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RELATING TRANSPORT APPRAISAL TO GDP IMPACTS

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Peak Economics and ECPC

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Final Report to Department for Transport

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Executive Summary

Government is committed to sustainable economic growth to fund high quality public services. This gives a direct policy interest in the ex ante quantification of Gross Domestic Product (GDP) impacts of transport projects. For large projects bespoke wider economy models are often developed, but for the smaller projects this is not usually feasible. This study therefore considers whether the transport cost benefit analysis can be used to develop an ex ante indicator of the GDP impact of a transport project.

GDP is a measure of the size of an economy. It measures the volume of final goods produced in the economy at a certain price level. Transport projects can change the GDP by increasing the productivity of the economy, but the size of this GDP change is dependent on a number of factors. Firstly, the work/leisure decision. Secondly, what we loosely term general equilibrium effects: the availability of new resources or a transfer of resources within the supply chain, and the value of resources being utilised in different sectors of the economy. Land value uplift from a transport project is not itself part of GDP, but induced investment will increase gross capital formation, and changes in land rents (both market rents and imputed rents) affect GDP. Additionally, national GDP impact will be affected by the interaction between imports and exports. There will always be some leakage of investment costs, so that there is not a 1:1 increase in gross capital formation (part of GDP) following investment. Transport projects favouring export intensive sectors will typically give higher national GDP impacts than those favouring import intensive sectors. This complex set of relationships within the supply chain, the international economy and the work/leisure decision mean that a series of assumptions are necessary to give an estimate of GDP impacts without recoursing to bespoke modelling.

GDP and the welfare metric from a cost benefit analysis, whilst interrelated, are two distinct measures of the economic benefit of a transport project. Most benefit categories in the cost benefit analysis have some impact in traded markets: business user benefits, monetary costs of transport services, wider economic impacts, health related impacts affecting mortality and morbidity and impacts that damage goods and property. Non-traded impacts of transport projects, which are important in welfare terms such as non-work time savings, can influence traded impacts in terms of the work/leisure decision, the spatial location of economic activity and land rents.

Subject to the economic conditions of negligible general equilibrium effects and negligible impact on imports and exports the GDP impact of a transport project can be estimated by summing the business and freight user benefits, the non-work changes in monetary costs for existing trips, the GDP impacts of changes in employment, the productivity and production/consumption aspects of safety, noise and air pollution costs/benefits and the changes in household residential rents (market and imputed). When presenting the GDP impacts of a transport project side by side with the welfare impacts it is important to ensure that both are based on the same assumptions. Care in the definition of the counterfactuals is therefore necessary. This can relate to the question the appraisal is being asked to consider, particularly in relation to the treatment of induced investment (including dependent development) and the how government finances the transport project. Further work is needed to implement this methodology. This includes a suggested validation of the labour supply model in TAG, the identification of the GDP components of the safety, noise and air pollution benefits and the development of a model that links changes in non-work user benefits to residential land rents. Importantly, it is also necessary to undertake research to examine the validity of the assumptions of negligible general equilibrium effects and negligible impact on imports and exports, before the methodology could be incorporated into TAG.

1 INTRODUCTION

1.1 Background

The government is committed to sustained economic growth to fund high quality public services, raise living standards and keep down government debt. Transport infrastructure investments form an important element of this (Her Majesty's Treasury, 2022)[1]. There is therefore a policy interest in how transport projects can contribute to the economy. This is notably in terms of increases in Gross Domestic Product (GDP).

Increases in GDP can arise through increases in productivity or the total resources used in the economy (e.g. an increase in labour supply). There is a well attested link between transport and economic growth (Melo et al., 2013, Deng, 2013, Holmgren and Merkel, 2017, Elburz et al., 2017). This evidence suggests a positive return on average to transport investment. It also however indicates decreasing returns to investment, in that modern day investments give lower returns compared to transport investments post World War 2 (Holmgren and Merkel, 2017). Additionally, transport has a displacement effect, as regions proximate to the transport project effectively get a productivity benefit, whilst other regions do not. This gives them an added competitive advantage. Therefore, at sub-national levels negative as well as positive economic impacts can be found (Elburz et al., 2017, Chandra and Thompson, 2000, Baum-Snow et al., 2020). Typically, this empirical work relates the transport investment programmes over several years if not decades and the aggregate performance of national or regional economies. A more micro-level approach by Holl (2016) and Gibbons et al. (2019) also found economic impacts specifically in the vicinity of the road projects. These studies looked at packages of motorway projects, in Spain and Great Britain respectively. Such studies find it difficult to identify whether these growth effects are due to new starts (pure growth) or displacement/re-location of economic activity to the project vicinity. Thus, whilst state-of-the-art, they are best viewed at demonstrating the range and scale of GDP type gains at a local level. They do not readily address the question as to what the net project economic impacts are, which is the question the Department is primarily concerned about.

Quantifying these project level economic impacts, at the ex ante stage, has taken on increasing interest to the DfT. There has been the development of several different wider economy models within GB. These Land Use Transport Interaction (LUTI) models that have supported the business cases of Transport for North, Transport for London, and National Highways. Furthermore, there has been the development of Spatial Computable General Equilibrium (S-CGE) models by DfT (for the Airport Commission), National Highways (for the Lower Thames Crossing) and HS2 (for HS2 Phase 2). Such models are costly to develop and use, in terms of elapsed time and resources. They are typically, therefore, only suited for large scale transport projects where significant land use change is expected.

For smaller projects, where such models are difficult to justify, the policy question still remains as to what the contribution to sustained economic growth will be. Therefore, is it possible to utilise the inputs and outputs to the transport cost benefit analysis to give an indication of the likely GDP impact of the transport project? This is the key question this research aims to address. Such an approach is being termed the 'CBA approach' in this think piece.

[1] There are 114 transport infrastructure projects named in Annex B of the 2022 Growth Plan .

1.2 Objectives

Specifically, the objectives of this think piece are:

1. Provide advice to the Department on how a TAG-style welfare appraisal can be (i) mapped to GDP or 'growth' impacts; and (ii) expanded and/or modified to better represent growth impacts.
2. Provide a thorough peer review of TASM's initial attempt at mapping GDP and welfare impacts alongside recommendations for refinement and further research.
3. Help assess and evidence the shortcomings in both (i) the purported 'CBA approach' to GDP impacts; and (ii) the ability of the current evidence base and literature to shed light on the true GDP impacts of schemes.

The Department also had a number of specific questions and concerns, which this think piece is required to address.

1.3 Report Structure

Following this introductory chapter, Chapter 2 sets out the basic building blocks of GDP National Accounts, and how a transport led productivity improvement would appear in them. Chapter 3 then looks at how changes in welfare and changes in national income may inter-relate to one another. Based on this, in Chapter 4 we set out some constraints that create an identity between changes in welfare and changes in national income, before relaxing each one. We consider at each stage the data necessary for this relaxation. Finally, in Chapter 5 we discuss a possible means to create a GDP measure from the transport cost benefit analysis, the data that would be required and the needs for further research.

2 GDP ACCOUNTS AND TRANSPORT IMPROVEMENTS

2.1 What is GDP?

In short, GDP is a monetary measure of the UK's (or any economy's) final goods and services produced in the UK in a given period (e.g. a year or a quarter). The measure was progressed by Simon Kuznets in the 1930s as a way for policymakers to gauge the recovery from the Great Depression and is widely used today, typically compiled using the United Nations 2008 System of National Accounts (SNA) methodology[2].

In more detail …

- The monetary measure used to calculate GDP at the time of measurement is the current price of goods and services, with prices estimated where not available.
- The current price applicable is the purchaser price which includes the price received by the producer of the good or service, plus any wholesale and retail margins and plus any indirect product taxes (e.g. fuel duties, VAT).
- Goods and services can be produced for sale in the market, such as cars and movies, or can be non-market production, such as defence or education services provided by the government or by non-profit institutions.
- One particular non-market product included in GDP is an imputed rent for persons who own and live in their home (more on this in a later section).
- The goods and services are generically referred to as "products".
- Final products are those bought by the final user, which includes households, governments, non-profit organisations and foreign buyers. Final use needs to be separated from their intermediate use, which is when goods and services are used in the production of other goods and services (e.g. petrol can be sold as final good to a household or as an intermediate good to a business)
- Production comprises all output generated within the borders of the UK, including production by foreign entities. Production abroad by UK entities is not part of UK GDP[3].
- Two related measures are (i) Net domestic product (NDP), being GDP less depreciation, and (ii) Gross National Income (GNI), being GDP less earnings of foreign entities in the UK plus earnings of UK entities abroad.

It may be helpful at this stage to give examples of what GDP is not.

- The measure is current production and not necessarily sales, (a) because sales can sometimes occur outside of the production period (e.g. stock held and sold next year) and (b) because some production occurs outside of markets (e.g. NHS hospital care).

[2] https://unstats.un.org/unsd/nationalaccount/sna2008.asp

[3] GNP is GDP less output within the UK undertaken by foreign entities (ie, output by resident output only)

- It does not measure the wellbeing derived from the production. Changes in prices, in theory, capture the monetary equivalent of the change in wellbeing to be derived from a change in consumption, measured either as a change in consumer surplus or by other monetary measures of welfare, but these wellbeing effects of consumption are typically constrained by the consumer's income so do not measure how one person's underlying benefit compares with that of another person (more on this in a later section).
- GDP is not a measure of the value of assets, such as houses or bridges or rivers, in the UK. The use of these man-made and natural capitals will be partially measured within GDP, to the extent that payments are made to use these resources e.g. the price of a product may include an allowance for depreciation of plant and equipment or for a fee paid to use water. However, even in these situations, the resource use component of the product price may not reflect the full cost of depleting the asset.
- Nor is GDP a measure of the purchase and sale of assets such as houses, buildings and vehicles as these transactions largely exchange an already produced asset rather than create a new product (note, the production of an asset enters GDP when the good is produced).

2.2 How do we measure GDP?

Logically, GDP, being a production measure, requires tallying production, which ONS does. However, the circular nature of the economy means that GDP can also be measured by summing expenditure or summing income. In theory, all three measurement methods will give the same GDP estimate. In practice, there will be a measurement discrepancy as not all information is perfect. In the UK, the ONS apply a balancing process within the supply and use tables shown below to provide a consistent figure across the three methods.

Before exploring each measurement method, it should be recalled when later examining changes in GDP arrived at by using a particular method that this amount must be matched by an equivalent change in the other two measures e.g. higher production must be met with higher incomes and higher expenditure. An inability to balance the three measures becomes a useful check that the logic being applied is correct.

An example of the three measurement methods is shown for UK GDP in 2020 in Table 2-1, when GDP was £2,109,594 million. It can be derived from the Use and Supply tables, two of the many tables collated by ONS on the way to measuring GDP. The Use and Supply tables provide summaries by products (the rows) while the Use table also provides intermediate use of products by industries, including Government-owned entities, and final use of products, whether it be for consumption, investment or export (the columns). The three GDP measures follow in Table 2-2, with colour coding used to match the GDP components to the source tables.

In this example, the industry sectors and product groupings have been condensed to three, namely the Transport and storage sector (hereafter referred to as the 'Transport' sector), a combination of mainly goods producing industries and a combination of mainly service producing industries.

TABLE 2-1 USE AND SUPPLY TABLES USED TO DERIVE UK 2020 GDP

Use table	OUTPUT OF INDUSTRIES at basic prices (£m)				FINAL USES at purchasers' prices (£m)						
					Final consumption expenditure						
	Goods	Transport	Services	**Sub-total: Inter-mediate demand**	by households	by govern-ment	Gross fixed capital form-ation	Exports	**Sub-total: Final demand**	**Total: Demand for products**	Imports
Product of agric, manu, construction, trade	603,700	25,698	200,134	**829,532**	619,934	17,647	252,062	320,141	**1,209,784**	**2,039,316**	456,469
Products of transport	54,388	31,924	31,760	**118,072**	18,065	4,080	0	18,841	**40,986**	**159,058**	13,723
Products of service entities	171,457	27,728	540,580	**739,765**	624,884	453,387	111,978	277,804	**1,468,053**	**2,207,818**	139,037
Sub-total: Intermediate consumption	**829,545**	**85,350**	**772,474**	**1,687,369**	**1,262,883**	**475,114**	**364,040**	**616,786**	**2,718,823**	**4,406,192**	**609,229**
Compensation of employees	365,326	55,755	673,731	**1,094,812**							
Other net taxes on production	-33,679	-10,644	-29,484	**-73,807**							
Gross operating surplus	275,732	16,853	589,985	**882,570**							
Sub-total: GVA at basic prices	**607,379**	**61,964**	**1,234,232**	**1,903,575**							
Total: Output at basic prices	**1,436,924**	**147,314**	**2,006,706**	**3,590,944**							
From supply table at basic prices (£m)											
Taxes less subsidies on products	154,706	121	51,192	**206,019**							
Sector contribution to GDP	**762,085**	**62,085**	**1,285,424**	**2,109,594**							

TABLE 2-2 THREE WAYS TO MEASURE UK 2020 GDP

GDP - production approach	(£m)	GDP - income approach	(£m)	GDP - expenditure approach	(£m)
Total: Output at basic prices	3,590,944	Compensation of employees	1,094,812	Final consumption expenditure by households	1,262,883
Sub-total: Intermediate consumption	-1,687,369	Other net taxes on production	-73,807	Final consumption expenditure by government	475,114
		Gross operating surplus	882,570	Gross capital formation	364,040
Sub-total: Gross value added (GVA) at basic prices	**1,903,575**	**Sub-total: Gross value added (GVA) at basic prices**	**1,903,575**	Exports	616,786
Taxes less subsidies on products	206,019	Taxes less subsidies on products	206,019	Imports	-609,229
GDP	**2,109,594**	**GDP**	**2,109,594**	**GDP**	**2,109,594**

Some matters to note, including using other data within supporting tables …

- The GDP of the Transport sector was £62,085m. This can be built up from the production method by deducting the goods and services input for intermediate use (£85,350m) from the total output above (£147,314m) and adding the product taxes collected net of product subsides (£121m).
    - The Transport sector in the UK (UKSIC Code H[4]), produced £147,314 million of products in 2020, broken down as Warehousing And Support Activities For Transportation (£50b), Land transport services and transport services via pipelines, excluding rail transport (£44b), Postal And Courier Activities (£24b), Water Transport (£11b), Rail Transport (£10b) and Air Transport (£9b). These figures, referred to as basic prices, exclude VAT and other taxes and subsidies that are applied to products[5].
    - The largest share of intermediate products used by the Transport sector are provided by the Transport sector itself, plus from outside the sector comes products from a range of other industry sectors such as fuel (from UKSIC C), new vehicles (C), vehicle repairs (G), banking services (K), property rental (L) and government services (O).
    - The relatively small "Taxes less subsidies on products collected on Transport products" are largely the VAT applied on Transport products[6] less the subsidies received in the rail sector (see more on taxes below).
- The income method of measuring GDP follows a similar route but recognises that the non-intermediate costs incurred in industry production are the income to the providers of these inputs (e.g. workers, investors, businesses, government).
    - The wages component of income is the gross income paid to employees (ie, before deductions of income tax and employer social contributions). Note, reimbursements for employee travel are not part of wages but rather are an intermediate use.
    - 'Other net taxes on production' are other non-income taxes and subsidies of central and local governments ie, they exclude the product taxes/subsidies above and they exclude corporate income tax. Examples are regulatory fees and levies, the National Non-Domestic Rate (based on property value) and vehicle excise duties paid by businesses. Subsidies include for R&D, affordable housing and rail administration, plus some Covid-19 support. 'Other net taxes on production' was a net subsidy in 2020 (due to Covid-19 measures).

