Squaring the circle – Reconciling the GDP and welfare impacts of transport interventions

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Glossary

Term	Definition
GDP	GDP captures the value of traded goods and services (net of the costs of materials) and is a market-based measure of economic w ellbeing. This definition is consistent with WebTAG guidance[1]: the 'measure of value of goods and services produced in an economy w ithin a specific time period'.
Business time savings	Time savings which accrue during journeys made in the course of work. This excludes commuting journeys. This is based on the definition in WebTAG A1.3.[2]
Commuter time savings	Time savings which accrue as part of journeys travelling to and from the normal place of w ork. This is based on the definition in WebTAG A1.3.[3]
Consumer surplus	The difference between the value a consumer places on a good/service and the price they actually pay for it.
Displacement	Our definition is consistent with the Department for Transport's definition used in WebTAG A2.1[4]: 'the extent to w hich economic activity is relocated from one area to another. Displacement can occur in labour, capital and product markets'.
Disutility of w orking	The loss of utility from reductions in leisure time as a result of the supply of additional hours of w ork.
Dynamic agglomeration	The change in productivity brought about by individuals and firms relocating, and hence altering access to economic mass w ithin each region.
Externalities	As defined by the OECD (2003)[5], 'Externalities refers to situations w hen the effect of production or consumption of goods and services imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided'. In this report, common examples of externalities w hich are referenced are changes in air pollution, noise pollution and safety.
Imputed rent	Reflects the value of the output of ow ner-occupied housing by approximating the market value of this "self-provision".
Inputs	Refers to factors of production (land, capital, and labour).
Land use change	As defined in WebTAG A2.1[6], this refers to 'changes in the purpose and/or intensity of usage' of land.
Leisure time savings	The time savings w hich accrue on journeys for non-work trips. This is based on the definition in WebTAG A1.3.[7]
Level	In the report the 'level of GDP' or 'level of w elfare' refers to the absolute size of GDP and w elfare.
Marginal rate of technical substitution	The rate at w hich inputs may be substituted w hile the output level is constant e.g. the additional number of units of capital that are needed in order to replace one labour unit to keep the output level constant.
Outputs	Outputs refer to intermediate or final goods and services produced by a combination of inputs.

1 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/712878/tag-unit-a2-1-wider-impacts-overview-document.pdf

2 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/603254/webtag-tag-unit-a1-3-user-and-provider-impacts-march-2017.pdf

3 IBID.

4 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/712878/tag-unit-a2-1-wider-impacts-overview-document.pdf

5 OECD (2003) 'OECD Glossary of Statistical Terms – Externalities'

6 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/712878/tag-unit-a2-1-wider-impacts-overview-document.pdf

7 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/603254/webtag-tag-unit-a1-3-user-and-provider-impacts-march-2017.pdf

Term	Definition
Producer surplus	Difference between the market price and the cost of producing that unit, summed over all units of production.
Productivity impacts	We define productivity impacts as 'the impact of transport investments on the efficiency with which the factors of production (such as land, labour and capital) are used in the production process: productivity may increase because either fewer factors of production are required to produce a unit of output, or there is a reallocation of the factors of production towards higher value added activities'. This definition is consistent with the definition of productivity impacts used in WebTAG A2.1[8]
Static agglomeration	The change in productivity to all firms in a region, as a result of changes in their access to economic mass.
Sticky Wages	When wages do not adjust in a timely manner to changes in labour market conditions.
Wedge	We define wedges as differences which arise between the GDP and welfare impacts from a given transport intervention or investment. We define a 'positive wedge' between welfare and GDP as when the level of welfare is increased by more than the level of GDP.
Welfare	Economic welfare is the sum of all household utility, measured in monetary units, including the value of income from all sources, and the value of non-market sources of well-being, net of dis-utilities from dis-amenities and foregone leisure. This is largely based on the definition adopted by Venables, Laird & Overman (2014, p.15): they state that welfare includes benefits that are un-marketed. Welfare is often operationalised as the sum of all consumer and producer surplus.

[8] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/712878/tag-unit-a2-1-wider-impacts-overview-document.pdf

1 Briefing note

1.1 Purpose of this report

1.1.1.1 This report is intended to assist policymakers and scheme promoters with the economic appraisal of transport interventions by showing how to reconcile the GDP and welfare impacts of transport interventions.

1.1.1.2 Economists generally agree that economic welfare is a more appropriate objective for public policy than maximising GDP (it is, by definition, what society 'cares about'). However, it is often important also to appraise the impacts of a scheme on GDP because of the scheme's specific objectives – which might, for example, be to increase the level of economic activity in the country or in a particular area.

1.1.1.3 Given that GDP and welfare are so frequently used when considering the impact of transport interventions, this report highlights the main ways in which a transport intervention can affect these measures differently – and when a difference (or what we refer to as a 'wedge') between the two measures can occur.

1.2 The relationship between GDP and welfare

1.2.1.1 GDP captures values associated with traded goods and services. Welfare does this but also captures a number of other important factors, such as the value of people's leisure time and externalities (e.g. safety, noise, pollution, and air quality), plus any value consumers enjoy from consumption over and above the price they pay for a good/service.

1.2.1.2 In this report, we identify the two main sources of 'wedge' between impacts on GDP and welfare. The first is that the transport interventions can affect things which are not traded through markets and therefore affect welfare but not GDP. The second is that the way in which markets operate can sometimes lead to different impacts on GDP and welfare.

1.3 Structure of our report

1.3.1.1 We structure our report as follows. We begin by presenting a relatively restrictive but frequently applied demand and supply framework as the starting point for our analysis. We then consider the different impacts of a transport intervention. These impacts include: reductions in travel times; agglomeration effects; and other externalities (such as changes in air quality, noise and visual amenity).

1.3.1.2 We find that a wedge can arise as a result of these impacts in two main ways:

A. Changes in leisure and commuter journey time savings affect welfare but they are not monetised and are therefore not captured in GDP; and
B. Externalities arising from a transport intervention (such as the impact of changes in the amount of travel on noise and air quality) also affect welfare but tend not to be fully reflected in GDP.

1.3.1.3 We then move onto what we refer to as the "knock-on impacts" of a transport intervention. We split the discussion into four distinct sections: the market for goods and services; the labour market; and the market for other inputs (i.e. capital and land). For completeness we also consider impacts on the housing market.

1.3.1.4 We find that:

- No wedge arises in the market for goods and services. Changes in the quantities and prices of goods that are brought about by the transport intervention affect welfare in the same way they affect GDP. Importantly, within the framework that we use for our analysis, this is true regardless of what assumptions we make about competition in the market.
- Wedges can occur in the labour market if the supply of labour is flexible (i.e. if people supply more labour in response to a higher wage, reflected by an upward-sloping labour supply curve. In this situation, GDP and welfare both reflect the higher income generated by increased working, but only welfare reflects the increased disutility of work.
- For other inputs (i.e. land and capital), the main wedge which could occur is a change in land-use pre and post intervention. For example, if land is converted to productive activity (e.g. from parkland to a business park) as a result of a transport intervention, then this might increase GDP but adversely affect welfare. Likewise, if a transport intervention was to lead to the conversion of a brownfield site to parkland, then this might increase welfare but reduce GDP.
- It is possible that an effect could occur in the housing market which we refer to as an 'inverse wedge' – in that the value of non-monetised impacts (such as the amenity value of living in a particular place) could become monetised through actual and/or imputed rents. The analysis suggests that these are unlikely to be material at a national level but might be more important regionally or locally.

1.3.1.5 Our final section discusses other potential issues and sources of a w edge, including:

- The **characteristics of the location** of a transport intervention and other surrounding areas. There are three key points to note here. First, individuals may value regions differently based upon the inherent characteristics of the regions (and w hether they consider the regions to be "good" places to live). If people relocate as a result of a transport intervention, then GDP might not fully account for the change in w elfare experienced by the individual that has moved. Second, w hile an increase in accessibility brought about by a transport scheme could lead to a similar increase in "GDP" in tw o regions, there could be different welfare effects for regions because of how: (i) individuals based in the more distant region might experience greater disutility of travelling; and (ii) individuals closer to the transport intervention might experience visual and noise effects during both the construction and operation of the intervention. Third, a transport intervention could have a significant impact on the movement of goods and services between regions. For example, an intervention could lead to more goods and services being imported from region B by region A. This could lead to a higher w elfare than GDP impact in region A because w hile goods are being consumed in region A (w hich is positive for welfare) money is flow ing out of the region in order to pay for the "imports" w hich are taking place (w hich is negative for the "GDP" of region A).
- **Utility functions and social welfare functions:** There are tw o key points to note here. First, depending on the social w elfare function society may place greater value on additional w ealth accruing to certain groups, and thus an additional unit of w ealth could have different welfare effects depending on w ho experiences a change in w ealth. Appraisers should be aw are that if a policy intervention is aimed at rebalancing the economy and tackling inequality, this could give rise to a w edge between GDP and w elfare (e.g. an economic boost to a relatively deprived area could increase w elfare in that area by more than GDP). Second, the utility that is experienced by individuals tends to be characterised by a "love of variety" (Dixit and Stiglitz, 1975) in that individuals' utilities tend to increase w ith the range of products they are able to access. An improvement in accessibility could therefore improve consumers' w elfare without altering GDP.
- **Interactions between factors of production:** While the main focus of our analysis has been on w hether w edges could arise in the markets for inputs (labour, land and capital), w e have also considered w hether and how a transport intervention may affect the relative demand for these inputs. Relative demand for inputs is determined by: (i) their relative prices; and (ii) marginal rate of technical substitution betw een them. If a transport intervention affects the relative demand for, and use of, inputs then this could affect w hether, and if so the extent to w hich, w edges occur.

1.3.1.6 In Figure 1 w e provide a summary of our main findings. We show : (i) our "default position" in terms of w hether (generally speaking) a w edge will arise in a particular area and w hat the size of this w edge will be; (ii) the main implications for appraisers in terms of w hat they should take into account w hen carrying out their analysis; and (iii) w hat further research, if any, should be carried out in the area. We also describe an example of how GDP and w elfare impacts have been assessed and reconciled during the course of an actual appraisal.

1.3.1.7 We hope that our analysis and findings are useful to appraisals that are carried out in the future and that, in "squaring the circle" of how to reconcile the GDP and w elfare impacts of transport interventions, our work will help to ensure that the correct investment decisions are made – to the benefit of the economy and the w elfare of the country.

2 Main findings

2.1 Introduction and purpose

2.1.1.1 The economic appraisal of transport schemes in the UK makes extensive use of WebTAG (Web-based Transport Analysis Guidance), produced by the Department for Transport (DfT). A key output of a WebTAG-based assessment is an estimate of the economic welfare impact of the scheme under consideration. Economic welfare captures the effects of transport on the economy (e.g. the value of journey time savings and the increase in business productivity from increased connectivity) but also on other important factors such as the value of people's leisure time and 'externalities' such as pollution, noise and safety.

2.1.1.2 Economists generally agree that maximising economic welfare is a more appropriate objective for public policy than is maximising GDP. However, it is often also important to appraise the impacts of a scheme on GDP because of the scheme's specific objectives – which might, for example, include increasing the level of economic activity in the country or in a particular area. In the past there has been considerable debate about how GDP impacts relate to measures of economic welfare and whether differences in estimates of the two measures indicate the potential for "missing impacts".

2.1.1.3 It is worth noting that DfT's recent guidance[9] on assessing wider economic impacts makes clear that:

- Economic welfare provides the best means of assessing value for money (VfM), as this is a broader and more comprehensive measure of well-being than GDP; but
- Where GDP is a strategic objective of a scheme, the impact of the scheme on GDP can be assessed within the strategic case of the business case, and that the VfM and GDP impacts should be reported alongside each other in a new Economic Impacts Report.

2.1.1.4 The Department for Transport commissioned PricewaterhouseCoopers LLP (PwC) to assess how the impact of transport schemes on GDP can be reconciled with their impact on economic welfare. This report shows how GDP and welfare relate to each other depending on various assumptions about how different markets are structured and behave, and in a manner that takes account of various "knock on effects" in the wider economy.

2.1.1.5 This report is intended to assist policymakers and scheme promoters with the economic appraisal of transport interventions. Our work is specifically intended for use in the appraisal of domestic surface transport schemes (primarily roads but also rail), but most of the principles in this report could be adapted and then applied to international and non-surface transport schemes (e.g. aviation and maritime).

2.2 The relationship between GDP and welfare

2.2.1.1 In order to identify how the GDP and economic welfare impacts of transport schemes differ from one another, we have structured our analysis in a way that examines the fundamental sources of potential divergence between the two indicators.

2.2.1.2 Throughout this report, any difference between the impact of a transport scheme on GDP on the one hand and welfare on the other is referred to as a 'wedge'. There are two fundamental sources of wedge:

- First, when there are impacts on goods and services which are **not traded through a market**. GDP is, by definition, a market-based measure of economic wellbeing. As such, if the transport intervention affects goods or services which are not traded through a market then GDP will not capture these effects. For example, since there is (usually) no "market" for the right to cause noise pollution (or many externalities more generally), the effects of noise pollution are not captured in GDP (indeed, as stressed in the seminal work by Coase (1937), externalities occur precisely because markets are "missing"). This source of difference can also be thought of as arising from the different definitions of GDP and welfare: if an effect is not captured in the marketplace, by definition it cannot by measured by means of GDP.
- Second, is because of **how markets operate**. GDP values goods and services based on the prices observed in the market, but the way in which markets operate (both for (a) final goods and services and for (b) inputs like labour, capital and land) has the potential to affect the impacts of transport schemes on GDP and welfare differently, thereby driving a 'wedge' between the two.

2.2.1.3 The approach we adopt in this report to consider these two sources of wedge is as follows:

- We provide context on transport appraisal and summarise the conceptual relationship between welfare and GDP.

- We set out the framework which we use throughout the report.
- We show how wedges arise between GDP and welfare as a result of what we refer to as "first round effects". We classify these first round effects into:
  - impacts – such as reductions in the time it takes to travel between places and agglomeration effects; and
  - externalities (other than agglomeration), such as the effects that a transport intervention could have on the environment.
- Finally, we consider what we refer to as "knock-on" effects, which show how agents in the wider economy respond to a transport intervention (e.g. through the market for goods and services, the labour market, the market for inputs). In the interests of completeness, we also consider potential impacts on the housing market.

2.3 Framework used for the reconciliation

2.3.1.1 The framework which we use starts from a standard demand and supply diagram. Initially we make the following assumptions:

a) all markets operate under conditions of perfect competition;

b) the supply of labour, capital and land is fixed; and

c) the impact occurs within a single region (or multiple identical regions, with no transaction costs involved in moving factors of production between regions).

We then go on to relax these assumptions and consider more complex situations.

2.3.2 Impacts and externalities

2.3.2.1 We consider four key initial economic impacts which arise through transport interventions and whether they will give rise to a 'wedge' between GDP and welfare: (i) business user time savings; (ii) leisure and commuter time savings; (iii) agglomeration; and (iv) other externalities[10]. We examine each in turn.

2.3.3 Business user time savings

2.3.3.1 As set out in Chapter 5, business user time savings and agglomeration effects can affect the economy by increasing productivity. We show that, under the assumptions above, these productivity-enhancing effects will not drive a wedge between welfare and GDP. This is because these productivity-enhancing effects will be captured in the marketplace (via reduced prices, and therefore higher real incomes, and/or increased wages[11]). These effects therefore have equal impact on GDP and welfare.

2.3.4 Leisure and commuter user time savings

2.3.4.1 Evidence from stated-preference willingness-to-pay research (such as that which currently underpins WebTAG[12]) suggests that leisure and commuter users generally attach a positive value to time savings. The implication of this is that leisure and commuter user time savings will, on average, result in welfare gains regardless of how those time savings are put to use. However, the extent to which time savings affect GDP depends on how much of the time saved is "spent" on "productive" activities (which are "valued" by the market and therefore enter GDP) rather than on other activities (which do not affect GDP).

2.3.4.2 In the short-run, it is reasonable to assume that any time saved by business users is effectively "owned" by the employer and therefore affects GDP (as well as welfare)[13]. This explains the conclusion in the previous sub-section. In contrast, for leisure users and commuters, it is reasonable to assume that the time saved is "owned" by the individual and that, in the short-run at least, any time saved is not used in productive activity. As leisure/commuting time is not valued in the marketplace, this time saving will have no impact on GDP. This means that leisure and commuter time savings are likely to create a 'positive wedge' between welfare and GDP (in the sense that the level of welfare is increased by more than the level of GDP). As the GDP effect is likely to be zero, this wedge is likely to be equivalent to the size of the welfare effect[14].

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[10] We refer to "other" externalities because, strictly speaking, agglomeration is an externality. Note also that, in the interests of brevity, we have excluded from our analysis a number of usually relatively small impacts such as fuel and non-fuel vehicle operating costs.

[11] Note that we are assuming perfect competition, meaning that firms only make normal profits. Under conditions of imperfect competition, the productivity effects could also manifest themselves as increased supernormal profits. As with wages, these profits would contribute equally towards both GDP and welfare.

[12] ITS Leeds (2013) 'Valuation of Travel Time Savings for Business Travellers: Main Report', Prepared for the Department for Transport [pdf], available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/251997/vtts_for_business_main_report-dft-005.pdf

[13] We relax the assumption of fixed labour supply in Chapter 8.

[14] There is potential for time saved to be converted to different uses and this is considered in our later analysis of 'second-round effects'. The extent to which this occurs will be determined in part by the flexibility of labour supply. In our section on direct impacts, the total supply of labour is fixed and therefore any change in leisure and consumer time will have no impact on the number of working hours. This suggests that, even in the long-run, individuals are unable to

2.3.5 Agglomeration

2.3.5.1 Under WebTAG, static agglomeration is defined as '*The change in productivity to all firms in a region, as a result of changes in their access to economic mass'*. Agglomeration is traditionally measured through changes in productivity and – for the reasons set out above – will therefore be captured by both GDP and welfare equally (i.e. there is no wedge between the two measures with changes in productivity being reflected equally in welfare and GDP).

2.3.6 Externalities

2.3.6.1 Transport investment also affects the level of "externalities" other than agglomeration – such as air quality, noise, greenhouse gases and accidents – which are not traded through the market and therefore unlikely to be fully reflected in GDP.

2.3.6.2 Some externalities from transport investment can be positive (for example if a new scheme reduces noise or pollution) and create a 'positive wedge' between welfare and GDP (in the sense that the level of welfare is increased by more than the level of GDP). Conversely, other externalities can be negative (for example if a new road stimulates new traffic that is likely to give rise to noise or air pollution) and create a 'negative wedge' between welfare and GDP (in the sense that the level of welfare is increased by less than the level of GDP).

2.3.7 Knock-on effects

2.3.7.1 Chapter 4 describes how wedges can arise either because impacts are not transmitted through a market (e.g. because of externalities) or because of how impacts which are transmitted through markets actually manifest themselves in the economy (i.e. because of how markets function).

2.3.7.2 Under the simplified assumptions above (perfect competition, fixed supply of factors of production, and a single region model), we have explained that key impacts of transport interventions – business time savings or agglomeration – do not result in a wedge between GDP and welfare impacts.

2.3.7.3 However, if we relax these assumptions about how markets operate, there is potential for differences between welfare and GDP impacts. We explore this by considering: competition in the markets in which firms compete (what we refer to as the market for goods and services); the labour market; the market for other inputs (e.g. capital and land); the housing market; and other considerations.

2.3.8 Market for goods and services

2.3.8.1 It is natural to consider whether assumptions that are made about competition in the market for goods and services can create a wedge between GDP and welfare – after all, our initial framework assumed that markets are characterised by perfect competition. Our main finding is that **a wedge does <u>not</u> occur when we relax the assumption of perfect competition**. A transport scheme that increases productivity therefore affects welfare and GDP equally, regardless of whether competition is perfect or imperfect in nature. This finding is driven by how, even under imperfect competition, any change in productivity must flow into either an increase in profits for firms, or an increase in real income for consumers. As both profits and real incomes contribute equally to GDP and welfare, there is no 'wedge' between welfare and GDP[15]. This is an important finding in its own right (e.g. because of how the impacts of imperfect competition are dealt with from a welfare perspective by WebTAG).

2.3.9 The labour market

2.3.9.1 It is natural also to consider how the productivity impact of a transport scheme will flow through to the labour market and to workers[16].

