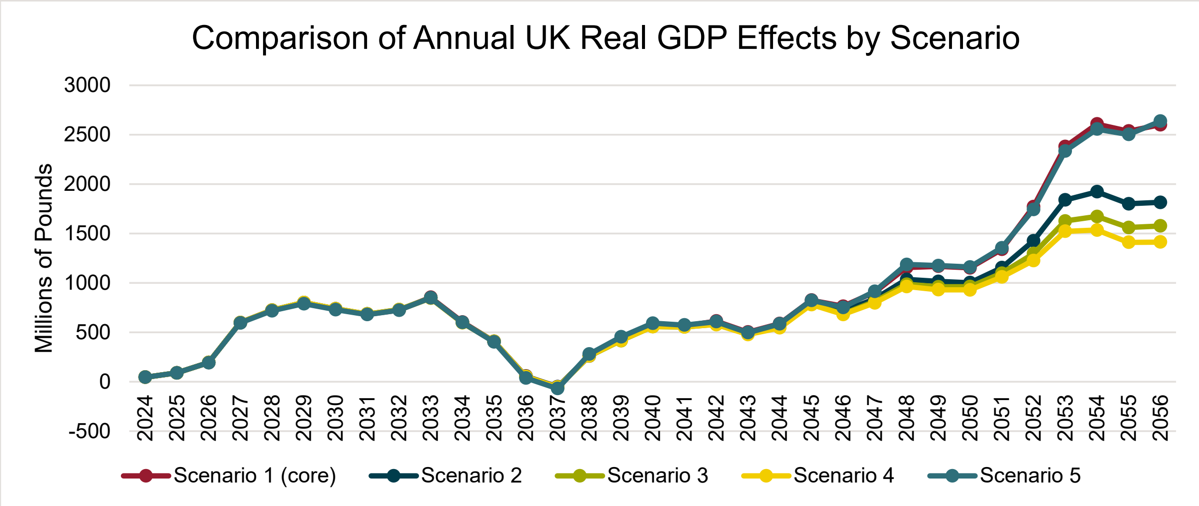
We report modelling results for the period 2024-2056.

Headline real GDP results for the UK are reported below for all five scenarios. We report the Net Present Value (NPV) of GDP increases over the modelling horizon, the monetary value of increased real GDP in 2056 relative to the 2056 baseline, and the percent increase in GDP in 2056 relative to the 2056 baseline (Table 1).

Table 1 GDP effects relative to baseline, all scenarios

Scenario	NPV real GDP increases over modelling period 2024-2056 (millions of pounds)	Increase in annual real GDP in 2056 relative to baseline (£m)	Increase in annual real GDP in 2056 relative to baseline (%)
Scenario 1 (Core)	14,521.8	2602.2	0.052
Scenario 2	13,069.7	1815.2	0.036
Scenario 3	12,536.2	1576.4	0.032
Scenario 4	12,254.6	1413.7	0.028
Scenario 5 (Alt pax forecast)	14,476.5	2637.9	0.053

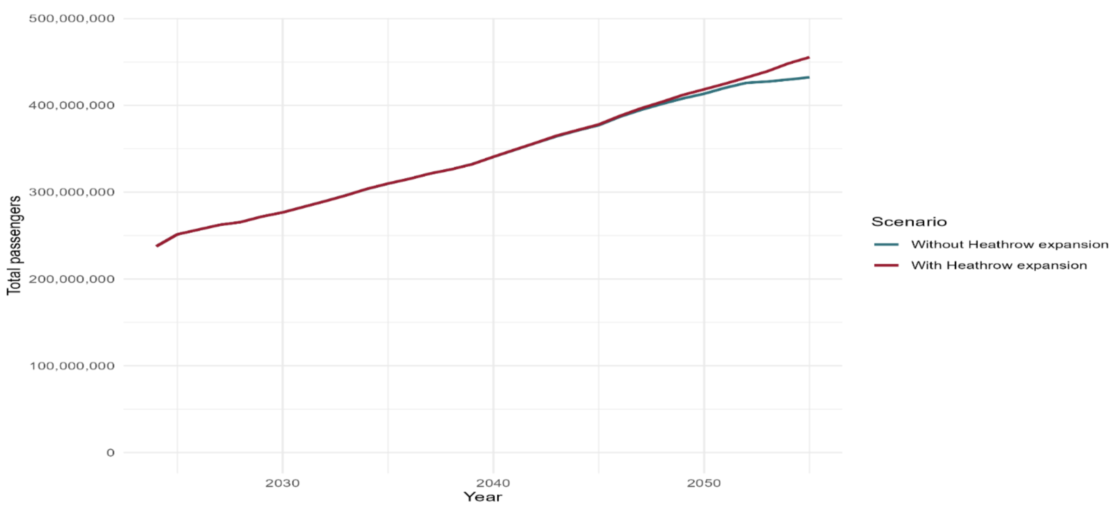
Figure 1 Comparison of Annual UK Real GDP Effects for all scenarios, 2024-2056



The growth effects are relatively modest. This is because passenger projections used as inputs into the modelling suggest limited net increases in direct passenger movements into and out of the UK until late in the modelling period. In the initial phase following capacity expansion, the DfT projections are of a nearly 1 to 1 displacement from other airports to Heathrow. DfT modelling is also predicated on a phased expansion in terminal capacity, meaning that even once a third runway is completed, passenger numbers remain constrained until the point increased terminal capacity is fully delivered, assumed to be in the 2050s.

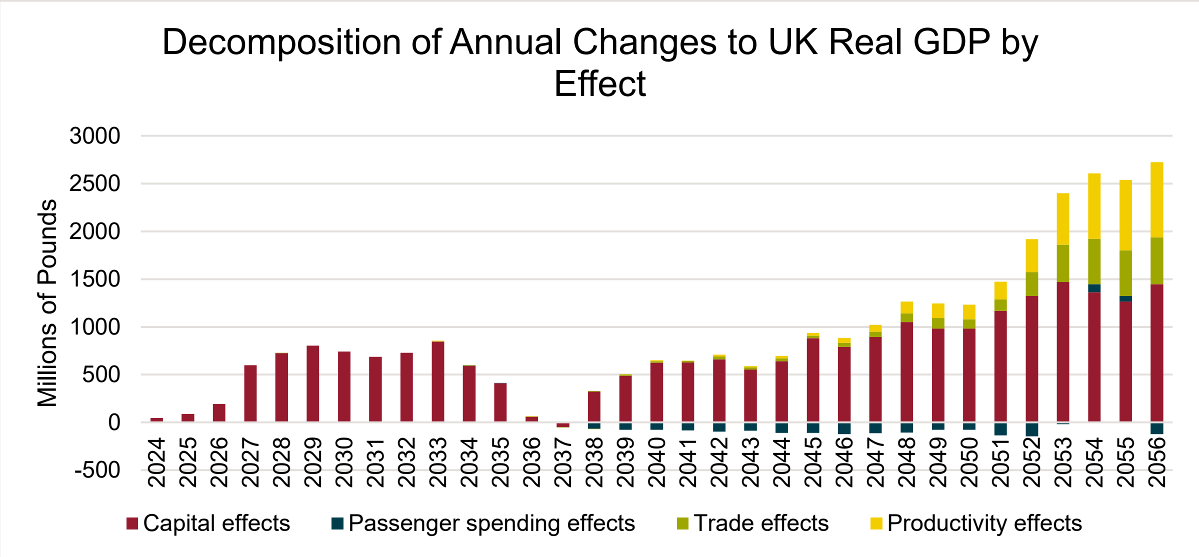
Passenger trends are reported in Figure 2 below (for direct passengers into and out of the UK). The increases relative to the baseline drive passenger spending effects, as well as trade and trade-induced productivity effects.

Figure 2 DfT Passenger projections for the UK, baseline versus expansion case



Given limited passenger uplifts, the primary driver of GDP growth effects is capital expenditure, which is a constant across all scenarios. Within a neoclassical framework, investment increases the stock of capital, which in turn increases growth (subject to crowding out effects). The relative weight of different contributors of growth effects is brought out by Figure 3 below, which reports results for the core scenario (scenario 1). The relative contributions do not differ significantly across scenarios.

Figure 3 Contributions to changes in Real GDP, 2024-2056



In the first instance, between 2027-2037 capital effects are dominated by runway expansion effects. In the operational period (post 2038), expenditures in other sectors, specifically in the London area, that are induced by spending on airport expansion (including operational expenditure) play a more important role.

In line with the passenger number projections, operational effects are limited. Passenger spending effects tend to be net negative in terms of GDP contributions as outbound spending by UK residents travelling abroad typically exceeds spending by in-bound visitors. Trade effects are modest, since the limited passenger uplift implies limited effects on reducing ad valorem trade costs, but are positive. Even though changes to imports are greater than to exports, the contribution to real GDP is positive since lower trade costs reduce the price of imports. Productivity uplifts, which are driven by the increases to exports and imports, are slightly bigger than the contribution to GDP of the trade effects themselves (which include a leakage effect associated with increased imports).

Table 2 reports GDP effects by region in 2056, for all scenarios.

Table 2 GDP effects relative to baseline, all scenarios, all regions, in 2056

Region	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)	Scenario 4 (%)	Scenario 5 (%)
NORTH EAST	0.03	0.01	0.00	0.00	0.03
NORTH WEST	0.03	0.01	0.01	0.00	0.03
YORKSHIRE	0.03	0.02	0.01	0.01	0.03
EAST MIDLANDS	0.02	0.01	0.00	0.00	0.02
WEST MIDLANDS	0.03	0.01	0.00	0.00	0.03
EAST	0.03	0.02	0.01	0.01	0.03
LONDON	0.19	0.17	0.17	0.17	0.19
SOUTH EAST	0.04	0.02	0.02	0.01	0.04
SOUTH WEST	0.04	0.02	0.02	0.01	0.04
WALES	0.04	0.02	0.02	0.01	0.04
SCOTLAND	0.03	0.01	0.01	0.01	0.03
N.IRELAND	0.02	0.01	0.00	0.00	0.02

Under the core scenario, all regions experience some uplift, though in line with the overall results, these are very modest. The results should be interpreted as increases relative to baseline GDP for that region in 2056. London experiences the biggest percentage uplift, and accounts for close to half the increase observed in real UK GDP in 2056.

Overall, the modelling suggests that under conservative assumptions relating to increases in passenger numbers, airport capacity expansion generates a small but positive effect on growth for the UK as a whole and across regions. It is important to emphasise that, consistent with the CGE framework, these are simulations, not forecasts. The simulations also help to identify how outcomes could change as a result of variations to key underlying projections, notably in relation to passenger numbers.

1 Introduction

1.1 Context and objectives

The Department for Transport (DfT) has commissioned Frontier Economics to model the economic effects of airport capacity expansion at London's Heathrow Airport on the UK and its regions. Specifically, we model the effects of adding a third runway to Heathrow Airport. We do this using a Computable General Equilibrium (CGE) model of the UK economy.

The context for this work is the announcement by the Transport Secretary, in October 2025, of a review of the Airports National Policy Statement (ANPS), and the intention to consult on a revised ANPS and supporting documents by July 2026. That process is set against the broader backdrop of the Government's commitment to support expansion at Heathrow Airport, subject to four tests': 1) that it would support economic growth across the country, and that expansion can be compatible with obligations relating to 2) climate change, 3) air quality, and 4) noise.

The focus of this report is on the first of these four tests i.e. on economic growth. CGE modelling can capture whole of economy and spatial – specifically, regional – effects of airport expansion. It does so by drawing on data on the expenditures associated with airport capacity expansion, and data on project changes to air traffic and passenger movements. Such data are provided by DfT; they are inputs and not generated by the CGE model itself. The data are then integrated into the model's broader database and computational structure, that represents the operation of the UK economy and of its regions. In such a way, the growth path of the UK economy can be simulated with and without the project over a specified modelling period.

In this case the modelling period is from 2024 to 2056. CGE modelling is thus best thought of as a counterfactual exercise: we estimate the effects of "what-if" scenarios, where the key parameters of the scenarios (in this case, expenditures associated with capacity expansion, and the operational effects of capacity expansion in terms of air traffic and passenger movements) are developed "off-model".

In this report we describe the CGE model and approach undertaken, the projections and inputs provided by DfT, the scenarios modelled, and the reported effects. The report is therefore structured as follows:

- Section 2 provides a description of the CGE model and the modelling approach.
- Section 3 reports the modelling inputs provided by DfT through its Aviation Modelling Suite.
- Section 4 described the modelling scenarios and reports results.
- Annex A reports the results of a "dummy run" in which project-related expenditures are not included.

- Annex B provides technical detail regarding TERM-UK and its calibration for this modelling exercise.
- Annex C provides more detail on our approach to estimating the connectivity effects.
- Annex D describes our approach to using OAG data to apportion DfT aviation projections for the purposes of calculating ad valorem trade effects.
- Annex E describes our approach to quality assurance and the management of conflicts of interest.

2 Description of the CGE model and modelling approach

2.1 UK-TERM: A dynamic, spatial CGE model

For the purposes of modelling capacity expansion at London Heathrow Airport, we have used a Spatial Computable General Equilibrium Model (SCGE) developed by the Centre of Policy Studies, in Melbourne, Australia. The model, known as TERM[1], was first developed in Australia to simulate the national and regional effects of economic policy reforms and interventions.[2] TERM models have been used for scenario analysis in Australia since the first application to the drought of 2002. Since then, TERM models have been applied to numerous studies in Australia and in other countries, including USA, Brazil, Indonesia, China, Canada, and Europe. TERM-UK is the version of the model that applies to the UK. It is calibrated to the specificities of the UK, in particular by using ONS data to populate its underlying data base.

TERM-UK is a multi-regional CGE model of the UK economy. The master database includes 107 industries in 361 Local Authority regions. Data is obtained from the 2023 ONS input-output tables.[3] This provides considerable sectoral detail at a small region level. In practice, sectors and regions of little direct interest in a particular project are aggregated up. We retain detail in sectors and regions of interest in a particular scenario. In this case, the master database is aggregated to 25 sectors, and 12 regions. The process of calibrating the database is described in more detail in section 3.

Instead of a commodity being produced by a single national industry as in a single region CGE model, in TERM-UK the commodity is produced by an industry in each region. Instead of having just two varieties of each commodity (domestic and imported), TERM-UK has a variety from each region within the model plus imports. Instead of having a single household, TERM-UK has a household in each region. Government spending is also depicted in each region.

Regions in the UK are specified as separate economies, linked by trade. TERM-UK imposes fixed exchange rates and free trade within the UK between regions. The degree of inter-regional factor mobility assumed in TERM-UK is much higher than the degree of international mobility normally assumed in multi-country models. Regions also trade with the rest of the world. They are subject to the UK's external tariff, which is common to all regions.

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[1] For The Enormous Regional Model

[2] Dixon, P. and Rimmer. M. (2002), Dynamic General Equilibrium Modelling for Forecasting and Policy: A Practical Guide and Documentation of MONASH, Emerald Group Publishing Ltd. doi.org/10.1108/S0573-8555(2001)256

[3] Downloadable from https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesdetailed

TERM-UK operates to neoclassical principles. Markets are competitive and industries are characterised by constant returns to scale.[4] The labour force grows in line with projected population growth. Full employment is assumed, though real wage rigidities mean labour markets clear with a lag. Government consumption and investment are financed from domestic savings and/or external sources. In the case of large infrastructure projects, the choice of financing will typically have different macro-economic effects: recourse to domestic sources would require a reallocation of savings from other uses; external borrowing can lead to real-exchange appreciation that crowds out exports. In the figure above, negative effects in the early years reflect net crowding out effects in the capital expenditure phase

More detailed information on the structure of TERM and its functioning can be found in Annex B.

2.2 Model Structure

2.2.1 The production side – industries, investment and technologies

Each industry in TERM-UK selects inputs of labour, capital and materials to minimise the costs of producing its output. There is competition for labour and capital between industries. That competition implies crowding out effects: if the profitability of an industry rises because activity is expanding, resources will tend to reallocate to the industry concerned and away from less profitable (non-expanding).

The levels of industry output are chosen to satisfy demands and demands reflect prices and incomes. The final users in the model include investment, households, government and exports.

Investment in each industry reflects rates of return and capital stock levels reflect past investments and depreciation. If an industry earns an above economy-wide average rate of return on capital, this will induce a percentage increase in investment above that of the economy-wide percentage change.

TERM-UK contains variables describing primary-factor and intermediate-input-saving technical change in current production and input-saving technical change in capital creation. Technology shocks are imposed in the baseline. To accommodate forecast GDP, an economy-wide technology change as explained above is endogenous. At the sectoral level, technological change is services is typically slower than in manufacturing or agriculture. This reflects limited scope for labour saving in many services relative to non-service sectors. Therefore, it is appropriate to impose industry-specific technology shocks in the baseline that reflect historical differences in services productivity growth relative to non-services. In the context of a scenario such as an airport upgrade, estimates of capacity increases arising from

[4] TERM has the option of allowing increasing returns to be specified for industries if required but this was not used in the course of the current modelling exercise.

the upgrade could be imposed on the policy run as output increases. To enable outputs to be targets, an industry-specific (i.e., air transport) technology shock would be endogenous.

Investment faces a borrowing constraint. Thus, we assume that the Heathrow expansion is partly funded from sources within the UK. That funding from domestic savings requires an increase in domestic saving or a reduction in consumption. Thus in our modelling, in each year the new Heathrow investments are accompanied by reductions in consumption spending sufficient to increase domestic saving by the necessary amount.

2.2.2 Demand side – households and government

A representative household per region buys bundles of goods to maximize a utility function subject to an expenditure constraint. The bundles are combinations of imported and domestic goods. Households have a budget constraint based on available nominal income. Household consumption is determined by relative prices and nominal income subject to a budget constraint. Current expenditure by the representative household is thus explained by a relatively simple function that links nominal consumption to nominal household disposable income (HDI) via a coefficient of proportionality – the Average Propensity to Consume (APC). Household disposable income is defined as labour income plus income from capital and land that accrues to the local population less taxes on individuals. The default assumption is that household consumption shares are set equal to each region’s share of national aggregate income. Some commodities are assumed non-tradable between regions. These local sectors include all utilities other than electricity, ownership of dwellings, health, residential care, sport & recreational services and domestic household services. Household consumption shares for local sectors are set equal to industry activity shares. All government consumption shares are set equal to household consumption shares

The national CGE database also includes model parameters. These include household expenditure elasticities, Constant Elasticity of Substitution (CES) parameters covering domestic-import and, for the multi-regional model, domestic-domestic substitution, and substitution between primary factors in each industry. Household expenditure elasticities are less than one for food items and more than one for services. Air transport and ownership of dwelling usually have the highest expenditure elasticities.

The national government demands commodities for consumption. We expect government expenditures to be determined in part by social objectives. There are several ways of handling these government demands, including:

- by a rule such as moving government expenditures with aggregate household expenditure, domestic absorption or GDP;
- as an instrument to accommodate an exogenously determined target such as a required level of government budget deficit; and

- exogenous determination.

For the baseline simulations, we have adopted the first rule, with government and household consumption moving together. For policy simulations, we used the second rule so that government consumption adjusts endogenously to maintain the fiscal balance at its baseline level. TERM-UK does not include government accounts. It includes government spending and indirect taxes, but these taxes are only a subset of the revenues collected by government.

2.2.3 Labour markets

TERM assumes full employment, with some stickiness in real wages. The latter property means that employment deviates temporarily from full employment in the short term but this is eliminated as real wages adjust. Long term employment growth is thus driven by population growth, via a labour force participation rate that is left unchanged under the modelling runs.

TERM's regional structure requires specific attention to regional dynamics. In the theory of regional labour market adjustment, if regional labour market conditions improve or deteriorate relative to forecast, adjustment occurs in the short term (the first two or so years of a construction phase) mainly via changes in employment. Regional wages adjust sluggishly, with gradual adjustment in regional labour market supply (i.e., through migration between regions). Rising real wages in later years of construction choke off additional jobs, closing the gap between employment and slowly adjusting labour supply. Once the deviation in employment is equal to the deviation in labour supply, real wages reach a turning point or flatten.

Within this theory, adjustment in the longer term occurs via a combination of altered regional labour supply and real wages that deviate relative to those in other regions. In the modelled example shown here, all adjustment in the long term at the regional level is via real wages relative to base. Real wages remain above base in this example due to productivity improvements arising from the construction project, without a long term regional employment increase. This is not always so: regional employment may increase in the long run relative to base. National employment, however, returns to base in the long run. Long-run national employment is determined by demography over time, not the individual scenario.