[4] Industries are classified by the UK's Standard Industry Classification (UKSIC) system. Other similar classification systems include ISIC (United Nations), NAICS (North America), NACE (Europe) and ANZSIC (Australia/NZ).

[5] But include personal, corporate and production taxes either explicitly or implicitly that pertain to transport sector production.

[6] VAT is zero-rated on public transport

  - The gross[7] operating surplus is the residual cost of production after excluding wages and intermediate good costs and is, as above, a pre-tax measure that will be used to cover costs such as rents, interest, profits and corporate income tax and, for self-employed (who receive mixed income) an undifferentiated wage component. It does not include capital gains/losses.
  - The combined cost of wages, government production taxes and gross operating surpluses (£61,964m) is the Gross Value Added (GVA) of the Transport sector.
  - To GVA is added the net product taxes collected, as above, to give the Transport GDP total.
- The expenditure method comes from a different angle and considers who used the final products and then deducts the share sourced as imports. It is not possible from the information available to derive the Transport GDP using the expenditure method but the UK Total GDP expenditure components are shown in the tables below.
  - Final household consumption includes products such as food, clothes, movies, accountancy services and the rent – actual or imputed – on housing but excludes paying interest on a loan or buying a house (note, if the house were built in the same period then this would show as investment expenditure but otherwise the purchase and sale of a house is a transfer of an asset).
  - Final Government consumption is the Government equivalent to household consumption, with the major difference being that a large proportion of consumption is a non-market activity (e.g. a heart operation in a public hospital).
  - Gross Capital Formation (GCF), also referred to as gross investment, largely consists of goods produced in the same period and purchased as investments (Gross Fixed Capital Formation) plus relatively small items such as a change in inventories and a change in price of valuables sold. GCF includes Government investment. Totals in 2020 included Transport equipment (£17b), dwellings (£78b) and Other buildings and structures (including roads) (£123b).
  - Exports are of goods and services, including to the EU and beyond. Transport exports are largely the sea, air and warehousing services provided when exporting goods.
  - Imports are also of goods and services and again Transport imports are services, although air and land transport play a larger role in importing (with less sea and warehousing services).

2.3 How do we measure changes in the volume of GDP?

The above example shows the current (ie, then) value of UK production in 2020. It is of interest to know how much GDP has changed over time, and whether the change is due to a higher volume of goods and services or simply to a higher average price.

[7] Again the 'gross' refers to before deduction of depreciation on fixed assets

It is not possible to directly measure the volume of production in a period [8], simply because the units of volume differ between goods, between services and between goods and services (e.g. it is not possible to sensibly add 1kg of apples to 4 pages of a book to 5 litres of petrol). However, the change in volume can be inferred by measuring how the prices of products change and using, for example, a price increase between two periods to deflate the production value in the second period (or to inflate the second measure in the case of a price decrease although generically the denominator is referred to as a "deflator").

ONS undertakes a range of volume and price calculations, estimating price deflators (often reported as price indices) for products or groups of products and then inferring an economy-wide measure of the average change of products. For example, current UK GDP in 2019 was £2,238,348 million (in 2019 prices) and £2,109,594 million in 2020 (as reported above, in 2020 prices). Between 2019 and 2020 the average price of UK products increased 5.9%, so a product price deflator with an index base of 1.000 in 2019 would be 1.059 in 2020. The measure of 2020 GDP in 2019 prices is thus given by

Real GDP (in 2019 prices) = £2,109,594 million / 1.059 = £1,991,439 million

In constant dollar (or real or volume) terms the change in GDP between 2019 and 2020 is given by

£1,991,439 million / £2,238,348 million - 1 = -11.0% (recall 2020 was a year of Covid-19 disruptions)

However, this example does simplify the issues of estimating volume changes. Some of the issues include:

- The GDP deflator (a price index) pertains to the current value of goods and services produced in the UK, including market and non-market products. This differs to other measures of price inflation such as the CPI, which only increased 0.9% between the twelve months of 2019 and 2020. The CPI pertains to the prices of consumer goods (including imported goods) whereas the GDP deflator pertains to goods and services produced in the UK (including goods exported or used for intermediate use and excluding imports).
- For market goods, prices are generally readily available via surveys or administrative data and are relatively simple to apply as described in the deflator example above.
- For market services, prices are evident but it can be challenging to recognise the per-unit price, especially when the quality of a service changes (e.g. higher standard management advice), with various measures of service price changes employed[9].
- For non-market goods and services there is no price to observe (e.g. for police services) and some measure of an equivalent price or an equivalent volume must be estimated. The latter

[8] In practice, efforts are also made to estimate some volume changes directly and then infer a deflator

[9] The quality adjustment issue also applies to some goods and has been a major challenge in recent years. The underestimation of ICT quality improvements (and hence under-estimation of the per-unit price reduction) may be leading to GDP growth rates being under-stated by 0.2-0.5 percentage points per annum AHMAD, N., RIBARSKY, J. & REINSDORF, M. 2017. Can potential mismeasurement of the digital economy explain the post-crisis slowdown in GDP and productivity growth? *OECD Statistics Working Papers.* OECD.

method has been traditionally applied by using labour and other inputs to estimate product volume (or at least a change in volume).

Another methodological issue with inferring volume changes from price deflators is that the method cannot perfectly differentiate volume from price changes over a period when both prices and volumes are changing (as is usually the case). An assumption is required as to whether the change in prices observed (or estimated) are weighted by the previous quantity mix (the Laspeyres formula) or by the current quantity mix (the Paasche formula) or by a geometric average of the two price indices derived (the Fisher formula).

The ONS (and others) use a chain-weighted method to reduce the risk of bias in the measurement of real GDP changes. This implicitly involves using a Paasche price index[10] for product groups between any two consecutive years, and then repeats the exercise for all years. Thus, the price deflator becomes a chain of annual price changes[11]. An illustration of the different price indices is provided in a later section.

2.4 Insights into GDP changes

This chapter has so far described how GDP and changes in real GDP are measured, illustrated with actual UK data. The chapter now turns to consider how an activity, and its associated activities, would show in the measures of GDP. For this, we turn to hypothetical situations and build up insights. Note, at this stage, this is largely an accounting issue. We will turn to predicting GDP changes in a later chapter – this requires economic models such as CGE[12].

2.4.1 A productivity improvement with prices fixed

Example 1. Consider a 2-good economy, whereby initially potatoes are locally produced and exported and clothes are produced abroad, imported and consumed locally[13]. Prices are fixed in the international markets and wages are initially derived as a combination of export prices and local productivity. These are the only activities in the economy ie, no other goods produced or consumed, no government sector and no investment.

Assume further that the production and export of potatoes entailed paying only wages of £2.5 for a week and the import and consumption of clothes amounted to spending £2.5 per week. At this stage, there are no marketing (or transport) fees or VAT to consider. Using the income method, GDP for the week is the GVA (£2.5) plus indirect taxes (£0), which equals £2.5; using the expenditure

[10] Which is equivalent to applying a Laspeyres volume index

[11] The GDP series that results from dividing current GDP by the Fisher deflator is known as "volume" series as it is not a constant dollar value.

[12] One bridge between national accounting methods and economic modelling is offered by TEN RAA, T. 2009. *Input-output economics: Theory and applications-featuring Asian economies*, World Scientific..

[13] This and the following examples match those of Mohring (1976) Chapter 9, with marketing replacing transport (to show this result is not specific to transport), potatoes replacing palm kernel and clothing replacing cloth. The reader may choose to think in terms of 'transport' rather and 'marketing', if preferred.

method, GDP is the sum of final uses (£5.0) less imports (£2.5), which also equals £2.5; using the production method, GDP is total output (£2.5) less intermediate output (£0) plus indirect taxes (£0), again £2.5.

TABLE 2-3 HYPOTHETICAL GDP EXAMPLE 1

(£)	OUTPUT OF INDUSTRIES (1)			FINAL USES (2)			
	Potatoes (3)	Marketing (4)	Clothes (5)	Final consumption (6)	Exports (7)	Imports (8)	GDP (9)
Products of firms: Potatoes (10)					2.500		
Products of firms: Marketing (11)							
Products of firms: Clothes (12)				2.500		-2.500	
Sub-total: Intermediate consumption	**0.000**	**0**	**0.000**	**2.500**	**2.500**	**-2.500**	
Compensation of employees (13)	2.500						
Sub-total: GVA (15)	**2.500**	**0**	**0.000**				
Sub-total: Output (16)	**2.500**	**0**	**0.000**				
VAT (17)							
GDP (18)	**2.500**	**0**	**0.000**				**2.500**

Notes 1 to 18 – See Appendix

Example1a. Take first a 25% productivity improvement in the production of potatoes. The change in GDP is simply £2.5 times 0.25, which equals £0.625. Note, it need not matter if potato production consisted of several steps and the productivity only improved within one step - if total production increased given the same total amount of inputs then the GDP increase is £0.625.

Key insight. The actual GDP change could be less than the productivity gain if working hours are reduced, explained as follows. There is an assumption implicit in the above calculation, namely that workers do not instead choose to work less given the now larger quantum of clothing potentially available for consumption. Should they prefer more leisure and less work then exports, imports, income and spending would all decline accordingly. The actual GDP response would be within a range of £0 to £0.625. This fundamental leisure-consumption 'leakage' exists for any productivity gain under more realistic scenarios than this although empirical evidence, such as income elasticities and relatively stable labour input, suggests this leakage will typically be small.

Example 2. Consider next that marketing (or transport if you prefer) was also required to sell potatoes to export markets and to sell clothes to domestic consumers (tabled below). Marketing becomes an intermediate service. Assume the cost of marketing is £1.25, split equally between export markets and local markets, both undertaken within the UK (and hence part of GDP). An equivalent GDP scenario to Example 1 would be a share of the export earnings being paid to marketing (and hence less to potato growers) and local consumers paying higher clothing prices to cover the local consumption marketing cost. GDP can be measured using the three methods, as above, but intuitively is recognisable as the £2.5 export income of Example 1 plus the £0.625 cost (and income) arising from marketing clothing to the local consumers.

TABLE 2-4 HYPOTHETICAL GDP EXAMPLE 2

(£)	OUTPUT OF INDUSTRIES (1)			FINAL USES (2)			
	Potatoes (3)	Marketing (4)	Clothes (5)	Final consumption (6)	Exports (7)	Imports (8)	GDP (9)
Products of firms: Potatoes (10)					2.500		
Products of firms: Marketing (11)	0.625						
Products of firms: Clothes (12)				3.125		-2.500	
Sub-total: Intermediate consumption	**0.625**	**0.000**	**0.000**	**3.125**	**2.500**	**-2.500**	
Compensation of employees (13)	1.875	1.250					
Sub-total: GVA (15)	**1.875**	**1.250**	**0.000**				
Sub-total: Output (16)	**2.500**	**1.250**	**0.000**				
VAT (17)	0.000	0.000	0.000				
GDP (18)	**1.875**	**1.250**	**0.000**				**3.125**

Example 2a. Consider again a 25% productivity improvement in the production of potatoes. As in Example 1, the GDP change could be simply calculated as £3.125 times 0.25, which equals £0.781, or intuitively the 25% gain in exports and the 25% extra clothing per marketing pound spent. However, the dynamics are quite different and now there is an implicit assumption that more marketing inputs will be made available:

- Potato production increases by 25%
- The increased marketing of potatoes and clothing requires 25% more inputs into marketing, given the productivity gain does not extend to this sector. This is important: the full potential of extra potato production, due to the potato productivity gain, will only be realised if more resources can be found for the complementary marketing activity – this will rarely be the case.
- The wage rate will increase, given higher potato grower productivity (and assuming an equal wage across all industries)
- The price of clothing, which includes the higher marketing cost, will also increase, which amounts to an increase in average consumer prices of 3.5% (so too is the change in UK product prices)
- The increase in current GDP would be £0.919 and the increase in real GDP would be £0.781, as initially calculated.

TABLE 2-5 HYPOTHETICAL GDP EXAMPLE 2A

(£)	OUTPUT OF INDUSTRIES (1)			FINAL USES (2)			
	Potatoes (3)	Marketing (4)	Clothes (5)	Final consumption (6)	Exports (7)	Imports (8)	GDP (9)
Products of firms: Potatoes (10)					3.125		
Products of firms: Marketing (11)	0.919						
Products of firms: Clothes (12)				4.044		-3.125	
Sub-total: Intermediate consumption	**0.919**	**0.000**	**0.000**	**4.044**	**3.125**	**-3.125**	
Compensation of employees (13)	2.206	1.838					
Sub-total: GVA (15)	**2.206**	**1.838**	**0.000**				
Sub-total: Output (16)	**3.125**	**1.838**	**0.000**				
VAT (17)	0.000	0.000	0.000				
GDP (18)	**2.206**	**1.838**	**0.000**				**4.044**
Change in current GDP from Example 2							**0.919**
GDP Deflator							1.035
Real GDP							3.906
Change in real GDP from Example 2							**0.781**

Key insight. The full GDP of a productivity gain that increases output of one product will only be realised if more inputs are made available elsewhere in the supply chain. Restraining this example to a fixed level of inputs and assuming free exchange of inputs between potato production and marketing implies the real GDP increase would be limited to £0.426 (Example 2b, not tabled). That is, some potential extra potato has been given up so that the inputs can be transferred to provide the extra marketing production required, retaining in this example the initial ratio of potato to marketing inputs. This is an example of the restraints that other parts of the supply chain – in this case the forward linkages – can impose on the GDP changes from a product of sector productivity improvement. This is likely to often occur.

Example 2c. Extending these examples, consider next the 25% export productivity improvement originating from a marketing sector improvement (which need not be the same percentage change). Given the numbers used here a 50% marketing productivity improvement is equivalent to a 25% potato productivity improvement. The same GDP improvement of £0.781[14] is implied by the simple scalar calculation although the dynamics again differ and the implicit assumption is now (assuming a fixed level of inputs) that marketers can seamlessly become potato growers:

- Marketing inputs decrease by 50%
- Some of these inputs are transferred to potato production to enable potato production and hence exports to increase (ie, this example assumes no extra inputs are provided to the economy and instead inputs are transferred between sectors to realise the full potential product growth)
- The (universal) wage rate increases due to the improved total output per inputs in the economy

[14] This example gives the same answers as Mohring (2009), albeit the wage assumptions differ, which he showed resulted in a change in consumer surplus of £0.703

- The net change in the marketing expense component of the clothing price is negative (the higher wages being less than the reduced marketing inputs) and hence the average consumer (and product) price declines by 8.6%.
- Current GDP increases by £0.446 and real GDP increases by £0.781.

TABLE 2-6 HYPOTHETICAL GDP EXAMPLE 2C

(£)	OUTPUT OF INDUSTRIES (1)			FINAL USES (2)			
	Potatoes (3)	Marketing (4)	Clothes (5)	Final consumption (6)	Exports (7)	Imports (8)	GDP (9)
Products of firms: Potatoes (10)					3.125		
Products of firms: Marketing (11)	0.446						
Products of firms: Clothes (12)				3.571		-3.125	
Sub-total: Intermediate consumption	**0.446**	**0.000**	**0.000**	**3.571**	**3.125**	**-3.125**	
Compensation of employees (13)	2.679	0.893					
Sub-total: GVA (15)	**2.679**	**0.893**	**0.000**				
Sub-total: Output (16)	**3.125**	**0.893**	**0.000**				
VAT (17)	0.000	0.000	0.000				
GDP (18)	**2.679**	**0.893**	**0.000**				**3.571**
Change in current GDP from Example 2							**0.446**
GDP Deflator							0.914
Real GDP							3.906
Change in real GDP from Example 2							**0.781**

Key insight. A cost decline in an intermediate market can pass through to an economy-wide gain in the form of lower prices for other products, although this will require the transfer of inputs (or otherwise an increase of inputs). A key difference between Examples 2a/b and 2c is that the productivity improvement arising from fewer inputs (Example 2c) potentially created the extra capacity to increase production elsewhere in the supply chain (assuming transferability) while a productivity increase arising solely from more outputs (2a/b) did not. The implication for the transport sector – as with marketing – is that a transport productivity improvement creates (a) a lower cost structure in the economy and (b) the extra resources (e.g. labour, fuel) to potentially enable lower costs to be transformed into higher production. How these relative cost changes and freed-up resources affect the economy is a matter for more sophisticated modelling.