2.3.9.2 If labour supply is assumed to be fixed, then any productivity impact will be captured fully by workers, and will also be quantified appropriately in measures of welfare and GDP. In effect, as productivity rises the (fixed) pool of workers is paid commensurately more for the increased value to businesses of its labour, and this increase in the aggregate wage bill adds equally to both GDP and welfare measures of the impact of a transport scheme.

2.3.9.3 However, assuming that the labour supply is fixed (i.e. that we have a vertical labour supply curve) is highly restrictive. It implies that as real wage rates rise, there is no impact on the (un)employment rate or on the number of hours that people are willing to work. The extent to which this is a reasonable assumption will depend on (often local) factors, such

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reallocate their time between work and leisure in response to changes in productivity. It therefore follows that, while time savings enjoyed by business users accrue to GDP (as well as economic welfare), time savings to leisure and commuter users accrue only to welfare. With a flexible labour supply this may not be true, and in that case, the extent to which individuals choose to reallocate time between leisure and work will determine the extent to which GDP and welfare differ. This is discussed more fully in Chapter 8.

[15] It is important to note that the assumption of imperfect, rather than perfect, competition will have an impact on <u>the levels</u> of GDP and welfare (as will the specific ways in which imperfect competition are assumed to occur), but our analysis suggests this will not create a wedge (i.e. the effects of such assumptions on the level of GDP and welfare are likely to be equal).

[16] For the avoidance of doubt, we note that the DfT bases its value of time for businesses purely on the value that firms place on that time (rather than the sum of the value which firms and individuals place on this time). It is also important to note that, for labour, we implicitly assume that "work is costly" in that it is regarded as a negative in people's utility functions (as they give up leisure time in order to earn money).

as the size of the real wage change, levels of unemployment, the availability of relevant skills, and the way in which wages are negotiated and set. These factors ought to be considered when making an assumption about an appropriate labour supply elasticity and preferably informed by empirical evidence.

2.3.9.4 If the labour supply curve is instead upward sloping – either because higher wages can induce existing workers to work more hours (the intensive margin) or can persuade inactive individuals to participate in the labour market (the extensive margin) – **the GDP and welfare effects may be different.**

2.3.9.5 Where the curve slopes upwards, an increase in labour productivity that pushes up wages will induce an increase in the supply of labour. The wages paid to these new workers adds directly to GDP. However, GDP does not account for the cost to these new workers in terms of foregone leisure time. Flexibility in the labour market can therefore drive a 'negative wedge' between welfare and GDP (in the sense that the productivity effects of a transport intervention can increase GDP by more than welfare).

2.3.9.6 Under the assumption that markets clear perfectly (i.e. the marginal worker is indifferent at the prevailing wage about whether or not to participate in the labour market) the size of this wedge will be determined primarily by the labour supply elasticity, i.e. the magnitude of the labour supply change in response to a change in the wage rate. The greater the elasticity of the labour supply curve, the more sensitive labour is to changes in the wage rate, which in turn leads to a larger wedge between GDP and welfare. In practical terms, all else being equal, we would expect those regions with higher rates of unemployment, or access to larger pools of available additional labour, to see more substantial increases in employment following a transport intervention, and hence a larger 'wedge' between GDP and welfare impacts.

2.3.9.7 In Chapter 9, we extend our analysis to consider additional factors in the labour market and how they alter the wedge between GDP and welfare. The first of these is the impact of market disequilibrium, resulting from fixed wage rates (such as a minimum wage or single-industry agreements). We demonstrate that the presence of a fixed wage rate influences the magnitude of the difference between GDP and welfare impacts, with larger negative wedges being driven the more distortive the fixed wage (i.e. we see a larger wedge the further away the fixed wage is from the equilibrium level).

2.3.9.8 We also relax our assumption about the transport intervention only affecting a single region. The presence of multiple regions allows for the possibility of displacement, as increases in GDP or welfare within one region could be partially or fully offset by decreases in other regions. If labour is mobile across regions then a rise in productivity and wages in one region could cause individuals to relocate. We therefore also explore how regional displacement can affect the size of the wedge between GDP and welfare and find that individual preferences to live in a given region may lead to an additional wedge arising between GDP and welfare. In light of this, appraisers should consider two factors (i) the determinants of worker's preferences for living in a specific region and (ii) the likelihood of displacement based on the industry and the type of jobs created.

2.3.9.9 One final point to note in this regard: our analysis (and the approach which underpins WebTAG) assumes that people attach positive value to leisure time and negative value to time spent working. We (and the approach which underpins WebTAG) therefore assume that people trade the "disutility" which they experience at work for money. We think the reality is likely to be less clear cut in that workers in some respects actually attach positive value to the time they spend at work. This is an area which should be researched in the future.

2.3.10 Market for other inputs (i.e. capital and land)

2.3.10.1 In chapter 11 we extend our analysis by considering capital and labour markets. Considering first the impact of a flexible supply of capital, we find that (unlike with labour) the GDP and welfare impacts are likely to be equal.

2.3.10.2 In essence this is because all key issues in relation to the demand and supply of capital are traded through (and therefore captured by) the market. This finding (of there being no wedge in relation to the supply of capital) depends on three assumptions: (i) that both GDP and welfare capture the additional return on investment following the transport intervention; (ii) that the opportunity cost of investment is also valued under both GDP and welfare; and (iii) that there is no value in the redistribution of capital. In practice, these assumptions mean that as long as capital is employed for activity-generating purposes both before and after the intervention, and it does not matter from a policy (or social welfare) perspective "where" this takes place, then there is unlikely to be a wedge between GDP and welfare.

2.3.10.3 In order for GDP and welfare effects to differ, one of the three assumptions identified above would have to not hold. For example: (i) if a transport scheme were to redistribute income to a relatively low income area then the welfare impact could exceed the GDP impact; and (ii) in the unlikely event that a transport intervention affects how individuals hold savings outside of formal financial institutions (which are not captured by standard estimates of GDP) then welfare could be greater than GDP.

2.3.10.4 When considering the impact of flexibility in the supply of land, the impact on GDP and welfare depends on whether the return on land before and after the intervention is captured by GDP. Rents on commercial land, for example, feed directly into GDP, whereas the public amenity of a region with substantial environmental capital may not.

2.3.10.5 The direction and magnitude of any wedge will depend on the specific scheme and land use change which is being appraised. For example, if a transport intervention results in land being put to more productive use (e.g. a park being converted to a business area), the GDP might rise at the expense of welfare. Conversely, if the transport intervention results in business moving away from an area, this could result in brownfield sites being converted to parkland which would result in a wedge with the opposite effect (i.e. GDP down but welfare up).

2.3.11 The Housing Market

2.3.11.1 In the interests of completeness, we also considered two main potential impacts on the housing market. First, and perhaps most obviously, increased wages earned by workers (or indeed increased profits earned by firms) could be spent on property. Second, and less obviously, is what would happen if benefits which occur to individuals outside of formal markets (e.g. savings in leisure time) were somehow monetised in the housing market by people being willing to pay more for property which would allow them to obtain more of these benefits (e.g. by having a shorter commute) or in an area they like (e.g. being close to a park or other social facilities).

2.3.11.2 The value of housing is captured in GDP in two ways: through rental payments and imputed rent. Rental payments and how they affect GDP is self-explanatory. Imputed rent reflects the value of the output of owner-occupied housing by approximating the market value of this "self-provision". Imputed rents are calculated from data on the size and nature of the owner-occupied housing stock, together with estimates of its private rental value. Imputed rent is included in GDP for a number of reasons, including how it avoids: arbitrary changes in the level of GDP due to changes in the share of the rental market (and which do not represent a real change in economic output); and discrepancies in GDP across countries due to differing structures to the housing market.

2.3.11.3 While in theory it is possible that transport interventions could drive a land-related wedge between GDP and welfare impacts, we think the scope for this to occur in practice is modest because: (i) it is important to avoid double counting between any increase in wages or company profits that trigger the effect on the one hand and the impact on house prices on the other; (ii) any impacts in the housing market will likely be purely **price** effects (i.e. changing the price, not quantity of output) and would therefore only show up in nominal rather than real GDP; and (iii) much of the impact is likely to take the form of displacement – so, for example, an increase in house prices in one region could be partly offset by declines in house prices in other regions and/or spending on other things (as demand is diverted).

2.3.12 Further considerations

2.3.12.1 Finally, we consider other potential sources of a wedge between GDP and welfare. These are:

- Regional characteristics: If regions have different characteristics which are valued by individuals (e.g. a place is considered to be a good place to live), then if people relocate between regions as a result of a transport intervention, this has the potential to affect welfare in ways not fully captured in GDP. There are two other points worth noting:
  - Welfare and GDP effects could also simply be distributed differently across regions. For example: (a) regions which are different distances from a given scheme could experience similar GDP increases, but there would be greater disutility for individuals living in a more distant region through the disutility of travelling; and (b) a transport intervention could lead to goods and services being imported by region A from region B, which would lead to a higher welfare than GDP impact in region A (and vice versa for region B).
  - When schemes affect multiple regions, it is necessary to understand their local characteristics (e.g. inter-regional travel and trade patterns), and model the GDP and welfare impacts in a manner which takes account of them.
- Utility functions and social welfare functions: There are two key points to note here. First, depending on the social welfare function society may place greater value on additional wealth accruing to certain (e.g. lower income) individuals or groups, then an additional unit of wealth could have a different impact on welfare (at a societal level) depending on where it is experienced. Wedges could therefore arise from policy interventions aimed at rebalancing the economy. Second, the utility that is experienced by individuals tends to be characterised by a "love of variety" (Dixit and Stiglitz, 1975), in that an individual's utility tends to increase with the range of products which he or she is able to access. An improvement in accessibility could therefore improve consumer's welfare without altering GDP.
- Interactions between factors of production: while our analysis has focussed on the wedges that could arise in the markets for key inputs (labour, land and capital), it is important to understand interactions between them. This is because if a transport intervention affects the relative demand for labour, land and capital then this could have an impact on whether and if so the extent to which wedges occur. Broadly speaking, there are two factors which can impact the relative demand for inputs: (i) the relative prices of labour, land and capital and (ii) the marginal rate of technical substitution between them. Appraisers should ensure that they consider these interactions and the likely size of any wedges in practice. For example, if a transport intervention were to result in labour being replaced by capital, then this could reduce the scope for wedges to occur (given that wedges arise in the market for labour but likely not in the market for capital).

2.4 Summary

2.4.1.1 Figure 1 provides an overview of our results. It is important to note that we have assumed that all impacts can appropriately and accurately be quantified. In practice, however, differences between GDP and welfare impacts could come from the approaches used to quantify them rather than the fundamental differences in the two measures (which has been the focus of our work).

Figure 1: Summary of identification of likely wedges between GDP and welfare

Section		Wedge between GDP and welfare	Analysis
Impacts	***Business time savings***	No wedge	• **Default position.** Time saved by business users will be put to productive use and contribute fully to GDP (as well as welfare). In this case, business time savings will not create a wedge between GDP and welfare. • **Further considerations.** The default position – that no wedge is created by business time savings – is most likely to hold true in the 'long-run' because competition in the labour market is likely to compel workers to spend time savings on productive activities. In the short-run – or if there is a lack of competition in the labour market – it is possible that the welfare effects of business time savings may not be fully reflected in GDP. • **Implications for appraisers.** Appraisers are encouraged to consider whether, in the short-term, business time savings will create a wedge between GDP and welfare in their modelling. In the event that they do create a wedge, a detailed rationale should be provided and the question should be asked as to whether such a wedge is sustainable over the long term (especially given competition in the labour market). • **Future work.** The argument for the default position – that business time savings do not create a wedge – is a theoretical rather than empirical one. Empirical research may help corroborate this position, and shed light on possible differences in the short-run and long-run.
	Leisure and commuter time savings	Wedge whereby welfare>GDP	• **Default position.** Time saved by leisure and commuting users will not be put to productive use, meaning that time savings will increase welfare but not GDP (resulting in a positive welfare-GDP wedge). This wedge is likely to be 100% of the leisure/commuter time saving. • **Further considerations.** Whilst the theoretical and empirical literature suggest that leisure and commuter time savings will create a wedge, there are two main reasons why this may not always hold in practice: (i) leisure passengers / commuters could use the time saved productively, especially if their working/contractual arrangements allow them to increase their income by deploying the time by working more and (ii) the time saved may encourage passengers to make different consumption decisions (for example, shifting towards more time-intensive consumption activities like eating out), which could have real economic effects. • **Implications for appraisers.** Appraisers are encouraged to consider whether leisure and commuting time savings result in real economic effects in their modelling. In the event that they are expected to create real effects, then a detailed rationale should be provided. • **Future work.** The evidence on 'how' passengers use freed up time from leisure/commuting trips – and the implications for their spending patterns and the extent of associated real economic effects – is limited. More research in this space would be useful to help to understand the extent to which the wedge created by leisure/commuter time savings is genuine or perceived.
	Agglomeration	No wedge	• **Default position.** Agglomeration effects − by definition − accrue as productivity benefits (to firms or workers). As such, they accrue to GDP (and welfare) and are not expected to create a wedge between GDP and welfare. • **Implications for appraisers.** The value of productivity improvements caused by increased agglomeration should normally be assumed to affect GDP and welfare equally.

Section		Wedge between GDP and welfare	Analysis
	Externalities	Wedge whereby welfare>GDP or welfare<GDP	• **Default position.** Externalities are not normally reflected in prices in market transactions (indeed, they often exist precisely *because* of 'missing markets'). Therefore, externalities form part of welfare but are not (typically) captured in GDP, resulting in a wedge. If a transport scheme generates positive externalities or reduces negative externalities, this will create a positive wedge (welfare will rise by more than GDP). If an intervention creates negative externalities or reduces positive externalities, this will create a negative wedge (welfare will fall by more than GDP). • **Further considerations.** Some externalities may have knock-on impacts on GDP. For example, more accidents and/or environmental or noise pollution could result in a fall in productive capacity. Whilst these effects could be substantial in some circumstances, they are extremely difficult to quantify. • **Implications for appraisers.** Whilst the default position is that externalities affect welfare only, appraisers are encouraged to consider if externalities they identify could have real economic effects (e.g. through increasing accidents) and if possible quantify these effects. • **Future work.** Further analysis may be helpful to develop some indicative 'rules of thumb' that could be used to assess the possible impacts of externalities in GDP metrics. For example, it is likely to be relatively straightforward to quantify the impact of a typical road traffic accident on hours worked, and therefore on GDP.
Knock-on impacts. This section focusses how agents respond to the transport intervention in three markets.	***Market for outputs***	No wedge	• **Default position.** Knock-on impacts through output markets (i.e. markets for goods and services) are not expected to result in a wedge between GDP and welfare. The reason is simple: goods and services are transacted for within markets, meaning that changes in their prices or quantities traded are captured by GDP. This holds under conditions of perfect and imperfect competition (see Chapter 6).
	Market for labour	Wedge whereby GDP>welfare	• **Default position.** If labour supply is **inflexible** (perfectly inelastic), then transport interventions are not expected to lead to a GDP-welfare gap. This is because all knock-on effects are captured in wage changes, which in turn are captured in GDP. However, if labour supply is **flexible,** in general a wedge will arise. This is because while people are paid for working, they also experience disutility from working. This disutility of working provides a 'drag' on welfare but not on GDP. Hence, to the extent that a transport scheme increases employment, there will be a negative wedge: GDP rises but welfare increases by less, since it also accounts for the disutility of working. • **Further considerations.** The size of this wedge depends on the flexibility of labour supply and how wages are set in practice (e.g. whether wages are fixed or sticky). • **Implications for appraisers.** Appraisers are encouraged to examine whether schemes under consideration are likely to have labour market impacts. In the event that they are, appraisers are encouraged to examine the labour market to assess the extent of any likely wedge between GDP and welfare. • **Future work.** It may be possible to develop a simple formula – based on existing employment levels and the assumed elasticity of labour supply – to calculate the percentage of the GDP increase that 'leaks' out of welfare as a result of the disutility of work. It is recommended that further work is undertaken to derive such a formula and suggest appropriate input assumptions (e.g. on the elasticity of supply).
	Market for inputs	No wedge	• **Default position.** If the returns from and opportunity cost of employing capital are captured in GDP, then having a flexible supply of capital is unlikely to create a wedge. • **Further considerations.** The main exceptions are the potential welfare impacts of income redistribution and if capital is stored outside the financial system.

Section		Wedge between GDP and welfare	Analysis
			• **Implications for appraisers.** Appraisers may wish to consider whether and to what extent a transport intervention might increase capital deployed in relatively low (rather than high) income areas.
	Land values	Wedge whereby GDP>welfare	• **Default position.** There is potential for an "inverse wedge" to occur via the housing market whereby the value of non-monetised impacts (like journey time savings experienced by leisure travellers and commuters) somehow become monetised through incorporation into house prices. This could take place via actual and/or imputed rents. • **Further considerations.** It is likely to be very difficult to robustly identify land value increases as a result of a particular scheme – particularly those which are additional to those captured elsewhere in the analysis. Moreover, it should be stressed that any changes in land value are likely to be monetary manifestations of the effects captured above (e.g. leisure time savings). • **Implications for appraisers.** Appraisers may find it useful to assess land value changes as a result of a scheme. However, care must be taken to ensure the true effect of the transport scheme is isolated. Moreover, the appraiser should be mindful of the potential for double-counting here (avoiding, for example, 'adding' land value changes to welfare estimates).
	Further Considerations	n/a	• Location. Individuals might attach value to where they live in a manner similar to the value of leisure time. If this does not get monetised into GDP (e.g. through property prices) then a wedge might occur if and when people relocate due to a transport intervention. • Wedges could also be caused by different amounts of travel disutility being experienced by people from different regions, and from trade between regions (imports add to welfare but detract from "GDP"). • Social welfare and the value of redistribution. Additional units of wealth may have different values placed on it by society depending where and to whom it accrues. This could lead to a wedge between GDP and welfare.

Source: PwC

2.4.2 Example of GDP and welfare reconciliation

2.4.2.1 In order to demonstrate the links between GDP and welfare, figure 2 shows illustrative results for an economic appraisal carried out on major road project.