2.2.4 Trade and balance of payments

TERM-UK is a single country model; that is, sectors and regions trade with the rest of the world, whose demand for UK exports is represented by export demand curves. Exports face down-sloping export demand curves. Export demand elasticities are usually set at -4. Thus, a shock that reduces the unit costs or trade costs of an export sector will increase the quantity exported, but reduce the foreign-currency price. By assuming that foreign demand schedules are specific to product, the model allows for differential movements in foreign-currency prices across exported products.

In the context of this modelling exercise, trade cost reductions may apply differentially across countries. To reflect this within the single country model, we weight the trade cost reductions by the shares of those regions in UK trade for the sector concerned, thus giving a proportionately greater weight to regions that trade more intensively with the UK.

Treatment of tourism sectors and trade

Demand for tourism exports and imports is of specific importance to this modelling exercise, as they capture the effects of changes to visitor spending associated with projected visitor spending under the baseline and simulation cases. We create "dummy" tourism sectors to capture both imports and exports. This is done by shifting proportions of household expenditures within the CGE database concerning accommodation, travel and other services are moved to the tourism sector. Similarly, export tourism sales are moved from the export column to inputs into a tourism exports sector, which is exclusively for export. UK tourism elsewhere is depicted in tourism imports sector. Tourism imports and domestic tourism are substitutable in household demands.

Outbound spending by UK residents adds to tourism imports; spending by inbound visitors add to tourism exports.

The methodology for estimating the effects of airport capacity expansion on tourism trade differs that applied to trade more generally. We explain this in greater detail in section 3.3.1.

2.2.5 Balance of payments and exchange rates

The UK economy faces constraints on the availability of foreign currency. This means that the real exchange rate changes depending on net changes to exports and imports, and changes to inflows. For example, increased foreign visitor (i.e. tourism exports) cause the (real) exchange rate to appreciate. Real appreciation reduces, all else being equal, the foreign competitiveness of other UK's traded-goods and services sectors leading to a loss of exports and increased import penetration on local markets. On the other-hand, domestic residents choosing to travel overseas rather than travel in the UK leads to increased imports and hence downward pressure on the real exchange rate. This tends to crowd in traded-goods sectors. Some of these initial effects can be overturned by further effects. For example, if increased connectivity reduces trade costs, these may in turn offset or overwhelm the effects of the initial real exchange rate appreciation and increase exports in non-tourism sectors.

Similar considerations apply to inflows and outflows of capital. Thus, we assume that part of runway expansion is financed by inflows of foreign capital. Such inflows require the purchase of pounds, which in turn leads to an appreciation of the real exchange rate, all else being equal. That in turn can reduce the competitiveness ("crowd-out") exports.

2.3 Approach to modelling

CGE modelling is a counterfactual exercise. In the context of airport capacity expansion, it compares the trajectory of an economy over time with the specified increase in airport capacity (the expansion case), with a counterfactual trajectory in which the expansion has not taken place (the baseline). The baseline is not a static state of affairs: it is a representation of the expected growth path of the UK that reflects standard drivers of economic growth (capital, the labour force and technological change) and that captures domestic sectoral interactions and external interactions between the UK and the rest of the world.

Modelling thus involves, in the first instance, projecting the trajectory of the economy over the specified time horizon in the absence of the intervention. In this case we use official data to capture key macroeconomic variables, demographic variables, unemployment and labour force participation, the terms of trade and trade variables, including exports and imports of tourism (see Annex B). We also capture data specific to the intervention under examination: capital expenditure and operational expenditure in the baseline (without capacity expansion) and flight movements and passenger numbers for the UK absent capacity expansion.

Capacity expansion scenarios are imposed onto this baseline. The specification of capacity expansion scenarios relative to the baseline depends on inputs developed “off-model”. These are:

- Profiles for capital and operational expenditures required for expanding, operating and maintaining airport capacity through an added runway.
- Profiles for the flight movements and passenger numbers as a result of capacity expansions.

In the case of changes to passenger numbers and flight movements, economy-wide modelling requires that the numbers used are at the national level. This is turn means that we need to take into account any substitution between other airports and Heathrow airport, and specifically the extent to which they may be diversion between airports. These nationwide projections were generated by DfT through its Aviation Modelling Suite and supplied as inputs into the modelling.

These projected changes to flight movements and passenger numbers supplied represent the direct operational effects of airport capacity expansion. The economic impacts that stem from these can potentially occur through a variety of channels. We explore the following mechanisms:

- Changes to spending by inbound passengers (visitors) to the UK and by outbound passengers (UK residents) travelling to foreign destinations. The spending decisions are derived from changes to nationwide passenger numbers.
- Changes to trade costs that result from increased connectivity between the UK and the EU. These can result to changes in UK exports and import, which in turn have direct

effects on economic activity. They may also induce further changes through shifts in productivity as a result of changes to trade openness (exports plus imports divided by GDP).

It follows from the above that the key steps in modelling expansion scenarios concern the treatment of spending associated with airport capacity expansion; estimated changes to passenger numbers and associated changes to inbound and outbound spending; estimated effects of changes to connectivity and trade costs, and any further effects of changes on trade to productivity.

As already observed, economic activity in TERM operates according to a set of rules that reflect the operation of a competitive economy. In particular, profit maximising sectors compete for labour and capital. Firms minimise costs, while household expenditures respond to a budget constraint. Governments also respect a budget constraint, and there is also a constraint on the availability of foreign exchange. These different rules mean that any shock – whether to capital expenditure under the construction phase, or via the operational effects – involve a mix of crowding out and crowding in effects. Overall economic impacts reflect the mix between the two. The inclusion of crowding out and crowding in effects is one of the distinctive features of CGE models, and one that differentiates these models from simpler Input-Output models.

3 Inputs into modelling Scenarios

As already observed, key inputs into scenario modelling are derived from off model sources. In this case, DfT supplied profiles for capital and operational expenditures obtained from Heathrow Airport Limited for respectively, the baseline / no expansion case, and the expansion case. DfT also supplied projections for passenger numbers and air traffic movements. These were the results of simulations undertaken by DfT using its internal Aviation Modelling Suite.

3.1 Spending on airport capacity expansion

Details of expenditures on airport capacity under the baseline and expansion cases have been redacted for reasons of commercial sensitivity. In practical modelling terms, the capital expenditures are accommodated within the London region's air transport services sector, in both the baseline and the expansion case. The expansion scenario modelling captures the effects of the difference between expenditures under the expansion case and the baseline case. In computational terms, the model captures the effects of an expenditure shock in the London region. The effects of the shock to that region are then mediated through the linkages, both sectoral and regional, that are captured in the model.

Figure 4 Capacity expenditures, difference between expansion and baseline, millions of pounds, 2024 unindexed.

[Redacted]

An important question concerns the financing of the modelling. We have assumed that the financing is split evenly between foreign and domestic private sources. The TERM model does not distinguish between sources of finance (e.g. equity versus debt).

3.2 Passenger numbers and spending

3.2.1 Passenger numbers

DFT's Aviation Modelling Suite reports passenger numbers by year and by major region of destination and origin, and by passenger type. We report the results supplied by DfT in **Figure 5** and **Figure 6** below.

Figure 5 Total passenger numbers UK with and without Heathrow Capacity expansion

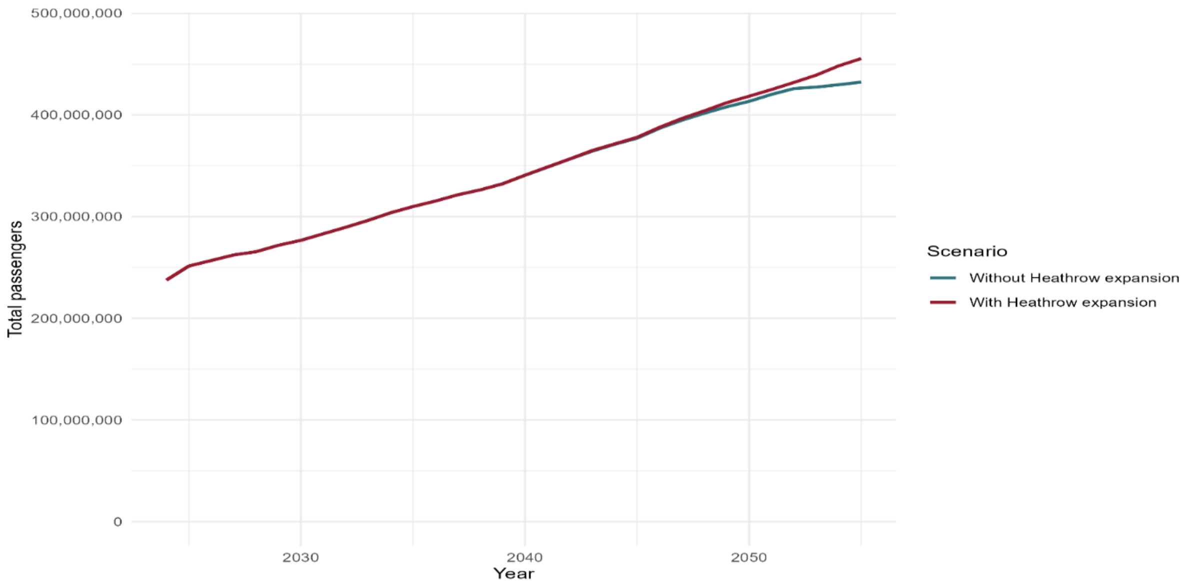
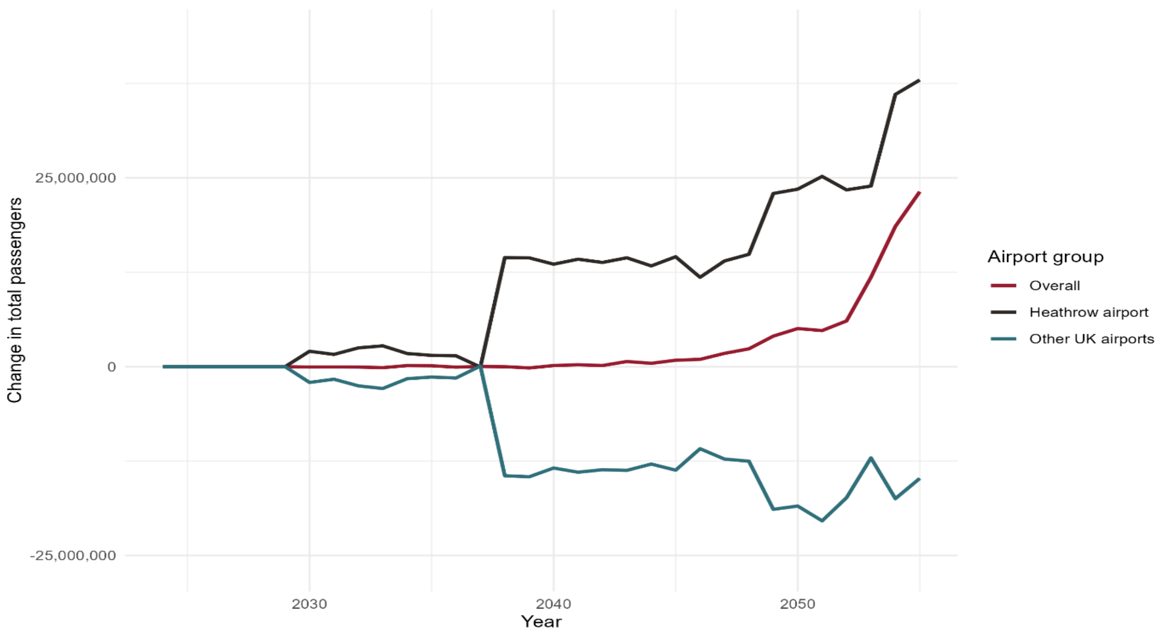


Figure 5 and **Figure 6** report changes to total passenger numbers in the UK. Extra capacity at Heathrow Airport following runway expansion is assumed to become operational by around 2038. However, there is no material change to passenger numbers across the UK as a whole, relative to the baseline, until the start of the 2050s. The reason for this is brought out in **Figure 6**, which reports the DfT Modelling Suite's projections for changes to passenger numbers relative to the baseline for, respectively, Heathrow and all other UK airports.

Figure 6 Changes to passenger numbers at Heathrow and other UK airports



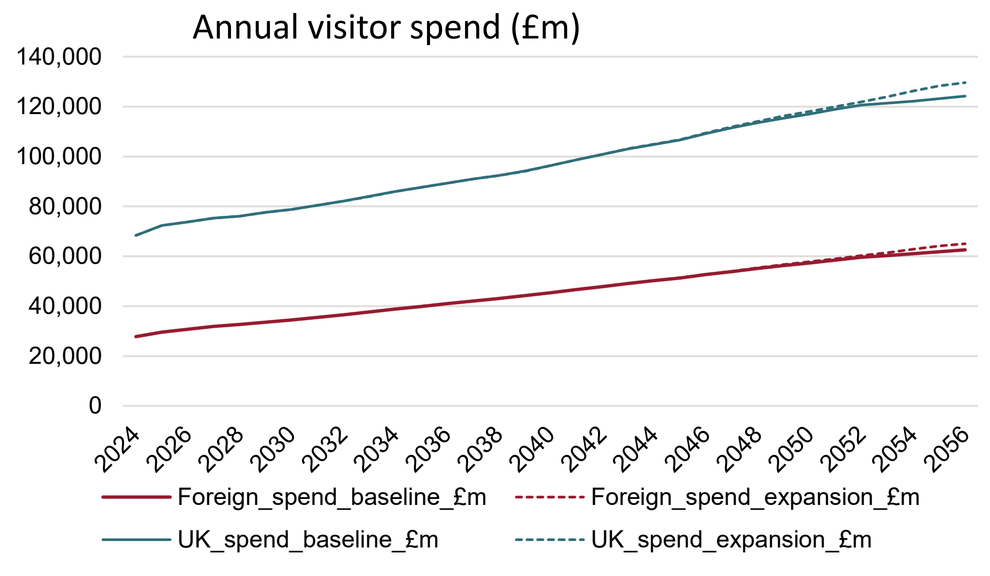
The projections assume that added capacity does not become fully operational until the 2050s, as even after an additional runway has been completed, passenger numbers are assumed to be constrained by the phased delivery of terminal capacity. Moreover, the increase in passenger movements from Heathrow is essentially matched by a decrease in movements through other UK airports. It is only in the 2050s that the increase in passenger movements through Heathrow materially outstrips the decline in movements through other airports.[5] As observed in the following sections, these specific trends are key determinants of impacts measured by headline indicators.

3.2.2 Spending by in-bound and out-bound passengers

These passenger movements are then converted into passenger spending using ONS data on spending by passenger destination, origin and type. As this data are for one year (2024), applying the data in this manner necessarily implies an assumption that spending patterns will remain constant over time.

Figure 7 reports annual spending by UK residents and foreign visitors under, respectively, the baseline and expansion cases. We distinguish between UK residents and foreign visitors as this distinction has an important bearing on the overall effects of airport capacity expansion. UK residents spending overseas reflects the consumption abroad (imports) of tourism and related services. Foreign spending in the UK reflects consumption by overseas residents of tourism and related services in the UK (i.e. exports by the UK).

Figure 7 Annual visitor spending under baseline and expansion scenarios.

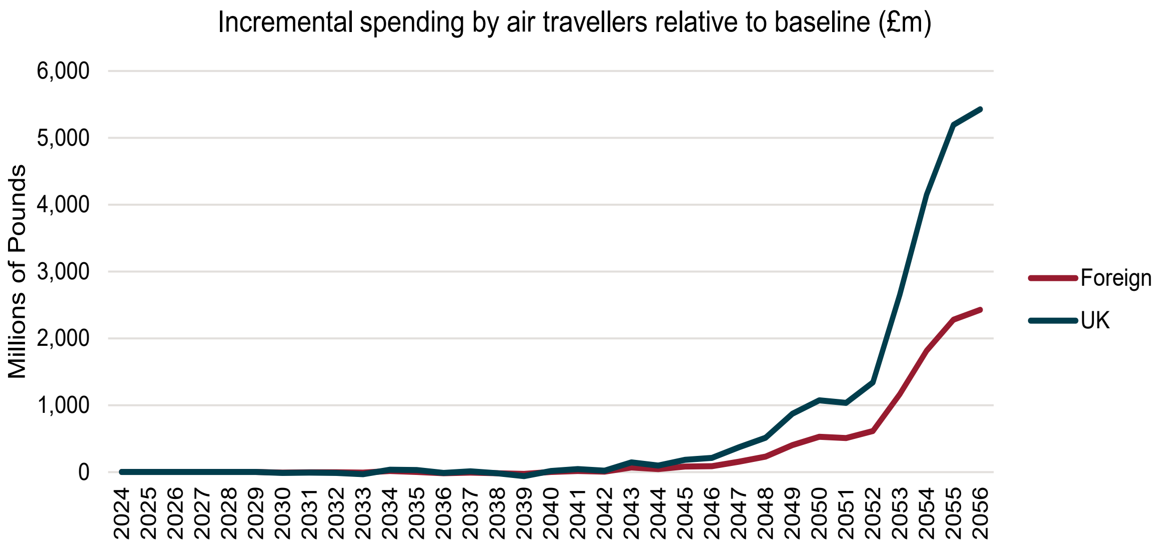


5 Prior to the extra capacity becoming fully operational, there is an increase in passenger movements at Heathrow as restrictions on the use of existing capacity, which have been placed pending authorisation for future capacity expansion, are relaxed. The increase in movements through Heathrow is matched by a reduction in movements through other airports.

Figure 8 reports the difference between expansion and baseline spending by UK residents and foreign visitors. The difference is the factor that contributes to the modelled outcomes of capacity expansion. We observe that:

- Effects of capacity expansion on increased passenger movements are mainly visible from the late 2040s.
- The effects of capacity expansion are more pronounced for the outbound travel of UK residents than they are for the inbound travel of foreign visitors; and that outbound spending is several times the magnitude of inbound spending under both baseline and expansion cases.

Figure 8 Annual visitor spending: difference between baseline and expansion scenarios, millions of pounds.



Visitor spending is accommodated in the dummy tourism sectors that have been developed in TERM (see also Annex B). We say “dummy” as these have been constructed on the basis of national accounts data. These sectors capture the effects of inbound visitor spending and foreign visitor spending. The effects of changes to spending are then mediated through the model structure.

3.3 Trade cost effects

3.3.1 Deriving ad valorem effects from changes to passenger numbers

As part of this project, Frontier undertook bespoke research into the links between airport capacity, connectivity are trade costs. The findings from this work are in a separate report.[6] We summarise the key findings in this section. More background is provided in Annex C

A body of empirical research finds that improved connectivity reduces trade costs through a variety of channels. The one we focus on in the role of passenger movements in reducing transactions costs associated with international trade in goods and services. This "trade facilitating effect" reflects the extent to which face-to-face contracts enable the conclusion of contracts by addressing problems relating to incomplete or asymmetric information.

In our approach, we draw on the trade-connectivity effects estimated by Wang et al (2025).[7] The authors find a positive effect of air connectivity on trade, with greater effects on sectors that are more 'contract-intensive'. Specifically, a 1% increase in passenger flows leads to a 0.031% expansion in trade for industries with average contract-intensity, rising by 0.011% per standard deviation change in contract intensity. So an industry with +1 standard deviation in contract intensity has an expansion in trade of 0.042% per 1% increase in passenger flows, while an industry with -1 standard deviation in contract intensity has an expansion in trade of 0.020% per 1% increase in passenger flows.

The sectoral estimates of contact intensity are recreated using the data published alongside Nunn (2007),[8] which in turn are used in the Wang et al paper. The data are reported at detailed NAICS code level for 222 different industries. The proposed measure of contract intensity is the share of inputs that are not exchange-traded or reference-priced. (mean 0.49, standard deviation 0.22). For the purposes of integrating into the TERM model, these NAICS codes are manually mapped to sectors in the database of the Global Trade Analysis Project (GTAP) CGE model, to create averages for UK imports and exports (weighted in line with UK trade flows reported in the Nunn file).