Example 3. A further variation of this example is to assume that half, say, of the marketing inputs are imports e.g. fee for international research that was applicable to both the potato and clothing markets. The initial GDP is now £2.5 (not £3.125 as per Example 2, as half the marketing inputs are imports).

Example 3a. What then is the GDP impact of a 50% decline in marketing costs (due to a productivity gain)? The change in current GDP is £0.625 and the change in real GDP is £0.918 (higher than the previous £0.781).

Key insight. Shifting production away or towards import-intensive products can increase (away) or decrease (towards) the GDP effect of a productivity gain in an intermediate market. The dynamics are similar to Example 2c with the added advantage of shifting production away from the import-intensive marketing sector to the potato growing sector where no imports are used (according to

our assumptions). The opposite effect – a lower GDP impact – would be expected if the input shift was towards import-intensive production. From a policy perspective, a larger GDP effect can be expected when reducing transport costs to less import intensive production chains.

TABLE 2-7 HYPOTHETICAL GDP EXAMPLE 3A

(£)	OUTPUT OF INDUSTRIES (1)			FINAL USES (2)			
	Potatoes (3)	Marketing (4)	Clothes (5)	Final con-sumption (6)	Exports (7)	Imports (8)	GDP (9)
Products of firms: Potatoes (10)					3.125		
Products of firms: Marketing (11)	0.446					-0.223	
Products of firms: Clothes (12)				3.571		-3.348	
Sub-total: Intermediate consumption	**0.446**	**0.000**	**0.000**	**3.571**	**3.125**	**-3.571**	
Compensation of employees (13)	2.679	0.446					
Sub-total: GVA (15)	**2.679**	**0.446**	**0.000**				
Sub-total: Output (16)	**3.125**	**0.446**	**0.000**				
VAT (17)	0.000	0.000	0.000				
GDP (18)	**2.679**	**0.446**	**0.000**				**3.125**
Change in current GDP from Example 3							**0.625**
GDP Deflator							0.914
Real GDP							3.418
Change in real GDP from Example 3							**0.918**

2.4.2 The effect on real GDP of different price indices

A deflator was applied in the examples above and a measurement challenge was mentioned in 2.3. This section illustrates the effect of the various weighting methods for the deflator, using a hypothetical example of an economy with three sectors using only primary inputs (hence output=GDP). The numbers chosen are not fully representative of the permutations possible but were chosen to give indicative effects for relatively large transport projects.

Consider a 3-product economy, where the price of a product 1 (say transport) declines substantially and is met with increased demand for that good, so that total spending is unchanged. The price and quantity changes can happen either within 1 year or gradually over 9 years. Assume further that spending on this product is 15% of total spending and spending on the other two products goes unchanged. For example, a 50% price decline for product 1 would be met with a 100% quantity increase for the same product and no changes in other products. If the initial price was £1 and the initial quantity was 1 (say 1 trip) then the 50% price decline drops the price per trip to £0.5 and the number of trips increase by 1, with the net effect that the spending on this product remains £1. In this case, it is known that the increase in trips is 1 but what is the value of these extra trips – is measurement at previous prices or subsequent prices?

The transport appraisal approach effectively bases the value of the extra trips on the average of the two prices ie, £0.75/trip, so the extra consumer surplus becomes the £0.5 saved on the initial trip and an implied £0.25 on the new trip, giving a total consumer surplus of £0.75.

The GDP approach is to calculate the current GDP, in this case an unchanged £1, and then deflate this value with a price index to derive a real GDP effect. In a multi-product economy – the norm – the form of the price index will lead to a different value being placed on the extra trip.

An example of the percentage difference between the real GDP effect thus derived and the extra consumer surplus of £0.75 is shown in Table 2-8 for a range of price changes (recall only 1 of 3 products decline in price and quantity adjusts to leave spending unchanged). If the price decline were to occur gradually over 9 years then the chain-linked Paasche price index method[15] delivers a real GDP effect that is within approximately 1% of the consumer surplus effect. This proximity of the GDP and transport appraisal does weaken for large 1-year price changes (say 50%) but the difference is still within 5% for modest price changes (say within 10%). The chain-linked Paasche price index method also delivers a GDP effect that is greater than the consumer surplus effect.

TABLE 2-8. GDP EFFECT RELATIVE TO CONSUMER SURPLUS EFFECT WHEN GDP DEFLATOR MEASURED BY PAASCHE INDEX, FOR COMBINATIONS OF PRICES CHANGES FOR 1 OF 3 PRODUCTS, WITH PRODUCT BEING 15% OF ECONOMY

Product 1 price decline	-1%	-5%	-10%	-50%
If price decline over 9 years	0.1%	0.6%	1.1%	0.8%
If price decline within 1 year	0.5%	2.6%	5.3%	33.3%

This same exercise repeated using a chain-linked Fisher price index delivers a GDP effect within 5% of the consumer surplus in all 8 permutations tabled[16].

In sum, large short-term changes in prices will cause a discrepancy between welfare measures and GDP measures but for other situations there is only a small difference between welfare benefits and GDP caused by the different pricing rules applied to the welfare and GDP measures when chain-linking is applied.

2.4.3 Investment and investment funding

Of interest is how an investment, either by government or the private sector, appears in the national accounts. There are three ways, each discussed below. First, there is the initial investment. Second, there is the funding of that investment. Third, the investment creates a fixed asset (e.g. a building, some machinery, a road) that will provide products in future periods. A related matter of interest is whether the government investment stimulates private sector investment as well; this is picked up in 2.4.4.

2.4.3.1 A new office block or road

An investment in, say, an office block is an increase in final demand and would largely[17] show as GCF e.g. a £100m office would increase GCF by £100m. However, the GDP effect will be the project costs less the imports required for the build. For example, an investment of £100m that entailed imports

[15] The volume effect derived by deflating current output with a Paasche price index is equivalent to directly calculating a Laspeyres volume index (likewise for a Laspeyres price index and a Paasche volume index).

[16] The Fisher price index result is consistent with the conclusion derived by DYNAN, K. & SHEINER, L. 2018. GDP as a measure of economic well-being. *Hutchins Center Working Paper.* Hutchins Center on Fiscal and Monetary Policy, The Brookings Institution. in Box 1 although they apply volume indices and allow the base year to change.

[17] Some components of the building project cost will show as current government expenditure but this will not significantly change the rest of the logic presented.

of £13m, either directly or indirectly, would show as GDP of £87m. We will return to the assumptions required if forecasting this effect for a new project – at this stage consider these numbers the accounting for an existing project.

An investment project will typically entail a wide mix of primary and intermediate inputs, with the intermediate production in turn requiring other primary and intermediate inputs. This chain of requirements is captured within the national accounts by the "Leontief inverse" table, the core matrix used in the popular multiplier analysis. This table measures the cumulative backward components required for each pound of final demand. The cumulative effect within the national accounts of an £100m office block project would be similar to the table below[18].

TABLE 2-9. CURRENT AVERAGE GDP EFFECT OF A £100M NEW OFFICE BLOCK

GDP - production approach	(£m)	GDP - income approach	(£m)	GDP - expenditure approach	(£m)
Output	210	Compensation of employees	42	Household consumption	0
Intermediate consumption	-127	Other net taxes on production	0	Government consumption	0
		Operating surplus, net	41	GCF	100
GVA	**83**	**GVA**	**83**	Exports	
Taxes less subsidies on products	4	Taxes less subsidies on products	4	Imports	-13
GDP	**87**	**GDP**	**87**	**GDP**	**87**

A road investment is fundamentally no different. It too is recorded as GCF, although this time due to government final demand. The road project will have a similar entwined and cumulative backward trail of inputs that will be recorded in a similar fashion to the above example, albeit the numbers will differ from those for a building (e.g. the ratio of GVA to GDP will differ and the mix of intermediate demands will also differ). For example, civil construction is likely to have fewer imports and hence the direct and indirect GDP associated government for a road invest of £100m will likely be of order £90m once imports are deducted.

2.4.3.2 Funding a government investment

As above, the initial discussion on funding largely pertains to how the funding mechanism will show within the national accounts and the general equilibrium effects related to new funding will be discussed later.

In broad terms, an investment is initially funded from current revenue, accumulated reserves, the sale of an asset or by borrowing[19]. Taxation is most of the government current revenue and, from a GDP perspective, the key split is between taxes on products and taxes on income.

[18] The numbers presented are for an average across all UK expenditure on construction and not necessarily for a new office block. They are sourced from the ONS 2019 "Effects" table.

[19] For private investment there is also the option of issuing equity, which can also be thought of as tapping into the revenue, reserves, asset sales and/or debt of other people and entities. The government can arrange a partly government owned corporate to undertake the investment, funded by new equity, but this is likely to be treated as a private sector investment.

TABLE 2-10. ENTRIES FOR FUNDING OF GOVERNMENT INVESTMENT IN THE CALCULATION OF GDP

Source of government funding for an investment	Entry in GDP calculation
Product taxes e.g. VAT	An explicit item within "Taxes less subsidies on products" in the production and income measures of GDP.
Income taxes	No entry in national accounts. It is paid out of the various forms of before-tax income (ie, GVA) that appears in the national account
Use of reserves or sale of an asset	No GDP entry (except for relatively small transaction cost)
Debt	No GDP entry (except for relatively small transaction cost)

The table describes how the funding method will or will not appear in the GDP calculation. At the margin, government undertaking new funding for an investment could appear directly as increased product taxes or decreased government consumption or decreased other investment, relative to the counterfactual. It could also indirectly show as lower private sector consumption or investment should the private sector decrease other activities to provide the funding (tax or debt) to government[20].

The combined effect of the government investment and funding will, given a fully employed economy, appear as the GCF less imports ie, £90m in the road example above or £87m in the office example. If it were part funded by VAT then this item would also increase in the national accounts but would be offset by a decrease in GVA. In other words, there is no double counting of the investment.

However, even in this constrained fully employed economy, there is a change in the make-up of GDP. The combined government investment and funding requires a transfer of funds from the private sector to the government and a change in the mix of products and services otherwise demanded, including in this case from a mix of general household consumption and investment to a road for government[21]. Going back to the simple examples at the start of this chapter, this falsifies the assumption that "inputs are mixed in the same ratio as applied in 2020", implying the static description presented so far in this chapter is unlikely to be valid and that economic modelling will be required to predict the GDP effect of the initial investment. The same logic applies with the debt funding scenario, albeit the channels of effect are more convoluted. In other words, while the above exercise is an example of what has recently been the GDP effect of an investment in a road, it is unlikely to be the only possible outcome in the future.

[20] The case of new government debt crowding out private sector expenditure is debated as the Ricardian equivalence theory

[21] Or a switch from other government spending

The two possible outcomes of particular interest are the extremes[22]:

- The combination of government spending and funding crowds out private sector expenditure or
- government investment triggers extra private sector investment, if not in total then at least by bringing the private sector investment forward.

A further complication comes in comparing the welfare effect with a GDP effect of government investment when a change in total government spending results. In this situation, a welfare analysis will also include the deadweight associated with raising extra government revenue. This is also known as the marginal cost of public funds (MCPF). The MCPF is not used directly in UK cost benefit analysis, instead a value for money approach is adopted, where projects with the best value for money are selected. Spackman (2021) argues such an approach is superior when government budgets are constrained.

2.4.3.3 Future production resulting from a current investment

Putting aside the initial indirect and induced effects[23] of an investment on the economy, there is also the ongoing production provided by the asset created by the investment[24]. For an office block, the provision of the service provided by the office space in each subsequent year appears in the product calculation of GDP, typically as an intermediate product, and in the income side as gross operating surplus (the direct effect). The rentals in turn will go towards expenses such as maintenance of the office block, which will likely entail importing some goods (the indirect effect). The GDP will net out as the component of rentals in final demand for products and services less the imports required to support office provision. For the £100m office block example above, a likely set of ongoing numbers would be £5m rental output (e.g. as final government consumption for an office block leased to government or as potentially intermediate consumption for private sector leases) and £0.03m imports (say), with an ongoing GDP component of £4.97m per annum.

For private sector housing, a rent component is not explicitly paid for owner-occupied housing but is imputed by ONS and hence housing rentals is also an ongoing item in GDP. The imputed rentals show as “gross operating income” received by the household sector and paid as an intermediate demand by a sector called “Owner Occupiers’ Housing”. The rent also shows as a product “Imputed rents of owner-occupied dwellings” that becomes a consumption product of the Household sector.

[22] A related and important issue is the extent that dynamic efficiency (the pace of innovation) is enhanced or diminished by the government intervention

[23] Indirect effects are the increase in business beyond the initial direct investment amount while induced effects are the higher activity levels that may result from higher incomes caused by the direct and indirect spending

[24] This apparent double counting is a matter of contention, including the widespread inclusion of imputed rents which does have the effect of removing GDP effect of changing from owner-occupied to rental housing – see BARRO, R. 2023. Double-counting of investment. Available from: https://cepr.org/voxeu/columns/double-counting-investment.

The same logic applies to the product created each year provided by a road except there is only a small equivalent to rentals, namely the tolls collected on some roads[25], and instead the supporting activities for the road, such as maintenance, become a final demand of government. Hence, as with the private sector office, the ongoing GDP effect is the extra maintenance costs of the road less any import component.

For other forms of transport infrastructure, transport operators will often pay infrastructure access charges (e.g. train operating companies, maritime shipping companies, airlines). These access charges are rentals. The London congestion charge, bridge tolls and motorway tolls (e.g. M6 Toll), would be viewed as rentals the road infrastructure owner receives.

2.4.4 Induced investment

We have largely put aside the dynamic issue of whether a government investment induces a private sector investment. In TAG, where the transport investment opens up a specific parcel of land for development, this is referred to as dependent development, but all types of land use change following a transport project can involve some form of induced investment by the private sector.

The description of GDP above has been largely in terms of what inputs are directly required to meet the final demand for a product and, in turn, what inputs are required indirectly to provide the intermediate products. The description is largely historical; these are a mix of primary inputs, imports and intermediate goods currently required to produce a good or service.

The point was made in 2.4 that capacity must be available across a chain of sectors for higher demand to be realised.

In the short-term, this either means that spare capacity is available or labour and capital switch to respond to the change in demand or productivity. This is relatively simple to envisage (although may be difficult to achieve) when it is observable that (a) capacity is available within an industry or within a region or (b) that wages, rents and profits are low or (c) opportunities for economies of scale exist.

However, longer-term, the comparison becomes more abstract as the counterfactual is not observable and hence the 'business-as-usual' future must be estimated. This is challenging whatever forecast model is used. From this longer-term perspective, there will always be spare capacity as resources have not yet been allocated and so the focus is primarily on what would have been the likely alternative use of resources and, in that sense, which of the resources will be switched because of the intervention[26].

LUTI and SCGE models are currently the models employed internationally to explore the expected and counterfactual effects of land use changes. Both do so by allowing land use development to occur following a change in rents. Both impose a constraint on the quantum of land available. An SCGE model allows consumption and production to respond more fully to price changes, including exchange rates.