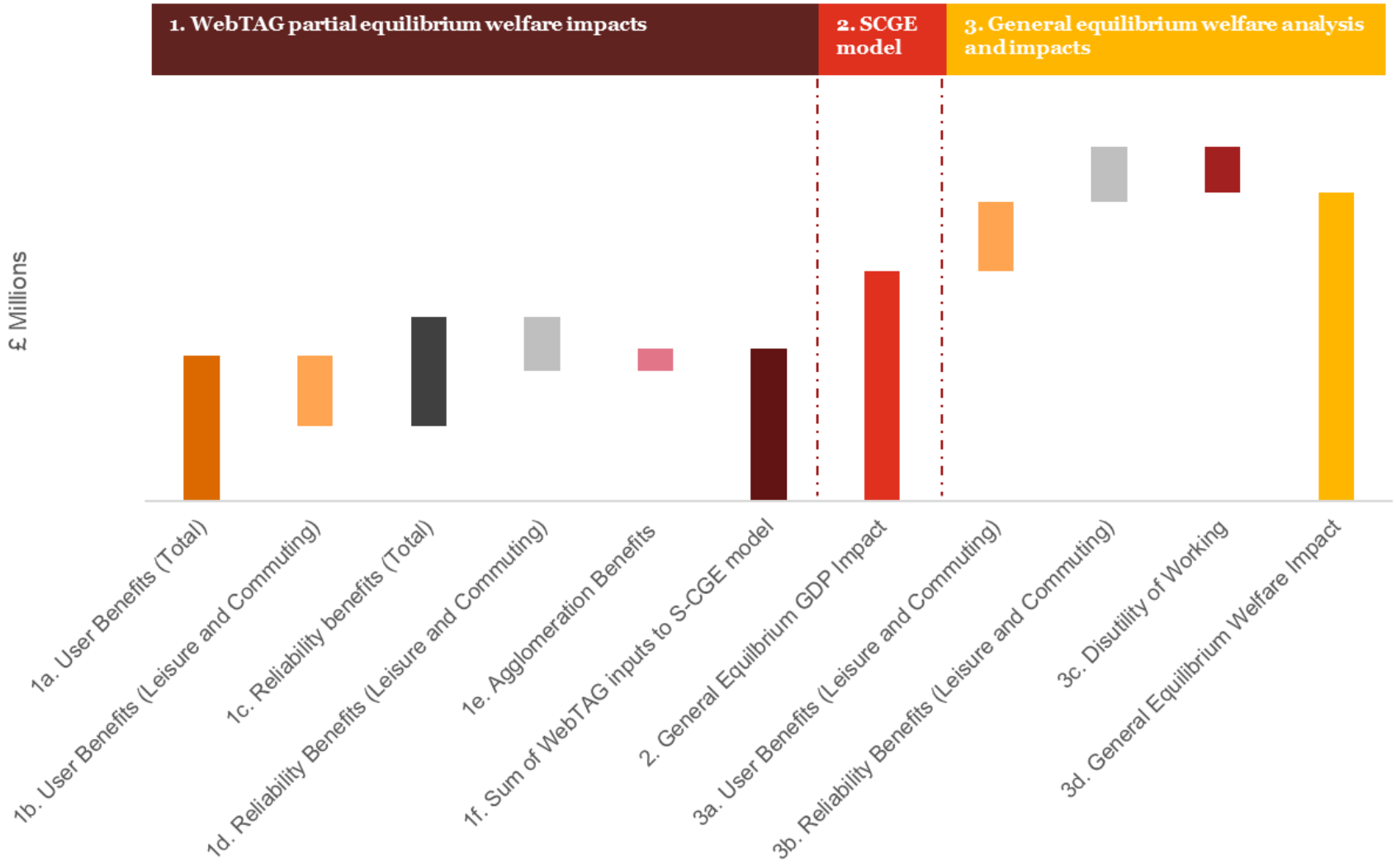
2.4.2.2 Working from left to the right:

- Standard WebTAG estimates were made of the values of user benefits (i.e. journey time savings), improvements in journey time reliability, accidents, greenhouse gases and indirect tax benefits.
- The value of journey time savings and improvements to reliability that were expected to accrue to non-business travellers were deducted from these totals. We did this because they were assumed not to have real economic effects (in contrast to those benefits which were expected to accrue to business travellers and which were assumed to improve productivity). We therefore assumed that a wedge existed for the journey time savings and reliability benefits which accrued to leisure travellers and commuters.
- Estimates were also made of the extent to which improved short and long distance connectivity would improve business productivity (via short distance and long distance "agglomeration" effects). We assumed that no wedge existed for these effects, i.e. that agglomeration affects GDP and welfare equally.
- The value of journey time savings, reliability improvements and agglomeration affects which accrue to businesses were treated as productivity "shocks" in a Spatial Computable General Equilibrium (S-CGE) model in order to estimate the various knock-on effects and the overall impact the intervention would have on the economy.
- The overall GDP impact of the intervention was then converted into an overall welfare impact by: (i) adding back the values of journey time savings, improved reliability and externalities which were deducted from the initial (and relatively standard) WebTAG analysis; and (ii) deducting estimates of the additional disutility work experienced by people as a result of working more. In other words, we adjusted for the wedge that existed as a result of the assumption in our S-CGE models that labour supply curves are upward-sloping.

2.4.2.3 The analysis can enable us to:

- Show how the estimates of GDP impacts – which were made using a S-CGE model because of the potentially transformational nature of the road project – relate to welfare impacts; and
- Make statements along the lines of "the £V bn project is likely to generate £W for every £X that is spent on it, increase the present value of GDP by £Y and create Z,000 new jobs".

Figure 2: An Example of reconciling GDP and welfare



2.5 Structure of the report

2.5.1.1 The rest of this report is structured as follows:

- **Chapter 3** provides a summary of the approach to transport appraisal in the UK.
- **Chapter 4** sets out the conceptual relationship between GDP and welfare.
- **Chapter 5** outlines the framework used within the report to structure the reconciliation.
- **Chapter 6** considers the initial impacts of a transport intervention.
- **Chapter 7** considers externalities which result from a transport intervention.
- **Chapter 8** reconciles GDP and welfare impacts in the market for goods and services, by relaxing the assumption of perfect competition.
- **Chapter 9** reconciles GDP and welfare impacts when considering knock-on effects in the labour market.
- **Chapter 10** reconciles GDP and welfare impacts when considering knock-on effects in the labour market in a two-region model.
- **Chapter 11** does the above in relation to other inputs (i.e. capital and land).
- **Chapter 12** considers potential impacts in the housing market.
- **Chapter 13** outlines other important considerations, including regional characteristics and the welfare functions of individuals and society as a whole.

3 Context of transport appraisal

3.1 Transport appraisal within the UK

3.1.1 WebTAG guidance

3.1.1.1 The economic appraisal of transport schemes within the UK makes extensive use of WebTAG (Web-based Transport Appraisal Guidance) produced by the DfT. This guidance outlines how a wide range of economic impacts of transport infrastructure should be appraised, from user time savings to effects (which often accrue to individuals and firms that are not users of the intervention) such as agglomeration and changes to air quality.

3.1.1.2 A key output of a WebTAG-based assessment of a transport intervention is a monetised estimate of the welfare impact of the intervention, which is consistent with the principle that the primary aim of government policy is to improve or maximise welfare.

3.2 Economic impacts of transport interventions

3.2.1 WebTAG guidance

3.2.1.1 WebTAG outlines a number of different direct economic impacts from transport interventions. Each of these could give rise to a change in GDP and/or economic welfare, and potentially stimulate knock-on impacts which could drive further changes in GDP and/or welfare. It is not the intention of this report to evaluate this list of impacts, or the methodologies used to quantify them (either from a welfare or GDP perspective), but rather to outline: (a) why; (b) under what circumstances; and where possible, (c) the extent to which the GDP and welfare impacts will differ.

3.2.1.2 In order to do this, we must first understand the different types of economic impacts which are recognised in WebTAG. For the purpose of this report, we use the hierarchy of impacts established in the most recent guidance on Wider Economic Impacts[17]. This identifies three distinct categories of impacts, which are defined in the guidance as follows:

- Level 1 includes impacts which assume fixed land use excluding wider economic impacts.
- Level 2 includes wider economic impacts which assume fixed land use (connectivity impacts) or do not require land use change to be explicitly quantified.
- Level 3 includes analysis in which either land use change is explicitly quantified (structural impacts) or supplementary economic modelling has been conducted.

This is referred to in the guidance as fixed land use. The transport scheme is assumed to have an impact by better linking up economic agents within this fixed structure (termed 'connectivity impacts'). In other words, the assumption of fixed land use which is made in Level 2 analysis means that intervention is appraised on the assumption that the location and level of each factor of production (i.e. the level of capital and labour) does not adjust in response to an intervention.

3.2.1.3 The important difference between Levels 2 and 3 in this framework is that under Level 2 it is assumed that the structure of the economy remains fixed. This is referred to in the guidance as fixed land use. The transport scheme is assumed to have an impact by better linking up economic agents within this fixed structure (termed 'connectivity impacts'). In other words, the assumption of fixed land use which is made in Level 2 analysis means that intervention is appraised on the assumption that the location and level of each factor of production (i.e. the level of capital and labour) does not adjust in response to an intervention.

3.2.1.4 By contrast, Level 3 analysis relaxes this assumption, allowing one or more factors of production to adjust in response to the introduction of a transport scheme. A typical example of this might be businesses relocating towards a scheme in response to improved connectivity. This structural change in the economy (termed 'structural impacts') can have additional impacts, which could be positive or negative. For example, a positive impact would be a boost to productivity brought about by businesses

[17] See WebTAG Unit A2.1: Wider Economic Impacts Appraisal, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/712878/tag-unit-a2-1-wider-impacts-overview-document.pdf

relocating to be close to a transport connection, but an associated negative impact might be a reduction in productivity in areas where those businesses were previously located.

3.2.1.5 The impacts outlined within each of these Levels could extend beyond those measured in terms of GDP or welfare. For example, the impacts could manifest themselves as changes in employment or investment patterns. The reconciliation in this report focuses solely on GDP and welfare, but the analytical framework and empirical evidence presented could be applied more widely.

3.2.1.6 Within each of these Levels is a range of different impacts which are summarised in Figure 3 below:

Figure 3: Summary of levels of different impacts

Impact level	Impact	Definition
Level 1	1. User time savings	The value of time saved, or lost, to users following the introduction of a scheme
	2. Vehicle operating costs	Changes in vehicle operating costs (e.g. fuel and maintenance) incurred by the user
	3. Journey time reliability	Changes in the variability of journey times, that individuals are unable to predict
	4. User charges (e.g. tolls, fares)	Changes in the amount of money spent on user charges, such as fares, tariffs and tolls
	5. Change in transport provider revenues	The impact on revenues received by public transport providers, following the introduction of the scheme
	6. Indirect tax revenue (e.g. fuel duties, VAT)	Changes in indirect taxation raised as a result of the scheme
	7. Air Quality	The value of changes in the concentration of pollutants following the introduction of a scheme
	8. Noise	The value of changes in the level of noise, based on the impact on annoyance, sleep disturbance and health
	9. Greenhouse Gases	The monetary value of changes in greenhouse gas levels
	10. Accidents and Social Impacts	The change in the number and severity of road accidents, and other social impacts such as physical activity
	11. Environmental Capital i.e. landscape; townscape; historic environment; biodiversity and water environment	The impact of a scheme on key environmental resources (often evaluated on a qualitative rather than quantitative basis, and rarely monetised)
Level 2	12. Impact from changes in labour supply	The additional tax revenue resulting from individuals' greater access to work (due to reduced commuting times) leading to greater labour force participation
	13. Reliability	Changes to the variation in journey times that individuals are unable to predict as a result of an intervention. Recent guidance summarises when reliability impacts should be identified – and when they should not[18]
	14. Static Agglomeration	The change in productivity to all firms in a region, as a result of changes in their access to economic mass

[18] Department for Transport (2018) 'TRANSPORT ANALYSIS GUIDANCE' Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/712965/webtag-transport-appraisal-process-may-2018.pdf

Impact level	Impact	Definition
	15. Output change in imperfectly competitive markets	As price exceeds marginal cost, each additional unit of output produced in an imperfectly competitive market leads to a net welfare gain
Level 3	16. Impact from move to more/less productive jobs	The change in tax revenue resulting from individuals being able to access more/less productive jobs
	17. Dynamic Agglomeration	The change in productivity brought about by individuals and firms relocating and hence altering access to economic mass within each region
	18. Dependent Developments (Induced Investment Effect)	The impact of subsequent investments which would not go ahead without the transport intervention
	19. Displacement	The degree to which local impacts involve the relocation of economic activity to/ from the rest of the country

3.2.2 Capturing a broader range of impacts

3.2.2.1 Section 3.2.1 shows that the range of impacts covered in WebTAG is broad. The monetisation (where possible) of this wide range of impacts allows for direct comparison between schemes which can have very different specific impacts. For example, it allows comparisons to be made of schemes which relieve congestion on intensively used motorways on the one hand with projects which are more focussed on easing congestion within towns or cities on the other. Use of the guidance also helps to shed light on who is likely to benefit, or face costs, as a result of a scheme and what form these benefits and costs are likely to take.

3.2.2.2 There is increasing recognition of the need for appraisals to be tailored towards individual schemes, and for appraisals to articulate clearly the form and drivers of any benefits and costs. This is particularly important for the most substantial investments in new infrastructure. In part, this is simply because greater levels of spending mean that more is at stake, but in addition larger schemes typically have greater potential to transform the nature of economic activity within and between regions. This means that more sophisticated analytical frameworks and modelling techniques may be required to accurately assess the economic impacts brought about by larger transport interventions.

3.2.2.3 In particular, there is substantial interest in the impact of larger projects, or packages of projects, on the economy or GDP. Much has been written on the link between transport infrastructure and the economy, for example in the 1999 SACTRA report[19]. Since then much work has been completed to further this understanding. This includes the Understanding and Valuing the Impacts of Transport Investment (UVITI) Analytical Strategy[20], launched in 2013 by the DfT and the Transport Investment and Economic Performance (TIEP) report, released by the DfT in 2014[21]. Jointly, this body of work has been pivotal in shaping the Supplementary Economic Modelling guidance released by the DfT in September 2016. This provided guidance on how modelling to assess the impact of schemes on the economy should be undertaken and reviewed[22].

3.2.2.4 Economists generally agree that maximising economic welfare is a more appropriate objective for public policy than maximising GDP (Bergheim,2006). Economic welfare is theoretically a broader and more comprehensive measure of well-being than GDP, as GDP captures only those values which are associated with traded goods and services. However, understanding the impact of transport interventions on GDP is important for a number of reasons.

3.2.2.5 First, the fact that GDP can be measured relatively easily means that it can be readily used to quantify impacts Even though measurements of GDP are far from perfect, the fact that they are often made (and in ways that are generally accepted, shortcomings and all) means that they often influence decision-making.

[19] Transport and the economy: full report (SACTRA, 1999)

[20] Understanding and Valuing the Impacts of Transport Investment (DfT, 2015)

[21] Transport investment and economic performance: Implications for project appraisal (Venables, Laird, & Overman, 2014)

[22] Department for Transport (2018) 'Appraisal and Modelling Strategy: Informing Future Investment Decisions'

3.2.2.6 Second, GDP is very clearly and explicitly a key focus of interest of stakeholders. For example, it is rare that the general public will refer to the Benefit Cost Ratio (BCR) of a project but they will frequently talk about the impact that a project will have on GDP, jobs or the economy more generally.

3.2.2.7 Third, GDP can provide useful detail on the nature of any impacts, e.g. being able to show which sectors and/or regions of the economy will be affected by an intervention can be valuable both for the purposes of informed appraisal and discussion with stakeholders.

3.2.2.8 The purpose of this report is not to debate the primacy of either metric. Rather, what is important is that the two measures can be understood in tandem, rather than providing competing and potentially conflicting views as to the impact of a scheme. This report therefore seeks to reconcile, at a theoretical level, the GDP and welfare impacts of transport interventions such that any differences between the two can be understood. It also provides clear and practical guidance as to how this reconciliation should be undertaken quantitatively, and the evidence which is either available or required to this.

3.3 Scope of the framework

3.3.1.1 In the interest of brevity, this reconciliation focusses on the most material impacts, as opposed to discussing each and all of the specific impacts in turn. The report seeks to provide both a theoretical framework which, subject to the availability of evidence, could be applied to any of the impacts listed above. The report is structured around the fundamental theoretical reasons why GDP and welfare differ, and how these vary when different economic assumptions are made and how these vary in different markets, rather than around the specific impact areas. Therefore, whilst the three levels of impact summarised in Table 2 above provide helpful context on the different types of impact which a transport intervention could have on either GDP or welfare, the reconciliation in this report does not specifically and separately deal with these three levels of impact – or indeed each and every impact listed under them.

4 Conceptual relationship between welfare and GDP

4.1 Defining GDP and economic welfare

4.1.1.1 The ONS defines GDP as the main measure of the level of UK economic activity based on the value of goods and services produced during a given period, and is the *'sum of all the valued added in the economy per year'* (SACTRA, 1999, p.42).

4.1.1.2 Economic welfare is a conceptually broader and more expansive definition of economic success than GDP. In addition to valuing the output that the market produces, a welfare approach includes un-marketed costs and benefits (Venables, Laird, & Overman, 2014, p. 15).

4.1.1.3 At the outset it is worth noting that:

- GDP is a measure of economic performance and is commonly used as an indicator of the overall health of the economy. There are three main approaches to measuring GDP – the income approach, the production approach and the expenditure approach. Subject to measurement error, all three approaches lead to the same estimate of GDP. The income approach to measuring GDP estimates the total of all real factor (labour, capital and land) incomes within an economy, and is the approach to measuring GDP that is generally used and referred to in this report.[23] This definition is most easily reconciled with welfare as it reflects income levels within the economy.[24] By contrast, the other definitions of GDP are measured using levels of production or expenditure (including where the expenditure drives no direct utility benefit, such as expenditure on investment), and are therefore less directly linked, and less intuitively reconciled, with welfare.
- Economic welfare is the sum of all household utility, measured in monetary units, including the value of income from all sources, and utility of non-market sources of wellbeing, net of disutilities from disamenities and foregone leisure. This is often operationalised as the sum of all consumer and producer surplus. It is a more expansive definition of economic success than GDP, and maximising economic welfare is a more complete, if less easily measurable, objective for public policy than maximising GDP. Pigou (1932), for example, defined the objective of economic policy as maximising the real value of social income i.e. surplus derived from commodities consumed weighted by their sets of prices (referenced in Hicks, 1939).

4.1.1.4 In addition to valuing the output that a market produces, a welfare approach includes the costs and benefits that are not valued in the marketplace.[25] For example, if a transport user benefits from a time saving as a result of an investment, GDP would only value this time saving if it were put to productive use (non-productive time is not valued by the market). By contrast, a welfare approach would value this time saving regardless of whether it is put to productive use or adds to leisure. Our definition of economic welfare therefore includes the value placed on non-market commodities.

4.2 The relationship between GDP and welfare

4.2.1.1 There are a number of reasons why there is divergence between economic welfare and GDP, which are explored in some depth in academic literature. Importantly, GDP fails to account for the benefits and costs for which there is no market (see for example, p.15 Venables, Laird, & Overman, 2014). A classic instance of this is how GDP fails to value the negative environmental impacts that arise from economic activity (see p.26 SACTRA, 1999). For example, if no charge is imposed on carbon emissions, then market prices are distorted such that they do not reflect the welfare costs of environmental degradation (See Stiglitz, Sen, & Fitoussi, 2009, pp8-9, for a fuller discussion specifically on environmental degradation).

4.2.1.2 More generally GDP does not account perfectly, if at all, for some of the fundamental influences of standards of living including mortality and inequality (see, for example, Jones & Klenow, 2010 pp2-3). Venables et al. also use the example of a traffic-jam to illustrate the difference between the two measures. When an individual is in a traffic queue, their fuel consumption increases, pushing up GDP, whilst their welfare falls due to lost time, a non-traded welfare-enhancing commodity (p.15, Venables, Laird, & Overman, 2014). The TIEP report summarised some of the key differences between the two

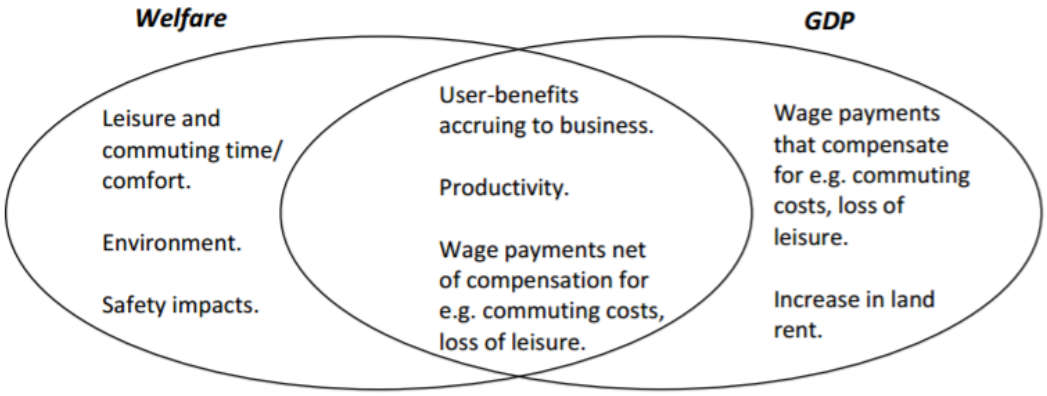
[23] The production approach is the sum of the value of all production activity within an economy, and the expenditure approach is the summation of all final expenditures in the economy. See Lee (2012) for further detail.

[24] The level of income provides a relatively direct link to economic welfare because of how it drives consumption.

[25] See, for example, Venables, Laird, & Overman (2014) for a discussion of costs and benefits included in welfare but not GDP.

measures, using Figure 4 This diagram show s how some effects w ill show up only in economic w elfare, some only in GDP and some (in the centre of the diagram) in both.