Table 3 Derivation of sector-level connectivity-trade parameters

1) Sector	Contract intensity		Connectivity-trade parameter	
	Exports	*Imports*	*Exports*	*Imports*
Agriculture, forestry, fish	28.9%	35.1%	0.021	0.024
Mining	21.2%	25.6%	0.017	0.020

[6] Frontier Economics (2026), Estimating the wider effects of air connectivity: assessing the evidence and proposed approach for CGE modelling

[7] Wang, F., Wang, Z. and Zhou, Z. (2025): All Roads Lead to Rome: Global Air Connectivity and Bilateral Trade, SSRN and American Economic Journal: Applied Economics (forthcoming).

[8] "Relationship-Specificity, Incomplete Contracts, and the Pattern of Trade"

Food and Drink	46.8%	35.4%	0.030	0.024
Textile, clothing, footwear	56.1%	58.7%	0.035	0.036
Wood and paper	42.6%	43.0%	0.028	0.028
Other manufacturing	67.3%	64.6%	0.040	0.039
Petrol and coal	6.9%	6.3%	0.010	0.010
Chemical and pharmaceutical	37.6%	33.3%	0.026	0.023
Transport equipment	87.5%	87.3%	0.050	0.050
Utilities	28.5%	28.5%	0.021	0.021
Services sectors[9]			0.042	0.042

Source: Frontier analysis of Nunn and GTAP data

Passenger increments

DfT aviation modelling suite (AMS) outputs are used to compare passenger numbers under baseline and expansion scenarios. Passenger numbers are summarised by partner zone and year and reported as percentage increments against the baseline. The passenger numbers are adjusted using OAG data (see annex D) to take into account onward destinations of transfer passengers for hub airports that are not explicitly modelled in the AMS. This reflects the notion that for trade facilitation purposes, the relevant connectivity is between the UK and the ultimate destination, not the intermediate hub. We also exclude from this calculus international-international passengers, as these are not likely to be relevant to the calculation of trade costs affecting the UK:

For each sector-pair, the connectivity-trade parameters are used to convert the passenger increment on that pair into a percentage change in trade for that sector. The percentage changes in trade are converted into ad valorem equivalent changes in trade costs using the formula:

$$AVE_{is} = \exp(\log(\beta_s dpax_i + 1)/\delta)-1$$

where $dpax_i$ is the percentage change in passengers on route i, β_s is the trade-connectivity parameter for sector s, and δ is the trade elasticity (assumed to be -4).

For each sector, a weighted average of the AVE is taken across partner zones in line with trade shares. This is done using GTAP data for 2023. This is done separately for imports and exports. Finally, a simple average is taken across imports and exports. This assumes that the trade effect is the AVE effect is the same regardless of direction; i.e. increased in-person communication affects importing and exporting similarly.

[9] Services sectors are assumed to have a +1 standard deviation contract intensity, and hence a connectivity-trade parameter of 0.042. This is applied to the following sectors: construction, trade, other transport, other services, owner dwelling, govt admin and defence, education, health. For air travel and related sectors (air transport, hotels, cafes, travel and tourism, holiday, foreign holiday, export tourism), so as to avoid double counting, a connectivity-trade parameter of zero is assumed.

This results in the following sets of AVEs for the year 2056, the modelled year for which the connectivity effects are greatest (**Table 4**). We report two different sets of calculations, respectively including and excluding connections to Europe. AVE's with European Connectivity are considerably larger than without, as the bulk of additional capacity under the expansion scenario is on European routes.

Table 4 Ad Valorem Equivalent trade cost change in 2056

Sector	With European connectivity	Without European connectivity
Agriculture, forestry and fishing	-0.031%	-0.004%
Mining and extraction	-0.022%	-0.004%
Food products and beverages	-0.038%	-0.004%
Textiles, clothing, leather and footwear	-0.039%	-0.009%
Wood and paper products	-0.038%	-0.004%
Other manufactures	-0.046%	-0.009%
Petroleum and coal products	-0.013%	-0.002%
Chemicals, rubber, plastics and pharmaceuticals	-0.033%	-0.004%
Transport equipment	-0.063%	-0.009%
Electricity, gas and water utilities	-0.038%	-0.001%
Construction	-0.049%	-0.009%
Trade	-0.052%	-0.009%
Other transport	-0.044%	-0.010%
Air transport	0.000%	0.000%
Hotels and accommodation	0.000%	0.000%
Restaurants and cafés	0.000%	0.000%
Other services	-0.050%	-0.010%
Ownership of dwellings		
Travel agency and tour operator services		
Public administration, defence, social security, education and health	-0.033%	-0.016%
Education	-0.035%	-0.015%
Health and social work	-0.039%	-0.013%
Domestic holiday expenditure	0.000%	0.000%
Foreign holiday expenditure		
Expenditure by foreign tourists	0.000%	0.000%

Tourism versus other sectors

We do not apply the ad valorem method described above to tourism exports and imports (hence in the table above the AVE rates are set to zero). Tourism trade effects are calculated directly from the spending changes for inbound and outbound passengers, which in turn rely on estimates of passenger movements under the expansion scenario. We use these separate approaches for, respectively, trade generally and tourism trade, for two reasons. First, for tourism we can draw on directly available estimates of passenger movements, and specifically how these change as result of airport capacity expansion. This explains why this approach is favoured more generally when modelling the effects of airport capacity expansion. [10] Secondly, the logic of the AVE approach for non-tourism trade is that airport capacity expansion improves connectivity which reduces trade costs - here characterised as a reduction in the transactions costs associated with concluding contracts. This approach makes sense for non-tourism sectors. But it makes much less sense to model changes to tourism trade as stemming from a reduction in the cost faced by tourism services providers when concluding contracts with potential tourists; and that this reduction in contracting boosts tourism. Rather, in the case of tourism sectors, improvement in connectivity and faster/ more connections reduce travel costs and the flow of visitors. This effect is directly captured in passenger data.

3.3.2 Trade openness and productivity

There is relatively well established relationship between changes to trade, or trade openness (measured as the sum of exports and imports, divided by GDP), on one hand, and productivity and national income on the other. Various studies have been published over the years. [11] The relationship captures various influences of trade on productivity, including the diffusion of knowledge and innovation, scale and agglomeration effects, and the reallocation of labour to more productive activities. Estimates of the responsiveness (i.e. elasticity) of productivity to changes in openness vary. We have chosen an elasticity of 0.3% which is a relatively conservative assumption, and line with choices made by modelling done by HM Treasury in the past. That parameter means that every percentage point increase in trade leads to a 0.3% increase in total factor productivity.[12] Note that this elasticity is applied to changes in exports and imports calculated via the AVE effect described above. We have not applied this to changes in tourism spending, which are allocated to passenger spending rather than trade effects. This reflects a relatively conservative assumption that tourism trade is less likely to generate productivity spillovers than other sectors via the mechanisms described above.

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[10] See for example, Melbourne Airport (2024), *Melbourne Airport's Third Runway Major Development, Volume 7, Chapter D2-, Economic Impact Assessmen*t, p.17. Available via https://www.melbourneairport.com.au/community/third-runway-mdp-and-supplementary-reports-?srsltid=AfmBOopkM4kOwV2yEOJX-w9T3P1-ku5hZy1QYS1K8ppez0zceDcVZ5Xm

[11] See for example, Feyrer, James. 2019. "Trade and Income—Exploiting Time Series in Geography." *American Economic Journal: Applied Economics* 11 (4): 1–35; Distance, trade, and income — The 1967 to 1975 closing of the Suez canal as a natural experiment, *Journal of Development Economics, Volume 153*; World Trade Organisation (2024), World Trade report 2024: Trade and Inclusiveness – Making Trade Work for All.

[12] See for example HMG (2016), *HM Treasury analysis: the long-term economic impact of EU membership and the alternatives*, p131.

4 Scenarios and results

We model a core scenario using the inputs described in the preceding section. Specifically, we assume:

- Spending on capacity expansion as reported in section 3.1.
- Passenger spending effects as reported in section 3.1
- Trade cost effects apply to all trading partners for which passenger flows change (including Europe).
- That there is an added productivity shock stemming from changes to trade openness (sum of exports and imports).

We then model four sensitivities around this core scenario. These are explained in section 4.2. Finally, we model a dummy scenario in which only the operational effects (and not airport expansion expenditures) are modelled.

4.1 Summary of results for key indicators under the core scenario

4.1.1 Real GDP and Real GVA effects for the core scenario

Figure 9 reports annual increases in GDP for the UK as a whole for each year of the modelling period. In NPV terms the cumulative value of increased real national GDP is around £22 billion. In 2056, real annual GDP for 2056 is 0.052% higher under the expansion case than it would have been under the baseline in that year.

Figure 9 Annual real GDP effects for the UK, millions of pounds, undiscounted

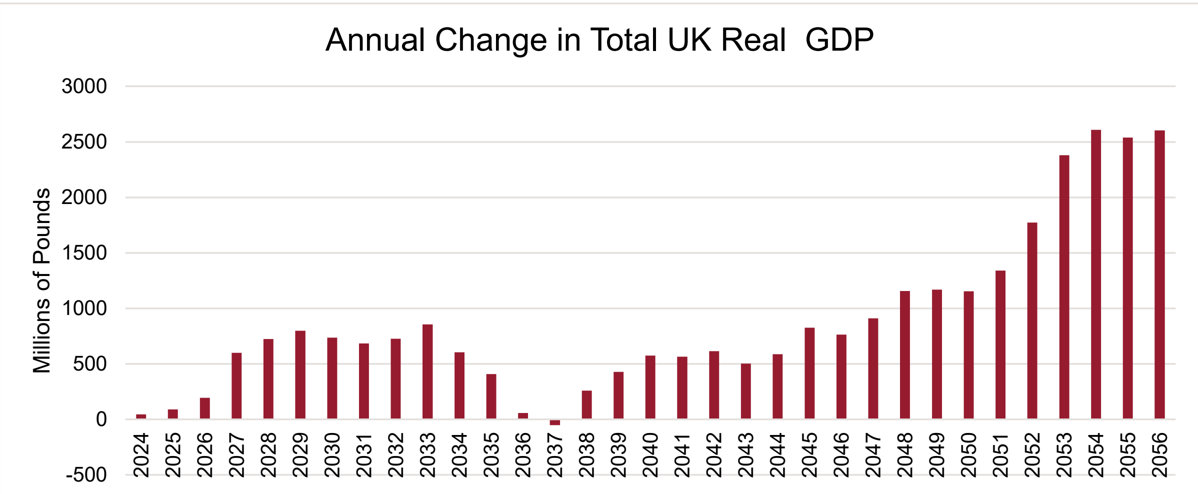


Figure 10 reports the decomposition of annual GDP effects by contributing factor: capital spending; passenger movements; and trade effects; and the induced productivity effects of

greater trade openness. The results suggest that the capital effects i.e. increases to the stock of capital is the largest contributor of GDP effects. This increases reflect both the increased investment related to capacity expansion, but also, in the latter years especially, induced investment in other sectors.

The contributions of operational effects i.e. passenger spending, trade effects, and the induced productivity effects of greater trade openness are relatively limited. This follows naturally from the profile of net passenger increases under the expansion scenario relative to the baseline. As observed in section 3.2.1, the overall uplift in passenger numbers, projected by DfT, is limited, and takes place late in the modelling horizon. As passenger numbers are the fulcrum on which visitor spending, trade and trade induced effects on productivity all rest, it intuitively follows that the effects are limited. The negative contribution of passenger spending effects to GDP reflects the fact that capacity expansion is projected to contribute more to outbound visitor spending than to inbound visitors i.e. imports of tourism sectors rise more than exports of tourism. Note that the GDP results will also capture effects induced by passenger movements - for example, outbound travellers may consume UK air services, which in turn has a positive effect on GDP.

Trade effects are relatively limited. Trade effects do not include tourism exports, which are allocated to passenger effects. Trade effects on real GDP are positive, even if increases in imports dominate increases in imports (see 4.1.2). This is because reductions in trade costs and consequent increases in the supply of imports on real GDP reduce the price of imports. Productivity effects are also limited because of the limited trade effects, on which they are predicated. They dominate trade effects as they are calculated off increases in exports and imports.

Figure 10 Decomposition of annual national real GDP effects by contributing effect

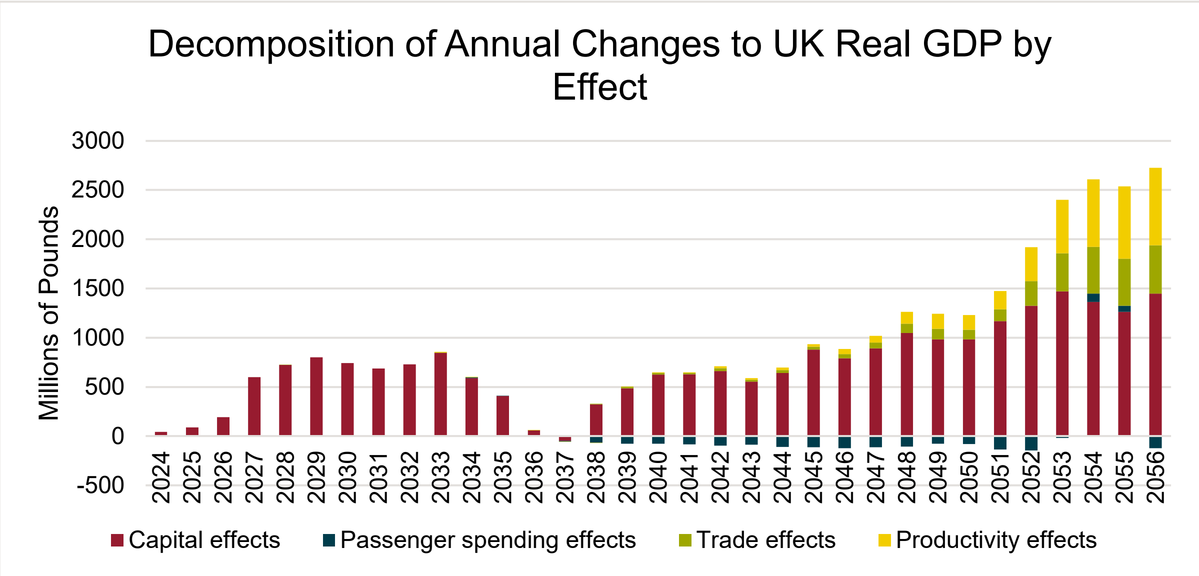


Figure 11 provides added detail on capital effects.[13] The red bars reflect the effects of exogenously imposed capital investment associated with capacity expansion and economic activity in constructions sectors. We see that in the construction phase, these are dominant. There is some degree of crowding out: hence the negative effects on other sectors. Crowding out operates through a number of channels: given that sectors compete for resources, an investment in capacity expansion draws resources from other activities. The model also accounts for interlinkages, which can be positive or negative, in construction between regions. In the operational phase, there is some capital investment related to airport capacity (mainly maintenance). These effects derive from the exogenous increases in capital expenditure. But there is also an endogenous increase in investment in other sectors. This stimulus to other sectors is partly a flow-on from investment associated with capacity expansion, but also the operational effects of runway expansion. That investment is the primary driver of growth is unsurprising in a situation of full employment (and assuming that there is no additional technological change in the expansion scenario relative to the baseline).

Figure 11 Decomposition of capital effects by sector

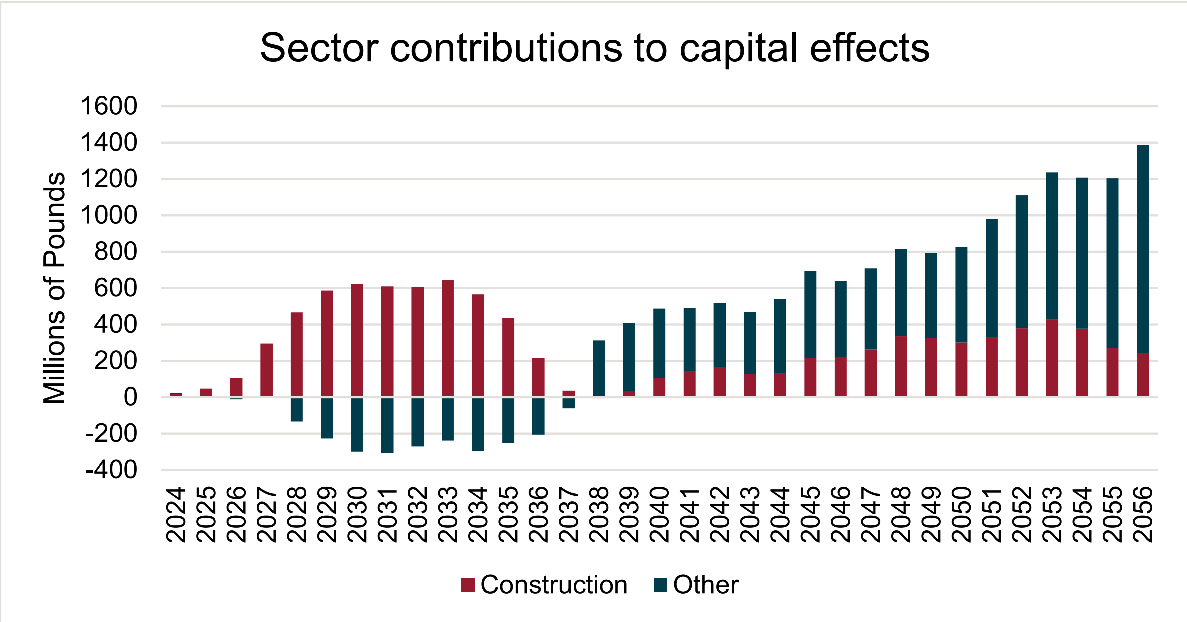


Figure 12 reports the decomposition of effects by major UK region at the International Territorial Level (ITL) 1. Regional GDP grows across all regions. We observe that London dominates these impacts, accounting for around half the total national GDP uplift in 2056. This is understandable given that the dominant driver of GDP impacts are capital expenditures, which are largely concentrated in London. Trade and productivity effects are small, but positive, across all regions. Passenger spending effects on GDP are negative across all

[13] Industry contributions are measures via Gross Value Added, which differ from the GDP figures reported for the aggregate impacts at national and regional level.

regions except Scotland and the Southwest, for which they are marginally positive when summed over the whole modelling period.

Figure 12 Regional GDP effects, millions of pounds

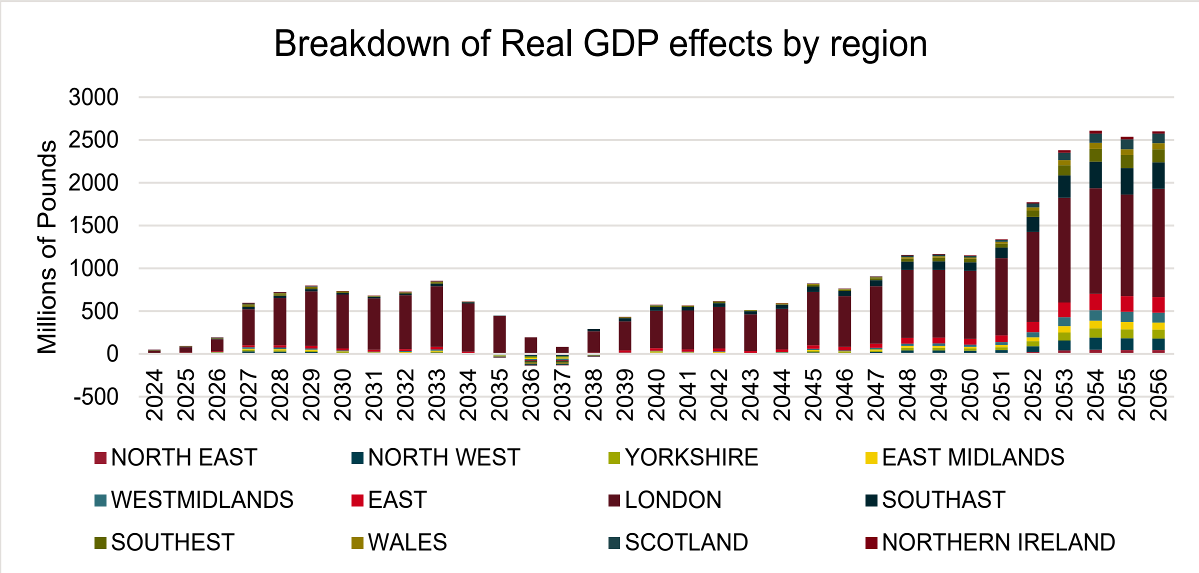


Table 5 reports percentage regional GDP increases for 2056 relative to the baseline for each region.