[25] Vehicle excise duty and fuel excise duty are taxes and not charges for access to the road network.

[26] Hence the key analytical focus is on a future with and without a scheme rather than necessarily today versus tomorrow

These models can show that induced demand is possible, often because of a reallocation of resources – relative to the hypothetical counterfactual – should production shift to products more suited to consumption preferences or to locations where capacity or economies of scale exist or where barriers to trade are overcome.

However, issues that remain challenging with GDP modelling and with government investment in general include:

- There is no consensus on which sectors for government spending will achieve the highest return from investment, be it transport, education, health etc.
- There will always remain uncertainty about the validity of the counterfactual.
- And, interdependent with both, the attribution that can be given to the government project is unclear.

2.4.5 Higher land values

One channel through which induced private sector demand is claimed is via higher land values. The higher demand for the land drives up land values. There is a large evidence base that more accessible land has a higher value. Transport projects by their nature change transport accessibility and as a consequence change land values. There is a robust evidence base to support this and the causality direction from transport accessibility changes to land value changes.

In a transport cost benefit analysis (CBA) context the change in land values is viewed as double counting other benefits in the appraisal (e.g. user benefits and local impacts on adjacent properties in terms of noise, safety, etc.). However, there can be several circumstances where land value changes might be utilised in a transport appraisal. In TAG, 'dependent developments' are valued through land value uplift with the user benefits associated with the dependent development being removed to avoid double counting. If market failures are present in the land market then surpluses in the land market may also be brought into the transport cost benefit analysis. A further use of land value changes might be to value urban realm projects which have both a 'movement' function and a 'place' function. Here the land value changes would be instead of the user benefits and other local benefits (e.g. noise, safety and physical health changes, etc.).

To be clear, the change in land value will not appear in GDP. This is not production. However, it is likely that an increase in land value arises because the expected annual income from the land is now higher and these higher future earnings, if and when realised, will appear as higher production of office space or retail space or factory space, which in turn will have associated operating activities. The net GDP effect will largely be the extra rental[27] less the imports required to support this production. In other words, a change in land value will not show in current year GDP but would be expected to show as a stream of higher GDP in the following years. In theory, the value of this ongoing stream when discounted back to today will be proportionate to the change in land value but they will not be the same.

[27] A higher rental will not show explicitly for owner-occupied property, other than housing where a rent is imputed, but instead will show as a higher gross operating surplus (if the higher rent opportunity cost is due to a productivity increase).

Three reasons can create a difference. First, the land value is a residual in a property development model and need not change in a one-to-one fashion with rents. Second, the land value will be determined, at least in theory, by a private sector discount rate that will differ to the public sector discount rate typically applied to transport appraisal. Third, there is also a mismatch between the private sector discount rate and the rental increase to expect due to the risky nature of property investment; e.g., land value can increase due to both an increase in expected rents and due to less risk being ascribed to this expectation.

For example, Table 2-11 uses an annuity discounting formula to estimate the current price of a property. If, say, the current discount rate applied to a one-off but perpetual 20% increase in rents was 10% and this discount was still considered apt following the transport intervention then the expected rent increase of 20% (which will appear in future GDP but less any associated imports) would be expected to prompt a current 20% property price increase. However, if the transport intervention reduced the risk of achieving the expected rent, say leading to an 8% discount rate applied, then the current change in property price would be 50%. Conversely, if the risk of rental flows was increased and led to a 12% discount rate applied then the current property price change would be zero. Put another way, an observed 0% or 20% or 50% property price change can, in this hypothetical example, coincide with the same (20%) rent increase.

TABLE 2-11 DIFFERENT THEORETICAL PROPERTY PRICE CHANGES CONSISTENT WITH THE SAME EXPECTED RENT INCREASE

Future rent increase	20.00%	20.00%	20.00%
Discount rate	10.00%	8.00%	12.00%
Current property price increase	20.00%	50.00%	0.00%

In sum, the relationship between land value changes and future GDP changes is an empirical matter.

Returning to the issue of counterfactuals raised in the previous section, a couple of examples involving land price uplift may be helpful to illustrate other measurement challenges.

1) Consider a city dweller in future chooses to commute further, from the city fringe, because of a transport cost reduction. The counterfactual, say, is that the person would otherwise live mid-distant from the CBD and hence is part of demand for mid-city housing. The project scenario, relative to the counterfactual, is that the person (a) lives near the city fringe which adds to housing demand on the fringe (higher price) and reduces mid-city housing demand (relatively lower price) and (b) spends more money and time travelling. The marginal welfare effect would be half the extra transport costs and time of the user[28] (using the rule of half) while the marginal GDP effect will be the higher vehicle operating costs (net of extra imports) plus a higher imputed rent for fringe housing and (relatively) lower imputed rent for mid-city housing. These relative rent effects are already challenging to estimate but are further complicated by considering price elasticity differences between the fringe and mid-city locations.

2) As a further example, consider a wholesaler centralising a warehouse because of a lower transport cost. The counterfactual is likely to be products stored across several warehouses or many shops. Similar to above, the alternative would be (a) a higher property price and rent for the

[28] Strictly speaking, it is half the GTC for the ij origin-destination pair that determines the welfare effect but the major components are typically travel time and trip costs.

warehouse location and lower demand for space elsewhere (a relatively lower rent) and (b) more transport. The extra GDP over time will be the extra transport costs (assuming business travel), the net difference in rents (of the warehouse less other locations) and any shift in export production or import sourcing.

2.5 Travel cost components

Turning to what constitutes a transport cost, there are many components. There are the costs of vehicles (motorised, non-motorised) and the fuel cost to use them. There can be additional costs associated with access to infrastructure (including parking infrastructure) for some modes. Transport projects change modal demands, switching demand between modes and generating traffic. The combined impact of this is to change the incidence of expenditure both within the transport sector and between the transport sector and the general economy. A summary of the travel cost components, their welfare measure and their GDP measure are provided in Table 2-12, to be expanded in the next chapter.

TABLE 2-12 TRAVEL COST COMPONENTS AND THEIR ENTRY IN WELFARE AND GDP ANALYSES

Transport cost	Where appears in welfare analysis	Where appears in GDP
Travel time (including comfort and reliability)*	Standard values reflect change in cost of travel time at average WTP by trip purpose, and for business only by mode and distance.	All non-business travel time components are not part of GDP. Cost of business travel, including waiting, IVT, delays, measured at wage rates applied (which vary by industry and job).
Vehicle operating costs (including user charges, fares)*	Standard model with parameters varying by vehicle type, including standardised product taxes and carbon taxes (if applied[29]).	All vehicle costs at cost.
Accidents and personal safety	Change in crash costs	Extra costs to avert accidents and treat the effects of accidents. Potentially, lower than otherwise output and consumption of person killed or injured.
Transport provider revenues	Change in subsidy included within BCR.	Subsidy within 'Product taxes and subsidies' (higher subsidy reduces GDP, as offset to gross operating surplus in private sector).

[29] Carbon taxes are not applied in the UK at present on transport

Indirect tax revenue (e.g. fuel duties, VAT)	Change in tax revenue (NB indirect tax rates vary by mode).	Tax within 'Product taxes and subsidies' (higher tax adds to GDP).
Agglomeration (static and dynamic)	Add-on to user welfare.	Likely to show as equivalent GDP
Output change in imperfectly competitive markets	Add-on to user welfare.	Likely to show as equivalent GDP
Impact from move to more/less productive jobs, Increase in labour supply	Add-on to user welfare (change in taxation)	Extra GDP differs to welfare effect and reflects increased output

Notes: * Calculated using rule of half

3 COMPARING CHANGES IN WELFARE AND CHANGES IN NATIONAL INCOME

3.1 Introduction

A transport cost benefit analysis calculates the total benefit (the net present value) as the sum of:

- changes in consumers surplus;
- changes in producers surplus for transport operators;
- changes in government surplus;
- changes in externalities; and
- changes in wider economic impacts (also known as wider impacts).

In this section we consider each of these in turn and their inter-relationship with changes in GDP.

3.2 On the equivalence between consumers surplus and national income

The change in welfare and GDP is compared in shown in Figure 3-1. The change in GDP (or national income) from a transport project is given by Area C+D+E if using a Laspeyres price index or Area C Paasche price index. This could be measured either as changes in total expenditure or changes in total production. It could also be measured as changes in income, which is the sum of changes in total wages, changes in firm profits and changes in some government tax revenues. The latter is not shown in Figure 3-1. As discussed in Chapter 2 the three methods (production, expenditure or income) should equal each other.

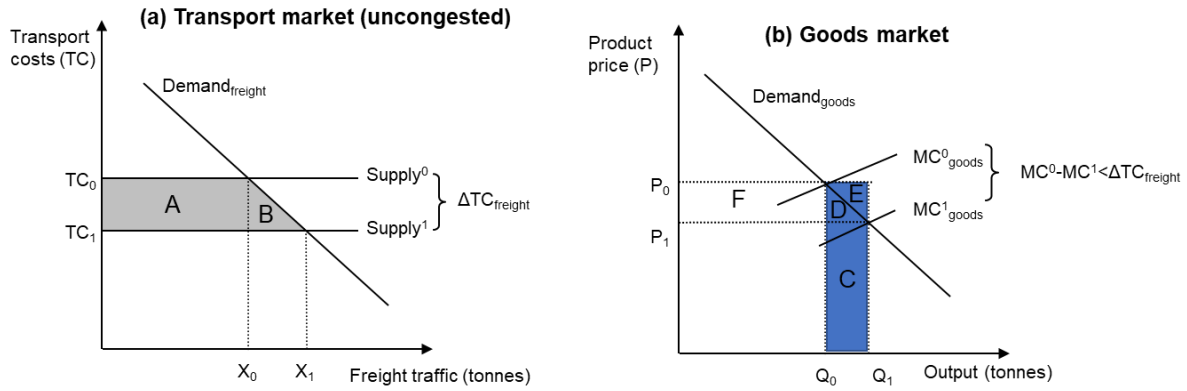
Our interest is whether the consumers surplus in the transport market (Areas A+B) should or would ever equal the change in national income (either C+D+E or C – depending on price base chosen for measurement of GDP). The first thing to note is that a change in consumers surplus also occurs in the goods market. This is given by the Area F+D. This double counts the change in transport users consumers surplus, which it is either equal to or less than. With elastic supply (as shown in Figure 3-1) it is less than the transport consumers surplus. We can see this in Figure 3-1 as the transport cost change (TC_0-TC_1) in the left hand panel, leads to an equivalent change in marginal cost in the product market (MC_0-MC_1) in the right hand panel. However, due to the elastic supply of and demand for goods in the product market, the corresponding price reduction (P_0-P_1) is less than the transport cost reduction. The change in consumer surplus in the goods market is therefore less than the change in the transport market. This is one of the reasons that economists measure changes in consumer surplus in the primary market where the intervention occurs.

Thus our primary interest is not whether changes in consumers surplus in the goods market equal changes in GDP, but whether changes in consumers surplus in the transport market equal changes in GDP. Mohring (1976 Chapter 9) sets out the conditions when this will occur. These are:

> *If* a change takes place which increases output obtainable from a given set of primary resources, and *if* the primary resources allocated to the market activities do not themselves change, and *if* the same pricing rules are used in consumers' surplus as in national income change benefit calculations, then both calculation schemes will yield the same numerical result.

Mohring (1976 p112)

FIGURE 3-1: CONSUMERS SURPLUS AND GDP



In other words, the two metrics can equal each other, but only under certain conditions. Mohring illustrates this with an example of a subsistence farmer who divides his time between work, non-work', and transporting produce to market (there are only time costs associated with this transport). Using his proceeds of sale to buy commodities for use in the household. A transport improvement (in this case the discovery by the farmer of a new shorter path) permits them to do one of three things: continue spending the same amount of time working as before, spend less time working, or more time working. The exact choice will be dependent on the farmer's personal preferences. For three illustrative scenarios he calculates changes in consumers' surplus and national income (see Table 3-1). These scenarios are: Scenario B transferring all the real income gain into leisure time (i.e. producing the same amount); Scenario C continuing to work the same number of hours each week (which with reduced travel time would result in more production, and consumption); and Scenario D working longer hours with the resultant higher levels of production and consumption. The transport demand (number of trips to market) is proportional to any increase in production. Transport demand therefore remains unchanged in Scenario B, but increases in Scenarios C and D.

TABLE 3-1: CHANGE IN CONSUMERS' SURPLUS AND NATIONAL INCOME FOR SUBSISTENCE FARMER FOLLOWING A TRANSPORT IMPROVEMENT

	Scenario B (decrease in working hours)	Scenario C (no change in working hours)	Scenario D (increase in working hours)
National income increase	$0.000	$0.781	$1.875
Consumers' surplus increase	$0.625	$0.703	$1.000

Source: Mohring (1976 p110)

In B there is no increase in national income, as the amount of labour devoted to work is reduced to maintain income/consumption levels to pre-intervention levels. The increase in consumers' surplus measures the value of additional leisure time. So, the change in consumers surplus is larger than the change in national income. In Scenario D the increase in working hours gives rise to higher levels of production (and consumption), but the reduced amount of leisure time means the change in consumers' surplus is lower than the change in national income. Scenario C is interesting as the same amount of primary resource (labour) is being utilised, but there remains a difference between consumers' surplus and national income. As the number of leisure hours remain unchanged none of

the difference can be attributed to the different treatments of leisure. The difference instead arises from different prices being attributed to the increase production/consumption between the two measures. The national income measure assigns a price equal to the pre-intervention price (equivalent to a Laspeyres measure) for the additional output produced. The consumers' surplus measure using a downward sloping demand schedule and a willingness to pay measure, which if evaluated using the rule of half attributes an average 'pre-intervention' price halfway between the pre-intervention transport costs and the post-intervention transport costs. Mohring shows that if the additional transport demand was all allocated the full price reduction and not half the price reduction then the Consumers' Surplus and the national income measures would be equivalent. The consumers' surplus pricing rules reflect that the marginal value of additional production/consumption diminishes as production/consumption increases. The Laspeyres and Paasche national income pricing rules do not. However, as discussed in Chapter 2 the chain volume approach to measuring national income results in similar pricing rules between national income and changes in consumer surplus for moderate price difference, probably sufficient that any differences can be ignored in practicality.

This example therefore illustrates that, for a productivity improvement, equivalence between consumers' surplus and national income: firstly needs primary resources allocated to market activities (e.g. quantity of labour supplied) to remain unchanged, but also the need for the same pricing rules to be applied to consumers' surplus and national income. Though as discussed in Chapter 2 and mentioned above, the latter is unlikely to be an issue for moderate price changes using modern approaches to measure changes in national income.

The argument therefore is that whilst there is an interrelationship between changes in consumers surplus and changes in national income, they are in actuality two different metrics measuring two different things. We should not therefore expect changes in consumers surplus to feed straight through into changes in GDP or vice versa. The corollary of this is that changes in GDP may exceed or be lower than changes in consumers surplus.

3.3 Producers surplus and government surpluses

Changes in transport producers' surplus (profits of transport operators[30]) and government surpluses (government funded investment costs and changes in indirect taxation) are important components of a transport cost benefit analysis. Whether they are readily recognised in a GDP calculation would depend on which method of calculus was adopted for measuring GDP (income, production or expenditure), and additionally whether they are viewed as an intermediate good supplier or a final good supplier.

As discussed in Chapter 2 changes in Government tax receipts and expenditures (government surplus changes) appear in the national accounts. However, their treatment varies. Indirect taxation is treated separately, investment costs will appear as changes in Gross Capital Formation, whilst income tax changes are embodied in changes to compensation to employees and corporation tax changes are embodied in firm's gross operating surplus.