Figure 4: Welfare and GDP measures

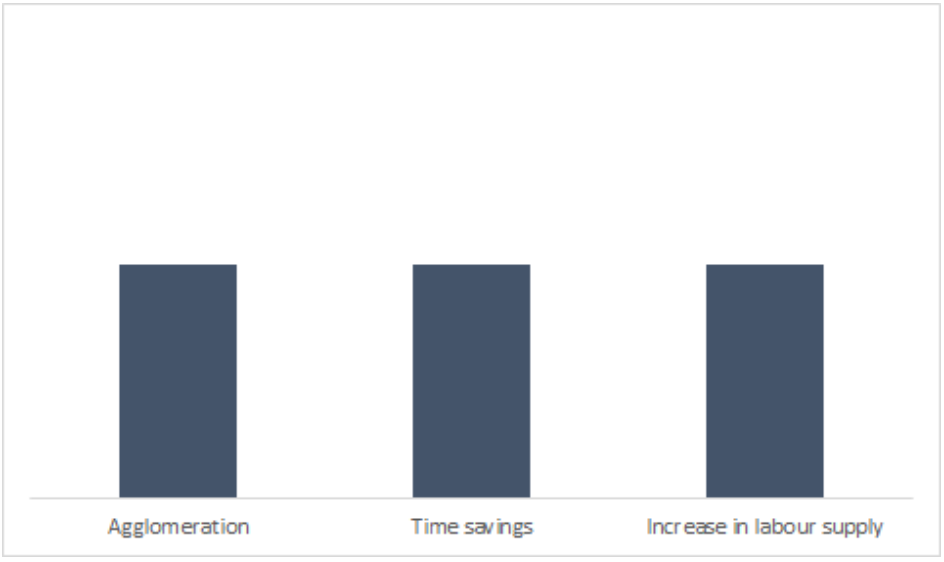


Source: Venables et al., 2014

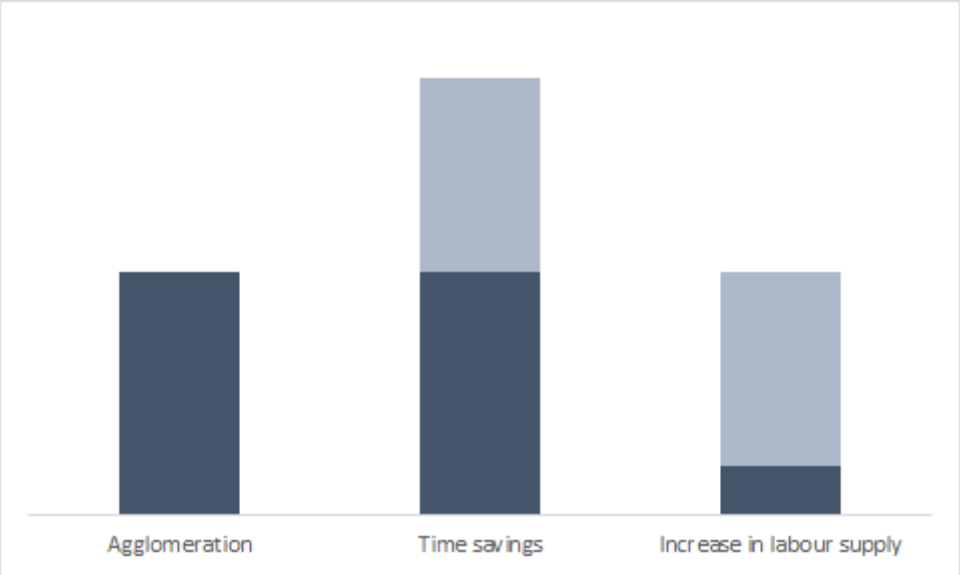
4.2.1.3 It is important to note at the outset that GDP changes w ill not be either alw ays low er or alw ays higher than w elfare changes. This is illustrated in Figure 5, w hich consider three effects of a transport intervention: an increase in agglomeration, a positive time saving and an expansion in labour supply. All of these three changes are assumed to have equal impacts on GDP.

4.2.1.4 The w elfare impacts differ though. The change in agglomeration is assumed to be equal in w elfare and GDP terms, as the effect flow s through an increase in productivity w hich affects GDP and w elfare equally. The time saving impact is assumed to be higher w hen considering w elfare, as it is likely that some of the time savings w ould affect only leisure time, w hich is a non-traded good that is not captured in GDP. By contrast, despite the likely positive impact on GDP, the expansion in labour supply leads to a loss in leisure time for individuals entering the labour market. In this illustrative example it is assumed that this loss in leisure time largely, but not fully, offsets the GDP gain and hence that the net w elfare impact is small and positive. The degree to w hich GDP and w elfare impacts w ould differ in each of these examples is discussed in more detail in future chapters.

Figure 5: Illustrative example of GDP and welfare differences from a transport intervention.



Impact on welfare

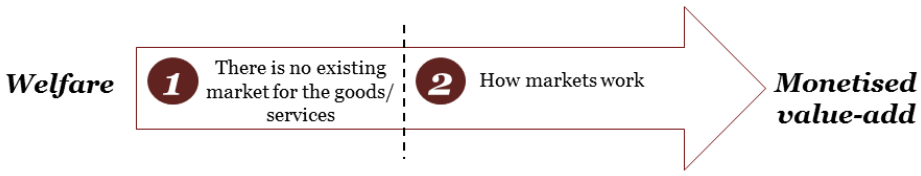


Source: PwC

4.2.1.5 A clear implication of this difference between the two measures for transport appraisals is that if the GDP impacts of a scheme are assessed, then it is better if this is not done in isolation from an assessment of the welfare impacts: the GDP and welfare impacts of a transport intervention are not separately additive, so assessing them in isolation from each other runs the risk of double-counting effects. For example, the user benefits from time saved by commuters is generally captured under WebTAG through reduced generalised travel costs faced by the user. However, some of these impacts might be reflected in house prices and property rents if increased access to transport were to raise demand for the land and thus the land value (Venables, Laird, & Overman, 2014). Given that the increase in property rent (the GDP impact) is the monetised effect of the reduced generalised travel cost (the welfare impact), summing the two effects would substantially over-state the impact of the scheme in question, i.e. in this situation, there is substantial potential overlap between the GDP and welfare effects.

4.2.1.6 In order to identify where GDP and economic welfare impacts genuinely differ, we have structured our approach around the fundamental channels through which divergence occurs. The purpose of this report is to explore the channels that create a 'wedge' between GDP and welfare, and the potential magnitude of this wedge, rather than a discussion of factors that affect the absolute size of GDP or welfare effects in isolation.

Figure 6: The fundamental differences between welfare and GDP



4.2.1.7 As shown in Figure 6, we think the extensive existing literature suggests that there are two fundamental sources of divergence between economic welfare and GDP.

4.2.1.8 First, a wedge between GDP and welfare arises when there is no existing market for goods and services. For example, when an individual chooses to increase their working hours at the cost of leisure time, GDP will rise by the full value of economic activity brought about by the increased working time. However, the net impact on welfare will also reflect the disutility caused by the additional working hours (assuming that individuals value leisure time more than time spent working). Notably, welfare may not rise at all depending on how the worker is compensated for the leisure time they have foregone. Another instance of divergence brought about by missing markets is the presence of externalities such as noise pollution. Unless a price is paid for noise pollution (e.g. through some form of tariff), when a production process leads to noise pollution the costs of this will not be factored into the market price of the good produced. Welfare will value the costs and benefits of externalities whilst GDP will not.

4.2.1.9 Secondly, divergence between economic welfare and GDP could arise due to how the existing market(s) value(s) goods and services. Estimates of GDP are based on the prices of goods and services that are observed in the market, but the same is not true for welfare. To illustrate this, note that firms often set relatively uniform prices and are unable to perfectly price discriminate despite frequently having a degree of market power. In such settings, for all except the 'marginal' consumer, market prices may be substantially lower than the willingness to pay of consumers (i.e. the welfare they enjoy). This means that the consumer surplus is greater than zero and therefore the aggregate value derived by society from consumption (welfare) is greater than the value of that consumption implied by the market (GDP). This is shown in Figure 7 in Chapter 5.

5 Framework used for the reconciliation

5.1 Overview of the framework

5.1.1.1 As discussed above, this report has two overarching objectives for considering the relationship between the GDP and welfare impacts of transport schemes:

- To identify the primary mechanisms through which GDP and welfare could differ; and
- To demonstrate how the impacts of these mechanisms change under different assumptions and in different markets (goods and services, labour, inputs and housing).

5.1.1.2 The topic is very broad, in terms of both the effects of transport infrastructure, and the range of assumptions which can be applied about how markets operate. In order to make the reconciliation tractable, it is therefore essential to have a clearly defined framework which is applied consistently. As described in Chapter 2, the intention of this report is not to provide a line-by-line reconciliation for each impact area, as this will depend heavily on the precise nature of the impact and the specific project context. The framework is, however, intended to provide a structure and way of thinking about the different effects, which can then be tailored to specific projects.

5.2 Economic framework for assessing impacts

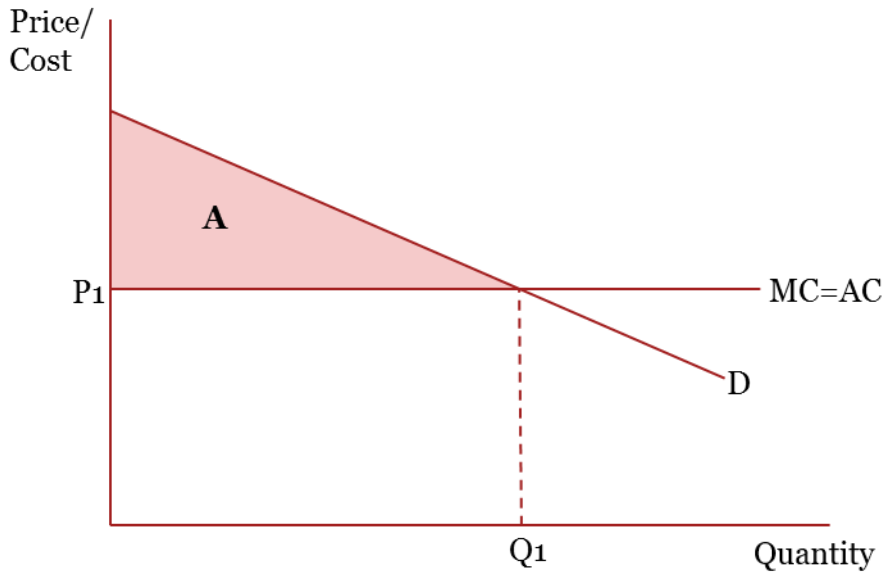
5.2.1.1 A primary objective of this report is to demonstrate the theoretical relationship between GDP and welfare. In defining our framework, we have focussed on two core principles.

1. The framework should be based on underlying economic theory so that it is robust and clear.
2. The framework should be internally consistent throughout our reconciliation.

5.2.1.2 Our reconciliations are therefore built on fundamental, and "first principles", economic theory. The appropriate starting point for the reconciliation is a standard demand and supply diagram under perfect competition, as shown below in Figure 7. Here, price is set to equal marginal cost, where price equals P1 and quantity, Q1. Consumer surplus is shown by the area A. As we have assumed perfect competition, firms in the long-run will always produce where marginal cost is equal to average cost. We have assumed that all firms have identical cost functions, and that new firms can always enter the market, so the price will always be equal to this minimum average cost. We have represented this at the industry level through a flat cost function. There is no producer surplus in the market as, under perfect competition, goods are produced at the point where the marginal costs of production are equal to the average costs[26].

[26] We note that the producer surplus is independent of the marginal cost function under perfect competition – although we have used a flat cost function, this could be increasing and there would still be no producer surplus

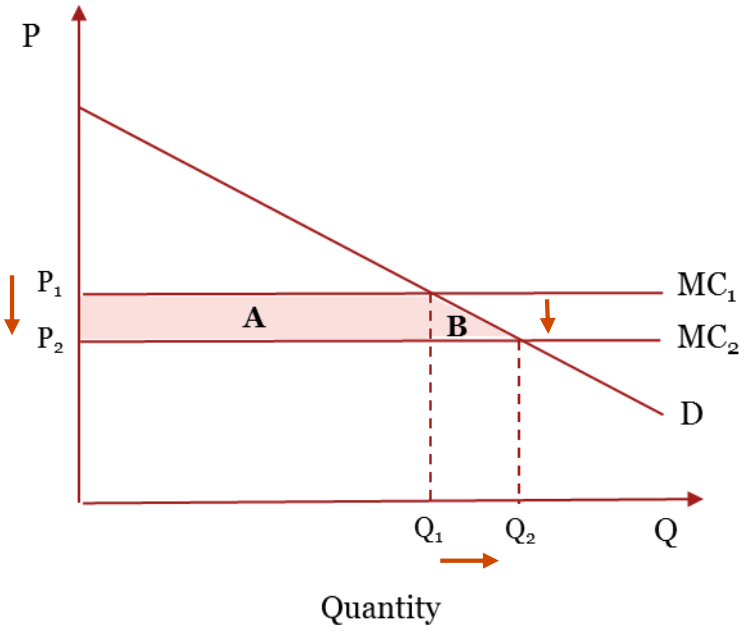
Figure 7: Demand and supply under perfect competition



5.2.1.3 There are three key points to note about Figure 7:

- While it is simple to observe the components of w elfare within this framework – consumer surplus (A in the diagram above) and producer surplus (which is zero in the diagram above) – the purpose of this analysis is to consider not the level of w elfare, but how welfare changes in response to a transport intervention.
- Where a change in economic w elfare comes about as a result of a good w hich is not captured w ithin GDP (e.g. a non-traded or non-priced good such as leisure time), the above framework is clearly inappropriate. When a good/service (or impact of consumption/production) is not priced, then there is no market in w hich the good is traded. In such situations, it can simply be assumed that the GDP impact of such a change w ill be zero.
- By contrast, w here a change in economic w elfare is driven by changes in the productive potential of the real economy these w ill manifest in the form of changes in the supply curve. A positive change in productivity w ill result in a shift dow n in the marginal cost curve, shown in Figure 8 below through a shift from MC_1 to MC_2. This causes the price to fall to P_2 and quantity to shift out to Q_2. As a result of this, consumer surplus w ill increase by the shaded area, A+B, w hilst producer surplus w ill remain zero. The total economic w elfare change will therefore be A+B.

Figure 8: Increase in productivity under perfect competition



5.2.1.4 As with welfare above, it is possible to consider how GDP will have changed in the movement from MC1 to MC2. Looking first at area A, this represents the fall in price experienced by existing consumers within the market. As we are assuming perfect competition, any cost fall will be fully passed onto consumers. This must be true by definition, as under perfect competition price must equal marginal cost. Note that under different assumptions, such as if competition were imperfect rather than perfect (discussed in chapter 8), this will not necessarily be true and the full reduction in cost may not be passed through to consumers.

5.2.1.5 Measuring GDP using an income approach, it can therefore be seen that area A is effectively an increase in real income to those consumers. Consumers are able to consume a larger quantity of the good at a lower cost – real output has increased and therefore GDP increases[27]. The entirety of area A would therefore contribute positively to GDP. Although nominal GDP may stay the same (or even fall if consumers do not spend their saved disposable income), real GDP will rise. Considering now area B, this represents a reduction in price that is experienced by new consumers to the market. Again, in effect this is an increase in real income to those consumers, as they will be able to consume a larger quantity of goods for the same fixed income, a change which is equivalent to an increase in real income.

5.2.1.6 The overall general conclusion of this is that **where there is an increase in the productive potential of an economy, the change in welfare will equal the change in GDP**. By contrast, where a good is not traded within a market, the change in GDP will be zero, regardless of the change in welfare. [28]

5.2.1.7 We use the above framework (Figure 7 and Figure 8) as the foundation of our reconciliation, and build upon it in later chapters to account for nuances in each market being discussed (particularly the later chapters on knock-on effects).

[27] We note this is true regardless of whether consumers spend or save the increase in their disposable income as both consumption and savings (via investment) enter into GDP.

[28] One caveat to this, which could be applied to the majority of discussions regarding the size of GDP, is that we have implicitly assumed that the measurement of GDP perfectly picks-up this real income shift. In this case the assumption is that the price index, and the weighting across the typical "basket" of goods, used to calculate GDP are sufficiently accurate. In order for the change in GDP to perfectly reflect the change in real income (and hence the change in welfare) this change in consumption pattern will need to be reflected in the data used to estimate GDP. In practice, of course, there are always likely to be challenges in measurement of concepts such as GDP but these are outside the scope of our reconciliation framework.

6 Impacts

6.1.1.1 In this chapter we apply the framework outlined in Table 2 in chapter 5 to specific Level 1 impact areas, as defined by the DfT. As explained previously we focus on those which are likely to be most material for transport investments:

1) User Time Savings; and

2) Agglomeration

6.2 User time savings

6.2.1.1 WebTAG shows that user time savings will result in welfare gains regardless of the user type (although the actual value of time saved does vary by type of user). However, whether and the extent to which time savings affect GDP will depend on how the time saved is "spent" and is therefore likely to vary by type of user. Similar to WebTAG, we classify travellers as being in three groups of users – business users, commuters and leisure/other users – and assess the value of time saved and the share of that which contributes to GDP based on several assumptions (specifically on who 'owns' the time saved), discussed below.

6.2.1.2 In the short-run, we assume for business users that any time saved is effectively owned by the firm which employs them. Thus in the short run, when there is a lack of ability to renegotiate contracts, the length of the working day will be unchanged. The implication of this is that any time saved during the working day will be used purely for work, and hence have a positive effect on productivity. As shown in Chapter 5 Figure 8, an increase in productivity is accounted for equally in both GDP and welfare so that there will be no wedge from time-saved through a transport intervention for business users.

6.2.1.3 For leisure users and commuters, we think it is reasonable to assume that the time saved is owned by the individual and that, in the short run at least, the length of people's working days will effectively be fixed. The implication of this is that any time saved by leisure users and commuters is used for leisure. As leisure time is not included within a typical definition of GDP, this time saving (and the associated welfare change) would have no impact on GDP but will impact welfare.[29] A difference between GDP and welfare will therefore arise for leisure users and commuters as a result of the time savings they experience from a transport intervention.

6.2.1.4 In reality, of course, transport projects are viewed over long time horizons. In the long run, the "endowment" approach to time which we have used above (whereby businesses own working time, and individuals own leisure/commuting time) still applies, but working contracts are more negotiable. There is therefore more potential for time saved to be converted to different uses. The evidence (see Altoni & Usai, 2001 and Pencavel, 2014) suggests that despite substantial changes in productivity, the average working week has remained almost constant since the 1940s. This implies that the number of hours worked is highly inelastic with respect to underlying changes in productivity and that the line of argument set out above (i.e. that time savings for business users will be put to productive use but that time savings for leisure users and commuters will not) will also hold true over the long run. This suggests that the change in economic welfare for business users will match the GDP impact but the changes which accrue to leisure users and commuters will not.

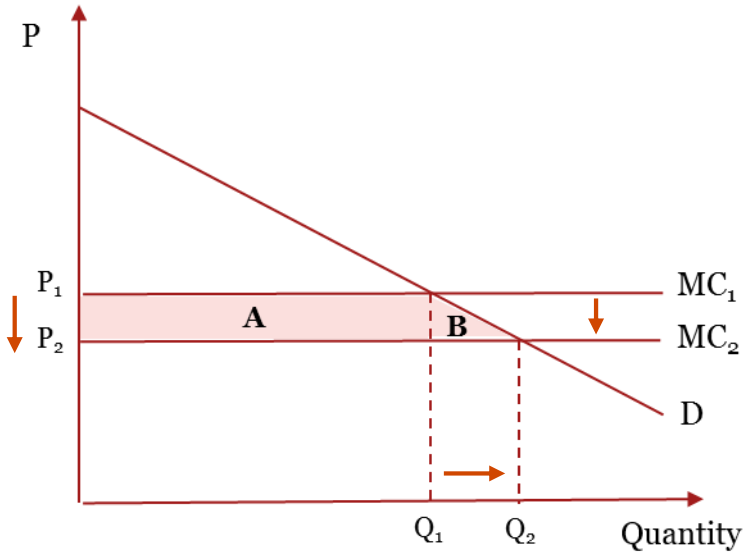
6.2.1.5 Importantly, while it is not impossible that, in the long-run, average working hours will change in response to a transport intervention, our review of the available literature did not identify any evidence for this.