Table 5 Uplift in regional GDP under expansion scenario 2056, percentages relative to baseline.

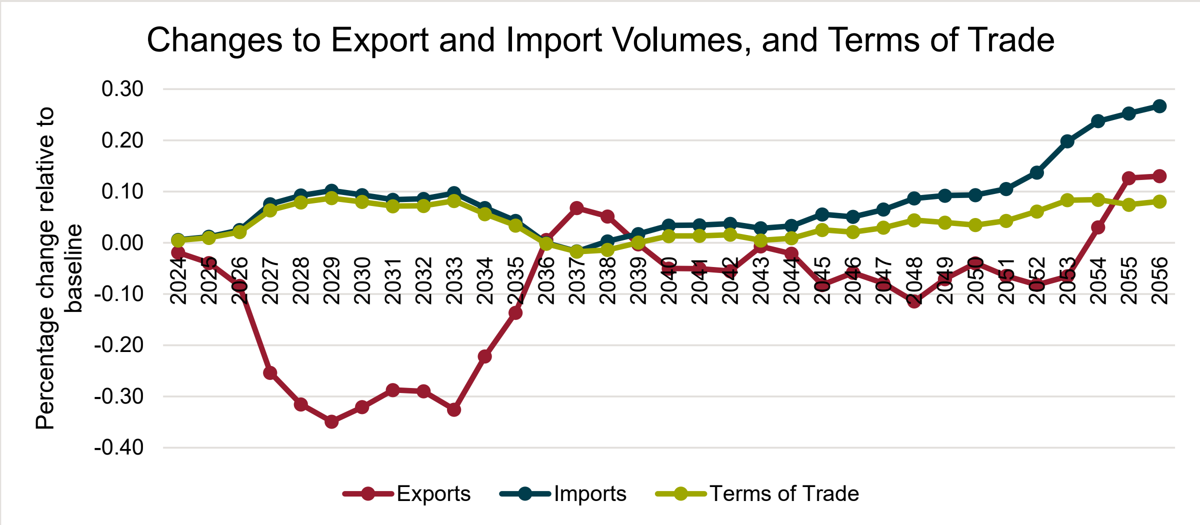
Region	Real GDP uplift in 2056 relative to the baseline in percent
NORTH EAST	0.03
NORTH WEST	0.03
YORKSHIRE	0.03
EAST MIDLANDS	0.02
WEST MIDLANDS	0.03
EAST	0.03
LONDON	0.19
SOUTH EAST	0.04
SOUTH WEST	0.04
WALES	0.04
SCOTLAND	0.03
N.IRELAND	0.02

4.1.2 Trade effects for the core scenario

Figure 13 reports movements in overall export and imports, as well as the terms of trade. They provide a basis for discussing crowding in and crowding out effects.

In the construction phase, increased domestic demands, and an inflow of capital required to finance spending, induce a real appreciation of the pound. As a consequence, imports rise, exports fall, resulting in a balance of trade deficit relative to the baseline. The appreciation of the pound also reflects an inflow of foreign capital required to finance the spending. As the construction phase unwinds, the pound depreciates, restoring export volumes relative to baseline levels. In the operational phase, we see a net improvement in the terms of trade, while exports as a whole are lower than in the baseline. Trends for imports reflect both the effects of ongoing capital expenditure, which place some upward pressure on the pound, and the effects of reduced trade costs in stimulating imports. Exports also respond to reductions in trade cost. As with imports, the trade cost reduction effect is more visible towards the end of the modelling period when passenger increments are largest relative to the baseline.

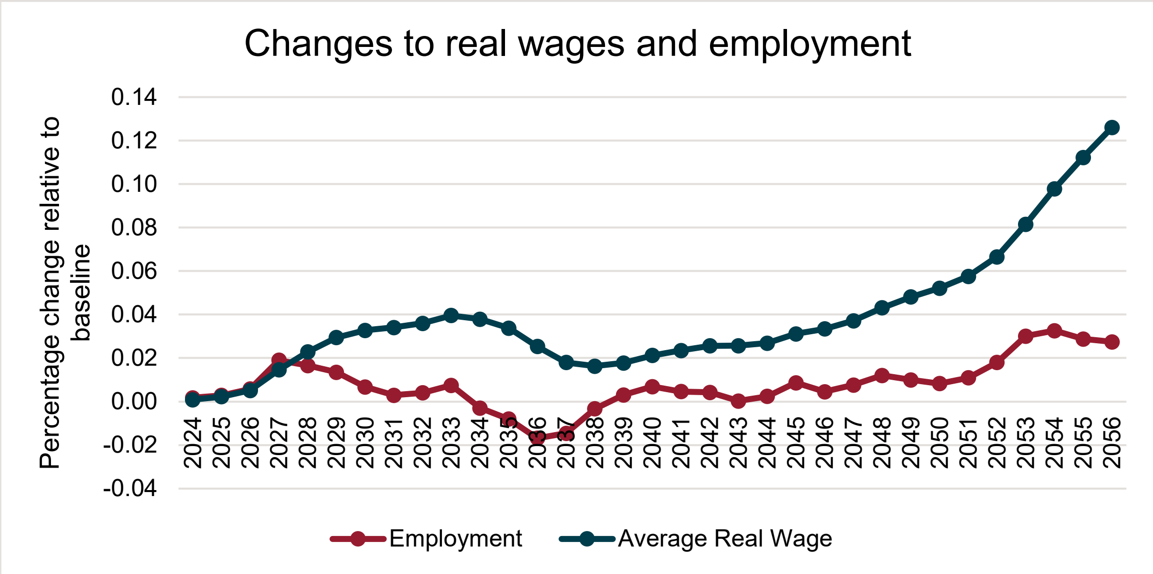
Figure 13 Imports, exports and terms of trade: percentage changes relative to baseline



4.1.3 Employment effects for the core scenario

Figure 14 reports percentage changes to employment and the real wage. The investment phase strengthens the labour market in London and UK overall. TERM-UK includes a theory of sticky real wages. As the labour market strengthens, employment increases relative to base, with a gradual rise in real wages. Rising real wages choke off additional jobs by pushing employment (labour demand) back towards labour supply. When real wages are neither increasing nor decreasing relative to base, this implies that labour supply and demand are in equilibrium. In the long run, the model assumes full employment, therefore any increase in employment is transient. This in turn means that airport capacity expansion does not stimulate growth by mobilising hitherto dormant resources that would have remained dormant were it not for the project.

Figure 14 Aggregate employment and real wage: percentage changes relative to baseline



4.2 Sensitivities -overview

We model various sensitivities as follows.

1. Scenario 2, in which we exclude from Scenario 1 (the core scenario) any trade-induced effect on productivity.
2. Scenario 3, in which we restrict trade cost effects to non-European trade and include trade-induced effects on productivity.
3. Scenario 4, in which we exclude the trade-induced productivity effect from Scenario 3
4. Scenario 5, which uses alternative passenger forecasts, reflecting a scenario in which capacity expansion costs are assumed to be passed through to users. These forecasts are also derived from the Aviation Modelling Suite operated by DfT. The other elements of this scenario are as in the core scenario.

Separately, in Annex A we also report the results of a "dummy scenario" that include the operational effects of capacity expansion (passenger spending, trade, and productivity), but exclude expenditures. This can be treated as a "control" run to isolate operational effects, as opposed to an actual simulation (given that we would not be able to have operational benefits without the spending required for capacity expansion).

4.3 Sensitivities with central passenger forecast

4.3.1 Real GDP and Real GVA effects for sensitivities

Figure 15, **Figure 16**, and **Figure 17** report Real GDP changes per year for the UK as a whole under each of the sensitivities described above.

Figure 15 Annual real GDP effects for the UK, millions of pounds, undiscounted. Scenario 2: Trade Cost Reductions Applied to all Trade, no productivity uplift

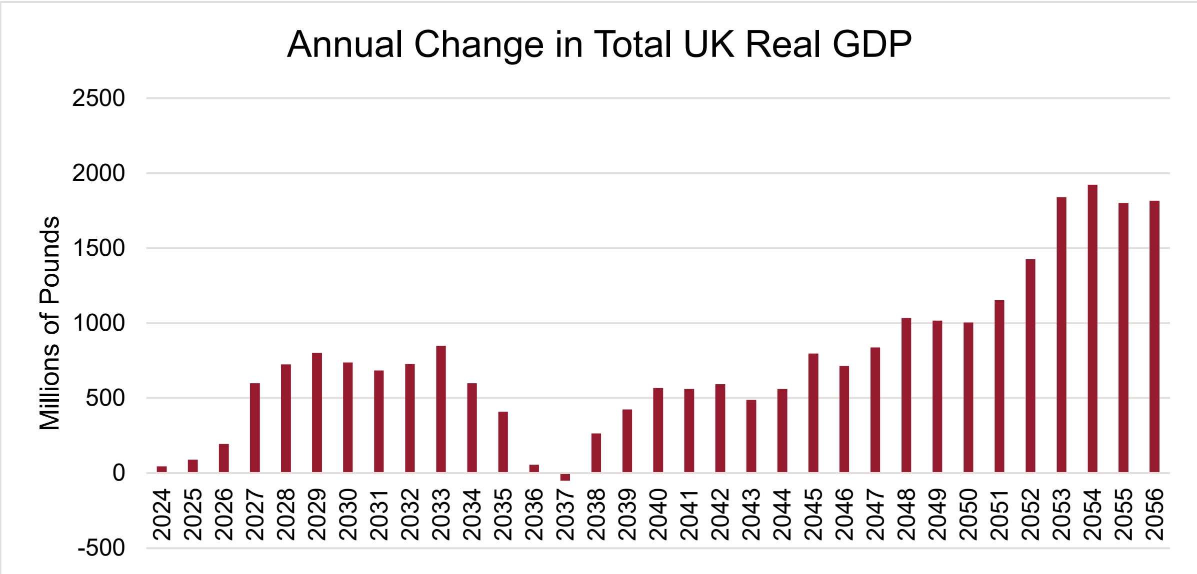


Figure 16 Annual real GDP effects for the UK, millions of pounds, undiscounted. Scenario 3: Trade Cost Reductions Applied to non-European Trade only, including productivity uplift

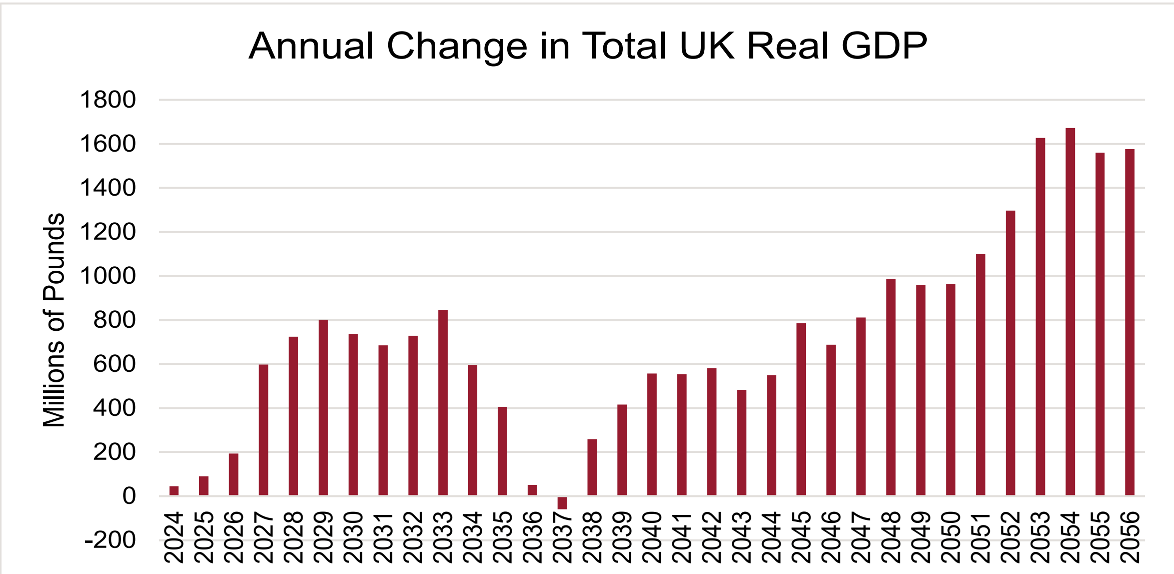
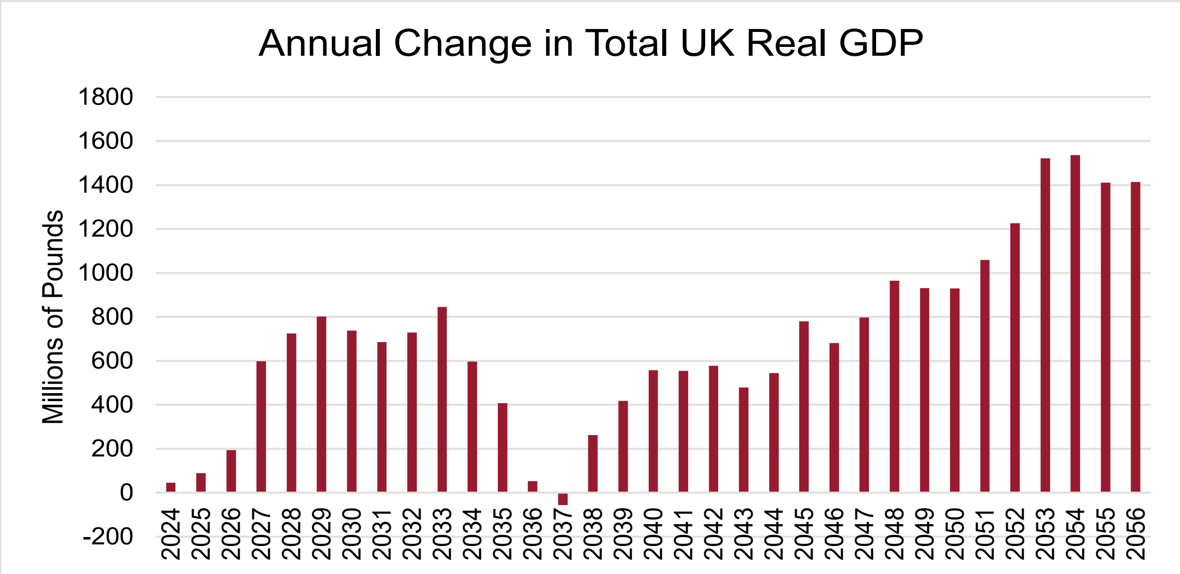


Figure 17 Annual real GDP effects for the UK, millions of pounds, undiscounted. Scenario 4: Trade Cost Reductions Applied to non-European trade only, excluding productivity uplift



Unsurprisingly, removing the assumption of induced productivity uplifts through greater trade openness and restricting trade cost reductions to non-European trade reduce GDP impacts. The greater impact comes from whether or not trade cost reductions are applied or not to European trade. This is demonstrated in **Figure 18** below. We focus on 2045 onwards as until then all scenarios are essentially the same because of the dominance of capital effects and the muted net passenger uplift.

Figure 18 Comparison of annual UK real GDP changes relative to baseline by scenario (2045 onwards)

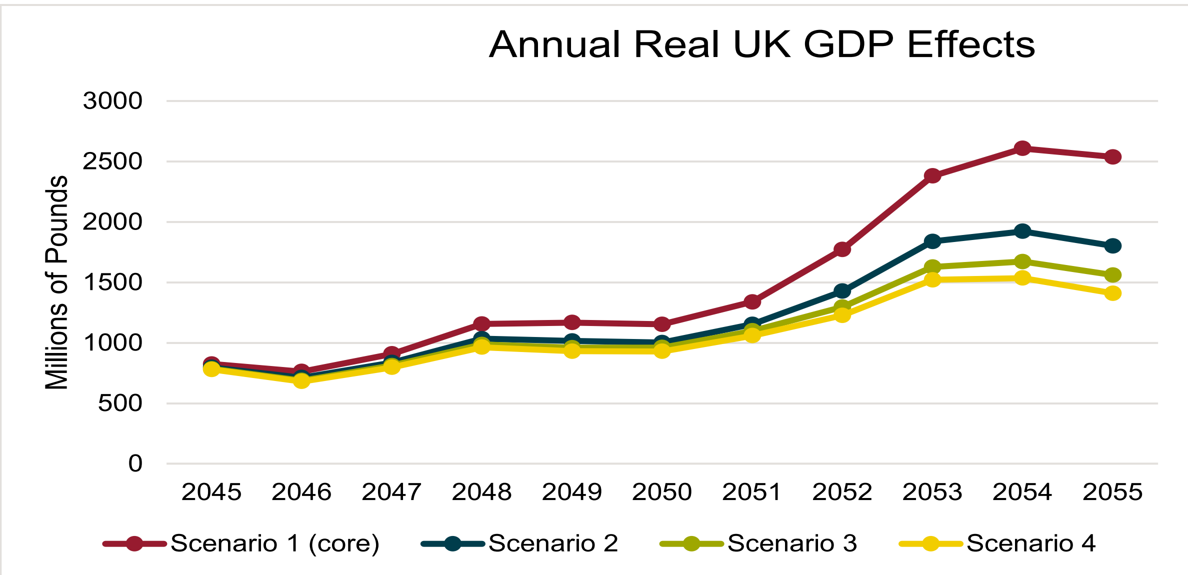


Table 6 reports NPV GDP uplifts across all four scenarios, and monetary and percentage difference between the scenario and baseline for the year 2056.

Table 6 Summary of GDP effects across scenarios: NPV real GDP and annual uplift in 2056

Scenario	NPV real GDP increases over modelling period 2024-2056 (millions of pounds)	Increase in annual real GDP in 2056 relative to baseline (£m)	Increase in annual real GDP in 2056 relative to baseline (%)
Scenario 1 (Core)	14,521.8	2602.2	0.052
Scenario 2	13,069.7	1815.2	0.036
Scenario 3	12,536.2	1576.4	0.032
Scenario 4	12,254.6	1413.7	0.028

Figure 19 to **Figure 21** report the breakdown of GDP effects by contributing factor. There is no material change relative to the core scenario: capital effects are the main factor. The other factors are in line with the assumptions underlying the scenario (scope of trade cost reductions, whether productivity effects induced by trade openness are modelled) and the passenger number forecasts supplied by DfT.