[30] More literally, the producers' surplus comprises Ricardian rents (mainly the widening gap between the price and the supply curve) and scarcity rents plus any pure rents earned by monopolistic behaviour. Collectively these are typically referred to as profits. SANDERSON, M. & WINTER, R. A. 2002. Profits versus Rents in Antitrust Analysis: An Application to the Canadian Waste Services Merger. *Antitrust LJ,* 70.

3.4 Externalities: health and the environment

The above illustration has been associated with leisure time as a non-market activity. Health and environmental related impacts are two other substantive non-market activities.

The consensus on the Value of Statistical Life (VoSL) is that it should be measured from willingness to pay for risk reductions and then extrapolated to that of a statistical life. This gives willingness to pay values far in excess of the financial costs of statistical life: either lost production, or lost consumption plus any material/damage costs with the manner that the life is lost. The difference between the financial costs and the WTP values is sometimes termed colloquially as the value of 'pain, grief and suffering'. The VoSL is £1,652,729 (at 2010 prices and values) in TAG, of which only 6.5% is associated with lost net output[31]. This would imply that the gross output of an average fatality is 32.5% of the VoSL (i.e. approximately £0.5M at 2010 prices and values). Thus, the cost of a fatality to national income is substantially less than the loss to national welfare.[32]

The VoSL is used to evaluate many health-related impacts such as: benefits of increased physical activity from active travel and impacts on life expectancy of reductions in environmental pollutants (e.g. NO2 and PM2.5 when valued via damage costs[33]).

Climate change and noise impacts[34], whilst valued using marginal abatement costs for climate change and hedonic pricing for noise, also impact on life expectancy and quality of life. With respect to other environmental goods (e.g. biodiversity, water quality, landscape, etc.) society may hold a value for these goods beyond the usefulness as inputs to the production process of goods and services. Thus, again the financial (GDP) costs of the goods will differ from the welfare costs for these environmental impacts.

3.5 Wider impacts

The standard wider impacts (WIs) included in TAG are: increased output with imperfect competition, agglomeration impacts, changes in labour supply and move to more/less productive jobs (M2MLPJ). Land value uplift is also included in dependent development appraisals. Land value uplift (LVU) is included instead of the user benefits to the development traffic.

Leaving land value uplift and dependent development to one side for the moment, these wider economic impacts stem from market transactions in the product or labour market. As such, if changes in quantities and prices, have been correctly measured then the any GDP measure of the increased output from a transport project (e.g. Area C+D+E in Figure 3-1) will already include these wider economic impacts. The imperfect competition WI reflects the increased profits of

[31] Net output is taken to be 0.2 of gross output (see Table A 4.1.1 in the TAG databook).

[32] The data on which these values is based is old, dating from 1997. BUT, B. 2021. PPR995: Improving our Understanding of the Cost of Injuries on the Road. Crowthorne: Transport Research Laboratory., in a recent TRL report, discusses the calculation and potential updates to the Gross Output Calculations used in the UK.

[33] https://www.gov.uk/government/publications/assess-the-impact-of-air-quality

[34] TAG disaggregates noise values between: amenity, direct AMI (heart attack), stroke, dementia, and sleep disturbance

monopolistic businesses. These comprise part of the GDP impacts of increased output, but are additional to the change in consumers surplus. Agglomeration impacts lead to productivity improvements which also increase GDP. The GDP impact from the increased productivity is additional to the change in consumers surplus. The labour supply and M2MLPJ WIs are associated with changes in employment and the associated GDP impact of those employment changes. The component of that GDP change that accrues to government as labour taxes is additional to user benefits.

Land value uplift associated with dependent developments differs from other wider economic impacts as it reflects an uplift in the value of an asset, rather than being an income measure[35]. Changes in GDP measure changes in income rather than changes in asset values. With respect to changes in land values, this would only feed into GDP effects as land rents change (included imputed rents).

In summary, wider impacts are GDP impacts that create additional welfare gains to those captured already by consumers surplus, rather than being welfare impacts that create additional GDP impacts.

3.6 Unit of account

An important difference between a cost benefit analysis and a GDP analysis is the unit of account. A GDP analysis is one of final goods and it is undertaken in nominal prices that include VAT, albeit adjusted to a base year for comparison. A cost benefit analysis is either presented in factor or market prices. In the UK market prices are used.

As part of the cost benefit analysis in which transfers (e.g. between transport operators and users, or government and transport operators) are explicitly shown, the following adjustments are therefore made to nominal prices to convert to market prices:

- Prices faced by households – no adjustment
- Prices faced by business and government (including willingness to pay values for time savings etc.) – uprated by 1 + t, where t is the average rate of indirect taxation in the economy. This is because prices faced by businesses are for intermediate goods, which would not be subject to VAT.

A GDP analysis, of course, is concerned with prices of final goods, not intermediate goods per se. Our interpretation of this is that in the UK the welfare appraisal is therefore in a unit of account that is broadly equivalent to the GDP unit of account. This intrinsically makes sense in the context of household consumption. For businesses this can also be seen in that a productivity improvement to business that leads to an increase in output of 1 unit of a final good for household consumption, would create 1+t value of goods to households.

[35] The construction cost of new homes/offices is not included in the Dependent Development wider impact, it is the change in land prices associated with the change in transport supply. Construction costs associated with Dependent Developments do though feature in the GDP account as a part of Gross Capital Formation, as discussed in Chapter 2.

4 CALCULATING GDP IMPACTS FROM TRANSPORT CBAs

4.1 Starting point for calculating GDP impacts from a transport CBA

A partial equilibrium transport CBA takes the change in welfare (the social surplus) to be the sum of the change in consumers surplus, the change in producers surplus, the change in government surplus and changes in externalities (De Rus, 2010 Chapter 2). To that we would add wider economic impacts if secondary markets exhibit market failures.

In this chapter we will build up an estimate of GDP impacts based on the output from the CBA. Our starting point is highly constrained, and then we relax each of these constraints, and consider whether by doing so GDP impacts will change and if they do whether estimates can be made of their magnitude by using the transport CBA. We identify additional data and model requirements. We take it that our transport project is funded by government, and delivers business and freight user benefits. Our starting point is akin to Mohring's subsistence farmer example presented in Chapter 3, but with additional constraints. The initial constraints that we impose on the analysis are:

1. Zero change in transport providers producers surplus and zero change in indirect taxation receipts by government;
2. No change in hours worked;
3. Zero non-work user benefits (with no change between the do minimum and do something of any component of generalised cost: time fares, petrol, etc.);
4. Perfect competition (no market frictions):
    - No externalities; and
    - No wider economic impacts;
5. Perfectly elastic supply of land in land market;
6. Constant returns to scale outside the transport sector and, in particular, that switching resources between sectors has no GDP effect;
7. Closed economy (i.e. no imports/exports); and
8. The government budget (fiscal position) is fixed

The business and freight user benefits delivered by the transport project increase the productivity of the transport sector. Under constant returns to scale and perfect competition these will be passed on directly into the goods and services markets leading to consumers surplus in those markets. Under perfect competition and constant returns these changes in consumers surplus will exactly double count the transport user benefits.

Following Mohring, the GDP impact of the transport project under the conditions above will be equal to this change in consumers surplus. This will be subject to slight differences in the pricing between changes in consumer surplus and national income, which has been argued will be small using chain volume measurements of GDP (as the UK does).

4.2 Step 1: Including transport operator producers surplus and indirect tax revenue changes received by the government

A transport project that reduces the cost of travel will change the profit margins of transport operators in a partial equilibrium analysis, and will likely also have impacts on government accounts

via the differing rates of indirect taxation, subsidies and grants between road, public transport and the general economy. Transport operators are those that own the infrastructure and provide the transport services (e.g. government who own the public roads, bus operators and train operators).

It is helpful to consider this step in two parts: the change to producer surplus; and the change to government accounts.

4.2.1 Change in producer surplus

A switch of resources from one sector to another has the potential to change profits and GDP. If the marginal value of using resources in any sector of the economy is equal then this switching of resources between transport modes or to the transport sector would potentially have no GDP impact. This might most easily be seen under the expenditure approach as firms have to switch expenditure from one resource (say office equipment) to another resource (rail fares), or alternatively from petrol to office equipment. Under the income approach, we would see inputs transferred from one sector to another, including any switch in profits between sectors, at equivalent factor prices.

We can therefore see that the increase in GDP from the transport project is primarily driven by the productivity improvement to the economy, and not switching expenditure between different sectors of the economy – this is of course under the constraint of constant returns throughout the economy, and the assumption that the marginal value of using resources in any sector of the economy is equal.

4.2.2 Change in government taxes, subsidies and grants

The impact of changes in taxes, subsidies and grants can likewise occur without a real GDP effect if resources are fully employed but are exchangeable and if market prices adjust. A summary of the steps involved are discussed in Box 4-1. However, to get these zero real GDP effects from impacts on government accounts there is a need to make some strong assumptions about transport sector prices and/or the sector's productivity. This should be explored in further research.

BOX 4-1: THE IMPACT OF CHANGING TAX REVENUE AND SUBSIDY IMPACTS: MODE SHIFT TO RAIL

There are four interactions between the private sector and the public sector that can potentially affect the measurement of GDP accompanying a mode shift to rail. Shifting expenditure between sectors:

1. can change VAT, as spending on rail is zero-rated[1] for VAT but 20% on many of the spending items foregone to pay rail fares;
2. can change the fuel duty collected (less on road fuels and more on rail diesel[1]), which will vary depending on the extent of electrification of road and rail vehicles;
3. can change the train operating company (TOC) subsidies[1], as extra fare revenue may reduce the subsidies under the TOC franchise contracts with DfT or, conversely, an increased subsidy requirement may be required if the mode shift leads to extra costs above the extra fare revenue[1];
4. and can change Network Rail income and expenditure, if the mode shift is large, as any extra Network Rail expenditure required, which is considered government expenditure,

would likely be jointly funded by extra Network Rail track charges (from the extra fares) and from extra Government grants.

A summary of the initial GDP effects of a mode shift from rail to road is shown in the table below. Keep in mind, there may be GDP effects beyond these initial accounting changes – of interest here is whether expenditure can be switched without changing GDP given existing resource constraints and productivity.

TABLE 4-1: POTENTIAL ACCOUNTING EFFECTS OF MODE SHIFT FROM ROAD TO RAIL

Item	Work travel on GDP	Non-work travel on GDP	Both on Welfare
1. VAT	Potentially no real GDP effect	Potentially no real GDP effect	PVB declines by VAT reduction
2. Duty	Potentially no real GDP effect	Potentially no real GDP effect	PVB declines by duty reduction
3. TOC subsidy	Potentially no real GDP effect	Potentially no real GDP effect	Included in CBA as extra PVC (which measures the productivity effect)
4. Network Rail grant	Potentially no real GDP effect	Potentially no real GDP effect	Any Network Rail costs above higher access charges in CBA as PVC

Note: A change in real GDP may occur due to general equilibrium effects or should the government budget increase/decrease.

Take (1). VAT is primarily paid by the end user, with a system of payments and claims for businesses to ensure VAT does not influence production decisions. Thus, businesses shifting expenditure between products and sectors is potentially possible without changing GDP. The channel of effect for non-work travel is more complicated. There will be a reduction in nominal GDP, as measured in purchaser prices, when final spending is shifted, say, to rail from road and other expenditure. But the reduced VAT also leads, all things being equal, to a lower price level in the economy. The net effect is no change in real GDP.

Consider (2). The fuel duty effect is likely to be much smaller than the VAT effect, as the fuel saving is typically a small component of the foregone spending (rail fares per km typically being higher than petrol costs per km) and will be partially offset by extra rail diesel duties (also a small component of the rail cost), with both being influenced by the proportions of electric vehicles. The channel of effect for work and non-work mode shifts to rail is the same as for non-work mode shifts in (1), namely nominal GDP declines but real GDP is unchanged.

TAG A5.3 include reduced welfare for reductions in VAT and duty, contrary to a lack of real GDP effects.

Consider (3). The TOC subsidy becomes relevant when TOC profits change because of the rail fare revenue increase. Any change in TOC profits is likely to involve a change in productivity of the rail sector (more output - passenger kilometres – for a less than proportionate increase in inputs). As discussed in the previous section, a change in productivity has the potential to change national GDP, however, whether the change in profit or loss is borne by the TOC or by the government (via a change in subsidy) need not affect GDP. The dynamics are similar to (1) and (2), but it does require an assumption that the nominal effect is being offset by changes in rail fares.

TAG A1.3 includes calculations for a 'subsidy effect' although this is foremost a productivity effect that then results in a change of subsidy. TAG A5.3 welfare analysis includes the subsidy effect as a change of costs in the BCR calculation. A BCR calculation of this nature is not necessarily incorrect but may be confusing if trying to align welfare benefits with GDP effects.

Consider (4). It is possible that the shift to rail is sufficiently large to require higher track expenditure. This brings in the interplay between the TOCs, Network Rail and central government. Track access charges to Network Rail are paid by the TOCs but a large proportion of Network Rail expenditure – and hence likely a proportion of extra expenditure – is provided by central government to Network Rail. Any increase in government spending on Network Rail would require reduced expenditure from elsewhere (e.g. health) or increased taxes from the public. This switch in resources can only occur without a change in real GDP if switching resources between sectors or raising tax revenue has no productivity effects (see subsequent steps on relaxing constraints on general equilibrium and government financing steps).

As has been seen from the above discussion, to get zero real GDP effects from changes in government accounts there is a need to make some strong assumptions about rail prices and the rail sector's productivity. This should be explored in further research.

4.3 Step 2: Considering changes in employment

The treatment of employment impacts is a key difference between the welfare and GDP economic metrics. Essentially, the opportunity cost of working (the loss of leisure time) is not included in the change in GDP metric, whilst it is in the welfare metric. This is because leisure time is a non-market resource. The Mohring identity between consumers surplus and GDP therefore requires that there is no change in hours worked. If we relax this constraint then there is a need to include any additional GDP, to that already associated with the change in consumers surplus. This requires an estimation of the change in quantity of labour that will be supplied, and also a valuation of that change. Taking each of these in turn.

As discussed in Chapters 2 and 3, hours worked may increase or decrease as a consequence of a transport improvement. It therefore becomes an empirical matter how the quantity of hours supplied may alter as a result of a transport project, and this is likely to be context dependent. Here modelling becomes essential, and it is important not to generalise.

TAG provides a labour supply model, but as can be seen from the discussion in Box 4-2 it imposes certain assumptions on the compensation for the commute, which implies certain land use patterns. As can also be seen from Box 4-2 forecasting changes in employment is non-trivial, and usually requires making assumptions about the labour market. Where wider economy models are constructed a scenario approach is usually adopted, testing the project appraisal to different labour market closure rules (e.g. inelastic versus elastic labour market). The key message here is that if employment impacts are deemed to be an important consequence of the project (in terms of GDP changes), then there is a need to avoid generalising as context is important, modelling is essential as is the need for sensitivity testing the results to different labour market assumptions.