6.3 Agglomeration

6.3.1.1 Under WebTAG, static agglomeration is defined as *'The change in productivity to all firms in a region, as a result of changes in their access to economic mass'*. Agglomeration is traditionally measured through changes in productivity and in chapter 4 we illustrated through the figure below (Figure 9) how a change in productivity is captured by both GDP and welfare equally in perfect competition. Area A represents the increase in real income to existing consumers of a good/service, and Area B represents the reduction in price to new consumers. Both of these areas will flow into GDP and also be accounted for in welfare.

[29] Note that an increase in leisure time might in some way increase the productivity of time that is spent but we are not aware of any compelling evidence to support and quantify the extent to which this is true.

Figure 9: Effect of a change in productivity under perfect competition



6.3.1.2 Given the above, we believe that a change in agglomeration that is brought about by a transport intervention will not create a wedge between GDP and welfare (its impact will affect GDP and welfare equally).

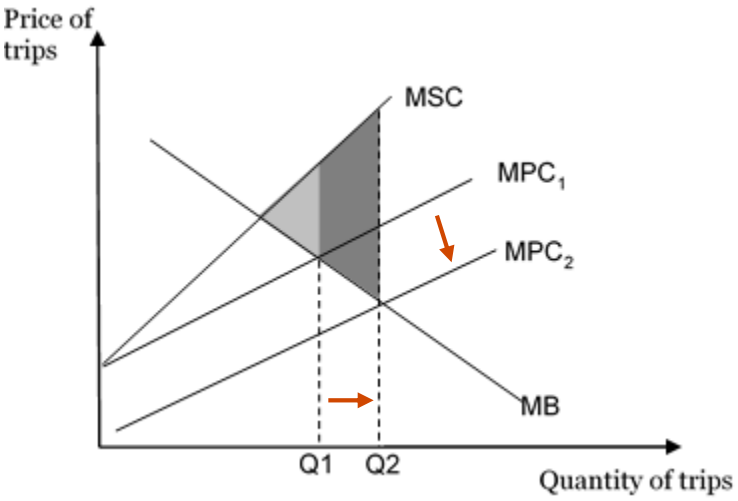
7 Externalities

7.1 Air quality, noise, greenhouse gases and accidents

7.1.1.1 A second direct impact of transport infrastructure investment is to affect the level of externalities – specifically considered here are changes in air quality, noise, greenhouse gases and accidents. If these externalities occur, then the marginal social cost (MSC) of, say, road transport usage is higher than the private costs faced by road users (MPC). To put this a different way, the costs faced by agents when generating additional units of pollution, noise etc. are less than the costs borne by society.

7.1.1.2 Where a transport infrastructure investment reduces the cost of travelling, for example by reducing the level of congestion on roads, this will cause an increase in the quantity of trips consumed. Assuming that prior to the transport intervention, the MSC was greater than the MPC, the transport intervention leads to further divergence between the private and social values (as MPC falls from MPC_1 to MPC_2). This will lead to a net negative impact on societal welfare (the welfare loss increases from the pale shaded area to the pale and dark shaded areas). This welfare loss is driven by an increase in trips consumed from Q1 to Q2. In this illustrative example it is assumed that the marginal social cost of transport is unchanged as a result of the investment, although this is of course not necessarily going to be true.

Figure 10: Potential negative externality associated with transport intervention



7.1.1.3 The change identified in the shaded area of the figure above is by definition a change in economic welfare. The question for this reconciliation is the extent to which, if at all, this has an impact on GDP. A natural starting point is that, by definition, externalities are costs borne by society, rather than by the individuals, and are therefore not priced by the market. This would suggest that any change in economic welfare would not flow through to a change in the level of GDP.

7.1.1.4 There are two main exceptions to this. First, it is possible that the externality could have an impact on underlying economic productivity, and that some of the social cost of the externality comes in the form of this lost productivity. Of the externalities listed, this is most likely to occur as a result of accidents, and the associated cost to the labour market. Previous studies have shown this cost to be material (see, for example Garcia-Altes and Perez, 2007), whilst Mohamed (2015), referencing research by the Transport Research Laboratory, summarised valuation methodologies across Europe and found that the lost productive capacity (i.e. the GDP impact, as opposed to the pure welfare "human cost" impact) varies from 29% to 100% of the welfare impact across different national authorities' methodologies. Of these, the willingness to pay approach used in the UK was found to have the lowest share of impact relating to loss of productive capacity (29%). A similar argument would likely be less direct or material for other externalities, such as noise or air quality.

7.1.1.5 Second, is that regulatory frameworks could be in place which ensure that the social cost of the externality is borne by the economic agent responsible. Such arrangements could effectively "internalise" the externality (e.g. by way of a tax), or require the purchase of a permit, or similar, to account for the social cost of the externality. Depending on the structure of the regime, and the calculation of GDP (e.g. whether the purchase of such a permit counts towards GDP) this could feed directly back into GDP. Contrary to the assumption stated above, under this type of regulatory regime,

each additional externality would pose an increased cost to producers or consumers and subsequently reduce the productive potential of the economy.

7.1.1.6 The key point to note is therefore that it cannot necessarily be assumed that externalities have no impact on GDP. However, any deviation from this assumption is highly dependent on the specific context and therefore ought to be considered on a case-by-case basis and supported with appropriate evidence.

8 Market for goods and services

8.1 Broadening the analysis

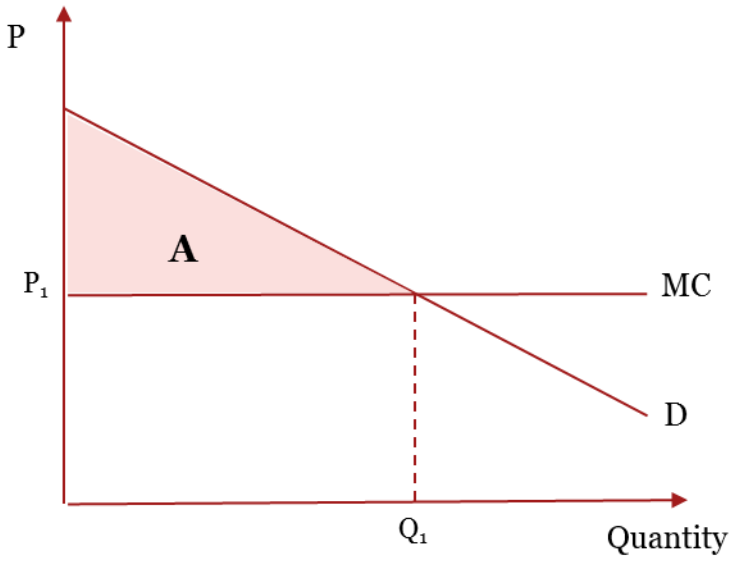
8.1.1.1 Until this point in the report we have considered impacts which directly occur as a result of a transport intervention and within a relatively simple and restrictive set of assumptions. In this and the next three chapters we broaden the analysis. In chapter 8 we consider what happens in the market for goods and services if competition in the market is imperfect rather than perfect. The following two chapters then address the market for labour and other inputs (land and capital). The final chapter focuses on the housing market.

8.2 Reconciliation under perfect competition

8.2.1.1 GDP and welfare can differ because of the value placed on each unit of output under the two measures. GDP will value output according to the market price paid by consumers. By contrast, it is likely that some consumers will value the consumption of a good or service above the price paid (i.e. there will be non-zero consumer surplus).

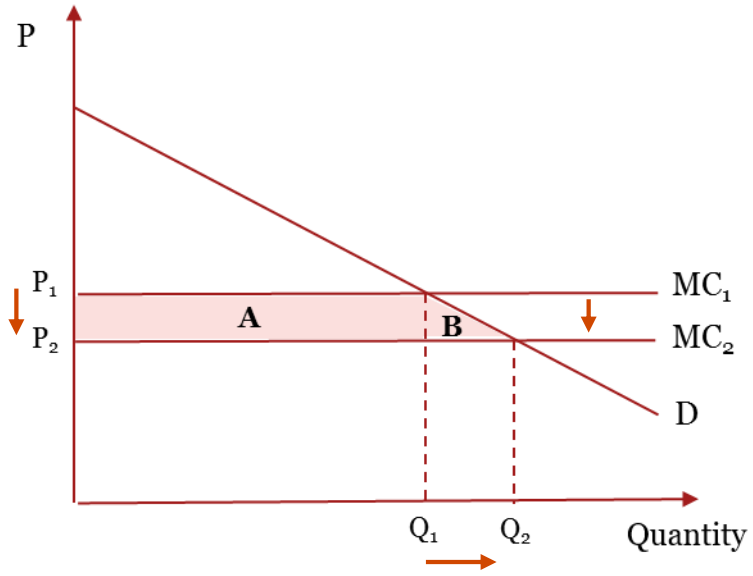
8.2.1.2 Figure 11 below demonstrates how the **levels** of GDP and welfare can be very different even under perfect competition. None of the Consumer Surplus (area A) will be captured within GDP. By contrast, were a firm able to perfectly price discriminate, i.e. charge every consumer precisely their willingness to pay, then each consumer would pay a price exactly equal to their position on the demand curve. In this case, the price would perfectly reflect the welfare value of the good or service (i.e. all welfare would initially take the form of producer surplus), and hence GDP and welfare would be equal. This example demonstrates that the functioning of the market, such as the ability of firms to price discriminate, can be an important factor in a reconciliation between GDP and welfare impacts.

Figure 11: Demand and supply under perfect competition



8.2.1.3 Having established this principle for differences in the *level* of GDP and welfare, however, we showed in Chapter 5 that when looking through the lens of consumers' real income levels any *change* in welfare will be fully reflected within GDP. This analysis, repeated below in Figure 12, showed specifically that Areas A & B on the chart would both be seen within both GDP and welfare.

Figure 12: Change in productivity under perfect competition



8.2.1.4 Having established that, in the context of consumers' real income levels, any *change* in welfare will be fully reflected within GDP. The remainder of this chapter considers:

- Whether this remains true under the assumption of imperfect competition.
- Some situations (which relate to how utility functions operate) where an additional unit of GDP may not equal an additional unit of welfare.

8.3 Reconciliation under imperfect competition

8.3.1.1 A key distinction between perfect and imperfect competition is the ability of firms under imperfect competition to set prices above marginal costs. As established above, a key difference between GDP and welfare arises from the different values placed on each unit of good/service, through market prices and consumer welfare respectively. The difference in prices set by producers under conditions of imperfect rather than perfect competition could therefore alter the relationship between the level of GDP and the level of economic welfare.

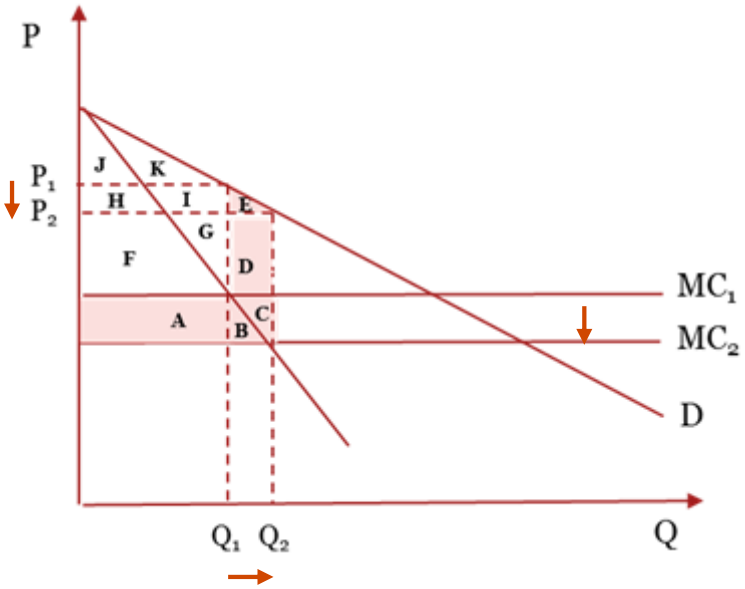
8.3.1.2 However, again, the important question is whether this difference between GDP and welfare persists when looking at changes resulting from a transport intervention. This is outlined in Figure 13 below, which investigates the impact of an increase in productivity (shown by the fall in costs from MC_1 to MC_2) under imperfect competition. This causes prices to fall from P_1 to P_2 and quantity to increase from Q_1 to Q_2.

8.3.1.3 First we consider the impact on economic welfare. Consumer surplus increases by the additional area above P_2, but under the demand curve, i.e. H+I+E. By contrast, producer surplus increases by the additional sales (D) and cost reduction (A+B+C), but reduces by the fall in price to existing consumers (H+I). Overall therefore, economic welfare changes by the shaded area, A+B+C+D+E.

8.3.1.4 The change in GDP can be calculated again using the real income approach. On the producer side, the increase in producer surplus is equivalent to an increase in profit, or return on capital, and would therefore be captured in GDP. This change is equal to A+B+C+D-H-I. Real income changes to consumers are again split into those which accrue to existing consumers (H+I), and those which accrue to new consumers (E). This conclusion, and the explanation for it, is exactly the same as was seen for perfect competition in Chapter 5.

8.3.1.5 This gives an overall change in GDP, A+B+C+D+E, which is the same as the change in welfare. This demonstrates that the presence of imperfect competition has no impact on the conclusion that changes in GDP and economic welfare will be the same following a transport intervention.

Figure 13: Change in productivity under imperfect competition



8.4 Welfare functions

8.4.1.1 A standard assumption in a WebTAG-based economic appraisal is that any increase in wealth (assuming no offsetting welfare effects, such as lost leisure time) will contribute to an equal change in welfare. There are cases where this assumption may not hold including:

8.4.1.2 1. The application of a social welfare function

8.4.1.3 A social welfare function characterises how the welfare of society as a whole (rather than the welfare of an individual) varies under different circumstances. By and large one would expect social welfare to increase in-line with increases in wealth, and the unwritten assumption within WebTAG is that this relationship is one-for-one. Under this assumption, the level of societal welfare is simply the unweighted sum of all individuals' welfare (a 'utilitarian' or 'Benthamite' social welfare function).

8.4.1.4 However, there are two potential exceptions to this. First, is if society places a greater weight on the additional wealth accruing to certain individuals or groups. In this case, an additional unit of wealth could have a different impact on societal welfare depending on who experiences it. In other words, the change in welfare would, in part, depend on where the additional wealth accrues. Second, there may be diminishing marginal utility of income as individuals increase in wealth (i.e. a wealthy individual may value an additional £1 earned/saved less than individuals in lower-income brackets). Both of these exceptions suggest that appraisers should consider the geographic and sectoral impacts of changes brought about by transport interventions – it is possible that efforts to "rebalance" the economy could increase welfare by more than GDP.

8.4.1.5 2. A love of variety amongst consumers

8.4.1.6 A number of economic models (originating with Dixit & Stiglitz, 1977) assume a love-of-variety amongst consumers. Simply put, all else being equal, consumers place greater value on consuming a broad range of goods, than the same quantity of a single good. A transport intervention has the potential to affect the variety of goods accessible to consumers (by reducing costs of travel). This could, without any improvement in productivity or change in price, more efficiently allocate goods to consumers and lead to an increase in welfare which would not necessarily be seen within GDP.

8.4.1.7 Notably, there is little evidence to identify the materiality of either effect. If a scheme appraisal identifies a difference between GDP and welfare due to either of these factors, evidence supporting the magnitude of the effect ought to be provided.

9 Labour market

9.1 Labour market single region model

9.1.1.1 In previous sections, we have shown how GDP and welfare impacts can differ as a result of direct impacts (such as user time savings) and externalities. There are two main reasons for a wedge between GDP and welfare: the first is based on differences in definition between the two measures; and the second is focussed on how the value of each unit of output differs for each of the measures (i.e. GDP and welfare).

9.1.1.2 In this chapter, we consider whether and how differences in GDP and welfare effects arise as a result of interactions in the labour market. In particular, we:

- Analyse the impact of increased productivity from a transport intervention in a market with fixed labour supply, and then relax this assumption so that the supply of labour is variable.
- Consider GDP/welfare impacts when the labour market is in disequilibrium (which we do by assuming fixed or "sticky" wages).

9.1.1.3 For the avoidance of doubt, in the interests of simplicity the analysis in this chapter assumes that the supply of other factors of production (such as land and capital are held constant). The impact on other factors of production, and the interactions between them, is considered in chapter 11.

9.1.1.4 As described in previous sections, we consider an improvement in productivity that could be the result of:

- Time savings to business users
  - A reduction in travel times increases the productivity of business users. A higher value and level of output can be created with a given level of input (i.e. total working hours) because
- Increasing levels of **agglomeration**.
  - Through **agglomeration effects**, transport infrastructure makes businesses and individuals "effectively" closer together. This increases their productivity, for example as a result of access to deeper labour markets and spill-over effects. For the purpose of the analysis in this section, we focus on the impact of static agglomeration effects but the underlying principles should also be applicable to dynamic agglomeration effects (i.e. agglomeration effects brought about by how businesses and individuals change their geographic or sectoral "location" in the economy).

9.1.1.5 The model set out in this section assumes only a single region. The slope of the labour supply curve therefore reflects the extensive or intensive margin within that region. We use the conventional definitions of these margins, where the intensive margin represents the hours worked by those who are actively participating in the labour market and the extensive margin is the measure of the extent to which people are participating in the labour market at all.

9.1.1.6 An improvement in labour productivity could manifest itself in this type of framework in three ways:

1. **Workers benefit:** if wages reflect the value of the marginal revenue product of labour, then workers benefit from a rise in wages (unless the wage rate is a fixed wage rate, which we discuss below).
2. **Consumers benefit**: an increase in productivity and associated reduction in production costs could lead to consumers benefitting through a fall in prices in goods/services.
3. **Firms benefit:** firms could benefit if some, or all, of the reduction in input costs is retained by firms in the form of increased profits.

9.1.1.7 In reality, the benefits from increased labour productivity are likely to manifest in each (or a mixture) of the above.

9.1.1.8 If we assume that both the labour and goods/service markets are perfectly competitive and clear perfectly, then: (a) the labour force is fully informed and there is an absence of 'search imperfections'; and (b) firms are 'price takers' and unable to make super-normal profits.

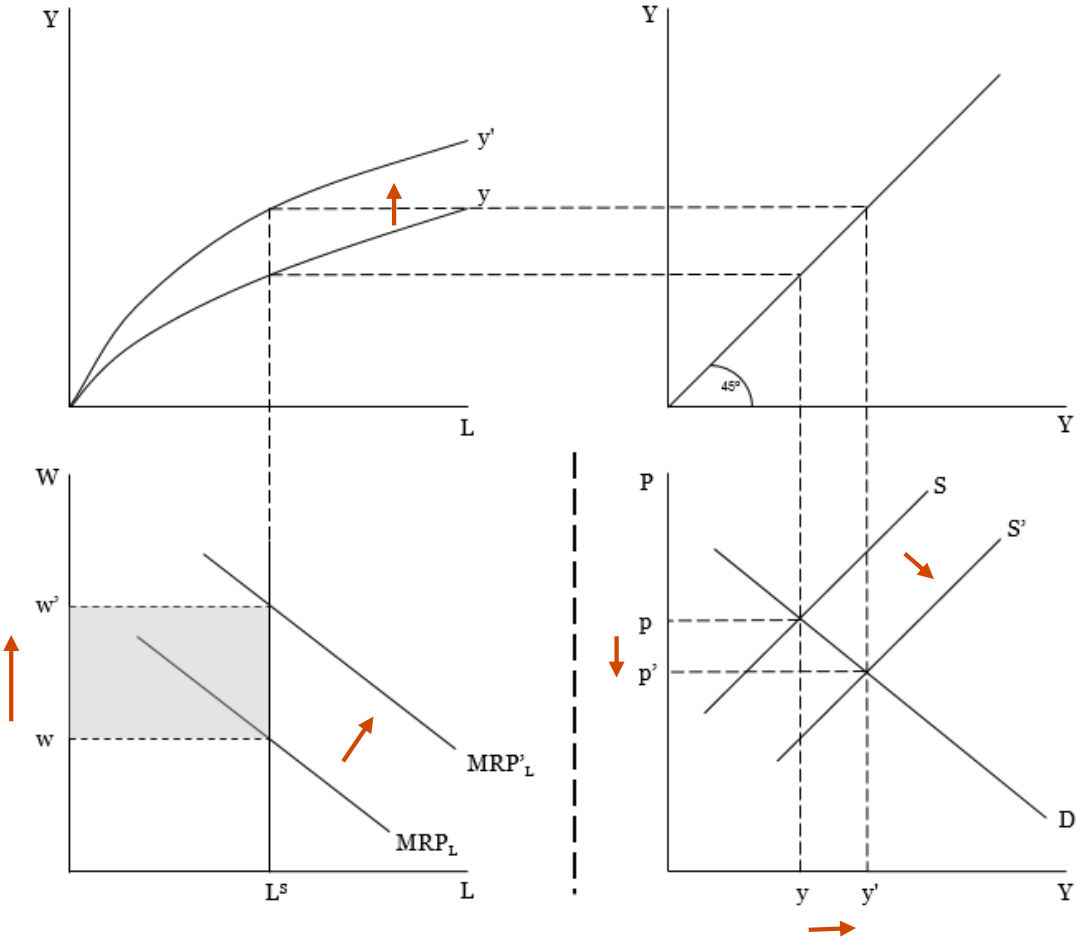
9.1.1.9 Our analysis in this section therefore focusses on the potential benefits that accrue to w orkers rather than to consumer or firms.[30]

9.1.1.10 We apply a simple framew ork as shown in Figure 14 below .

9.1.2 Fixed Labour Supply

9.1.2.1 In the labour market, w e initially assume a fixed labour supply, and that w ages are set to equal the value of the marginal revenue product of labour[31] (MRP_L)[32].