Figure 19 Decomposition of annual national real GDP effects by contributing effect, Scenario 2: Trade Cost Reductions Applied to all Trade, no productivity uplift

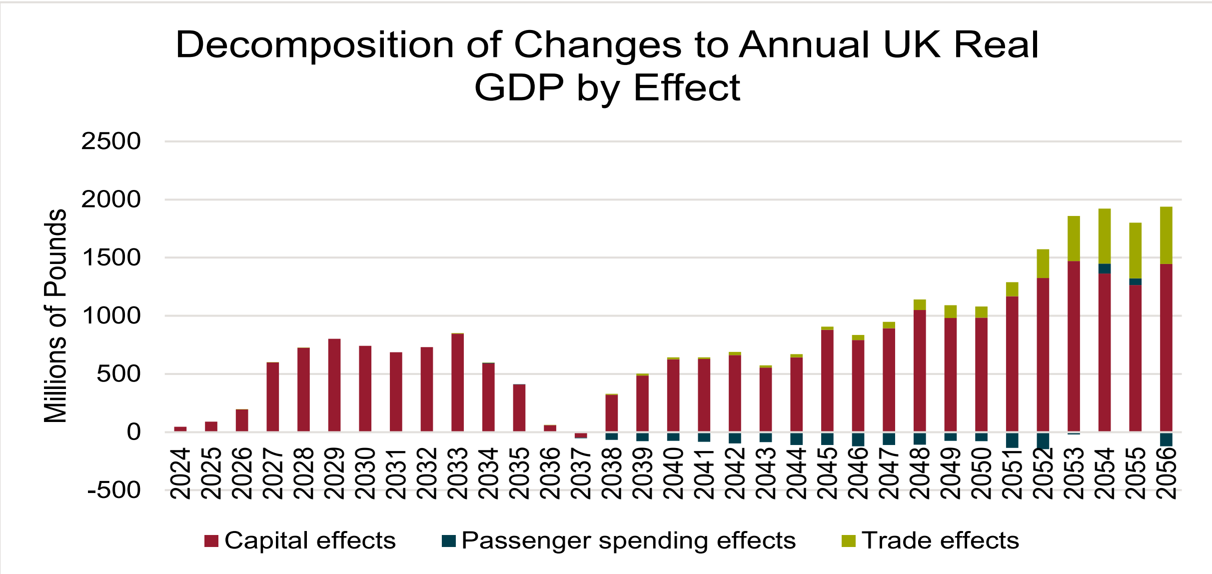


Figure 20 Decomposition of annual national real GDP effects by contributing effect, Scenario 3: Trade Cost Reductions Applied to non-European Trade only, including productivity uplift

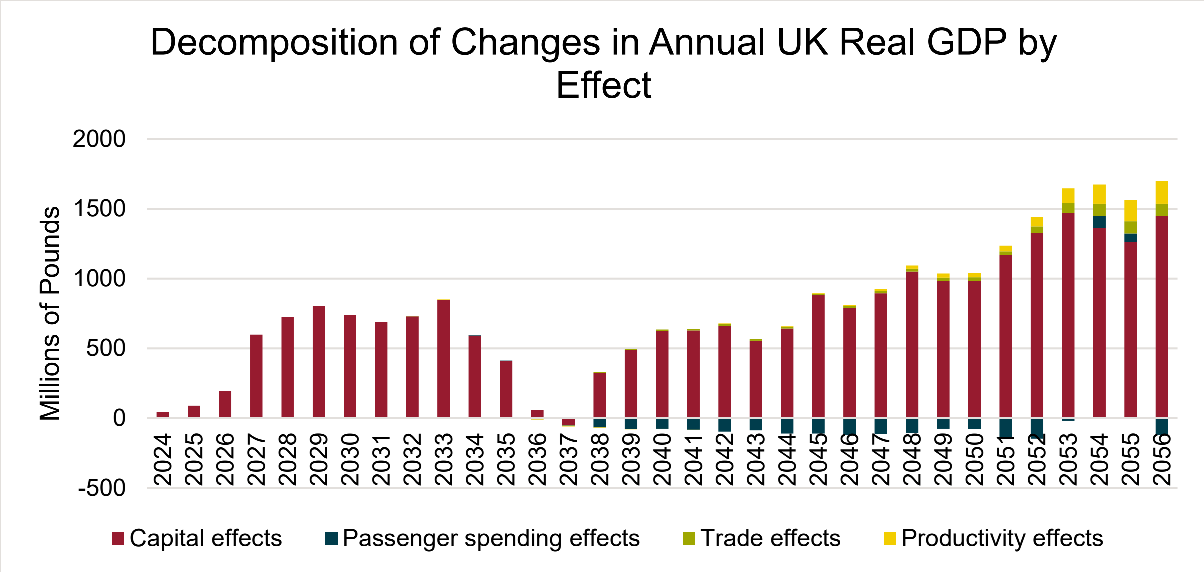
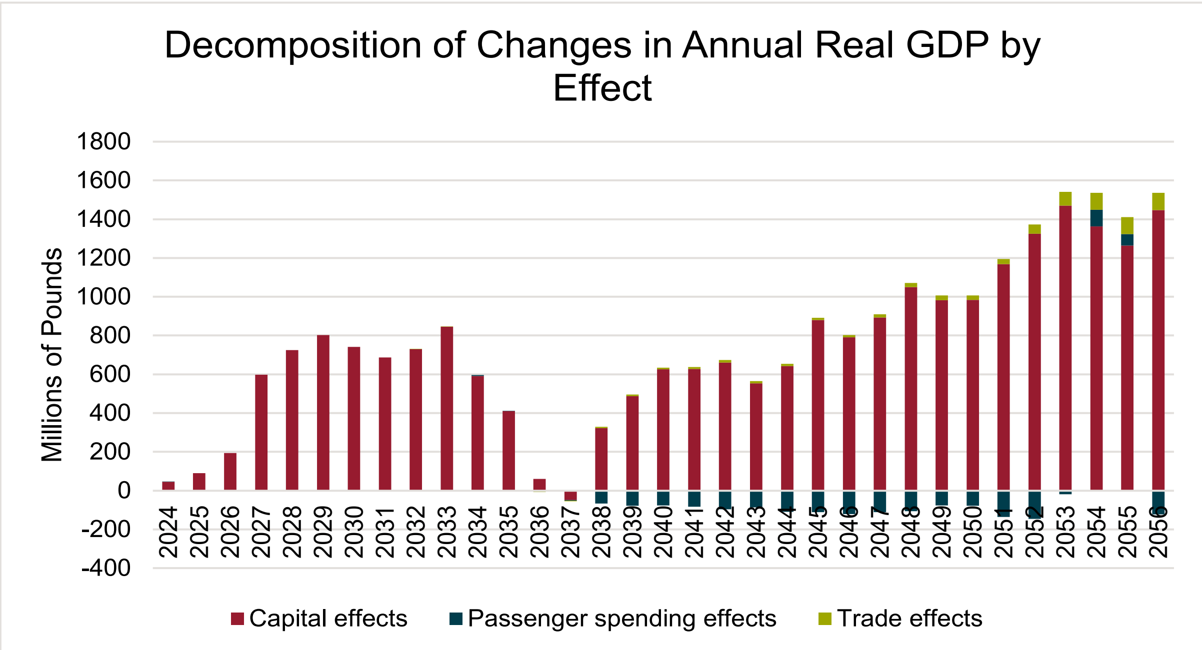


Figure 21 Decomposition of annual national real GDP effects by contributing effect, Scenario 4: Trade Cost Reductions Applied to non-European trade only, excluding productivity uplift



The decomposition of capital effects (see **Figure 11**) does not change across scenarios.

Regional GVA patterns vary little relative to those reported in section 4.1.1; the bulk of the effects are concentrated in London. **Table 7** below reports the GVA uplifts for regions in the year 2056 relative the baseline for that year, across the three sensitivities. It shows that restricting trade effects to non-European partners, reduces the uplift to a number of regions close to zero. Excluding productivity effects in addition to trade effects on European partners further increases the number of regions that report zero effects in 2056.

Table 7 Summary of real GVA uplifts for regions in 2056, relative to baseline.

Region	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)	Scenario 4 (%)
NORTH EAST	0.03	0.01	0.00	0.00
NORTH WEST	0.03	0.01	0.01	0.00
YORKSHIRE	0.03	0.02	0.01	0.01
EAST MIDLANDS	0.02	0.01	0.00	0.00
WEST MIDLANDS	0.03	0.01	0.00	0.00
EAST	0.03	0.02	0.01	0.01
LONDON	0.19	0.17	0.17	0.17
SOUTH EAST	0.04	0.02	0.02	0.01
SOUTH WEST	0.04	0.02	0.02	0.01
WALES	0.04	0.02	0.02	0.01
SCOTLAND	0.03	0.01	0.01	0.01
N.IRELAND	0.02	0.01	0.00	0.00

4.3.2 Trade effects

Figure 22 reports changes to exports, imports and terms of trade when trade cost reductions apply to all trade, but there is no productivity uplift. There are some very small differences, mainly in the outer years when deviations are smaller in this sensitivity, reflecting an economy that has a marginally lower rate of growth relative to the baseline. Again, we note the fact that trade effects align with projected net increases to inbound and outbound passenger movements, which are modelled by DfT to take place in the outer years of the modelling horizon.

Figure 22 Changes to Exports, Imports and Terms of trade, Scenario 2

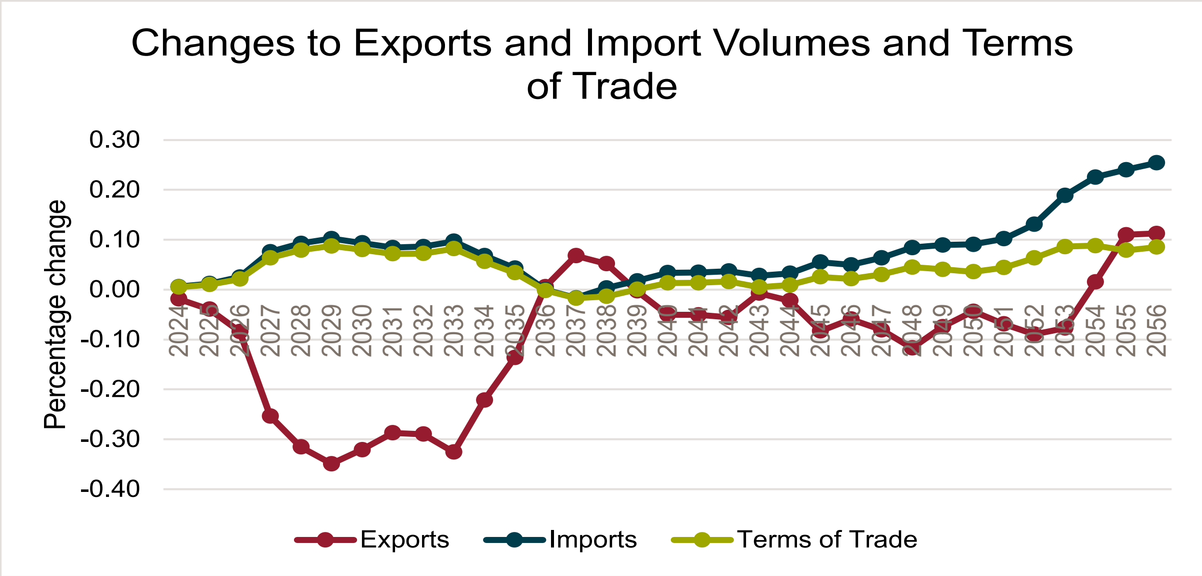
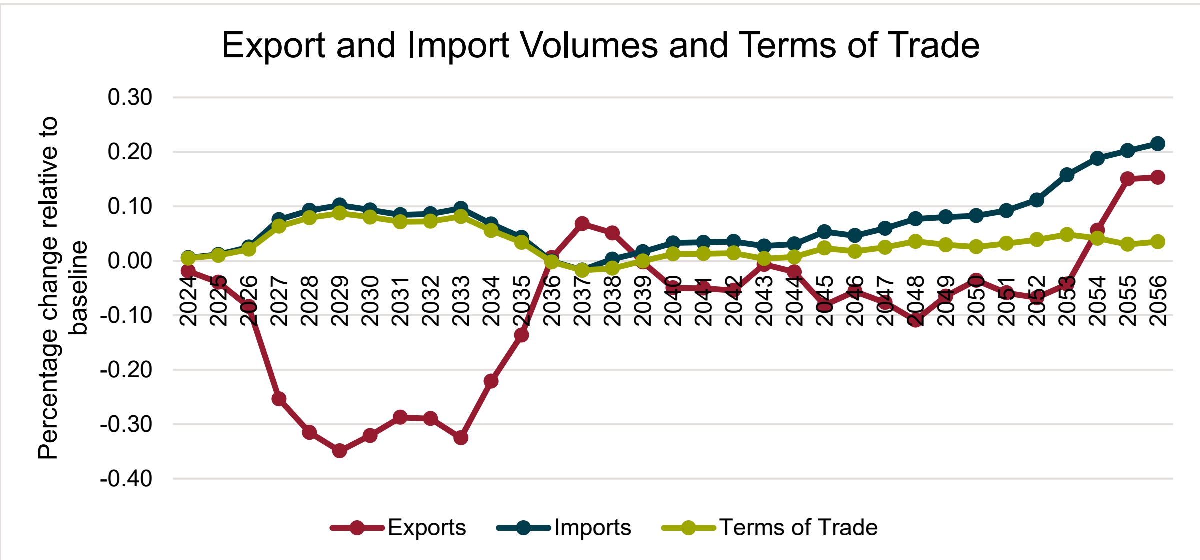


Figure 23 reports changes to exports, imports and terms of trade when trade cost reductions apply to non-European trade only. The results are the same regardless of whether induced productivity effects are modelled: the uplifts are marginal enough so as not to provide an impact. Trade effects are more muted when European trade is excluded. This is because, even though elasticities estimated by Wang that map passenger movements onto trade changes do not vary by destination, the ad valorem trade cost effects do vary depending on whether or not European trade is included (They are greater when European trade is included reflecting the share and structure of UK trade with European partners).

Figure 23 Changes to Exports, Imports and Terms of trade, trade cost reductions apply to non-European trade only

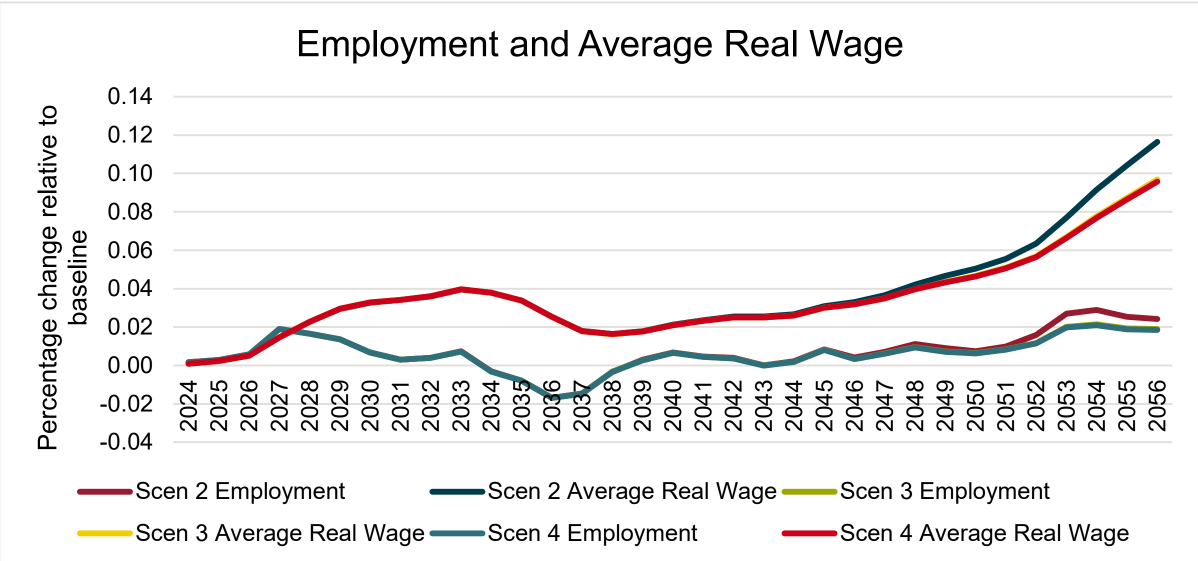


The results for the sensitivity in which trade cost reductions are applied to all trade between the UK and partners are reported in section 4.1.2. They do not change as a function of imposing a productivity shock related to trade openness.

4.3.3 Employment and wages

Figure 24 reports changes to employment and real wages for the sensitivities. We see that differences between the sensitivities are marginal, as indeed are differences between the sensitivities and the core scenario. As with the core scenario, the initial construction phase causes a slight increase in real wages with employment sticky. A more visible, but still very modest, increase in real wages occurs in line with increases in net passenger movements.

Figure 24 Changes to real wages and employment for the Scenarios 2-4 relative to the baseline



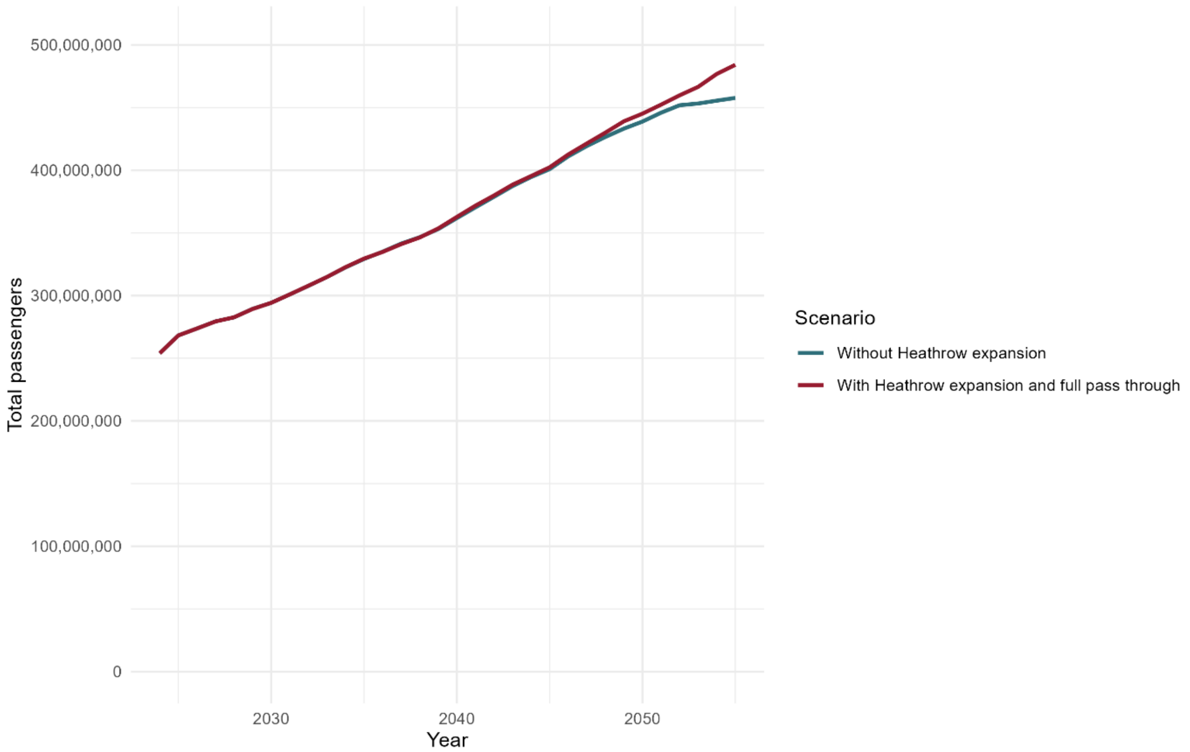
4.4 Sensitivity with alternative passenger projections

4.4.1 Overview and passenger projections

Under this scenario the costs of Heathrow expansion are assumed to be fully passed-through into ticket prices via Heathrow's aerocharge. This would mean that under this scenario Heathrow's aerocharge would be higher than in the main expansion case for some period of time. As a result, passengers shift away from Heathrow to other airports provided that spare capacity is available at those airports.

The effects on passenger movements are projected by the DfT Aviation Modelling Suite.[14] The projections are reported in **Figure 25** below. The main points to note are that, firstly, the charge out leads to a displacement of passengers from Heathrow to other airports in the earlier years of the modelling horizon. As this is a displacement effect, it does not affect overall macro-economic aggregates. The second is that under this scenario, the Modelling Suite projects a slight increase in passenger movements relative to the central scenario, over the whole time period. This has a marginal effect on some macroeconomic aggregates. **Figure 25** reports the projections.

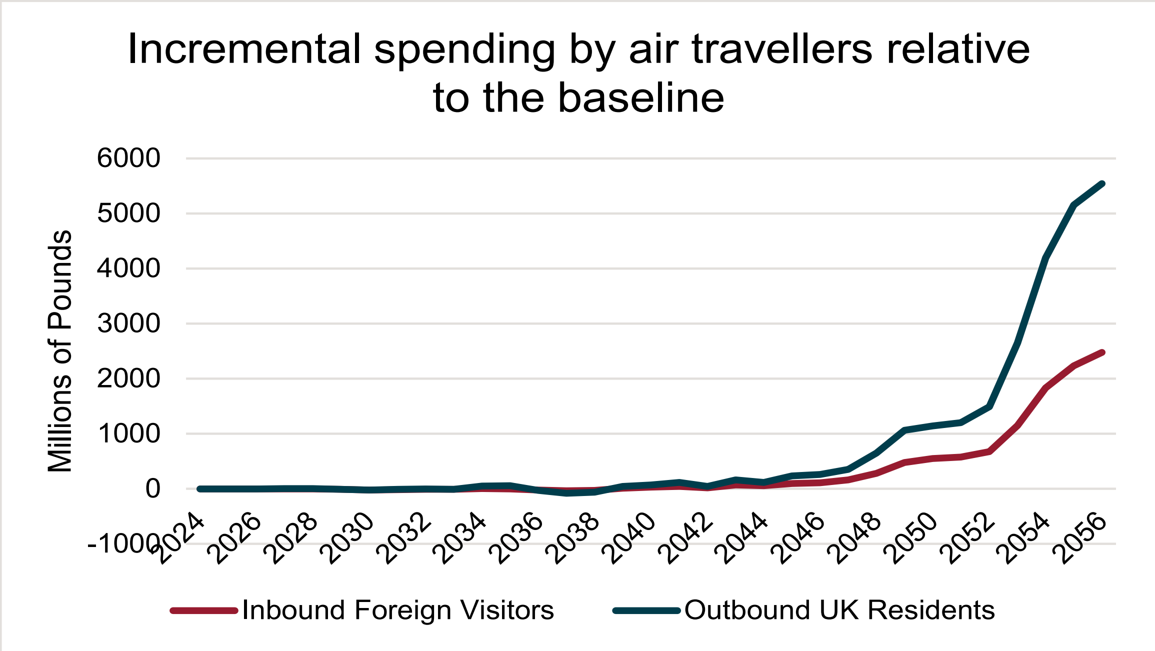
Figure 25 Passenger projections under the alternative scenario



As under the core scenario, using central passenger projections, we also derive passenger spending effects for inbound and outbound travel. These are reported in **Figure 26** below.