Putting to one side the challenges of predicting the changes in employment, and taking it that a model is available that is able to predict the change, the question then arises is what the GDP impact of this change is. In Mohring's example he shows that the additional hours of labour produce output

valued at the selling price of the goods produced. This is the production approach. As the worker is self-employed it is also expenditure and income without any third party involvement. This simple example is unlikely to apply in most real applications. Firstly, some capital (e.g. machinery, office equipment, buildings, etc.) will be involved in the production of goods and services in addition to labour. These will also produce a return. Hence the reason that GDP/worker exceeds the compensation costs to employees. How businesses choose to expand capital (i.e. invest) as they expand their workforces will be individual decisions. Ideally modelling is required to determine investment, and therefore the full GDP impact. In the absence of such modelling, it is typically assumed that GDP per worker rates remain the same before and after the transport project, and that the newly employed workers are on average 'average'. TAG makes this assumption for workers that are displaced from one region to another (i.e. for M2MLPJ), but for increases in labour supply it assumes new workers produce only 69% of the GDP of 'average' workers.[36] These assumptions are currently under review. In principle we see it as reasonable to base the valuation of increases in employment on some function of the average GDP/worker noting that consistency between the CBA and GDP analysis needs to be maintained. That is if new workers output is valued at 69% of the average in the CBA then it should also be so in the GDP analysis. We also note that a more sophisticated analysis would require modelling of investment, as would occur in an S-CGE model.

BOX 4-2: EVIDENCE ON AND MODELLING OF EMPLOYMENT IMPACTS

There is evidence that employment rates are higher in areas with higher accessibility (see Bastiaanssen et al. (2020) for a review). This empirical work is often associated with spatial mis-match theory, where jobs and workers are located in different locations, but workers cannot access those jobs. The inability to access employment is due to the presence of market imperfections that prevent workers being fully compensated for their commute (see Paul Leigh (1986), Manning (2003), (Van Ommeren and Rietveld, 2007) for evidence of partial compensation).

Theoretical models based with fully functioning labour markets also predict variations in labour supply with accessibility. The different models would predict different responses due to a change in commute costs. TAG uses one of these model types. In it changes in real wages from reductions in commuting costs are used to estimate changes in employment levels via an elasticity of hours worked to real wages (Department for Transport, 2018). Such a model is predicated on all commuting costs being compensated via wages. This is likely most appropriate in an environment where housing and jobs are spread evenly through space. Where jobs are concentrated in particular locations then compensation for the commute also occurs through housing rents as well as wages (Moses, 1962, Sivitanidou and Wheaton, 1992, Timothy and Wheaton, 2001). Though, as noted above, market imperfections are likely to dampen this compensation response. If employment is concentrated in a single location, as in the mono-centric urban model, then residents receive no compensation for the commute through their wages, and full compensation through housing costs. In such a model, a transport project induces an increase in city level labour supply via migration (see Venables (2007) for an elaboration in the context of transport commuting project). This is more a displacement of

[36] There is an inconsistency in TAG in that all M2MLPJ employment changes, even if they stem from changes in regional labour supply, are valued at GDP/worker, whilst 'increases in labour supply' are valued at 69% of GDP/worker. These assumptions are currently under review.

labour rather than an increase in labour supply, although it is an increase in labour supply at the city level.

The above discussion has focussed on the extensive margin. That is the increase in labour supply by more workers entering the labour market following a transport project. The intensive margin is concerned with the numbers of hours that will be supplied. This is the leisure-consumption trade off. If workers choose to only consume the same amount of 'market goods' but consume more 'leisure time' than a productivity improvement can be associated with a reduction in GDP. If this effect dominated then over time significant real increases in incomes would be associated with reductions in working hours. The PwC S-CGE model of HS2 also predicted reductions in working hours as a consequence of the project, which significantly dampened the GDP impact. How realistic this mechanism is also an empirical question. The limited evidence to date suggests that whilst there have been reductions in working hours, with associated increases in leisure time, the effects on total hours worked have not been that large. In the US over the course of the twentieth century leisure time increased by around 4 to 5 hours per week for prime age workers up until the 1980s, and then returned to the levels seen in the 1900s (Ramey and Francis, 2009). This is in aggregate. So, whilst the length of the working week may have reduced for those in employment over the course of the century (the intensive margin), workforce participation, particularly that of women, has increased (extensive margin). Gratton and Taylor (2004) in their survey of the literature also report no increase in leisure time since 1985 for those in full-time employment within the UK.

Changes in employment may also occur at a regional level if employment is displaced from one location to another by a transport project. This is known as Move to More/Less Productive Jobs (M2MLPJ) in TAG. This can occur through inter-regional migration, inter-regional commuting, or expansion/contraction of regional labour markets. The latter would occur via the labour supply mechanisms discussed above. These displacement effects arise through a variety of mechanisms surrounding competitive advantage and plant/office re-organisation to benefit from economies of scale. They are not straightforward to model and typically require some form of land use model or spatial general equilibrium model. In terms of evidence for these displacement effects of transport projects, this is similarly limited in depth as with the labour supply evidence. Chandra and Thompson (2000) is often viewed as a classic study on the displacement effects of transport projects. They show that the interstate highway network displaced economic activity from rural counties that were not connected to the network to rural counties that were connected to the network. Duranton and Turner (2012) find that a 10% increase in a city's initial stock of inter-state highways causes about a 1.5% increase in city employment over a twenty-year period. This employment is taken to be displaced within their model. Within the city itself increased road provision has been found to increase the level of suburbanisation (or spread) of the city in both the US (Baum-Snow, 2007) and China (Baum-Snow et al., 2017). Thus, we can see that road provision affects both micro-choices within a city, and more macro choices such as location choices between cities. Baum-Snow et al. (2020) in looking at the impact of the construction of the Chinese highway network find that economic activity is displaced to 'primate' regional cities from the hinterland including the hinterland cities. For example, they identify that a 10% increase in roads within 450 km of a prefecture city reduces non-primate prefecture population by 1.7%, but increases primate prefecture population by 1.1%.

4.4 Step 3: Considering non-work user benefits

Monetary non-work user benefits

Monetary non-work user benefits include changes in fares, tolls, petrol costs, etc.

The same lines of argument as applied to changes in costs for transport operators and government apply to the non-work user benefits when transport prices (ie, VOC, fares) do not change. Switches in demand between modes that cost different amounts per trip impact on household budgets, and switch expenditure between the general economy and the transport sector. With the assumption that the marginal value of a resource in any sector of the economy is the same, then there is no GDP impact between switching expenditure between these economic sectors.

Alternatively, changes in transport charges (e.g. fare reductions or increases) do have a GDP impact. In a similar dynamic to that described in §2.3, a lowering in transport price will start as a lower current GDP but an unchanged real GDP (due to the lower average price). Subsequent spending with the funds now available to the non-work traveller will then lead to a GDP increase.

Cognitive non-work user benefits

'Cognitive' user benefits refer to the time savings and other non-financial aspects of non-work user benefits (e.g. comfort, travel information, etc.). There is no direct market for these travel aspects and therefore there is no direct impact on GDP. Effectively time is switched between non-market activities: travel time and leisure time. Comfort, travel information, etc. impact on the quality of that non-work time and increases its usefulness, but it is still a non-market activity. Non-work user benefits may affect land values, and we discuss that further in Step 5.

Changing attractiveness and the spatial equilibrium

Non-work user benefits change the attractiveness of destinations. Destinations that may have been out of reach, due to time budget constraints, now become in reach. Origins (housing locations) that were once out of reach become in reach, etc. This not only switches 'consumption' expenditure (e.g. grocery shopping, leisure activities, etc.) and therefore resources between different businesses and locations, but may also switch between different industrial sectors (e.g. hospitality versus fitness industry). There may also be switches between holiday and leisure expenditure local to the area. The changes in attractiveness of different locations, and consequential business performance in these locations, will impact on the demand for land in these areas. Subject to the constraints in in §4.1, namely constant returns outside of the transport sector, equal marginal of resources in all sectors, a perfectly elastic land market and a closed economy, there will be no additional net GDP impacts at the aggregate level.

At a regional or sub-regional the changes in consumption patterns by households will change GDP at these sub-levels, but these will net out. If these sub-level changes are of interest then to model them would require data on expenditure patterns of households per trip. Such data are not

generally available. However, for some bespoke economic impact studies, passenger, household and business surveys have been undertaken that demonstrate the potential of this approach.[37, 38]

The work/leisure decision

Changes in the time spent travelling for non-work purposes, change not only the amount of time that is available for non-work activities, but also may impact on the work/leisure decision. It is standard practice to assume that savings in non-work travel time will increase the amount of leisure time available, and savings in business travel time increase the amount of work time available (see e.g. Mackie et al. (2001)). However, in reality non-work time savings may also affect the work/leisure decision at both the intensive margin and the extensive margin. This then returns us to the discussion on the need for modelling of employment impacts contained in Step 2 and Box 1 above. On one hand workers with higher levels of income may choose to increase the amount of leisure (as per the discussion in Chapter 2 and made by Mohring and modelled in the PwC HS2 S-CGE model), whilst on the other hand workers who are no longer constrained (or burdened) by commuting time may take on more work at either the intensive or extensive margin. The latter decision is modelled in TAG as a labour supply employment impact.

4.5 Step 4: Allowing market distortions: Price ≠ Marginal Social Cost

In a transport CBA there a number of benefit categories that are driven by the existence of market failures. These include safety and environmental externalities, as well as wider economic impacts. In considering the GDP impact of these benefits it is useful to think of how they either impact on productivity or on resources. If they impact on productivity this then leads to the discussions about work/leisure trade-offs (and employment impacts), as well as those on resource constraints in the supply chain as well as on forward linkages. If they impact on resources, then this may just result in a diversion of economic activity from one sector to another, which has no additional GDP impact with constant returns everywhere. However, in some circumstances more or less resources may become available which can impact on GDP.

Safety

Changes in the number of accidents primarily impact on resources. This occurs in two ways:

(1) By saving lives, transport projects can increase the number of people who are alive increasing consumption and production. For a reduction in mortality, this will unequivocally increase GDP over time.
(2) By avoiding damage repair costs. If property and vehicle damage occur then the repair costs divert expenditure (and production) from other economic sectors. Under our assumption of constant returns, no supply chain constraints, and resources have equal marginal GDP value

[37] Peter MACKIE, James LAIRD and Daniel JOHNSON (2012) Buses and Economic Growth. Main report. Report to Greener Journeys. Report dated June 2012. https://greener-vision.com/publication/buses-economic-growth-full-report/

[38] Steer Davies Gleave (2003) *The case for rail in the Highlands and Islands*. Report to Highlands and Islands Enterprise.

in all other sectors, then this diversion from producing goods to repairing damaged vehicles and property has no impact on GDP.

If reducing accidents also reduces morbidity, then we would expect that worker productivity to increase. This will have a positive impact on production and therefore consumption and therefore GDP, subject to the usual caveats on constant returns and no frictions in forward and backward linkages.

In the CBA the values of safety also include social values, associated with what is known as human costs. The values used in the CBA cannot therefore be taken to represent a GDP impact. GDP 'equivalent' values would need to be derived, for any GDP calculation, the existing evidence base is likely to provide sufficient data for this.

Noise and air pollutant impacts

Noise and air pollutants impact on public health, the natural environment and the economy. See for example DEFRA guidance on the impact pathway approach to modelling air pollutants[39], and the disaggregation of noise impacts between amenity, direct AMI (heart attack), stroke, dementia, and sleep disturbance. In considering the GDP impact once again there is a need to distinguish between resource availability, worker productivity and avoidance of damage costs.

Resource availability. By increasing life expectancy transport projects that reduce noise and air pollutants increase production and consumption. This would have an unambiguous positive impact on GDP.

Avoiding damage costs. By reducing damage costs to buildings and materials from air pollutants, this would allow expenditure on repair costs to the buildings to be spent in other sectors of the economy. Under constant returns, no supply chain constraints and equal marginal value of resources in all sectors of the economy this change in sectoral expenditure has no impact on GDP.

Increasing productivity. Improved public health reduces absenteeism and increases presenteeism. Reduced damage on ecosystems would also positively affect agricultural output. This would be seen as a productivity improvement in the agricultural sector. As with other productivity impacts the impact on GDP is dependent on the upstream and downstream linkages in the economy, as well as the work/leisure trade off.

As with safety, the values used in the CBA reflect social as well as financial impacts. The CBA values could not therefore be used directly in any GDP calculation. However, it should be possible to derive 'GDP equivalent' values from the evidence base – particularly those associated with public health, but less so with changes in agricultural output.

Carbon

Undoubtedly increased climate change as a consequence of a transport project will impact on public health, worker productivity, agricultural productivity, capital productivity (e.g. increased outages due to weather events), and also create damage costs. These will all impact on GDP. These impacts will

[39] https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-impact-pathways-approach

also be felt internationally, so carbon produced in the UK will be creating GDP impacts all over the world[40]. The ability to model these impacts are a science in themselves and on the knowledge frontier.

We can however utilise the carbon values in the appraisal to make some judgement on GDP impacts. These values, in the UK, are based on marginal abatement costs. That is the cost associated with abating the carbon impact. Therefore, an interpretation of these carbon values is the additional expenditure that will need to be made to abate the carbon produced by the transport project. If there is a legally binding commitment to abate the carbon impacts, as there is in the UK[41], then there will be a need to increase expenditure on (and production of) carbon mitigating activities. This will divert expenditure on (and production of) activities that would have been chosen in their stead. Under constant returns to scale etc, equal marginal value of resources in all sectors of the economy, there will be no GDP impact of switching between these economic activities. However, if these conditions are relaxed there could potentially be large and negative effects on GDP from having to increase activity in carbon mitigating activities in response to an increase in carbon produced from the transport sector. This is on the basis that the economy would likely to have to shift to a less efficient balance of economic activity, than if the carbon had not been produced by the transport project. There is also the complicating effect of relative price changes, e.g. if higher fuel prices disfavour import or export intensive sectors.

Agglomeration

Agglomeration benefits arise as a result of a positive externality. They increase productivity of both labour and capital. Subject to the conditions in §4.1 these will lead to an increase in GDP of the same size as the productivity benefits, as there will be no crowding out of the productivity gain, nor any general equilibrium effects that could increase it.

Increased output in imperfectly competitive markets

Imperfect product and services markets will lead to excess profits (operating surplus) by businesses. In this instance the consumer surplus in the product and services market will not capture all the welfare benefits from the associated increase in output, and the additional operating surplus needs to be included in the welfare appraisal. The identity between the change in consumer surplus and the change in GDP change will also not hold under these conditions, and the additional operating surplus also needs to be included to capture the full change in GDP with these market imperfections present.

Increase in labour supply, move to more/less productive jobs

If the project induces a change in either the quantum of employment or the location of that employment (and there are spatial differences in productivity), then with labour taxes there is an additional welfare benefit, to the user benefits, that needs to be included in the CBA. This is

[40] These general economy impacts are different to the monetary impacts associated with emissions trading programmes. Here the net carbon emissions traded between the UK and other countries do not enter as an item in GDP calculations, but are an entry in Gross National Income

[41] Administered through carbon budgets under the auspices of the Department of Energy Security and Net Zero. See e.g. the March 2023 Carbon Budget Delivery Plan https://www.gov.uk/government/publications/carbon-budget-delivery-plan.

equivalent to the change in labour tax revenue received by the government. There has to be changes in employment for this to occur. The impact of such changes on GDP impacts have been discussed in Step 2 above. In that step the full production value (and income or expenditure values) of the change in employment would be included in the change in GDP calculation. There is therefore no additional GDP impact, to that already included from including employment impacts, from this WEI.

Summary

Bringing this step together there exist a number of benefits in a transport appraisal associated with market distortions. Some of these will have a GDP impact under the constraints of §4.1. These are: safety benefits, noise and air pollutants, agglomeration and increased output in imperfectly competitive markets. Labour market wider impacts have already been in included in Step 2. Of these the agglomeration benefits and the benefits from increased output in imperfectly competitive markets can be added to the transport user benefits to give a fuller estimate of the GDP impacts. Further research would be required to identify the GDP contributions of the changes in safety, noise and air pollutants.