Figure 14: Increase in labour productivity, with fixed labour supply



9.1.2.2 A transport intervention improves labour productivity. This change in productivity leads to an increase in the marginal revenue productivity curve in the labour market. This outw ard shift in the marginal revenue product of labour curve increases real w ages for workers. It does this because w orkers are able to produce more for each level of labour supplied, so the value of their output (for which they are recompensed) increases.

9.1.2.3 Figure 14 show s that – if w e have a fixed labour supply – the GDP and w elfare changes are also equal in the labour market. Here, the real w age rate rises from w to w', with the total w age bill rising by the size of the grey shaded area. This increase in w ages will cause both an increase in GDP and an equal increase in w elfare through raising real incomes of w orkers. Note that, as stated above, w hile in reality

[30] Note that we do consider (toward the end of this section) what happens when for markets do not clear. However, when we do this we continue to assume perfect competition, so our frame of reference (which focusses on benefits which accrue solely to workers) remains.

[31] As we are assuming perfect competition, firms must pay workers a wage equal to their marginal product. If this assumption were to be relaxed then it could be assumed that firms discriminate such that they pay each individual worker their reservation wage as defined by the labour supply curve. This would increase profits earned by firms, at the expense of wages paid to workers. As both the increased profits and reduced wages flow equally into GDP and welfare, relaxing this assumption should not have a substantial impact on the overall reconciliation between the two metrics.

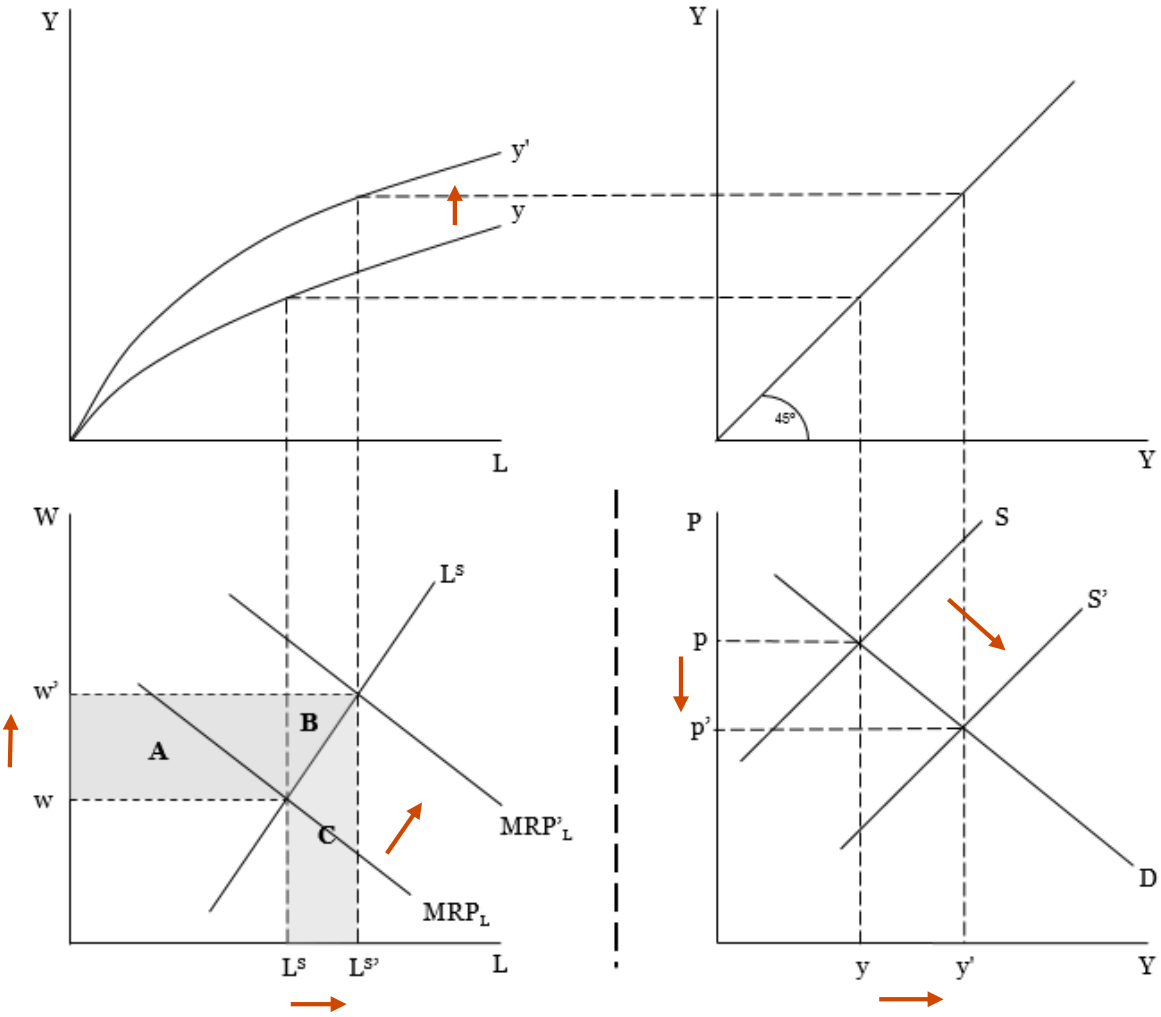
[32] We refer to this henceforth as the marginal product of labour, although all references infer that this is the 'value' of the marginal product of labour.

there would be knock-on effects on firms and in product/service markets, we have not incorporated these impacts into this analysis.

Flexible Labour Supply

9.1.2.4 In Figure 15, the assumption of a **fixed labour supply** is relaxed. An increase in labour productivity pushes wages up as the demand for labour increases. Under the assumption of an upward-sloping labour supply curve, this wage increase incentivises new workers to enter the labour force and/or existing workers to supply more labour. Labour supply subsequently increases from L^S to $L^{S'}$.

Figure 15: Increase in labour productivity, with flexible labour supply



9.1.2.5 As explained in Section 9.1.2, when labour supply is assumed to be fixed, the impact of a transport intervention on the labour market affects GDP and welfare equally. However, when this assumption on labour supply is relaxed, the GDP and welfare effects diverge.

9.1.2.6 As shown by Figure 15, the increase in GDP which accrues in the labour market consists of the rise in wages to current workers on the basis of their existing hours (A) and the wages which are received by additional "new" workers (B + C) (and/or existing workers supplying additional labour). These changes also flow through identically to welfare, but we also have to account for the disutility of individuals joining (or working for longer in) the labour force, represented by C. Consequently the overall GDP and welfare changes are as follows:

- **Welfare** = **A** (increase in wages to current workers) + **(B+C)** (wages of new workers) – **C** (disutility of work) = **A + B**
- **GDP** = **A** (increase in wages to current workers) + **(B+C)** (wages of new workers) = **A+B+C**

9.1.2.7 Therefore, the difference in the GDP and welfare change from a transport intervention for the labour market is shown by C: GDP does not capture the opportunity cost that workers experience as a result of

working. This opportunity cost of working therefore forms a new "channel" of difference between GDP and welfare, which is not present under the assumption of fixed labour supply.

9.1.2.8 Focussing on the labour market, the greater the elasticity of labour supply, the greater the difference between GDP and welfare impacts. Following the intervention, GDP will rise by the additional total amount of wages paid (A+B+C). On the other hand, voluntarily inactive individuals will be encouraged to join the workforce, which will increase the disutility of working (C). The net welfare change will therefore be the sum of the increased wages earned by existing workers (A) and the return on working (the difference between wages and disutility of working) experienced by new workers (B) minus the disutility of increased working (C).

9.1.2.9 In our analysis, we assume the conventional upward sloping labour supply curve, however the transport appraiser should assess the elasticity of supply among the specific labour markets impacted from a given transport intervention. In this regard, it is worth noting that much of the current literature focusses on the differences in elasticities of labour supply as a consequence of the demographic groups to which individuals belong (Heckman and Ashenfelter (1974); Triest (1990); Ecklof and Sacklen (2000); Blundell et al. (1992)).

9.1.3 Voluntary Unemployment

9.1.3.1 On the supply side, some individuals may be unwilling to supply their labour at their marginal product for a number of reasons. These could include:

- High levels of voluntary unemployment may be present due to the value which labour places on the perception of jobs. For example, Klundert (1990) adopted a two-sector model to depict the process of 'wait unemployment': labour supply is lower in a secondary sector due to people caring about their 'status in society'. Their preference to be employed in the 'primary sector' therefore leads to higher levels of unemployment in the secondary sector.
- Voluntary unemployment could result from low demand for skills pushing down wages within a particular industry, to the point which individuals choose not to work.

9.1.3.2 These discussions show how unemployment in itself is not necessarily indicative of a market which is not clearing. The position and slope of the supply and demand curves are determined partially by factors, such as those above, which can explain why labour may be unwilling to work at a specific wage. These factors consequently affect the magnitude and relative GDP/welfare changes from a transport investment – if there are high levels of voluntary unemployment in industries which are to be affected by a given transport intervention, then scheme appraisers should consider this.

9.1.4 Disequilibrium

9.1.4.1 So far we have analysed the GDP/welfare effects of a transport intervention when the labour market is in equilibrium. However, there are reasons why the labour market might not be in equilibrium.

Sticky Wages

9.1.4.2 There are numerous reasons why wages might be "sticky", for example national single-industry agreements (Elhorst and Oosterhaven, 2008), long-term contracting (Barro, 1977) and union-negotiated wages (Bryson, 2007). These factors may mean that wages may respond slowly to changes in labour productivity, and potentially remain out of equilibrium in the long-term. If this is the case, then the assumption that workers are paid their marginal product will not hold, and wages could remain at an alternative equilibrium. This is analogous to a situation of a fixed wage rate, discussed below, at least in the short run, and the implications on GDP and welfare are the same as those discussed in this context.

Fixed wage rate

9.1.4.3 In this section we analyse the effect of improving labour productivity through a transport intervention, where there is a labour market disequilibrium that is driven by a fixed wage rate in the labour market and which leads to 'involuntary' unemployment. We show that disequilibrium from fixed wages can affect the relative GDP/welfare changes from a transport intervention.

9.1.4.4 First, we evaluate the GDP and welfare effects where there is a relatively large difference between the fixed wage rate and the equilibrium wage. We then compare this to when the fixed wage is closer to the equilibrium wage level. We adopt our disequilibrium approach from Elhorst and Oosterhaven (2008). In both cases we assume that the productivity shift (from the transport intervention) is not large enough for the new equilibrium wage rate to rise to the fixed wage rate in the market, i.e. the fixed wage rate continues to 'bite' (in the sense that wages are determined by the fixed wage rate rather than the market equilibrium).

9.1.4.5 Figure 16 considers the case where the fixed wage rate is substantially above the equilibrium level, and hence leads to a disequilibrium which is "large" in magnitude. A change in the labour demand from MP_L to MP_L', increases welfare as shown by the grey shaded area (A+B).

- A represents the surplus which new workers gain from being able to enter work through the improvement in productivity.
- B represents the disutility of new workers providing work.

9.1.4.6 New workers entering the market are paid a significantly higher wage (w*) than the wage they were willing to supply at (w). Consequently the disutility of entering work (B) is much smaller relative to the welfare gain these new workers obtain (A).

9.1.4.7 In contrast, Figure 17 considers a market where the fixed wage rate (w*) is close to the equilibrium at both the pre-intervention and post-intervention labour demand curves. The welfare gain for new workers is relatively small compared to **Error! Reference source not found.**, given there is a smaller difference between the wage these workers were willing to supply at (w) and the wage being offered (w*). Consequently the disutility and therefore welfare loss is far greater when the disequilibrium is relatively small as shown by B in Figure 17.

9.1.4.8 Overall, in the case of a fixed wage rate, the change in GDP (A +B) is greater than the change in welfare (A) in both cases Figure 16 and Figure 17). However, the smaller the disequilibrium, the greater the gap between GDP and welfare. The degree to which the labour market is in disequilibrium therefore acts as a "scalar", which does not necessarily create a new wedge between GDP and welfare, but augments the existing wedge caused by the disutility of working.

Figure 16: Labour market with a fixed wage rate ("large disequilibrium")

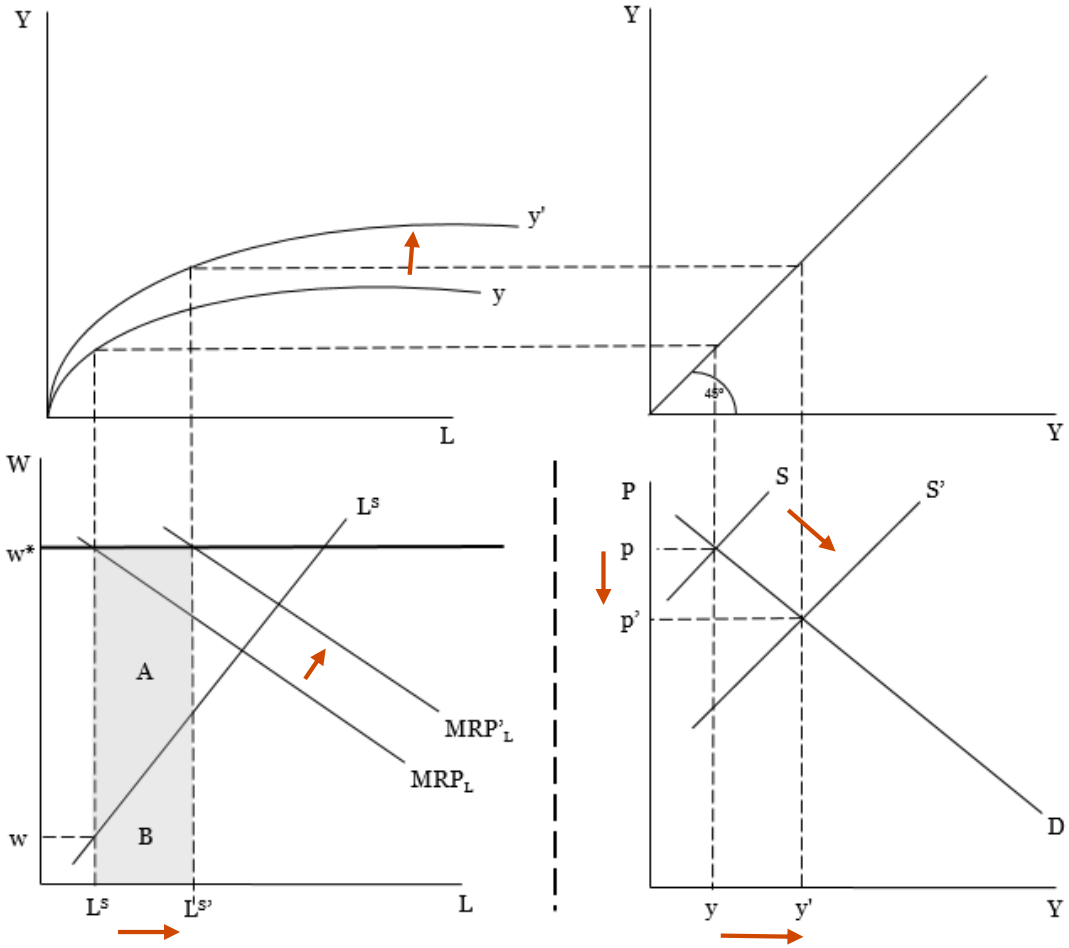
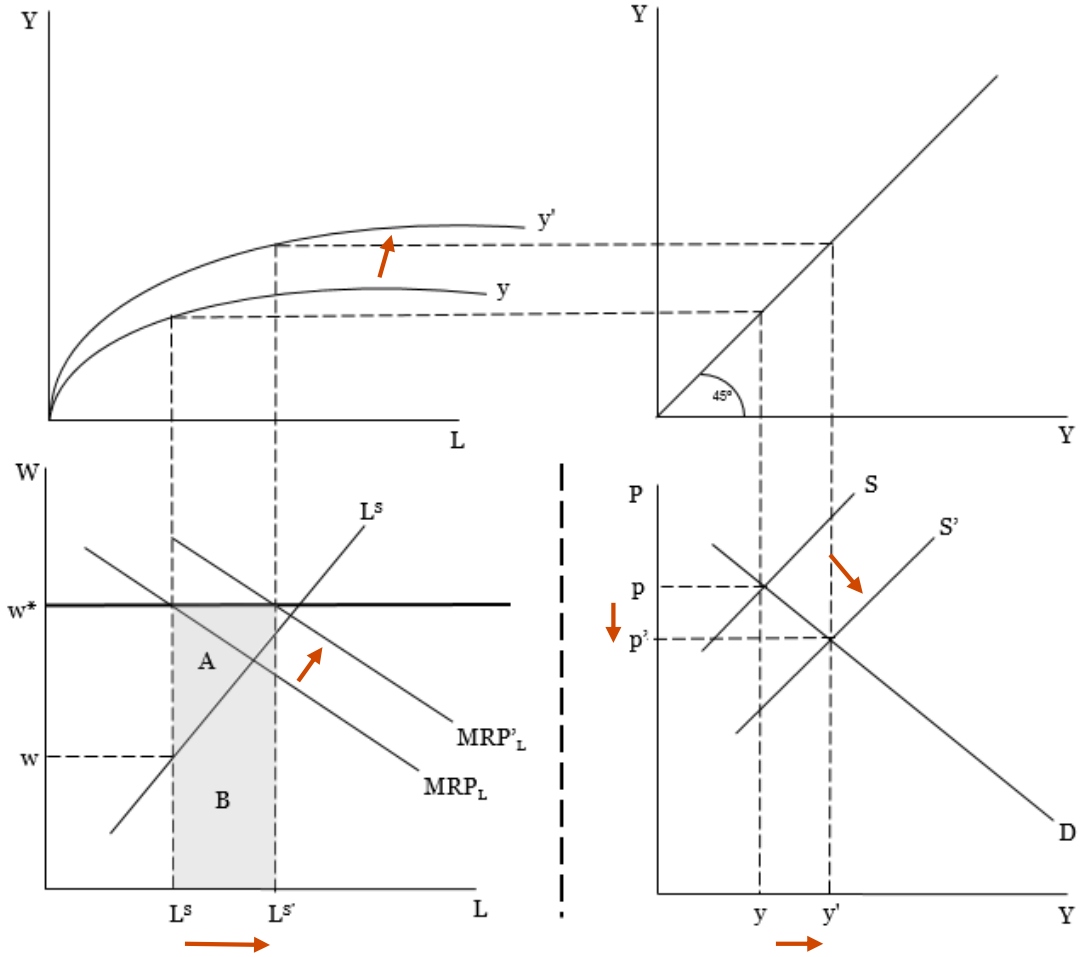


Figure 17: Labour market with a fixed wage rate ("Small disequilibrium")



9.1.5 Extensions of analysis and Conclusion

9.1.5.1 We have shown how the GDP/welfare effects can vary depending on the assumptions made about the functioning of the labour market in the following situations:

- **Fixed labour supply:** the GDP and welfare impacts which arise through the labour market will generally be equal, with productivity benefits flowing to existing workers in the form of higher wages and in a way that reflects identically in both GDP and welfare.
- **Flexible labour supply**: some of the increase in GDP from the intervention will be driven by an increase in labour supply but some of this will be offset by greater disutility of working. By extension, when assuming that labour supply is flexible, a more elastic assumption of labour supply in response to changes in the wage rate will lead to a greater divergence between GDP and welfare impacts.
- **Disequilibrium through fixed/sticky wage rate:** when labour markets are in disequilibrium (e.g. due to fixed or sticky wages), there will be a wedge between GDP and welfare impacts. The size of the wedge will be driven by the level of disequilibrium, i.e. the extent to which the fixed wage rate is higher than the equilibrium wage rate.