14 International transfer passengers (e.g. JFK-LHR-DEL routings) were separated out by DfT in the output of the aero-charge scenario, though not in the main scenario.

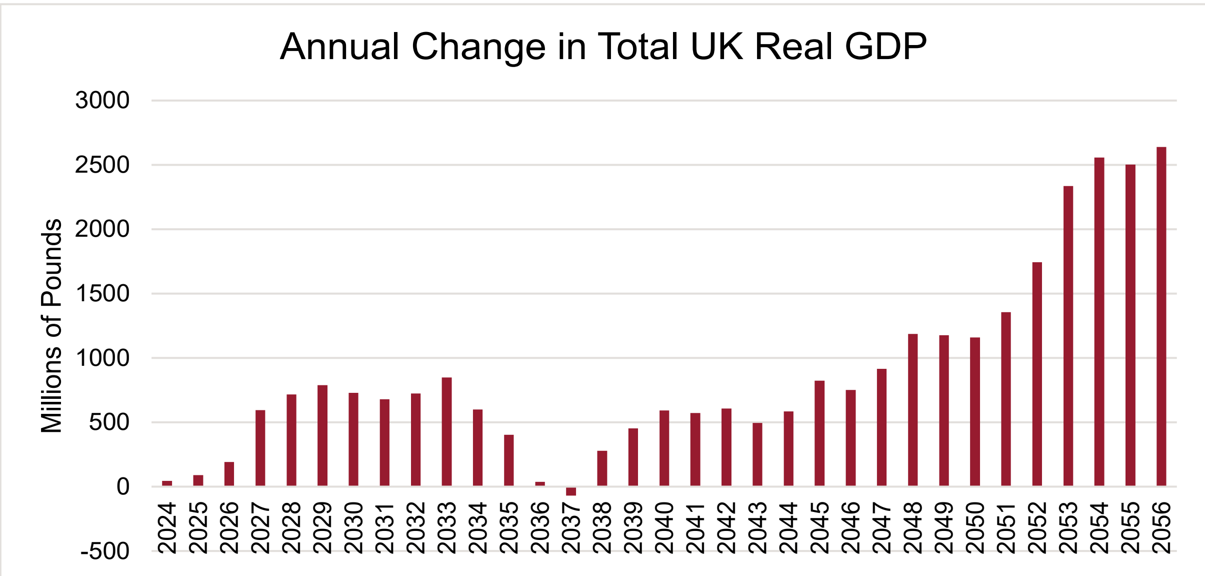
Figure 26 Passenger spending effects, alternative passenger projections



The profiles are very similar to that in the core scenario. There is a slightly stronger uplift in the final years.

4.4.2 Effects on GDP

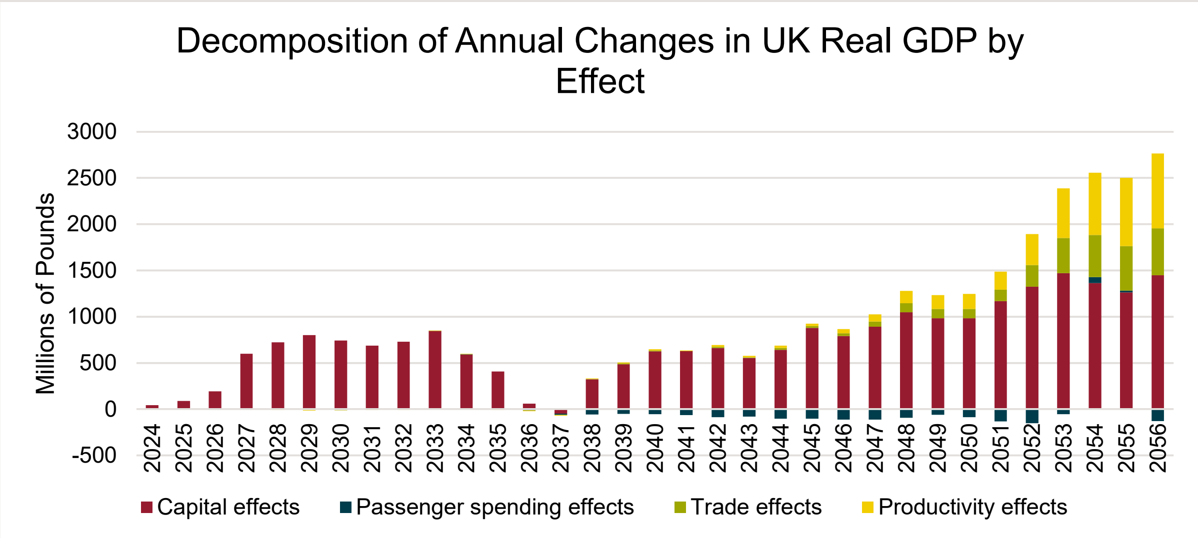
Figure 27 Changes in UK Real GDP under alternative passenger scenarios, millions of pounds



The results in **Figure 27** are essentially the same as the core scenario when taken over the whole modelling period. The NPV of real GDP effects are essentially the same as in the core scenario. GDP effects are very marginally higher in monetary terms in the outer years under the alternative than under the core scenario because of a higher passenger uplift. That then feeds through to passenger effects, trade effects, and productivity. GDP in 2056 is 0.053% higher than without expansion.[15]

Purely for the sake of completeness, we report the decomposition to GVA changes by effect and breakdown by region in **Figure 28** and **Figure 29**. There are no material differences between these results and those reported for the core scenario.

Figure 28 Decomposition of Annual GDP changes by effect, alternative passenger scenario, millions of pounds.



[15] Differences would be detected if reported at third significant figure but this could be considered well within the bounds of modelling error.

Figure 29 Regional breakdown of GDP effects, alternative passenger scenario, millions of pounds.

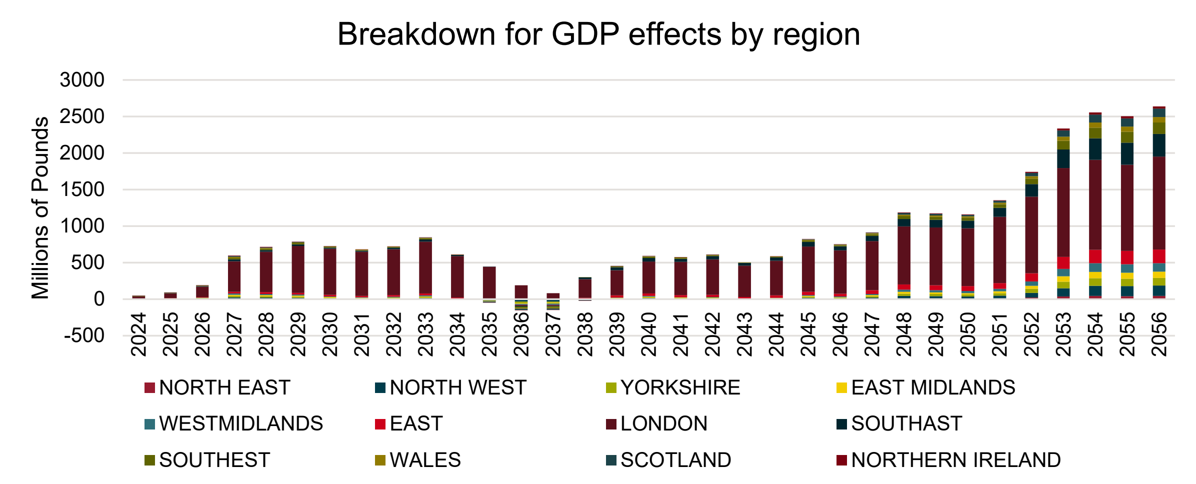


Table 8 reports GDP uplifts for 2056 by region relative to the baseline for that year under the alternative passenger scenario.

Table 8 Uplift in regional GDP under expansion scenario2056, percentages relative to baseline.

Region	Real GDP uplift in 2056 relative to the baseline in percent
NORTH EAST	0.03
NORTH WEST	0.03
YORKSHIRE	0.03
EAST MIDLANDS	0.02
WEST MIDLANDS	0.03
EAST	0.03
LONDON	0.19
SOUTH EAST	0.04
SOUTH WEST	0.04
WALES	0.04
SCOTLAND	0.03
N.IRELAND	0.02

4.5 Discussion

The modelling results of this core scenario suggest modest effects of runway capacity expansion at Heathrow airport on headline economic indicators. These largely reflect the profile of expected effects on passenger movements. In particular, passenger uplifts for the UK as a whole are relatively modest against the baseline, and occur towards the end of the modelling period. The operational effects of runway expansion are also muted by the fact that modelled passenger movements generate more outbound than inbound visitor expenditure; and the relatively modest effects of connectivity on trade costs. Nevertheless, the modelling suggests that under conservative assumptions relating to passenger growth, capacity expansion meets the test of contributing to economic growth as measured by changes to GDP.

The project generates positive growth effects in all regions, though the large majority of these effects are located in London because of the magnitude of effects relating to project expenditures and induced capital expansion effects, relative to other effects. The strict operational effects, and trade effects notably, are spread more evenly across regions (cf Annex A), though they are small in magnitude.

Finally, it is important to reiterate that CGE modelling involves the simulation of counterfactual scenarios relative to a baseline. These are not forecasts per se. In this case, simulations are based on projections regarding spending on capacity expansion, and on passenger movements, which are themselves the product of modelled simulations developed outside the CGE framework. One of the key advantages of this framework is that it shows how growth and other outcomes vary under different assumptions around the trajectory of key variables. In particular, variations in passenger forecasts feed through into spending, trade cost and productivity effects. That in turn enables the policymaker to understand the range of plausible effects under various hypothetical scenarios.

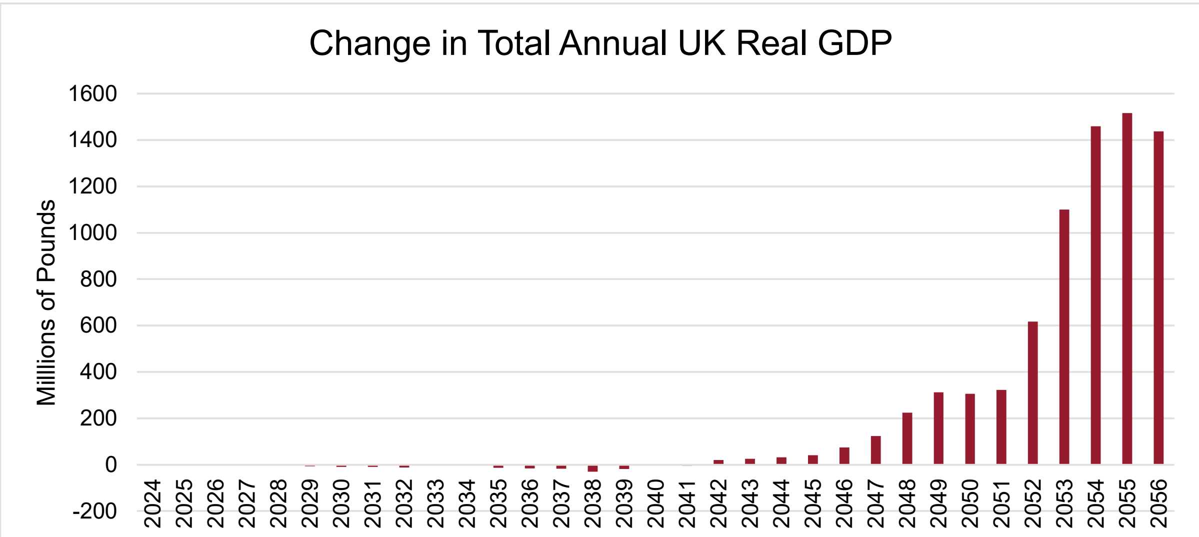
Annex A Dummy scenario excluding effects of expenditure on capacity expansion

This section reports modelling results for the operational effects of capacity expansion only i.e. excluding capital and operational expenditure. This is intended to provide some insight into the weight of operational effects relative to the effects of expenditures on capacity expansion. Though in modelling this, we need to be aware that removing expenditures is not a simple mechanical adjustment of GDP effects via the subtraction of the expenditure related component modelled in the core scenario. This is because expenditures are associated with crowding out effects and these are removed with expenditures. This "dummy scenario" is not intended to simulate an actual counterfactual, since clearly there could not be any operational effects of capacity expansion without expenditures required to achieve that expansion in the first place.

The operational effects are changes to passenger spending, effects on international trade (with trade cost reductions applied to all UK trade), and productivity uplifts induced by greater trade openness. That is, in essence, the core scenario minus any of the expenditures directed to capacity expansion.

Figure 30 reports annual changes to UK real GDP.

Figure 30 Effects on real GDP, operational effects of capacity expansion only

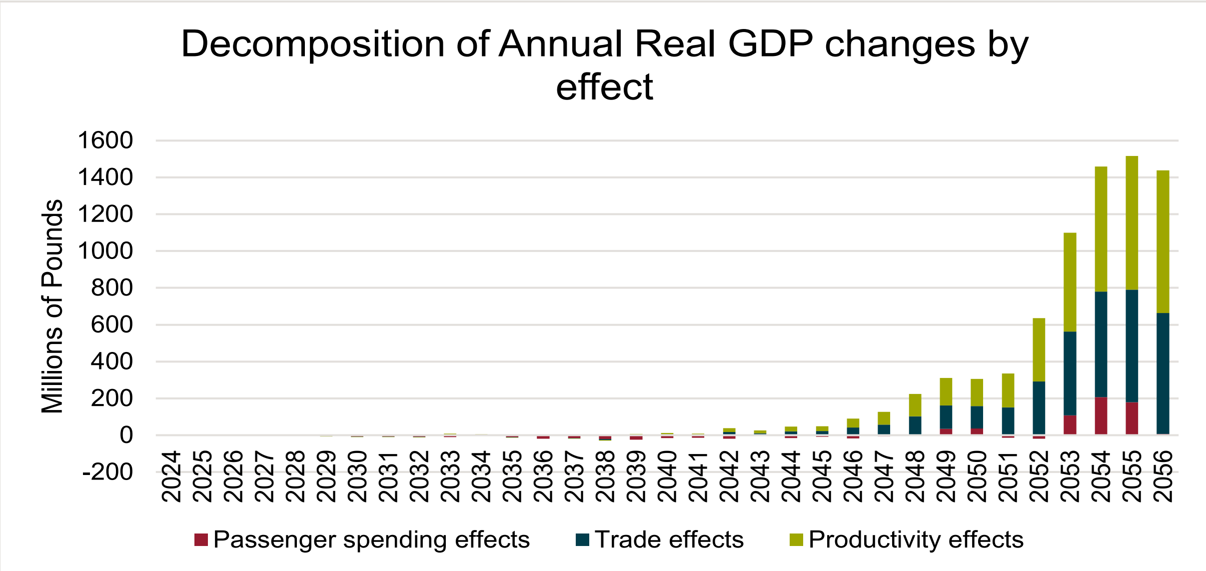


The effects follow the profile of passenger numbers projected by DfT. This means that material increases in GDP relative to the baseline occur in the late part of the modelling period, from the late 2040s onwards, with the bulk of the impacts in the period for 2053 onwards, which is when passenger numbers are projected to increase materially in line with assumptions around expansions in terminal capacity. The main drivers of these impacts, in line with the results reported in section 4.1.1, are increases in trade (and exports specifically) and induced effects of greater trade openness on productivity. In the period 2024-2045, impacts are minimal. The very small negative impacts in the late 2020s and 2030s are linked to limited increases in passenger numbers. The reduction in GDP reflects greater effects on outbound spending than on inbound spending.

Under the dummy run, total NPV of the monetary uplifts in real GDP is just under £2.7 billion. In 2056, real UK GDP is 0.018 % higher than it would have been in that year without the effects of capacity expansion.

The decomposition in GDP effect is reported in **Figure 31** below. This brings out that under the dummy scenario, trade effects are more substantial than in the core scenario. This is because the absence of capital effects reduces crowding out on trade, notably by reducing foreign borrowing, and thus pressure on the real exchange rate. This underscores the point that the dummy scenario is not simply a mechanical removal of expenditure effects from modelled results.

Figure 31 Decomposition of annual real GDP changes by effect



The regional breakdown of GVA uplifts is depicted in **Figure 32** below. London has the highest uplifts, though its dominance is considerably more muted than under the core scenarios. This follows logically from the exclusion of capacity expansion-related spending. It also suggests that the operational effects of capacity expansion – specifically those related to trade - are spread more evenly across regions.

Figure 32 Breakdown of regional effects, excluding effects of spending on capacity expansion

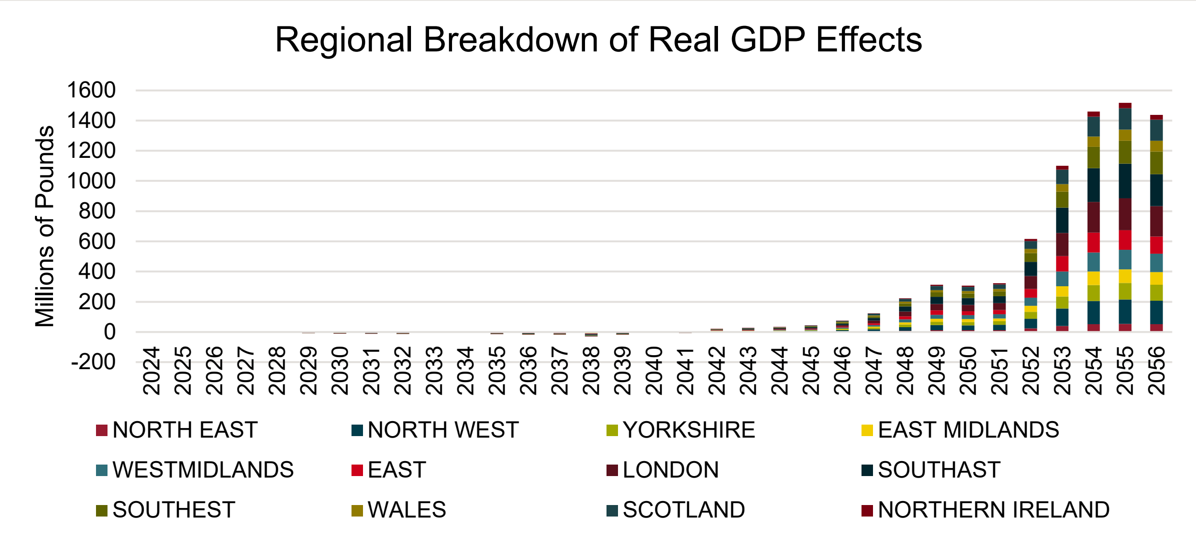


Figure 33 reports changes to average real wages and employment. These are minimal over the course of the project, suggesting that the bulk of such impacts that do occur under the core scenario are attributable to the effects of spending on airport expansion.