Carbon impacts would affect GDP if the valuations were based on an impact pathway approach, however, with a legal commitment to reduce carbon impacts and the use of marginal abatement costs for valuation, the impact of increasing greenhouse gases is to divert resources away from some sectors to sectors that deliver carbon abatement. Under the assumption of equal marginal value of resources in all sectors of the economy then this has no GDP impact. Understanding the impact further is a matter for further research. The expenditure diverted would be the PVB value of the carbon in the transport appraisal.

4.6 Step 5: treatment of land value uplift

In this step we remove the constraint of a perfectly elastic land market. In such a market, land prices would not change following a transport project. In reality, we expect there to be some movement in land values and there is a significant evidence base that demonstrates that. These changes in land values would represent a capitalisation of all 'spatial' elements of the PVB in the land market. This would include a capitalisation of business user benefits, non-work user benefits, some safety benefits and some environmental benefits and some wider economic impacts (e.g. agglomeration benefits).

Chapter 2 set out that the increased land values themselves do not form part of GDP, but the increased rents (net of import costs) that would flow from higher land values would. For owner occupied properties these rents are imputed. This therefore provides a good argument for the inclusion of increases in rents stemming from land value uplift into the GDP calculation. Two problems however present themselves in trying to do so. (1) How do transport project benefits capitalise into land values? Is it a 1:1 ratio or is it something else? (2) How do changes in property values manifest themselves into changes in rents? Can a straight rent to price ratio be applied?

Our view on this is that these are empirical questions, as theory is ambiguous on the matter. On the first question the most basic economic model shows that the capitalisation of transport benefits into the land market is a function of the elasticity of the supply of land. If land is perfectly elastic, then there will be no uplift in land values (as in our constraint in §4.1). If the supply of land is inelastic then all user benefits will be capitalised, and if it is somewhere in between then there will be partial capitalisation. Within cities economic theory goes further and suggests the inter-relationship between plot size, price and substitutability between housing and other goods in the economy mean

that transport project benefits may exceed, be equal to, or be less than aggregate land rent changes (Arnott and Stiglitz, 1981, Mohring, 1993). Empirically, work by Nellthorp et al. (2019 p132) estimating the impact of transport accessibility on residential value uplift found, when applied to the Northern Powerhouse Rail project (NPR), that residential value uplift was likely substantially lower than the corresponding user benefits.[42] In contrast ex post work by Grimes and Liang (2010) on the Auckland Harbour Bridge suggest that the ex ante benefits have been more than fully capitalised ex post into the land market. The, authors, though do attribute the differences between the ex post and ex ante measurements to the narrowness of the ex ante CBA, at least in part. The ex ante CBA assumed fixed land uses, whereas in reality the Harbour Bridge led to significant land use change on the North Shore. Our view therefore is that any model that links transport user benefits to land value uplift for use in GDP calculations should be based on GB specific empirical evidence and not theory. Several models already exist, such as that developed by Nellthorp et al. (2019) for TfN.

On the second question, the relationship between changes in property values and changes in rents. Chapter 2 sets out some of the potential issues here. This relationship has also been studied in the real estate literature. This is both in terms of the heterogeneity in rents and land values (see e.g. Clark and Lomax (2020)), and also in terms of growth in rents following growth in property prices (see e.g. Rambaccussing (2021)). Potentially models based on these empirical observations could be utilised, or a new model developed. However, given the interest is on changes in GDP, and the ONS uses a model for imputed rents for making its GDP estimates, then this ONS model or a derivative of it is likely to be the most appropriate tool to use to estimate changes in rents.

It is important to recognise that land value uplift and associated rent increases occur with both business and non-work user benefits. Work and freight related benefits would be associated with commercial rents, and non-work benefits would be associated with household rents. Some commercial rents may also be associated with non-work user benefits, where for example customers travel to the premises (e.g. retail). Changes in GDP are a measure of changes in final goods. Housing is a final good, but commercial properties are intermediate goods and are part of the production of final goods. Thus changes in household rents change GDP, but changes in commercial rents do not. Including them in addition to the productivity benefits from the transport improvement would double count. This can be seen with an example. If the supply of land is perfectly elastic and with constant returns in the goods market then a transport cost reduction will be passed fully through into the goods market. The benefits of the transport improvement are therefore taken entirely by consumers of the goods produced whose prices have reduced. If, however, the supply of land is elastic, then this will give rise to a rising marginal cost curve, as per Figure 3-1. This will crowd out some of the increase in demand for goods as prices of final goods will not fall as much, vis a vis a perfectly elastic supply of land. Land rents will also rise. The transport user benefits are therefore shared between the consumers of goods, and landlords who receive higher rents. As can be seen in this situation it would be inappropriate to add the increase in land rents to the transport business user benefits, as it would double count the GDP impact.

The Dependent Development wider impact in TAG also deserves a specific mention. The underlying concept to Dependent Development is that the development occurs on a particular parcel of land and is additional. That is it would not happen without the transport project. There is a specific

[42] They estimated residential property uplift of £6.2 billion. This is compares to a project with a capital value of almost £40 billion and a BCR in the region of 2.0. The latter data was not presented in their report.

treatment in TAG for this type of Dependent Development, which has implications for its treatment when using the welfare analysis to estimate a change in GDP. This is detailed in Box 2.

BOX 4-3: GDP CHANGES AND TAG DEPENDENT DEVELOPMENTS

TREATMENT IN TAG

The Dependent Development wider impact in TAG utilises the anticipated land value uplift (LVU) associated with a development site in the cost benefit analysis instead of the user benefits of the development traffic. Thus, if a new station leads to the development of 300 new houses, and these houses are considered additional at the national level, then the user benefits from the residents of the new houses are excluded from the welfare analysis, and the land value uplift associated with the development are included instead. Similarly, if a new station leads to the development of an office block, which would be additional at the national level, then the user benefits associated with any development traffic to/from the office block would be excluded and the LVU of the land the office block is built on is used instead.

TAG adopts this approach as it captures the social surplus from an expansion in land supply (when there is market failure in the supply of land), without double counting user benefits (which would also appear in the LVU). This social value of increasing the supply of land would fall to landlords (and homeowners) as increased rents.

In practice the Dependent Development guidance in TAG is typically only applied to a change in use (e.g. agricultural to residential). Thus, lookup values on land values in different uses in different parts of the country, as published by the Department for Levelling Up, Housing and Communities, are usually utilised. This also avoids the need to estimate the before and after prices for land, houses, offices and their development costs. If before and after property prices were used, then the development costs would need subtracting from the differences in before and after property prices to obtain the LVU.

GDP IMPACT OF RESIDENTIAL DEPENDENT DEVELOPMENTS

To apply a GDP lens to a residential Dependent Development analysis the first thing to note is that as a construct of the TAG guidance there are no user benefits from the development traffic in the welfare analysis. We know from earlier discussions that non-work user benefits do not directly influence GDP, but that work/business related user benefits have a GDP impact. It would therefore be necessary to estimate the work related user benefits for the development site as part of a GDP calculation.

Secondly, the transport project via several different mechanisms is expected to lead to LVU. This LVU is itself a change in asset value. It should not therefore be included in the GDP metric. However, the change in residential rents (including imputed rents for homeowners) that might be expected from LVU should be included. This is as per the general treatment of changes in residential rents as discussed in the main body of the report.

Thirdly, the premise of Dependent Development is that the investment is additional (see also section 4.9). That is it would not occur anywhere in the nation without the transport project. This means that the Gross Capital Formation of the construction of the houses and supporting infrastructure is additional and not displaced. It should therefore also be included in a GDP

calculation. These are the development costs (predominantly construction) adjusted for any import/export leakage, not the LVU.

GDP IMPACT OF COMMERCIAL DEPENDENT DEVELOPMENTS

For a commercial development the situation is similar. There is a need to estimate the business/work user benefits for the development traffic and include the development costs net of imports (see Section 4.8) (primarily construction costs). The difference with the residential analysis is that changes in commercial rents would not be included. Commercial rents are payment for intermediate goods, whilst GDP is a value of final goods. The value of the increase in production of final goods associated with the development site is captured by the business user benefits plus the increase in Gross Capital Formation.

In summary, there are good grounds to include estimates of changes in residential rents from land value uplift driven by all spatial aspects of the PVB (user benefits, local safety and environmental benefits), net of the counterfactual rent effect, when converting a TAG transport appraisal to an estimate of a change in GDP. However, we would caution against the application of an across the board factor converting user benefits to 'rents' without further empirical research on the capitalisation of transport benefits into land values, and an understanding of how the ONS model of imputed rents operates. Changes in commercial rents would not be additional to user benefits, as they are payments for an intermediate good (akin to payments by businesses for transport). A TAG Dependent Development appraisal where the development is additional at the national level would also include the development costs net of imports (not the LVU) as part of Gross Capital Formation in the GDP estimate.

4.7 Step 6: General equilibrium effects

General equilibrium effects are a catch all phrase that we have been using to describe how the economy adjusts following a transport project to channel economic activity into the most productive activities, whilst reflecting constraints within the economy (e.g. labour supply, and supply of other resources). By allowing general equilibrium effects into the analysis we are also allowing resources to have different GDP values in different sectors. Both positive and negative general equilibrium effects can occur. We discuss each in turn, and the circumstances that can lead to them.

Following a productivity improvement, and subject to sufficient resources being available in the supply chain (see discussions in Chapter 2), these general equilibrium effects would lead to an increase in output (and GDP) beyond that we might have expected under constant returns throughout the economy. We would expect these benefits to be occurring in the transport using sectors of the economy and their respective forward and backward linkages. They occur for amongst other reasons due to the presence of internal economies of scale, which the transport improvement now allows businesses to exploit.

In terms of the potential size of general equilibrium effects we can look to the Type 1 output multipliers associated with the input output tables produced by the ONS. Type I output multipliers capture direct and indirect effects of an increase in £1 of final demand. These multipliers range from

1.0 to 2.6[43] with an industry average of 1.7[44]. The implication is that an increase in demand of £1, would for the average industry create an additional £1.70 of economic activity in the supply chain. The ONS do not calculate a Type II multiplier. Such a multiplier would typically be around 0.5 higher and calculate the induced demand effect of the new workers in the industry affected and the supply chain having more income to spend. These multipliers should be viewed as an absolute maximum, as the additional economic benefit can only be realised if there are sufficient resources in the economy to create that output, and in an economy like the UK that is unlikely.

In reality, it will be constrained to the available resources, of which one of the most important is labour supply. If labour supply is fixed then, effectively, we are just moving economic activity between industries as workers move from one industry to another (as production shifts between industries). If workers cannot move between industries, then that imposes a further constraint on the economy. The impact on GDP will be determined by the relative productive capabilities of the industries and their supply chains between which economic activity shifts. As an example of the impact of these constraints, the general equilibrium effect of HS2 in the PwC S-CGE model was estimated to be zero. That is the ratio of the GDP estimate from the business user benefits and the agglomeration benefits to the final modelled GDP impact was 1.0.[45] This is substantially different from the Type I multiplier cited above. Quoting from the peer review report:

> *For example, in relation to Network S3 (the full HS2 Phase 2b Western Leg Network) in 2051:*
>
> - *The change in employment (actually hours worked) is -0.105% of GDP*
> - *The change in the capital stock is 0.180% of GDP.*
> - *PWC advise that factor shares for the change in GDP are 62%/38% respectively (though we have not seen that data), implying a change in total factor inputs of 0.003%.*
> - *User benefits plus both types of agglomeration shocks are 0.065% of GDP.*
> - *So the total change in effective factor inputs is 0.068%.*
> - *The change in GDP that emerges from the model is also 0.068%, implying a 'multiplier' of 1.00 – in 2051.*
>
> *The main explanation for this unexpectedly low result for the implied multiplier seems to be the fall in total employment coupled with the relatively high labour intensity and high value of marginal product of labour in the industries that are modelled as receiving most of the direct user benefits, namely businesses that use rail for business travel.*
>
> Source: Stroombergen and Laird (2022 p7)

[43] UK Input-output analytical tables, product by product 2019 edition (ONS,2023). https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesdetailed

[44] This is an unweighted average for the UK economy. That is not weighted by the size of the industry in UK.

[45] Additional GDP in the PwC model came from bringing private sector investments forward.

General equilibrium effects will not always be positive. In Chapter 2, example 2b, we illustrated that a very constrained economy may in fact crowd out some of the productivity improvements from a transport project. Effectively, this implies that general equilibrium effects are negative.

General equilibrium effects may also be negative if expenditure (and production) is forced into less 'productive' sectors of the economy. Primarily this comes about as the transport project increases output of low productivity industries. For example, projects that favour tourism may lead to an increase in hospitality industries which are typically low productive sectors, displacing economic activity from higher value sectors. Alternatively, the economy may be less productive if economic activity is displaced into carbon abatement industries (to counteract the impact of producing more carbon) or into industries that form part of the transport sector (via increased expenditure on transport).

Once the assumption of constant returns (and switching resources between sectors has no GDP effect) is relaxed, and an economy is considered constrained as the UK is, then it becomes difficult in the absence of a general equilibrium model to give guidance as to the likely scale of the additional GDP that general equilibrium effects may generate, or even the situations where the general equilibrium effects might be negative. If the Department wishes to derive a multiplier for general equilibrium effects, to go from a transport appraisal to a fuller GDP analysis, it will likely need to consider commissioning research using S-CGE models in which a variety of transport projects can be tested. See for example the Norwegian PINGO model application to nine different transport projects where a welfare multiplier has been calculated as an example as to what could be done, though in a GDP context (Hansen and Johansen, 2017).

4.8 Step 7: Open economy

Up until now we have taken it that all the economic impacts are contained within the UK. The economy is closed. In reality it is open. As discussed in Chapter 2 this will likely create some GDP leakage via imports. The example given was importing materials for project construction. Here the GDP increases at less than the project cost (the GFC increases the same but GDP then required deducting imports), that is the GDP increase is less than the project cost.

Similar arguments are also applicable to the benefits. We see three different scenarios:

- If the project benefits an average sector (from import/export) perspective then no adjustment to the GDP estimate from the transport CBA would be needed. In this instance the impact on imports/exports will be similar and the balance of trade will not be affected.
- If the transport project benefits export intensive sectors, then the balance of trade will improve and additional GDP impacts for the UK, to those captured via the transport appraisal, would need to be included. Exchange rate changes would of course crowd out some of these additional GDP impacts.
- If the transport project benefits import intensive sectors, then the balance of trade will worsen. This will dampen the GDP impacts, and the GDP estimate from the transport appraisal would need to be reduced by a factor. Again, exchange rate movements would 'crowd out' some of these negative impacts on GDP.

Whether a transport project impacts on import intensive or export intensive sectors will likely be hard to determine for the 'average' transport appraisal. Looking to the national accounts, it does however appear that road transport is more associated with import activities, whilst ports and

airports are more associated with export activities. Likely export orientated firms are located near to ports and airports, whilst road transport is used to distribute imported goods to households and firms that serve local markets.

The implication of this is that road projects would have more muted effects than might be anticipated from the transport appraisal benefits, but ports and airport projects would likely have a bigger impact on GDP than the transport appraisal would suggest. 'City' projects associated with commuter behaviour and daily interactions would likely be unaffected by whether the economy is open or closed.

In the near term rather than generalise when a transport project might reduce import-intensity, it is recommended that consideration is given to potential import leakage in the narrative and modelling for a transport project. In the longer term consideration to modelling how different transport projects may affect imports and exports could be considered, and whether some simple rules could be developed on the back of that.