9.1.5.2 In practice, it will be important for the transport appraiser to consider the characteristics of 1) industries, 2) the product/service markets and 3) the labour markets on which the intervention impacts. Appraisers should dedicate significant attention to the functioning of the labour market, as this will have a material impact on the level of both GDP and welfare, and the relationship between them. Key factors to consider include skill levels, unemployment and the availability of local labour in the short- and long-run – together with empirical evidence on how labour has responded in the past to changes in real wages.

10 Labour market – Two-region model

10.1.1.1 In this section we expand the analysis to consider the movement of workers between regions and sectors to gain a fuller picture of the impact of a transport intervention on GDP and welfare.

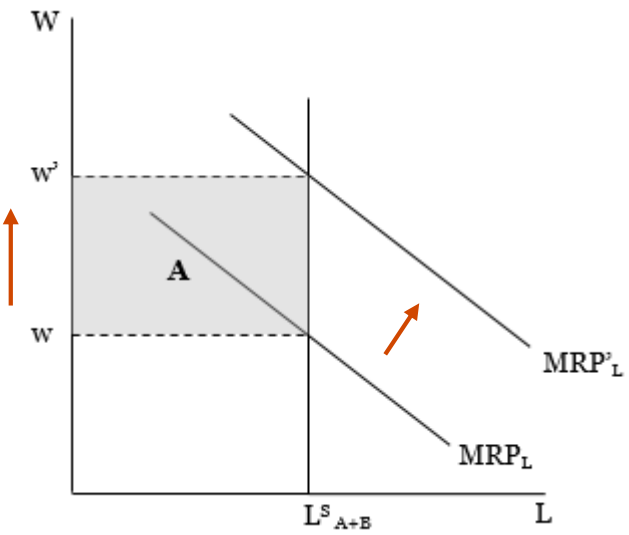
10.1.1.2 In Chapter 9 we considered the impact of a transport intervention solely within a single region. It was therefore assumed that any increase in labour force participation in the region would be from the labour pool within that region. However, large transport interventions may lead to movement of workers between regions the impact of this needs consideration. In this case the 'net' effect on GDP and welfare will depend not only on the change in the labour force within the region but in other regions too.

10.1.1.3 Economic literature commonly addresses the importance of assessing the 'net' effect of a policy or intervention by accounting for displacement. For example, O'Fallon (2004) stresses how growth in one region from a transport investment could be the result of diminished growth in another. In addition, Gibbons (2015) discussed how any effects from a transport investment could merely be from a 'zero-sum displacement of economic activity'. This report concluded that job creation from the UK's road building programme during the 1990's and 2000's came from the entry of new firms, which led to incumbent firms losing workers. Although this report does not deal specifically with labour moving between regions, it highlights how both "winners" and "losers" of an intervention should be considered in order to appropriately estimate the net impact of a scheme.

10.1.1.4 We use a two-region model to account for displacement in the labour market and to assess its relative effect on both GDP and welfare. In our model there are two regions, Region A and Region B, with the transport intervention taking place in region A. We assume that workers in region A and region B are identical in their marginal revenue product, *ceteris paribus*.

10.1.1.5 First we analyse the impact of a new transport intervention at a national level. We assume that the national economy is at the long run natural rate of unemployment from which it cannot deviate. Hence, we assume there is a fixed labour supply, which is simply a sum of the labour pools in region A and region B. Note how the mechanisms and final conclusions for a national aggregate of region A and region B are identical to the one-region model with a fixed labour supply discussed earlier.

Figure 18: National labour market

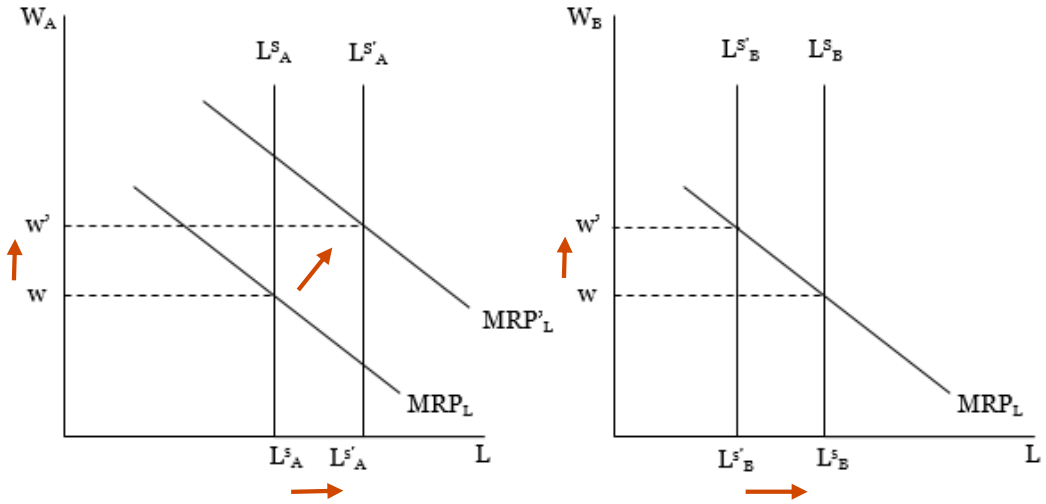


10.1.1.6 The key conclusion from an aggregate perspective is that the GDP and welfare increase is identical. This implies that any loss in welfare in one region from the movement of workers will be offset by a gain in welfare in another region. In effect with a fixed labour supply, national displacement effects are a zero-sum game and offset each other. It is important to remember this result in our two-region model, where we assess the effect of displacement on region A and region B separately.

10.1.1.7 In Figure 19 we move on to analyse the same scenario from the perspective of two-regions. We show how improved labour productivity from a transport intervention in region A leads to increased demand

for labour in region A from MRP_L to MRP_L', with wages rising from *w* to *w*'. This increase in the labour supply is the result of workers moving from region B to region A, as we assume that the labour supply in A is constant – there is full employment. Thus the difference between L^S_a to L^S_a' is entirely through the movement of workers from region B to A. This leads to a contraction in the labour supply curve in region B to $L^{S'}_B$ from L^S_B increasing wages in B to *w*', as a result of diminishing marginal returns. Thus L^S_a to L^S_a' and L^S_B to $L^{S'}_B$ are identical in size, as it is merely the reallocation of the same workers from region B to region A.

Figure 19: Regional labour markets – Fixed supply with movement between regions



10.1.1.8 Under this simplified model, there are three groups of workers, which experience a wage increase from *w* to *w*', leading to a rise in GDP and welfare.

- *Workers in region A:* experience an increase in wage resulting from the increase in productivity brought about by the scheme (and shift upwards in the labour demand curve).
- *Workers who remain in region B:* experience an increase as labour supply in B contracts from workers moving to region A. This stems from an increase in the marginal revenue product of labour in B as the number of workers falls, which leads to an increase in their wages.
- *Workers who leave region B to work in region A:* experience a wage increase through the increased demand for labour from the transport intervention in region A as a result of higher productivity.

10.1.1.9 As shown in Figure 18, at a national level increases in GDP and welfare will be equal where national labour supply is fixed. This increase will be the sum of the three bullets above. This implies that any wedge between GDP and welfare in one region, as shown in Figure 19, is fully offset by changes in the other region from the transport intervention. There is no additional gap between GDP and welfare created through displacement from a transport investment, when the national economy is at a natural rate of unemployment and has a fixed labour supply.

10.1.1.10 We have shown that in the case of a fixed national labour supply, any difference between GDP and welfare in one region is simply displaced by an equal and opposite wedge in another region. However, if the assumption of a fixed labour supply in Region A is relaxed, than a wedge between GDP and welfare may arise. This will be dependent on the source of additional workers. There are three distinct pools of additional workers, who could enter employment in A under the two-region model following a transport intervention:

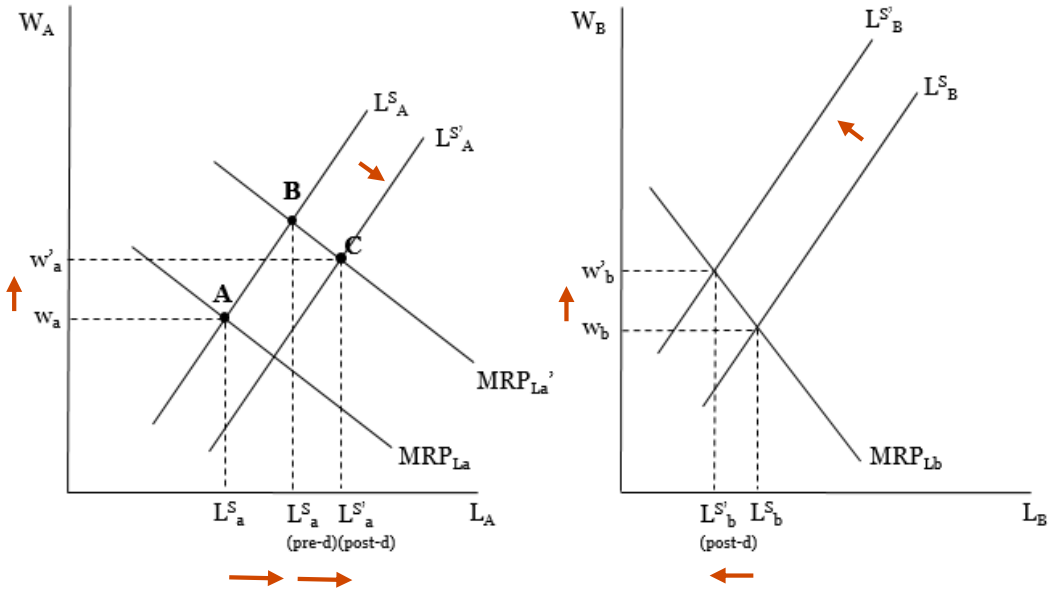
1. Those who were unemployed in region A's labour market pre-intervention
2. Those who were unemployed in region B's labour market pre-intervention
3. Those who were employed in region B pre-intervention

10.1.1.11 Sources 1 and 2 above allow the labour supply nationally to expand, and therefore GDP and welfare changes to differ. Therefore as we will discuss below, the appraiser should consider the sources of additional labour in region A, as different sources have different implications for GDP and welfare.

10.1.1.12 In Figure 20 shows workers in region A move from unemployment to employment following a labour productivity improvement. The MRPLa shifts outwards to MRPLa' leading to a movement along the

current labour supply curve from A to B. Given that these workers sacrifice leisure to work the disutility of work is included in welfare measurement but not in GDP and a wedge between them is created.

Figure 20: Regional labour markets – Flexible labour supply with movement between regions



10.1.1.13 The second source of workers in Figure 20 is shown through the movement from B to C which represents the influx of workers from region B who are moving from employment in B to employment in A (the third labour pool source listed above). There is no 'wedge' between GDP and welfare created by this movement if there are no welfare effects from moving regions or working in a region other than where an individual lives, which we discuss later in this section. For simplicity, we have assumed in this model that there are no workers who move from unemployment in region B to employment in region A. This would create a gap between GDP and welfare in exactly the same way as for workers moving from unemployment to employment within region A.

10.1.1.14 So in conclusion, under this framework labour sources 1 and 2 will lead to a wedge between GDP and welfare. The larger the proportion of individuals from sources 1 and 2 filling the additional demand for workers in region A due to a transport investment, the larger the gap between GDP and welfare. The third source of labour does not create a gap between GDP and welfare as workers were already employed before the transport intervention.

10.1.1.15 It is important to note that Figure 20 depicts the equilibrium situation where wages are equalised in region A and B from w to w'. This is unlikely to be an immediate outcome because of labour market flexibilities but a long-run result. It ignores other factors which may drive a wedge between wages across A and B such as the characteristics of different regions and moving costs.

10.1.1.16 The two regions in our model could reflect geographies at different levels: Region A and Region B could reflect two towns, counties or countries. Although there may be different external factors which impact the magnitude of displacement between the two geographies, the underlying theoretical mechanisms are likely to be the same given the assumptions that we have set out that underpin these models.

10.1.1.17 In summary, whether considering a fixed or flexible labour market at a national level, there is a need to recognise that wedges between GDP and welfare may occur at a regional level, and therefore solely focussing on the region directly impacted by a transport intervention will not necessarily lead to the same reconciliation as when considering the national picture. The degree to which labour is mobile between regions could also affect the regional labour supply, and hence act as a "scalar" through augmenting the size of the existing regional wedge between GDP and welfare.

10.2 Factors to consider when analysing displacement

10.2.1.1 In order for an appraiser to understand the extent to which displacement will impact relatively on GDP and welfare changes, it is important to consider:

- The determinants of worker's preferences for living in a specific region
- The likelihood of displacement based on the industry and the type of jobs created

10.2.1.2 The appraiser should consider the attractiveness of region A for additional workers from region B. There are many other factors, beyond work-related reasons, why workers move between regions: a study conducted by the O'Fallon (2003) found that housing costs, educational opportunities, and area-related factors influence decisions on internal migration within Great Britain. This study found that job-related migration is more common among higher-skilled workers and those with higher qualifications (Dixon, 2003). It is therefore important for appraisals which analyse welfare and GDP impacts to consider the types of jobs which will be created following a transport intervention.

10.2.1.3 Regional characteristics are also important because they affect the welfare that workers attain when moving regions. This welfare impact will be dependent on an individual's preferences. For example, in the two-region model above we assessed the impact of the movement of workers from region B to region A. An ONS report (Dixon, 2003) highlights the importance at the aggregate level which individuals place on the housing characteristics of an area. Thus if region A has a poor quality of housing and poor levels of educational opportunities, then a £1 increase in GDP is likely to be reflected by a less than £1 increase in welfare. For a given wage, workers will experience a disutility from moving to region A from region B, given A's regional characteristics. This could create a gap between GDP and welfare.

10.2.1.4 Some regional characteristics may be 'priced' in property prices. For example, if region A has poor quality of housing and poor educational opportunities than this is likely to be reflected in property prices in region A. As a result the regional characteristics would be equally accounted for in both GDP and welfare if the characteristics were reflected in the housing market in region A. Therefore, appraisers should consider the extent to which individual regional characteristics and individual's preferences towards regions are reflected in the property market.

10.2.1.5 These preferences and characteristics will influence the likelihood of workers moving between regions, assuming that they have perfect information regarding the regional characteristics in both regions and how this aligns with their preferences. However, in practice it is unlikely that workers will have perfect information prior to moving on all of these factors and thus their actions may not be entirely rational either.

10.2.1.6 It is important for an appraiser to account for these differences in regions. The specific indicators which an appraiser should utilise will be dependent on the location of the two regions. However, a common proxy is the Human Development Index (HDI), which the appraiser could use as an estimate of quality of life differences between two regions to account for the dynamics discussed in this chapter.

10.2.1.7 To conclude, there is an additional wedge that may arise between GDP and welfare that is brought about by differences in characteristics between region A and region B, and the value which individuals place on these characteristics. The first case is where individuals moving to region A experience a disutility of moving, and thus the welfare increase is lower than the GDP increase. The second case is where individuals experience an additional gain in welfare through moving to region A, beyond wage changes. In either the example, the additional channel of impact is that by moving the individual experiences a higher/lower quality of life which is either partially or fully not picked up within GDP. This would lead to a wedge between GDP and welfare.

10.3 Application of two-region model to two sectors

10.3.1.1 The above two-region model could be applied to a two-sector model, with sector A and sector B. The elasticity of the supply curve for sector A would be a function of the wage rate in sector B. Sector B could represent one sector or an aggregate of the other sectors within a region. At an aggregate level, we assume that the supply of labour is fixed, and merely the sum of labour across all sectors within the region, given that we are at a natural rate of unemployment. Thus, as with our two-region model, a transport intervention would improve labour productivity, and lead to the movement of workers from other sectors as wages rise in sector A. This leads to an equal increase in GDP and welfare, at the aggregate level, showing how any additional welfare changes from the movement of workers between sectors simply offset each other, under these assumptions. Thus in this model, there would be no wedge created between GDP and welfare through the movement of workers between sectors.

10.3.1.2 Alternatively, if we relax the assumption of fixed labour supply, then gaps between GDP and welfare may be created. One wedge could arise, if workers enter sector A, when they were initially unemployed in sector A or sector B. Another wedge could arise if there are additional welfare effects from moving to sector B from sector A, beyond wages. Therefore the same theoretical approaches, which we discussed in our two-region model could be applied to a two-sector model.

10.4 Application of two-region model to firms

10.4.1.1 There could also be the movement of firms between regions, aside from the movement in labour. A transport intervention in region A will lead to region A being more attractive to firms, as labour in region

A will have higher productivity levels. Firms would have a greater incentive to move to region A and this would lead to higher levels of dynamic agglomeration. As more firms move to region A this increases demand for labour further shifting out the marginal revenue product of labour curve. This does not create an additional wedge between GDP and welfare but leads to a larger wedge between the two measurements, as the MRP curve is shifting out further than it originally would have. The movement of firms to region A through this mechanism affects the size of the gap between GDP and welfare, rather than creating a gap itself.

10.4.1.2 One exception to this is that through dynamic agglomeration and increased connectivity between regions, there may be some impacts which purely affect welfare and do not affect GDP. For example, 'love-of-variety' can create differences in GDP and welfare measures. Through more firms moving from region B to region A, or consumers in A having greater access to firms based in region B through transport connectivity, there is access to a greater range of goods. This increases the welfare of consumers without increasing overall levels of economic output and therefore leads to different impacts on welfare and real GDP.

10.5 Summary

10.5.1.1 In this section we have extended the one-region model to a two-region model at both the national and regional level.

10.5.1.2 We first discussed the impact on GDP and welfare, assuming we were at the natural rate of unemployment and there was a fixed supply of labour nationally. In this case, the effect of a transport intervention is the same on both GDP and welfare.

10.5.1.3 Wedges can, however, arise when labour supply in the two regions is flexible.

10.5.1.4 An additional gap may arise between GDP and welfare when there are differences between the characteristics between region A and region B. If an individual is relocating from region A to region B, but prefers to live in region A, they will experience a negative welfare impact, even if the GDP impact is positive as a result of changes in the labour market. Notably, the wedge will be smaller the more that individual preferences are priced into various markets (e.g. the property market).

10.5.1.5 The intuition behind this model can be easily extended to the movement of workers between sectors – and, indeed, the movement of firms.

10.5.1.6 The final mechanism discussed is how dynamic agglomeration creates a gap between GDP and welfare, because as discussed in an earlier chapter, there will be increased access to a greater variety of goods, which will not necessarily be picked up within GDP.

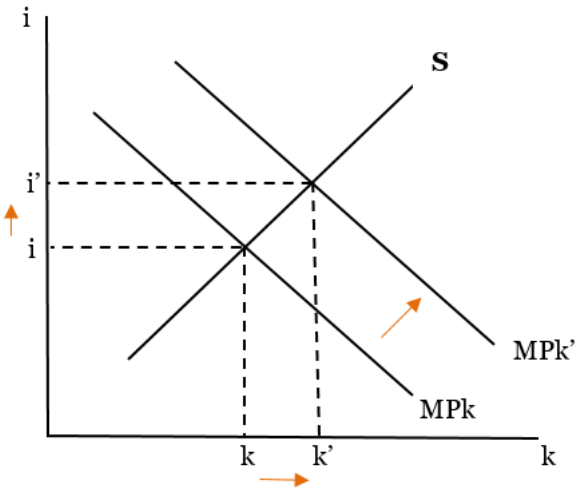
11 Market for other inputs

11.1 Capital

11.1.1.1 A transport intervention that brings improved accessibility could increase the productivity of capital. This could result in the reallocation of economic funds to increase spending on capital, at the expense of consumption, or less productive factors of production such as labour or land.