Figure 33 Changes to average real wages and employment, excluding effects of capacity expansion

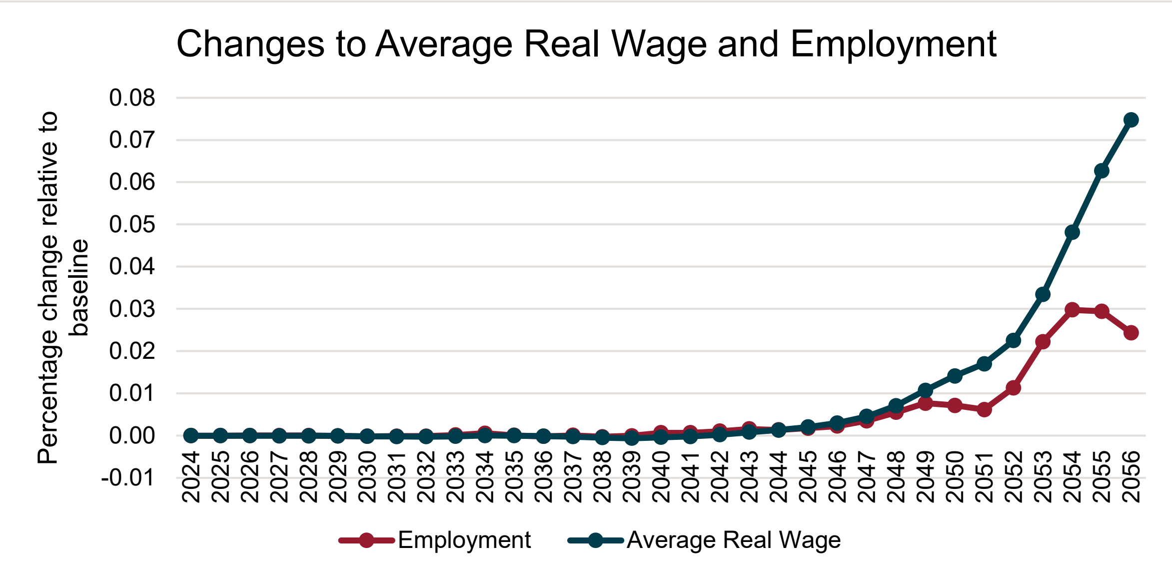
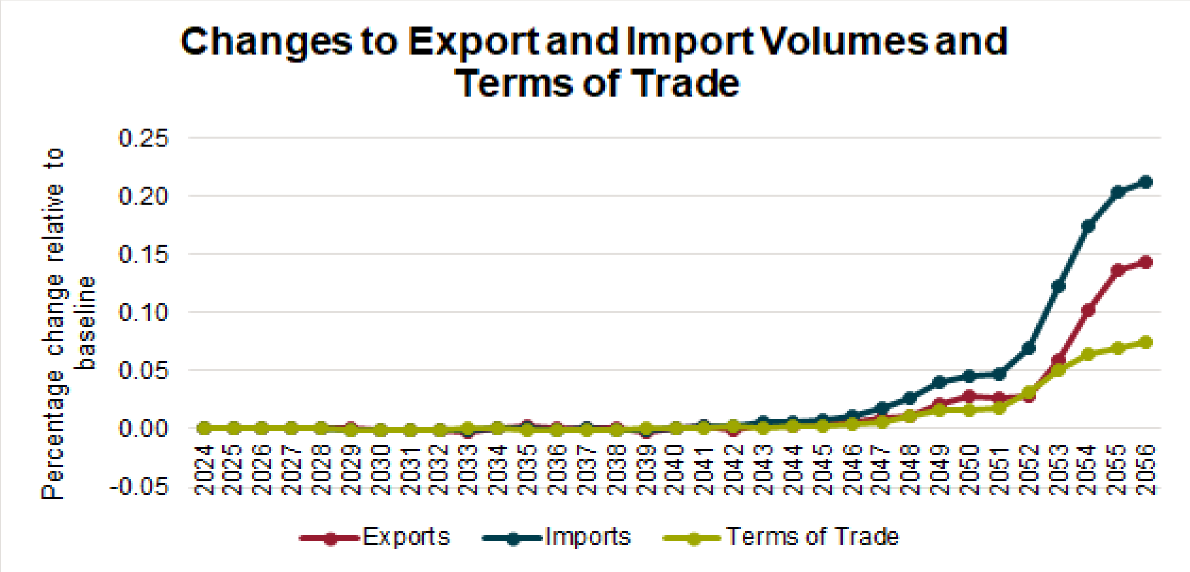


Figure 34 reports changes to exports, imports and terms of trade under this sensitivity. The exclusion of spending on capacity expansion means that we do not observe any crowding out effects of construction spending on exports in the early part of the modelling horizon. In the latter part, we observe uplifts to trade that are follow the trend of passenger number increases projected by DfT.

Figure 34 Changes to exports, imports and terms of trade, excluding effects of capacity expansion



Annex B TERM model calibration for estimating the effects of Airport Capacity Expansion

B.1 Preparation of the underlying database

Use of ONS data

We use the 2023 ONS input-output tables. [16] These were reviewed and corrected for some anomalies.[17] Publicly available input-output tables typically include an investment sales column for each commodity, without details of industry investment composition. A modelling convention within the Centre of Policy Studies (CoPS) is that each industry has a specific investment structure. Health, for example, may include medical appliances that do not form part of the capital in other sectors. Aircraft are allocated to the air transport industry. ONS elsewhere provides data on broad industry investment detail.[18]

These are used, combined with judgments about the distribution of the 26 non-zero investment commodities within the input-output table, to estimate the investment composition for each industry.

Within the CoPS school, margins are treated as separate from direct use of margins commodities. In the UK CGE database, the margins are TradeMV (CPA_G45), WTradeOth (CPA_G45), RetailTrdxMV (CPA_G45), RailTransprt (CPA_H491_2), RoadPipeTran (CPA_H493_5), WaterTrnsprt (CPA_H50), AirTransport (CPA_H51) and Warehousing (CPA_H52). The margins are separated from direct use. The default shares allocated to margins use instead of direct use are TradeMV (1.0), WTradeOth (0.7), RetailTrdxMV (0.7), RailTransprt (0.2), RoadPipeTran (0.3), WaterTrnsprt (0.2), AirTransport (0.1) and Warehousing (0.7).

As already observed the national CGE database also includes model parameters. These include household expenditure elasticities, Constant Elasticity of Substitution (CES) parameters covering domestic-import and, for the multi-regional model, domestic-domestic

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[16] https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesdetailed

[17] First, basic non-ferrous metals (i.e., gold) includes a change in inventories of minus £15,473 million. In processing, the changes in inventories and acquisitions less disposables of valuables (columns P52 and P53 of the IOT sheet from the above link) are added together to be depicted in the CGE database as the change in inventories. To bring the changes in inventories for the sector closer to zero, £14,260 million is added in this column, and subtracted from exports of the commodity. The exports column of the CGE database adds columns P61EU and P61RW. A second adjustment concerns an apparent error in the database. The input of finance (row CPA_K64) to ownership of dwellings (CPA_L68A) in the ONS table is minus £20,184 million. In basic flows in an input-output table, excepting changes in inventories and taxes-cum-subsidies, negatives are illegal. The cell in the corresponding 2022 table is positive. This is rectified by adding £20,184 million to capital rentals (GOS) in the finance sector and subtracting the same value from the ownership of dwellings GOS.

[18] https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/businessinvestmentbyindustryandasset

substitution, and substitution between primary factors in each industry. Household expenditure elasticities are less than one for food items and more than one for services. Air transport and ownership of dwelling usually have the highest expenditure elasticities. When it comes to sensitivity analysis, parametric choice is usually of fourth order importance. Scenario shocks, database weights and closure choice, particularly concerning labour and capital market adjustment, are of greater importance. Export demand elasticities are usually set at -4. This means that changes in export supply, for example, will impact on export prices.

The re-allocation from direct use to margins use covers both domestic and imported merchandise commodities. This may result in small database imbalances that are corrected at a later processing stage.

Treatment of tourism and tourism satellite accounts

As already observed, the tourism sector requires specific handling. The Office of National Statistics (ONS) produces tourism satellite accounts (TSA).[19] The TSA details the link between tourism expenditures and national accounts. In creating a dummy sector for domestic tourism, proportions of household expenditures within the CGE database concerning accommodation, travel and other services are moved to the tourism sector. Hence, the tourism proportions of initial direct final demands are treated as inputs to tourism. Any demand shifts can be imposed on the tourism sector instead of being allocated to individual goods and services. Similarly, export tourism sales are moved from the export column to inputs into a tourism exports sector, which is exclusively for export. UK tourism elsewhere is depicted in tourism imports sector. Tourism imports and domestic tourism are substitutable in household demands.

There are two problems arising from reconciling TSA data with the input-output table. First, in export tourism (ExpTour), the “Other” sector accounts for a large share of spending, which does not seem intuitive (**Table 9**). That is, accommodation, dining and food, travel, museums, entertainment, rental services, transport and insurance should account for most expenditure. Key categories such as “Hotels” and “Cafes” have larger values in the CGE database than is implied by TSA for this reason (comparing tables 1 and 2), bringing the CGE database total closer to the TSA total.

Concerning imports of tourism (UK citizens travelling overseas), the import values in the input-output table are too small for subtraction of the entire value given by TSA to be possible. An assumption that £8,800 million of foreign travel is spent on domestic travel agents, tour operators and reservation services (“TravelTourSv” in **Table 9**) brings activity within the CGE database close to the TSA value.

Table 9 Tourism Satellite Accounts, 2023 (£million)

[19] https://www.ons.gov.uk/economy/nationalaccounts/satelliteaccounts/datasets/uktourismsatelliteaccounttsatables.

1		2	ExpTourism	3	Holiday	4	FgnHoliday
5	Hotels	6	6131	7	8267	8	13866
9	FoodBev	10	3761	11	24612	12	9432
13	RailTransprt	14	544	15	3349	16	1163
17	RoadPipeTran	18	594	19	1153	20	1989
21	WaterTrnsprt	22	261	23	534	24	880
25	AirTransport	26	4002	27	1212	28	17526
29	RentLeaseSv	30	260	31	770	32	199
33	TravelTourSv	34	124	35	6239	36	249
37	ArtsLIBMus	38	248	39	4917	40	2775
41	SportRecSv	42	187	43	4593	44	7674
45	ExhibConf	46	114	47	151	48	196
49	Other	50	19115	51	25261	52	32785
53	Total	54	35338	55	80157	56	88734

Table 10 : CGE allocation of tourism expenditures (£million)

	Export Tourism		Holiday		Foreign Holiday	
	Dom	Imp	Dom	Imp	Dom	Imp
DairyProds	97	0	194	147	0	446
MilledProds	50	0	24	48	0	145
Bakery	66	0	2884	1980	0	449
OtherFood	234	0	140	326	0	986
AlcoholBevTb	407	0	395	1171	0	1327
SoftDrinks	43	0	100	83	0	250
Clothing	0	0	0	0	0	642
LeatherProds	0	0	0	0	0	206
SawmillProds	0	0	0	0	0	15
PulpPaper	0	0	0	0	0	76
PetrolCoal	573	0	981	4215	0	1911
OtherManufac	288	0	109	843	0	0
RetailTrdxMV	0	0	3489	0	0	0
RailTransprt	0	0	3349	0	0	1045
RoadPipeTran	0	0	1153	0	0	1989
WaterTrnsprt	1448	0	534	0	0	880
AirTransport	6506	0	1076	0	0	16775
Hotels	10065	0	8267	0	0	15291
Cafes	5710	0	24612	0	0	10401
MediaBrdCast	0	0	0	0	0	253
Finance	1274	0	0	0	0	0
InsuranceSup	428	0	1029	0	0	170
OwnerDwellng	704	0	2860	0	0	5814
OwnerSrv	0	0	0	0	0	1901
LegalSrv	192	0	0	0	0	0
RentLeaseSv	2981	0	0	0	0	276
TravelTourSv	206	0	6239	0	8800	293
OfficeAdm	0	0	0	0	0	255
Health	295	0	301	0	0	2841
ArtsEntrtain	2515	0	4917	0	0	2573
LibMuseum	1398	0	0	0	0	2027
Gambling	186	0	0	0	0	7368
SportRecSv	656	0	4593	0	0	1085
HHCompRepr	0	0	0	0	0	96
OthPrsServ	0	0	0	0	0	252
DomHHServ	0	0	0	0	0	70
TOTAL	36319	0	67246	8814	8800	78108

Estimating regional industry activity shares

There are two sources for estimating regional industry shares. One resource provides data on employment for around 90 industries in 175 ITL local-authority regions within England and Wales.[20] The other resource provides value-added estimate for around 38 industries in 361 ITL local authority regions.[21]

The estimation procedure starts with mapping broad sectors in the value-added data to I-O sectors. Then the industry employment data are used to revise regional activity shares for local authority regions within England and Wales.

At this point, the ownership of dwellings sector is checked for outliers. Value-added data for regions including Bristol and Cornwall do not provide defensible ownership of dwellings activities. Simple rules revise regional shares for the sector: an upper limit is imposed so that in no region does the sector's value added exceed 25% of the all-industry value added; and a lower limit is imposed so that the sector's share of total value is not below 6%.

The TSA data did not include activity estimates for local authority regions. For UK domestic tourism and tourism exports, accommodation and food service activity shares (I55 and I56) provide a proxy. Imports of tourism (i.e., UK citizens holidaying overseas) are based on regional aggregate income shares.

Industry investment shares are set equal to industry output shares.

Regional jobs by industry: Two sets of data provide a base for regional job numbers by industry. First, employment data are sufficient for most of the 175 local authorities within England and Wales. An exception was Staffordshire, in which the raw numbers appeared to be the aggregate of 7 local authority regions. Jobs numbers are allocated to Staffordshire's local regions using estimated value-added shares.

On the assumption that London's wages are higher than elsewhere, estimated employment numbers for regions other than the 175 covered above are based on average factor earnings per worker by industry in non-London regions of England and Wales. Finally, these estimates are scaled to fit total regional employment provided by ONS data.[22]

Household consumption shares by region: The default assumption is that household consumption shares are set equal to each region's share of national aggregate income. Some commodities are assumed non-tradable between regions. These local sectors include all

[20] https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/workforcejobsbyregionandindustryjobs05

[21] https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/nominalandrealregionalgrossvalueaddedbalancedbyindustry

[22] https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/li04regionallabourmarketlocalindicatorsforitl3geography

utilities other than electricity, ownership of dwellings, health, residential care, sport and recreational services and domestic household services. Household consumption shares for local sectors are set equal to industry activity shares. All government consumption shares are set equal to household consumption shares.

Estimating international trade shares

Processing export and import data and assigning exports to ports

UK Customs provide detailed international trade by port. The site for downloading in bulk is:

https://www.uktradeinfo.com/trade-data/latest-bulk-data-sets/

There are around 250,000 line entries for both exports and imports each month. Data need to be formatted prior to processing. In a single country model, the origin, in the case of imports) or the destination, in the case of exports, are not of interest as in a multi-country model. Each of the codes requires a mapping. SITC commodities need to be mapped to input-output merchandise commodities in the ONS input-output table. SITC definitions, from which a concordance is prepared, are readily downloadable.

Table 11 : Model of transport codes

Code	Description
10	sea transport (not vehicle on ferry)
20	rail transport
30	road transport
40	air transport
50	Mail
60	Roll on Roll off (RORO)
70	fixed installations, e.g. pipeline & Channel Tunnel
80	inland waterway transport
90	own propulsion, e.g. imported vehicle driven across land boundary

Source: https://www.uktradeinfo.com/trade-data/latest-bulk-data-sets/bulk-data-set-data-dictionary/

The mode of transport is relevant in, for example, obtaining perspective on how important air transport is in international merchandise trade. However, in construction of a national multi-regional CGE database, the mode of transport for exports and imports is not relevant. This is because national input-output tables report imports inclusive of costs, insurance and freight (“c.i.f”), the latter applying to all modes: i.e., freight costs are already included in the value of imports in the input-output table. Export values are reported in Free-On-Board values. These exclude freight costs beyond the port.

Ports are assigned to specific ITL local authority regions. This is important to understand the regional effects of changes to trade. A program based on minimum distances assigns each port to an appropriate ITL local authority region. This uses the latitude and longitude of each port and each local authority region. Some three digit ports in UK Customs data without a clear region are assigned to London: namely NHV, ELL, NGO, XXX. EUT, ZZZ, ZLC, QVV and ZYY. It may be that some of these regions are assigned an inappropriate location. The attribution of ports to ITL local authority regions increases the coverage of trade from Customs data in the estimation process to over 98% of recorded trade value.

Customs data are used to estimate port shares of international trade. They are not used to impose absolute values of trade on the CGE database. Absolute values come from the national ONS input-output tables. In processing Customs data, only 6 months of data covered both imports and exports, using July 2023 to December 2023. The expectation is that use of all months of 2023 would have led to only minor alterations to estimated shares. 12 files of trade data are processed using CSV2HAR (see *https://www.copsmodels.com/gpmark.htm*). These are combined to form a single exports and single imports file. 391 3-digit SITC commodities are mapped to 48 input-output merchandise commodities.

Concerning services, export shares are set equal to industry activity shares. Import shares are set equal to household consumption shares.

Regional trade

The modelling approach taken in TERM is that sub-national trade matrices are best estimated using a series of assumptions concerning tradability of individual goods and services, and a modified gravity formula in which tradability is inversely proportional to distance between an origin and destination. Estimates of regional supplies and demand are a starting point for allocating sub-national trades following the above assumptions.

Regional freight data are an unsatisfactory starting point for estimating inter-regional trades. Such data do not report values, usually being confined to mass or volumes, unlike customs data. They are not comprehensive and lack fine commodity detail. Moreover, they may not include the port of origin/destination, or the final destination of a good, instead reporting activity through transport nodes. Such data may report only a small percentage of the total value of inter-regional trades, being skewed towards high weight per unit value items.

The TERM approach requires a combination of known international trade data by port and a modified gravity assumption. If a region uses an import commodity or produces an export commodity, the movement of the traded good will have two entries in the multi-regional TERM database. For an import, there will be an import recorded at the international port in the import slice of the TRADE matrix, assigning the port as the origin. The destination will be the region at which the commodity is used. The import slice of the USE matrix at the destination will record imports by specific user, summed over all domestic origins.

For exports, the TRADE matrix will record the sale from the origin to the regional port for all users in the domestic slice. The port will record the sales of the export, summed over all domestic origins. In both the export and import example, the port activity is based on regional trade shares elaborated as described above. The trade between the domestic origin and destination is estimated using the modified gravity formula.

Annex C Air connectivity and trade – evidence from the literature.

C.1 The effect of aviation connectivity on distance costs in the existing literature

Modern trade theory, and specifically the theory underpinning applied trade policy analysis, is based on the principle that trade flows between countries are affected by the distance between pairs of countries. Trade costs are factors that increase this distance. They include, besides physical distance, policies such as tariffs, and other frictions that make it more expensive to supply goods and services (or undertake investments) across borders, rather than domestically. These insights are captured by an approach referred to as structural gravity modelling.[23] Research by the WTO, using this modelling framework, suggests that transport and travel costs have accounted for around 20-30% of overall trade costs, depending on country and sector, with information and transactions costs (factors that may also be reduced by contact facilitated by travel - see below) accounting for a further 10%-20% of trade costs.[24] While these estimates pre-date the recent upswing in tariff measures, they are nevertheless indicative of the importance of connectivity to trade costs. This justifies a focus on the way in which connectivity impacts on trade costs.

The existing literature we have reviewed consistently supports the hypothesis that aviation connectivity has a positive impact on trade values. Two main transmission channels have been proposed and studied.

Aviation transport reduces transportation times

The first transmission channel builds on the time saving from air transport compared to other methods of transportation. Consequently, the conduit through which aviation connectivity affects trade values in this mechanism is the transport of cargo.

For example:

- Besedes et al (2024)[25] study increases in flight distances as a result of airspace closures to estimate the link between transport costs and trade values. They find a distance elasticity of around 2, implying that a 1% increase in flight length reduces trade flows by

[23] See Yoto V. Yotov, Roberta Piermartini, José-Antonio Monteiro, and Mario Larch, (2016), *An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model*, WTO

[24] Stela Runbinova and Mehdi Sebit (2021), The WTO Trade Cost Index and its determinants”, *Staff Working Paper ERSD-2021*, WTO,

[25] Besedes T., Chu J. and Murshid, A. P. (2024): Fly the unfriendly skies: The role of transport costs in gravity models of trade, Journal of International Economics 152 (2024), Article 103994.

around 2%. More frequent air connections, by reducing schedule delays[26], may therefore increase trade flows. This effect is highly heterogeneous by product type, with almost the entire effect being driven at the extensive margin (that is the set of products traded reducing) rather than the intensive margin (that is the trade value reducing for all products individually).