11.1.1.2 Chapter 6 **shows that** user-time savings and agglomeration effects are some of the mechanisms though which transport investment results in productivity gains. A transport intervention could therefore improve the economic environment such that the productivity of capital will increase, and owners of capital are able to get a higher return. In the short run, the intervention could benefit either businesses (who get a greater return on the capital employed) or holders of capital who benefit from increases in real interest rates.

11.1.1.3 In a competitive capital market in the long-run, the real interest rate will adjust such that it equals the marginal product of capital in equilibrium, and hence all benefit will flow through to owners of capital. This can be seen in Figure 21 below, where the demand for capital rises in line with increases in the return on capital (illustrated by the outward shift of MPk to MPk'), and investment in capital at an economy-wide level increases. Consequently, the interest rate on capital, i.e. the price of capital, rises (from i to i'), and the quantity of capital available increases from k to k'.



11.1.1.4 In the short run, there will be adjustment costs to moving capital, so in order to attract capital to a different region/sector businesses will need to pay a premium to motivate holders of capital to bear the costs of moving assets from one region and investing in another. In addition, not all investment comes from moving around the existing capital stock – some might come from foregone consumption, leading to new investment. Again, some adjustment cost could be borne in attracting this investment.

11.1.1.5 The important question for this report is the relative degree to which changes in the capital market will drive changes in GDP and welfare. In order to answer this, we refer back to the two fundamental reasons explaining the divergence between the GDP and welfare effects of transport intervention, identified in chapter 4:

1. Definitional differences
2. Differences in how the market functions and GDP is measured

11.1.1.6 If we assume that capital is fixed, which seems reasonable when considering effects in the short-run, neither of these two reasons will lead to a wedge between GDP and welfare. Returns on capital will increase, leading to greater income for owners of capital which will contribute equally to both GDP and welfare.

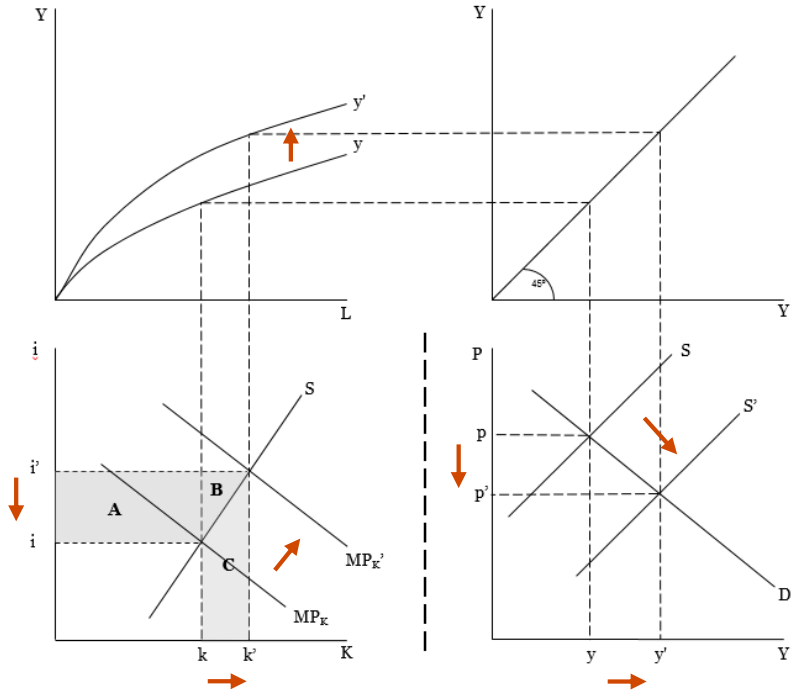
11.1.1.7 Under the assumption of a flexible supply of capital, three key assumptions need to hold for the conclusion that GDP and welfare effects are equal to be valid.

1. Both GDP and welfare capture the additional return on capital investment, following the transport intervention. This is not an unreasonable assumption – all else being equal the additional return on investment will take the form of greater profits for businesses, or additional returns on investments for individuals, which feed into both GDP and welfare.
2. The opportunity cost of investment is also valued under both GDP and welfare. Typically the opportunity cost of investment would be either the interest rate which could be gained from investing elsewhere, or the welfare which would be gained from consumption which is now foregone. Both consumption and the return on alternative investments would be captured in both GDP and welfare. There are possible exceptions to this rule, for example if individuals were to invest outside of formal financial institutions which are not captured in GDP, but these are very much exceptions rather than material alternative scenarios.
3. There are no distributional effects in the allocation of capital. For example, if capital holdings are skewed towards the wealthy then the social welfare impact of an additional £1 of capital income may be less than the associated GDP gain (and vice versa for poorer households). Similarly, if interest rates were to rise then welfare impacts would be skewed towards individuals and demographics who place a higher value on saving.

11.1.1.8 Assuming these three assumptions hold, Figure 21 below shows that GDP and welfare would be affected equally by a transport intervention which improved the productivity of capital. The increase in GDP which accrues in the capital market consists of the rise in interest rates on capital (A) and the interest which accrues from new capital (B + C). Assuming the three assumptions outlined above hold, these increased economic returns will also contribute positively to welfare. Under the same assumptions, the opportunity cost of allocating funds to capital (C), i.e. the interest that would be accrued if those funds were saved, is valued by the market and is therefore accounted for both in GDP and welfare. Consequently the overall GDP and welfare changes are as follows:

- **GDP = A** (increase in interest rates on existing capital stock) **+ (B+C)** (interest on new capital) **– C** (interest that could be accrued if those funds spent accumulating the new capital were saved instead) **= A + B = Welfare**

Figure 21: Increase in the productivity of capital



Source: PwC

11.1.1.9 We note that impediments to perfect capital mobility may temporarily restrict the ability of firms to increase output. With higher capital adjustment costs, when a transport intervention increases productivity, firms cannot easily increase their output. This could be visualised as a curved supply curve in place of the linear one shown in the bottom left quadrant of Figure 21. In the short run, capital adjustment costs result in an inflexible capital supply curve (i.e. a vertical supply curve), whilst in the long run these frictions no longer arise and thus the supply curve is flexible (horizontal). As such output increases are dampened and the effects of the transport intervention on both GDP and welfare will be reduced.

11.1.1.10 Overall, the argument is the same as the discussion regarding labour in chapter 9. If the opportunity cost of employing capital affects welfare but not GDP (as seen with disutility of work), then there will be a wedge between GDP and welfare from employing additional capital. However, given the nature of capital as a factor of production this is a less reasonable assumption, so we would not expect that allowing for flexible capital supply will lead to an additional wedge between the two measures.

11.2 Land

11.2.1.1 The implications of a transport intervention in the context of land are more complex. Transport interventions can improve the accessibility of land and prompt agglomeration effects, hence increasing the efficiency with which land can be used. This increases the productivity of land and thus brings output gains that boost both GDP and welfare. We assume that the overall supply of land is fixed, but that mix of land usage is flexible, i.e. land used for non-commercial purposes can be converted into commercial land. In practice this flexibility is likely to change over time − land use will be fixed in the short-run but become increasingly flexible in the long-run.

11.2.1.2 Transport interventions bring increases in Total Factor Productivity. As the marginal productivity of land increases (see Figure 22 MP_L increases to MP_L'), the demand for land rises and accordingly so does the price of land (represented in Figure 22 by the increase from p to p'). As the productivity of land rises, land that was previously used for non-commercial purposes, may be increasingly used for commercial purposes. For example, where previously a brownfield site was too costly to redevelop, following the transport intervention and the associated increase in the productivity of land, it may be worthwhile redeveloping the site. As productivity increases, both GDP and welfare increase.

11.2.1.3 However, as Venables, Laird, and Overman (2014) note, private and social values may diverge when developments result in significant land-use changes. As such a wedge between GDP and welfare may arise when there is land-use change. Fundamental to understanding this wedge is the opportunity cost of the land-use change. There are fundamentally two types of land:

1) **Land for which the return is reflected in GDP** e.g. land used for commercial purposes where the rent net of costs enters into GDP. We refer to this as land used for '*economically active'* purposes.
2) **Land for which the return does not enter into GDP** e.g. brownfield sites where the land was left derelict and unused so that there are no rents; or public parks which generate no explicit economic value.

11.2.1.4 When type 1 land is converted into a different form of type 1 land (e.g. residentially rented property is converted to commercially rented property) no wedge between GDP and welfare is likely to arise, as the opportunity cost of the land-use change is valued by GDP and welfare identically. However, if following a transport intervention, type 2 land becomes type 1, (e.g. a public park is converted into a commercial private property) then the value from a commercial setting appears in GDP whereas the detriment to people's utility or welfare of losing a park does not, and as such a wedge will arise between the two.

11.2.1.5 Welfare effects associated with changing land use from type 2 to type 1 could be a positive or negative. For example, if prior to a transport intervention, land was publicly owned and a natural amenity, then following the transport intervention there could be a welfare loss associated with the land use change. However, if an area of land was previously a brownfield site and following the transport intervention is converted into a park, there may be a positive welfare effect associated with the land-use change.

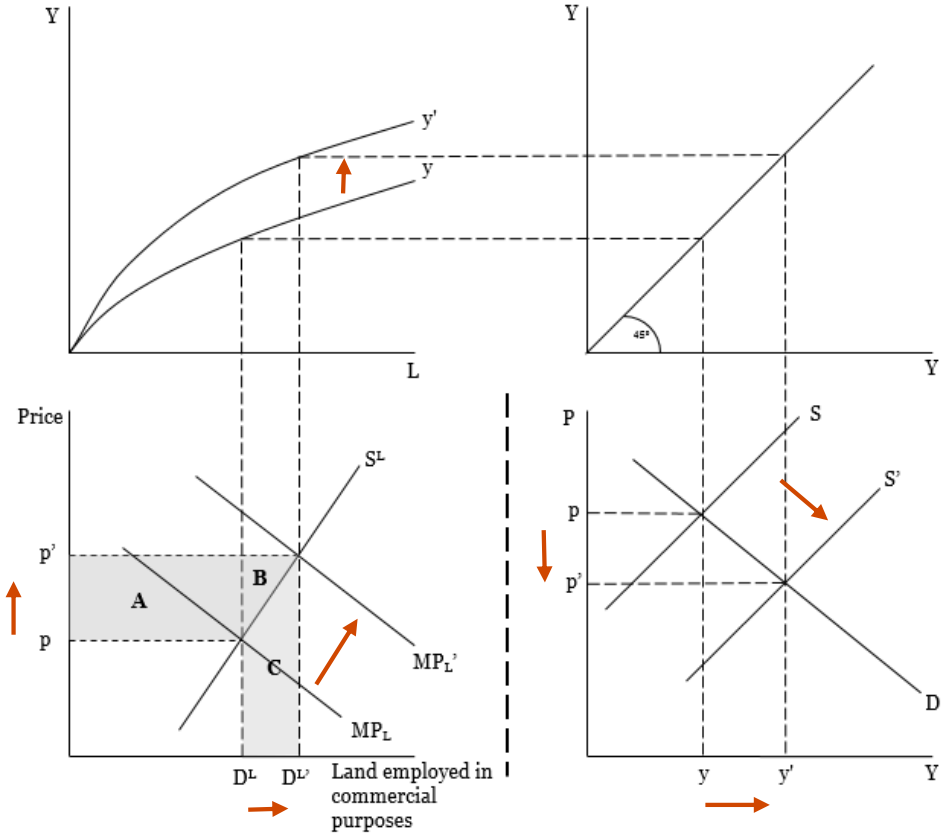
11.2.1.6 In either case, this opportunity cost of changing land-use is not valued in GDP, given that no economic rent is accrued from land that was not economically active prior to the transport intervention. The change in GDP will be equal to the entirety of the additional output resulting from the land use change. By contrast, the welfare impact of the land use change will be specific to the amenity impact of each individual investment, but will broadly be proportional to the size of the land use change. We therefore use the notation αC to represent this welfare opportunity cost. Data on the value placed on the natural amenity of the land before and after the intervention will be needed to quantify this welfare impact.

11.2.1.7 Overall, the GDP increase which arises as a consequence of a change in the productivity of land, consists of the rent paid for land (A); the rent which accrues as a result of land that was previously being used for non-commercial purposes being used commercially (B + C); and, if prior to the transport intervention land was economically active, the opportunity cost of the land use change (C). These additional rents will increase the real income of land owners, and therefore have an equal effect on welfare. However, when considering welfare changes there is an opportunity cost of land-use changing from type 2 to type 1 of αC. As such the overall GDP and welfare changes are as follows:

- **GDP = A** (increase in the rent on land) **+ (B+C)** (rent on land that was previously used for non-commercial purposes) **– C** (the opportunity cost if land was previously used for economically active purposes) = **A+B [+C]**, with the [+C] element only applying if the land was previously employed for non-productive use.

- **Welfare = A** (increase in the rent on land) **+ (B+C)** (rent on land that was previously used for non-commercial purposes) **– αC** (welfare associated with the previous land use –this value may be positive or negative) **= A + B +C [+/- αC].**

Figure 22: Increase in the productivity of land



11.2.1.8 When, prior to transport intervention, land has environmental capital, land-use change is more likely to lead to negative welfare effects. Previous studies (such as Gibbons Mourato and Resende, 2014) have monetised the impact of changing environmental capital. Gibbons *et al.* suggest that proximity to natural amenities such as gardens and designated areas substantially increases the house market value in the surrounding area indicating there is a high amenity value attached to them. For example they find the presence of a national park designation added approximately 5% to the mean house transaction price. Similarly, Leggett and Bockstael (2000) suggest, based on the positive effect on property values of factors such as air quality and noise pollution, that the quality of the environment is highly valued by residents.

11.2.1.9 Following a transport intervention, if land with substantial environmental capital moves to commerical use then the welfare impact will be the net of the positive increase in rents and negative loss of environmental capital. If it is the case that the nature of the land means that the environmental capital is not reflected within the land value or rents which can be extracted (e.g. because the amenity is an externality, such as with a public space, as opposed to a private dwelling) then the impact on GDP will only reflect the additional commercial rents available. Even in this instance it could be that some, if not all, of this value is captured in the rents of surrounding land which benefits from the amenity.

12 Housing market

12.1.1.1 The housing market is the final market where a real economic impact could materialise as a result of a transport intervention. While the housing market is inextricably linked to the discussion in the previous, we make a few concluding comments in relation to it here.

12.1.1.2 The value of housing is captured within GDP in two ways: through rental payments and imputed rent. Imputed rent reflects the value of the output of owner-occupied housing through approximating its market value. This is done by capturing the size and nature of the owner-occupied housing stock, and estimating its private rental value. One benefit of including this within the GDP calculation is that it avoids arbitrary changes in the level of GDP due to changes in the share of the rental market, which do not represent a real change in economic output. It also removes discrepancies in GDP across countries due to differing structures to the housing market.

12.1.1.3 One can therefore imagine a road infrastructure investment which better connects certain housing to local leisure activities. In this instance, individuals who live in this housing stock will experience a positive benefit through the time saved, which will manifest in the short run as an improvement in welfare. However, if individuals recognise this and take it into account when buying or renting property, then this welfare could be captured through an increase in the price which they are willing to pay.

12.1.1.4 However, there are two important caveats to the assumption that wellbeing changes would manifest in higher house prices and accordingly GDP. Firstly, any change will likely purely be a price effect (i.e. changing the price, not quantity of output), and one would therefore only expect to see it show up in nominal rather than real GDP. This will occur because there is no expansion in the supply of housing as a result of the infrastructure investment, simply an increase in demand for the existing stock.

12.1.1.5 Secondly, it is likely that there would be at least some displacement in that an increase in house prices in one region would partly be offset by falls in other regions as demand is diverted. In effect, individuals could perceive that the value of the housing stock has increased relative to other housing, but that for every relative improvement there must have been a relative decrease in value elsewhere. Similarly, individuals may choose to spend more on housing (which will increase GDP) but with fixed income levels have to spend less on other goods, which would have an equal and offsetting effect.

13 Further considerations

13.1.1.1 In this section, we briefly outline other potential sources of a wedge occurring between GDP and welfare, by considering regional characteristics, individual and societal welfare functions, and the interaction between factors of production. Some of these factors have been discussed in previous chapters but, in the interests of completeness, are recapped here.

13.2 Regional characteristics

13.2.1.1 Different regions have different characteristics and individuals who are relocating between regions might experience further welfare effects which are not captured in GDP. In short, in the same way that economic agents attach value to their leisure time which are captured in welfare but not in GDP (as discussed in chapter 9), individuals might attach value to the location in which they live and which might not be fully reflected in GDP (e.g. through the price they pay for their property). This could therefore give rise to a wedge between welfare and GDP impacts because of how transport schemes can lead people to move location. This effect is discussed at length in Chapter 10.2.

13.2.1.2 In addition to this, welfare and GDP effects could simply be distributed differently across regions. There are a number of ways in which this could occur including:

1. Travel

   Welfare effects may be disproportionately large in the region directly affected by the investment as local users benefit from the scheme for both business and leisure travel. By contrast, individuals in more distant regions may need to travel further or to relocate in order to experience the benefits which they enjoy from the scheme. So users in more distant regions may make similar contributions to GDP (e.g. by accessing employment and higher wages) but experience greater disutility simply through the inconvenience of travelling.

2. Inter-regional trade

   If the transport intervention causes more goods and services to be "imported" to one region (say region A) from another (say region B), then the welfare impact in region A will be greater than the GDP impact in region A (and vice versa in region B). This is because while money is transferred from region A to region B (which detracts from GVA in region A but adds to it in region B), the goods themselves flow to and are consumed in region A (which is good for welfare in region A).

   A classic example of this – albeit in relation to services and in an international context – is tourism. Inbound tourism (i.e. people travelling to the UK from elsewhere) adds to GDP in the UK but outbound tourism (i.e. UK travelling abroad) detracts from GDP (because money flows out of the country) but makes people happy and is therefore good for welfare.

   The level of export-import content in a region could therefore be important in determining the overall distribution of GDP and welfare effects from a transport intervention.

13.2.1.3 Overall, each of the above effects is heavily determined by the specific characteristics of the regions affected by a scheme. For example: (i) the quality of life in each region (and the question of why people live where they do) will affect the travel effects referred to above; and (ii) the import-export content of different regions will drive the trade effect. Therefore, for a scheme which will affect multiple regions, it is necessary to understand these local characteristics, and model the GDP and welfare impacts in a manner which takes account of them.

13.3 Individual and societal welfare functions

13.3.1.1 The impact of individual and societal welfare functions was discussed in chapter 8.4, in the context of the market for goods and services. Individuals' utility may be characterised by a "love of variety" (Dixit and Stiglitz, 1975),[33] i.e. an individual's utility increases in line with the range of products which he or she is able to access. An improvement in accessibility could improve the welfare of consumers without any change in economic output, simply by broadening the range of products which individuals are able to purchase.

13.3.1.2 If society were to place a greater weight on the additional wealth accruing to certain individuals or groups, then it could be the case that an additional unit of wealth could have a different impact on welfare (at a societal level) depending on where it is experienced. Wedges could therefore arise from policy interventions aimed at rebalancing the economy. For example, if the GDP of a relatively deprived area were to increase by X, then the welfare effect of this could be greater than X and greater than if

[33] Dixit, Avinash K., Stiglitz, Joseph E. (1975), "Monopolistic competition and Optimum Product Diversity", Warwick Economic Research paper No. 64

the same GDP impact were to be experienced in a more affluent area. This concept of a social welfare function is discussed in greater detail in the Green Book[34] (Annex 3: Sub-national and Distributional Analysis, p.78).

13.4 Interaction between factors of production

13.4.1.1 Given that we have identified potential wedges which could arise in the markets for various inputs (land, labour and capital), it could be important to understand the marginal rate of technical substitution between these inputs. This is because if a transport intervention affects the relative demand for labour, land and capital then this could have an impact on whether and if so the extent to which wedges occur. Broadly speaking there are two factors which can impact the relative demand for inputs: (i) the relative prices of labour, land and capital and (ii) the marginal rate of technical substitution between them. Appraisers should ensure that they consider these factors in order to understand the size of the wedges we have identified could arise in the market for inputs.

[34] HM Treasury (2016); "The Green Book", available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

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