- Hummels and Schaur (2013)[27] consider the choice between transporting goods by plane or ship and find that an additional day of transportation time depresses trade flows by the equivalent of a 0.6 to 2.3 percent ad-valorem tariff. Consequently, the introduction of new or quicker air connections may increase trade values by reducing trade costs. This effect is found to be most pronounced for parts or components that are likely to be time-sensitive intermediate inputs.
- Finally, indirect evidence is provided by Feyrer (2019)[28], who leverages the introduction of long-distance air travel as an instrument for trade values to explain variation in incomes. This identification strategy exploits that the introduction of air travel cut transportation times to a greater extent between countries where existing transportation routes (e.g. via sea) were constrained by geography. Whilst Feyrer estimates the elasticity of air distance to trade as immaterial in 1950, by 1985 he finds it had risen to 1.3, implying that a decrease in air distance of 10% increases trade values by 13%. This adds support to the results presented by Besedes et al (2024) and Hummels and Schaur (2013).

Air transport facilitates trade through relationship formation

In the second transmission channel, business travel acts to facilitate trading relationships. In other words, aviation connectivity increases the number of relationships (or their intensity) between potential buyers and sellers. This in turn reduces the transaction costs associated with cross-border trade and investment thus making it more likely that trade between them occurs. Here, the conduit through which connectivity boosts trade is passenger travel. For example:

- Yilmazkuday and Yilmazkuday (2017)[29] extend the time savings channel directly to business passengers and propose that the time-saving from direct flights compared to indirect itineraries acts to reduce trade costs. In their preferred specification the existence of a direct flight between two cities reduces trade costs by about 1.3%.

26 Schedule delay refers to the mismatch between the desired time of travel and the schedule of available connections. For example, a product that is ready to be shipped at 10am but can only be loaded onto a flight departing at 10pm, incurs a schedule delay of twelve hours.

27 Hummels, D. L. and Schaur, G. (2013): Time as a Trade Barrier, American Economic Review 2013, 103(7): 2935–2959.

28 Feyrer, J. (2019): Trade and Income – Exploiting Time Series in Geography, American Economic Journal: Applied Economics 2019, 11(4): 1–35.

29 Yilmazkuday, D. and Yilmazkuday, H. (2017): The role of direct flights in trade costs. *Review of World Economics,* 153**,** 249-270

- Alderighi and Gaggero (2017)[30] study the Italian manufacturing industry and propose that direct flight connections allow buyers and sellers to form deeper relationship and increase the likelihood of trade occurring. Studying changes in the frequency of short-haul flights from Italy to other European countries, they find that a 1% increase in the number of flights between two regions increases the value of exports by 0.03-0.08%.
- Furusawa et al (2024)[31] develop a model in which business travel acts as a means of communication. By engaging in air travel a potential buyer can gain information about the quality of the seller's product. Thus, the availability of air travel increases the likelihood of a potential buyer seeking to trade with a foreign seller. The authors construct a regional connectivity index based on the presence of direct flight connections and find a positive relationship between aviation connectivity and trade values, which is strongest for products that are poorly substitutable.
- Wang et al (2025)[32] also highlight business travel as an enabler of in-person communication. In their framework in-person communication can overcome contractual frictions, thus enabling trade. They estimate that a 1% increase in passenger flows leads to a 0.031% expansion in trade for industries with average contract-intensity, which rises to 0.042% for industries with exceeding the average contract intensity. An increase of 100% in aviation connectivity is estimated to be equivalent to a 15.3% reduction in imports tariffs (20.8% for high contract-intensive industries).

C.2 Application to the expansion of capacity at Heathrow Airport

The parameter estimates from the literature quantify the effects of air connectivity on trade in the specific setting that is studied. Before using such an estimate in the modelling of Heathrow expansion it is necessary to consider whether the estimate is likely to be informative of the effect of additional aviation connectivity induced by Heathrow expansion.

In the specific context of the UK economy an area of particular interest is trade in services, which in 2024 made up just under 50% of UK trade and over half of UK exports. Whilst the UK ran an overall trade deficit of just under 1% of GDP in 2024, its trade surplus in services amounted to more than 6% of GDP.[33] Financial and professional services make up a material portion of UK services trade.[34] To the extent that improvements in aviation connectivity boost

30 Alderighi, M. and Gaggero, A. A. (2017): Fly and trade: Evidence from the Italian manufacturing industry. *Economics of Transportation,* 9, 51-60.

31 Furusawa, T., Sun, C., Tang,H. and Zhang, Jiaxu (2024): Communication Costs, Direct Flights and International Trade, CESifo working paper No. 11364

32 Wang, F., Wang, Z. and Zhou, Z. (2025): All Roads Lead to Rome: Global Air Connectivity and Bilateral Trade, SSRN and American Economic Journal: Applied Economics (forthcoming).

33 https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/bulletins/uktrade/december2024#annual-trade-in-goods-and-services

34 ONS (2025), The Pink Book 2025

trade values, this would be particularly beneficial to the UK economy through an increase in services exports.

Consequently, studies considering the trade facilitation mechanism described in the previous subsection are of particular interest to us. However, the existing body of literature consistently relies on data on trade in goods. For example, Yilmazkuday and Yilmazkuday (2017) construct their estimate of trade costs using price data on a basket of products that only contains goods and no services. Whilst we are aware of one recent paper that explicitly studies services trade, we have concerns about the robustness of its results and their applicability to Heathrow expansion.[35]

Nonetheless, **we consider that a transmission mechanism where an increase in aviation connectivity leads to an increase in business travel, that in turn enables trade by deepening relationships or reducing information frictions, extends to trade in services**. This is because:

- Business travel in services sectors not only facilitates future trading relationships but often represents trade in services itself (e.g. consultants travelling to undertake a project at a client's side). Thus services trade requires that the buyer and supplier enter into contact with each other. Empirical studies suggest that this "proximity" burden makes services more responsive to changes to distance costs than goods.[36] If that is the case, it would also mean that elasticities estimated in the context of goods trade may understate the responsiveness of services to reductions in distance costs.
- The evidence presented in Furusawa et al (2024) and Wang et al (2025) highlights that the effect on trade is greatest for goods sectors with large frictions that can be overcome by relationship formation. Since the provision of many services is itself relationship-intense and we would expect that the effect of the availability of business travel on trade in professional and financial services is also comparatively large.
- A material proportion of the value added of goods trade are services embedded within the goods traded (e.g. design of a turbine to be exported or a contract for ongoing maintenance of the turbine at its destination).

Based on these considerations, we adopted the following approach. For goods trade, we selected elasticities from the recent study by Wang et al (2025). We have chosen this paper as applicability to the Heathrow expansion scenario is strong. In particular, the paper's sample variation is largely driven by greater utilisation of existing services (fuller flights, more frequency, larger aircraft, etc.) which is closer to the Heathrow expansion case. Moreover, the paper uses passenger data, which is one of the key outputs from the aviation modelling suite.

35 Oum T. H., Wu X. and Wang K. (2024): Impact of air connectivity on bilateral service export and import trade: The case of China, Transport Policy 148, 219-233.

36 WTO (2019), *World Trade Report 2019 : The Future of Services Trade*, p 53

The paper uses global itinerary level passenger data from OAG matched with CEPII-BACI trade data with a large sample over 2013-2018.[37] It uses a gravity framework and instrumental variable approach which exploits variations in connectivity between an origin country and destination country through an increase in capacity on direct flights to the destination country from third countries, which could form part of an indirect itinerary from the origin to the destination country.

As already observed, the headline result is that a 10% increase in passenger flows leads to a 0.31% growth in trade for an industry with average "contract intensity". By this is meant the extent to which there are information frictions that raise the costs of contracts, and require relation-specific investments (e.g face-to-face meetings to build trust) to overcome them. The contract intensity measure is taken from Nunn (2007)[38] and is derived from the value share of relationship-specific inputs. The intuition is that passenger flows facilitate these inputs and therefore cross border commercial transactions. Wang et al (2025) report elasticities varying by sector based on a measure of each sector's contract intensity. Sectors with a higher contract intensity are expected to have higher information frictions and rely on relationship-specific investments.[39]

For services trade, we have used the same elasticities as for goods trade. There is limited literature directly assessing services trade. However, in our view the key mechanism assessed in Wang et al (2025), is highly applicable to services. This is because of the particular nature of services trade, where modes of delivery require suppliers to enter into contact with purchasers, and where consumption and production are not separable as they are in goods. Wang et al focuses on information sharing barriers and relationship intensive transactions, which are highly relevant for services, in particular business and financial services which are of primary relevance for the UK and Heathrow expansion context. As with goods trade, we have reflected variations in contract-intensity across sectors.

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[37] BACI is a harmonised dataset of annual bilateral merchandise trade flows, covering around 200 countries at detailed product level. It is produced by the Centre d'études prospectives et d'informations internationales (CEPII). Products are classified using the Harmonized System at the 6-digit level, with roughly 5,000 products. The dataset is built from UN Comtrade data and reconciles exporter and importer declarations to reduce inconsistencies in reported flows. This harmonisation makes trade values and quantities more comparable across countries, products and years, and suitable for empirical analysis at the granular product level.

[38] Nunn (2007): Data for 1997 Disaggregated According to the BEA's 1997 I-O Industry Classification (based on 6-digit NAICS), https://nathannunn.arts.ubc.ca/data/.

[39] Note, the headline finding of 0.31% rises to 0.42% for sectors with a contract intensity one standard deviation above the average.

Annex D Use of OAG data to apportion aviation modelling data to destinations.

One channel through which Heathrow expansion is likely to impact UK economic growth is by the cost of trade with other countries. To accurately capture these effects, it is important to accurately identify the geographic breakdown of the increase in passenger volumes as a result of expansion to ensure that the reduction in trade cost is mapped accurately to each trading partner.

For this purpose we use data from the Official Airline Guide (OAG) in addition to DfT Aviation Suite Modelling data. The OAG is a commercial aviation data provider, which collects and publishes flight schedule and passenger travel data. OAG's passenger travel data is based on actual booking data in the Global Distribution System (GDS) used by e.g. travel agents and can therefore reveal actual travel routes (including connecting flights). Since not all passenger bookings are processed through the GDS, the available data is adjusted to estimate overall passenger flows

The DfT’s approach to passenger estimates

The DfT’s aviation modelling suite models passenger volumes from the UK to each of its model regions and vice versa. However, we understand that the DfT’s aviation model does not explicitly account for indirect routings, where passengers travel via one or more intermediate airports before reaching their final destination (other than the four modelled overseas hubs of Amsterdam, Dubai, Frankfurt, and Paris).

As a result, we understand that the model would record indirect passengers at the first model region within a passenger’s journey. For direct routings, this corresponds to the passenger’s final destination. However, for journeys involving transfers, passengers may be assigned to a different model region than the region of the airport at which they ultimately end their journey.

In practice, this means that journeys involving onward travel beyond the first international airport (for example, London - Dubai - Sydney) are attributed to the intermediate gateway rather than the passenger’s true final destination. We note that the model explicitly considers UK domestic transfers, meaning this truncation occurs at the first non-UK gateway.[40]

[40] The exception to this are the four hub airports AMS, CDG, FRA and DXB, which are modelled explicitly in a similar manner to UK airports.

Our approach to assessing passenger volumes

To augment the estimates from the DfT's aviation modelling suite, we have used data on passenger's itineraries from OAG covering the calendar year 2024 to analyse indirect routings with transfers outside the UK.

Our approach proceeds as follows:

1. First, we map the airports in the OAG dataset to the DfT model regions, using a combination of airport-level, country-level and region-level rules.
2. We then calculate for each DfT model region the total number of passengers travelling from the UK directly to an airport in that region. In this calculation passengers transferring at that airport to an onward connection are assigned to the first non-UK airport they travel to. This creates a measure of passenger volumes, which is consistent with the DfT's aviation modelling suite outputs.
3. Following this, we calculate for each DfT model region the total number of passengers from the UK who complete their overall journey in this region. This means, that transfer passengers are assigned to the airport they finish their journey at.
4. We then compare these passenger figures and derive the ratio of the number of passengers whose final destination is within each model region (step 3) over the number of passengers whose first non-UK airport is in that region (step 2).
5. Finally, we use this ratio to scale up the total number of passengers travelling from the UK to each model region in the DfT's aviation modelling suite outputs.

Our approach assumes that the travel patterns observed in the OAG itinerary data are representative of the potential travel patterns of the additional passengers caused by Heathrow expansion. In particular, we assume that the proportion of passengers travelling via indirect routes, and the distribution of their final destinations, remains stable when scaling passenger volume.

Consistent with our assumption that Heathrow expansion is unlikely to lead to a reduction in trade costs with other European countries, we restrict the analysis to itineraries with a final destination outside Europe.

Results and observations

The results of this exercise suggest that for some regions total passenger volumes can differ materially once onward travel is taken into account.

Table 12 presents the detailed results of this comparison. For each DfT destination, the table shows the number of passengers who complete their journey in the same region as their first non-UK airport, the number of passengers who complete their journey after having transferred at an airport in a different region and the resulting uplift once actual final destinations are considered.

Table 12 Summary of Results

DfT Area Name	DfT Zone	Total passengers (Direct or first Non-UK connection)	Total passengers (final destination)	Difference in passengers from DfT method	Uplift factor	Uplift (%)
Canada East	North America	76,572	75,165	1,630	0.98	-1.84%
Canada West	North America	69,509	73,529	4,836	1.06	5.78%
Mexico	North America	314,673	322,100	7,466	1.02	2.36%
US East	North America	2,243,746	2,175,329	1,608	0.97	-3.05%
US West	North America	750,039	772,748	26,557	1.03	3.03%
Israel	Other European	57,235	57,236	1	1.00	0.00%
Russia & non-EU former Soviet	Other European	27	33	6	1.22	22.22%
Africa East	ROW	93,101	94,355	1,351	1.01	1.35%
Africa South	ROW	329,949	330,171	417	1.00	0.07%
Africa West	ROW	538,715	538,600	43	1.00	-0.02%
African Mediterranean	ROW	1,886,653	1,885,570	14	1.00	-0.06%
Caribbean	ROW	600,668	623,086	28,087	1.04	3.73%
Chile	ROW	18,781	19,539	1,031	1.04	4.04%
China (Incl.Hong Kong)	ROW	205,265	196,167	114	0.96	-4.43%
Dubai	ROW	176,573	177,233	660	1.00	0.37%
Far East (other)	ROW	109,638	98,900	2,563	0.90	-9.79%
Indian Sub-continent	ROW	616,626	627,365	10,907	1.02	1.74%
Japan & South Korea	ROW	106,766	107,567	897	1.01	0.75%
Middle East	ROW	258,465	246,599	1,055	0.95	-4.59%
South America (other)	ROW	108,857	120,662	12,806	1.11	10.84%
South Pacific (other)	ROW	22,675	42,579	19,905	1.88	87.78%

Source: 2024 OAG itinerary data; DfT model aviation analysis

Note: Of primary importance here is our 'Uplift (%)' column, which calculates the ratio of the number of passengers whose final destination is within each model region over the number of passengers whose first non-UK airport is in that region.

Overall, the pattern of uplift aligns with expectations based on global hub structures. That is, regions that are typically reached via intermediate hubs show higher uplift, while regions that act as hubs themselves tend to show lower or negative uplift.

For example, the South Pacific exhibits a significantly large uplift of approximately 88%, which is consistent with passengers travelling via major hubs such as Dubai or Singapore before reaching Australia and neighbouring markets. By contrast, some destinations show a small negative uplift, indicating that some passengers use airports in these regions for onward travel. Examples of a negative uplift include US East (-3%), Middle East (-5%), and Far East (-10%), which is consistent with these areas including major transfer hubs such as JFK, DOH or SIN, where a proportion of passengers continue onwards to other final destinations.

Annex E Quality Assurance and management of conflicts

E.1 Approach to quality assurance.

Quality Assurance for this research was structured in different tiers:

1. The structure of the CGE model and its simulations
2. Inputs into the modelling that were the responsibility of Frontier Economics.

CGE models and simulations

A first step in quality assurance lies in model validation. This in turn requires following established good practices. These are documented in the peer-reviewed literature.[41] The main steps are to ensure that the model:

1. Exhibits computational stability;
2. Incorporates accurate and up-to-date data;
3. Represents relevant behavioural and institutional structures;
4. Aligns with historical patterns, and
5. Provides credible forecasting performance.

With regard to (1), we conducted test simulations in the initial phase of the project based on early inputs relating to capital expenditures and limited operational effects. TERM-UK is an extension of the TERM class of models, configured specifically for this exercise. The initial runs helped to test the stability of the model, particularly in relation to its handling of regional effects and interactions. Model structure and initial runs were documented and presented to DfT.

On (2) and (3), the most effective approach for displaying the relevant data and describing what is going on is via a back-of-the-envelope (BOTE) model. A well-designed BOTE model has two properties: it reveals the roles of major behavioural, institutional and data assumptions in causing a model to generate a particular result; and it is small enough to be managed with pencil and paper (on the back of an envelope). Based on the initial runs, BOTE tests were undertaken to test whether the results were sensible.

Points (4) and (5) drew on findings from the early runs. These in turn could be compared to results from other infrastructure projects that exhibit splits between a construction phase and an operational phase. Model runs were also undertaken which combined expansion-related

[41] Peter B. Dixon, Maureen T. Rimmer, Chapter 19 - Validation in Computable General Equilibrium Modeling, Editor(s): Peter B. Dixon, Dale W. Jorgenson, Handbook of Computable General Equilibrium Modeling, Elsevier, Volume 1, 2013

expenditures with baseline domestic and foreign passenger demands (i.e. as measured by spending). This helped to identify the responsiveness of outcomes to fluctuations in passenger projections and associated spending profiles. A major internal point of discussion from this phase of work was the delayed nature of operational benefits under the expansion scenarios. This structure of operational benefits is not typical of large infrastructure projects that are modelled using CGE techniques. The structure reflects outputs from the DfT aviation modelling suite which are independent of the CGE modelling. Testing under this stage helped to identify shifts in outcomes that stemmed from shifts in profiles and the stability of the model as a consequence.

All modelling steps and decisions were logged to ensure traceability.

In addition to these steps relating to model structure and performance, specific steps taken to quality assure model outputs included:

- The GEMPACK programming language was used to generate outputs that corresponded to the reporting requirements for the project e.g. decomposition of GDP effects by drivers of these effects.
- Model outputs were transmitted in spreadsheet form to the wider analytical team at Frontier to check calculations and interpretations. This was an iterative process.
- Internal review of modelling output by CGE modellers not involved in the project to review modelling outputs and results.

Inputs into CGE modelling

Initial research conducted by DfT identified a range of possible channels through which capacity expansion could generate wider economic effects. Based on this work, we identified effects on trade costs as the channel which could be most readily adapted to the outputs generated by the DfT modelling suite and combined with the structure of the model. Changes to trade costs would enable to quantify effects on exports and imports, and through that, induced productivity effects reflecting the relationship between trade/ trade openness and growth. This approach has the advantage of: drawing on advances in methods to quantify trade costs based on gravity modelling principles, and an extensive empirical literature on trade/ growth effects.

Further literature reviews identified plausible parameters for the responsiveness of trade to changes in passenger movements. Gravity modelling principles were then used to derive trade cost effects (see Annex C and section 3.3.2). Both the literature review and trade cost estimation stage were reviewed by an external expert – Dr. Ben Shepherd – who is an internationally recognised expert in the area. Trade cost calculations went through several iterations, based on that review, feedback from DfT, and feedback from the CGE modelling team.

E.2 Conflicts of interest

Frontier Economics (Frontier) was previously commissioned by Heathrow Airport Limited (HAL) to undertake Computable General Equilibrium (CGE) modelling of airport capacity expansion at Heathrow Airport. In undertaking this work for the Department for Transport (DfT), we have, in collaboration with DfT, implemented a number of steps to manage any actual or perceived conflicts of interest. The Frontier project director for this work has not participated in previous modelling work undertaken for HAL. The project manager oversaw prior CGE modelling work for Heathrow as part of his work on international trade, but has no other involvement with HAL. External review was undertaken by a peer reviewer commissioned by DfT, and DfT staff were closely involved in reviewing the modelling approaches.

All key inputs relating to capacity expansion scenarios, notably in relation to passenger forecasts, were provided by DfT and were not shared outside the project team working for the DfT. Other data inputs required for scenario modelling have been sourced from public sources. All data, including inputs and modelling results, have been stored securely in folders with access restricted to staff working on this project.

The CGE modelling was led by the Centre of Policy Studies (CoPS) in Melbourne, by personnel who have not worked with HAL on previous modelling projects. CoPs is a research centre of international standing with no affiliation with Heathrow Airport. The CGE model used – TERM-UK – was specifically configured for this work undertaken for DfT and is separate to and distinct from the modelling infrastructure used for the modelling work Frontier undertook for Heathrow Airport.

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