4.9 Step 8: Government financing of the transport project

How government raises funds to finance the public sector and public sector projects has both welfare[46] and GDP implications. Whether this raising of funds by government is material to the appraisal depends on what question the appraisal is being asked to consider. How big should the government's budget be? Or how big should the Department's budget be? Or, how best to spend either of those budgets?

In TAG the benefit cost ratio is calculated with respect to the Department for Transport's budget (not the government's budget nor the resource cost of the project). The Department's budget is the scarce resource and by implication is fully spent. This interpretation leads to a particular counterfactual position: if the project does not go ahead then an alternative project, at the margin of the Department's portfolio of projects, would go ahead instead. Implicitly therefore:

1. The GDP impact of the transport project is not affected by the manner that the government finances/funds the project, as the government's budget is unchanged. Chapter 2 contains a discussion of the GDP implications of some different financing approaches.
2. Private sector induced investment, from the government funded project, does not generate additional GDP. This is on the basis that in the counterfactual to the project, an alternative project funded by the government would go ahead, which would induce similar levels of investment.

Of course, alternative counterfactual positions could be considered where the government's budget is either not assumed fixed or could be spent in alternative ways. For example: funding education instead of transport, or funding a transport capital and revenue project (e.g. building and subsidising the operation of a rail line) versus building a purely capital transport project such as a road. Additionally, even with a fixed budget different levels of induced private sector investment could be considered. How we define the counterfactuals becomes very important in understanding both the GDP and welfare impacts of the transport project. This can be illustrated by drawing from the recent

[46] The marginal cost of public funds captures the welfare impact of raising taxes to fund the marginal public sector project.

HS2 work. Here the rational expectations model, which drove induced private investment, used in the PwC HS2 model gave an uplift in GDP of 30%. What was the counterfactual here? It was one in which the funding for HS2 effectively evaporated, neither funding an alternative transport project, nor being returned to tax payers. I

Clearly total GDP impact from a base year with no investment to one with investment will depend on assumptions regarding how the project would be financed, what the government funding is spent on (e.g. in the construction sector or elswehere), and the how much private sector investment will induced by the project.

For the majority of transport appraisals we are effectively comparing different transport investment counterfactuals. In this situation there would be no additional GDP impact arising from government financing options. This is probably sufficient for all projects of the scale that the proposed 'CBA Approach' to measuring changes in GDP would be applied to.

If there was a need to explore the ramifications of the different options for government budgets (and financing) then it would likely be necessary to build a general equilibrium model to explore them. Here the construction sector and taxation system can be explicitly represented. In such modelling there would also be a need to ensure that the CBA reflected the same scenario as the GDP impacts. The marginal cost of public funds is relevant to the debate on the size of the government budget in a social welfare sense. Such modelling could also consider the different levels of induced private sector investment in the different counterfactuals. Here again care in the counterfactual definitions is needed to ensure like for like comparisons.

4.10 Further Discussion

Relative to TASM's initial mapping GDP and welfare impacts, our analysis and conclusions are very similar. There are slight differences in that we have extended our analysis by separating the transport market from the final goods market, and extending the analysis over all the impacts that feature in a transport appraisal. Conceptually, we find it useful to think of resources being freed up by a transport improvement, than thinking of all welfare analysis as either income, expenditure or production

The DfT posed a number of specific questions:

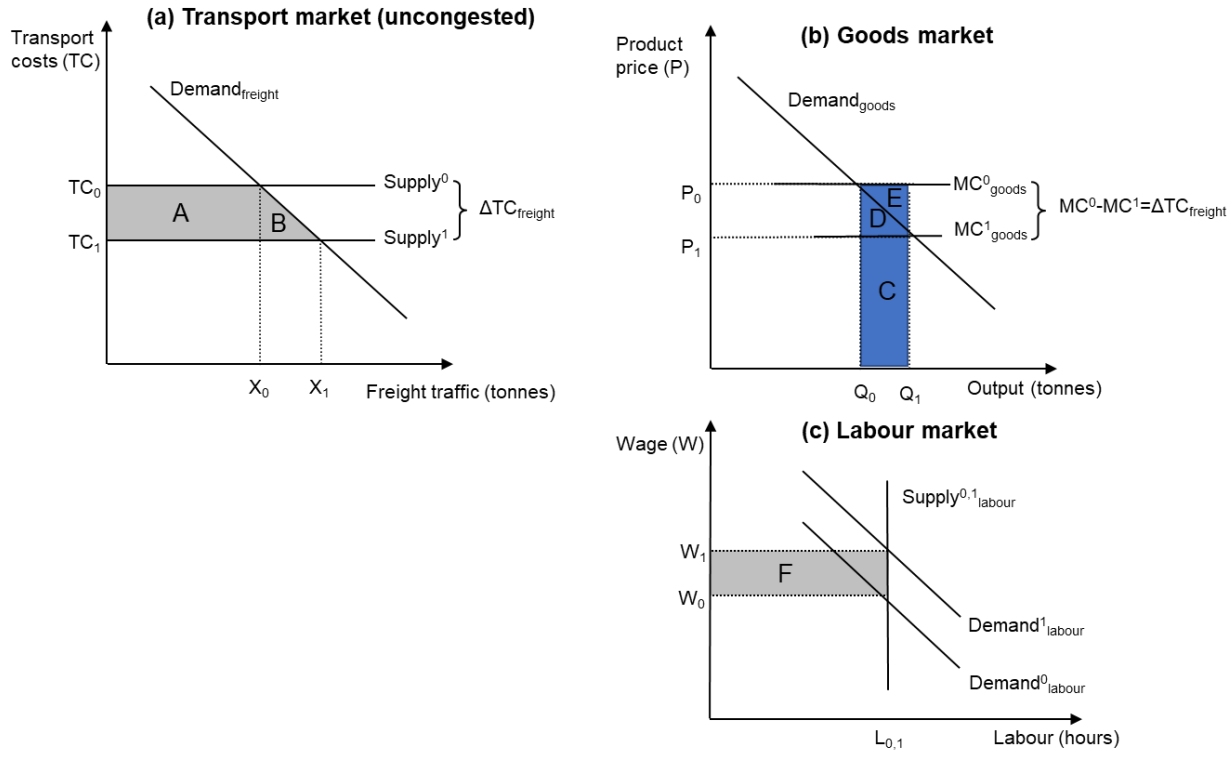
a. Given the three standard approaches to measuring GDP in the national accounts, which approach(es) can be most easily and readily applied to transport appraisal?

Transport appraisal measures the economic benefit of the transport project in welfare terms. The full economic measure consists of changes in consumer, producer and government surpluses, all of which are calculated in the transport market, plus changes in externalities and wider economic benefits. These do not readily align with any particular GDP measurement, of changes in value of final goods produced. Changes in consumer surplus in the transport market can be thought of as real income gains, but are not the 'income' measure used in national accounts as one of the methods for measuring GDP. The GDP income approach, as discussed in Chapter 2, utilises changes in gross operating surpluses to firms in the final product markets (not in intermediate markets such as transport), plus changes in compensation to employees. Also, there is the advantage of using multiple GDP measurements to both (a) elucidate key effects, such as change in imports (expenditure approach) or change in intermediate production (production approach) or change in GVA (income or production approach) and (b) validate estimates provided by any one measure.

We illustrate this difference below for a hypothetical transport project, similar to Mohring's Scenario C in which labour supply is inelastic (see Table 3-1) but with only one final good. Here following a transport improvement there is an expansion in output, whilst workers hours remain constant, and there is no change in the operating surplus of the firms producing the final goods. The change in consumer surplus is measured in the transport market is A+B. This cost reduction is passed through to the final goods market with no crowding out. For simplicity, using the Laspeyres measure of GDP change, extra output is produced given by Areas C+D+E. This would be the Production approach to measuring GDP. All this output is consumed, and as it is a single good economy, then using the Expenditure approach to measuring GDP, the change in GDP is therefore also given by Areas C+D+E. The productivity improvement leads to real wages rising, see Chapter 2 and Mohring for a discussion of the mechanisms, and using the income approach to measuring GDP gives the change in GDP as Area F. There is no operating surplus by firms making final goods. Area F is equivalent to Areas C+D+E. We therefore see that the change in transport consumer surplus is not equivalent to any particular approach to measuring GDP.

When building a model of changes in GDP from a transport CBA, it is therefore important to consider each of the CBA's components individually and determine whether or not these surpluses themselves lead to changes in GDP.

FIGURE 4-1: MEASUREMENT APPROACHES TO GDP FOLLOWING A TRANSPORT IMPROVEMENT



b. While the level of GDP at a given time will differ from the total economic surplus in a market, the PwC report linked above argues that changes in GDP and economic surpluses can be equivalent under certain conditions. This is contrary to the worked example given in Button (2010, pp. 385-388). If this difference cannot be reconciled, which framework is correct and why?

The PwC analysis is constrained, though the constraints are not made explicit. The conditions for equivalence between a transport CBA and a change in GDP are as follows:

1. Zero change in transport providers producers surplus and zero change in indirect taxation receipts by government
2. No change in hours worked
3. Zero non-work user benefits
4. Perfect competition (no market frictions)
    - No externalities
    - No wider economic impacts
5. Perfectly elastic supply of land in land market
6. Constant returns to scale outside the transport sector (in particular that switching resources between sectors has no GDP effect)
7. Closed economy (i.e. no imports/exports)
8. The government budget (fiscal position) is fixed

The Button example relaxes the fourth constraint, that of perfect competition, and shows a lack of equivalence between the CBA and the GDP analysis in that circumstance. Thus the PwC and Button cases do not describe the same circumstance.

c. To what extent might significant growth impacts arise as an indirect consequence of 'non-growth' direct impacts, such as non-business time savings or urban realm improvements stimulating inward investment and economic prosperity?
d. Might time savings from non-business trips be invested in other activities which generate GDP; and if so how material might this impact be and how could we quantify it?

Addressing questions (c) and (d) jointly.

A key impact of non-business user benefits is the impact on the work/leisure decision, affecting labour supply, and the choice of where to work and live. The latter can impact the economy via agglomeration benefits or a move to more/less productive jobs. The modelling of wider economic impacts and land use change modelling will be essential to capture these employment impacts, for projects where they are expected to be significant. Employment impacts can be difficult to model, and there are a number of alternative viewpoints on the ability of the economy to create employment opportunities following a transport improvement – see Box 4-2 for a rehearsal of these employment models.

Non-work user benefits also change the attractiveness of destinations. Invariably these destinations are businesses, or in the case of the natural environment (e.g. National Parks) may have businesses associated with them that for example serve the visitors. Effectively output is being switched from one expenditure item (or production activity) to another. Under constant returns to scale this will not have any additional GDP impact, beyond the productivity impact.

We would expect transport projects to induce investment. However, in the context of a transport appraisal in which the government fiscal position is fixed, and all potential projects being considered by the government, would induce investment, then it seems difficult to argue that the GDP private sector induced investment is additional against the counterfactual. Possibly one circumstance where it might be, would be where the project stimulates investment in an area subject to market failures: agglomeration benefits, FDI, or even high levels of unemployment.

With respect to urban realm improvements. Urban realm has both a movement benefit and place benefit. Arguably transport appraisal can capture the movement aspect, but not the place aspect. Alternative approaches would be required, such as land value uplift, to capture these place based benefits. The implication is that the transport appraisal is deficient for an urban realm project. As such a GDP change analysis based on the transport appraisal will also be deficient.

e. Non-business time savings are likely to lead to changes in property demand, and thus rents. Would this mean that a so-called 'welfare' impact ends up in GDP? If so, how can we assess this, and does existing literature tell us how important such effects are?

In principle we see this would be the case. We see a number of challenges regarding implementation surrounding the extent that transport benefits (of all types) are capitalised into land values and also how the ONS imputed rent model functions. Given that business user benefits also will give rise to higher rents, care needs to be taken to ensure that the GDP impacts of transport projects are not double counted if including changes in land rents for commercial properties. It is likely to be easier to assume a full pass through to the final goods market, and exclude changes in commercial land rents from the calculus.

f. Is it correct to treat changes in tax paid and the monetary (e.g. fare, VOC) elements of consumer surplus for all purposes (i.e. not just business) as contributing towards GDP?

Yes, but only when transport prices change (for non-work trips).

g. How can input-output modelling approaches be reconciled with S-CGE modelling, and which is preferred for estimating GDP impacts?

Input-output (I-O) tables are embedded in the Social Accounting Matrix (SAM) in an S-CGE model. I-O tables allow the calculation of multipliers, which take into account the direct effect and the indirect (supply chain) effect of additional demand for an industry (Type I multipliers). Type I multipliers range between 1.0 and 2.6 for UK industries. Thus, the supply chain effects can be large. However, this extra demand can only be supplied if resources are available or, more relevant looking forward, if resources are pulled from other production.

S-CGE models are able to constrain the 'additional' demand, though the closure rules (the constraints) are user input. A typical constraint might be an inelastic labour supply. Others would usually include the government's budget and the balance of trade. TASM has recently commissioned a 'Deep Dive' on S-CGE models, which will give a fuller treatment of their strengths, limitations and applications.

5 DISCUSSION AND CONCLUSIONS

5.1 Implications for policy and further research

Returning to the core objectives of the think piece, without further research GDP impacts of a transport project could be estimated from a transport CBA as follows:

GDP =

+ Business & freight user benefits
+ Employment impacts based on the TAG labour supply model or a wider economy model modelling changes in employment locations
+ Agglomeration
+ Increased output in imperfectly competitive markets
+ Changes in spending by non-work trips due to lower monetary travel cost resulting from a price change.

Relative to Department for Transport (2005) this only includes the additional item of changes in spending by non-work trips following changes in transport prices. As the cost benefit analysis is in market price unit of account, no adjustment to the unit of account is necessary for the GDP estimate.

This is of course only a partial measure of the change in GDP, but to expand it further would require further research to calculate:

+ GDP components of safety, noise and air pollutants (via health impacts)
  This should be reasonably easy to undertake, as there is a substantial evidence base on the Value of a Statistical Life (VoSL) and how gross output calculations for the VoSL differ from the human cost values used.

+ Rents from land value uplift for non-work user benefits only[47]
  The objectives of this research would be to identify the extent to which transport accessibility is capitalised into land values of residential property, and to identify a link between this and the change in rents that would be received. This potentially could be a substantive piece of research. However, an early literature review may identify that existing models may be fit for purpose. For example the hedonic pricing model developed by Nellthorp et al. (2019) and the ONS imputed rent model.

This 'CBA Approach' to measuring changes in GDP does make certain assumptions:

[47] Changes in commercial rents from land value uplift will double count the GDP impact from the productivity improvement if a full pass through from the transport market to the final goods market has been assumed.

1. Full pass through of transport user benefits to changes in consumer surplus in final markets (a lack of resources in the economy may crowd out some of the productivity gain, leading to higher rents on factor inputs to the production process (e.g. wages and land rents));
2. Zero real GDP effects from impacts on government accounts;
3. No general equilibrium effects (these could be both positive and negative); and
4. A closed economy (import leakage or export gain could create positive and negative effects)

At this point in time, it is not clear how large an impact these four assumptions will have. Will there be some crowding out of transport user benefits? Is there a typology of transport projects that switch resources to low value-added sectors, and conversely a typology that switch to high value-added sectors? Excluding general equilibrium effects might not therefore give a conservative estimate of the GDP change, as these effects might be negative. For example, where the economy is resource constrained, or where economic activity is diverted to lower productivity sectors. Similarly, the closed economy assumption may not always give a conservative estimate of GDP change. Is the assumption of zero real GDP impacts from changes in government accounts justifiable?

In our view research is therefore needed to investigate how robust the CBA model for estimating GDP change is to these assumptions. Such research could be staged:

i. A review of CGE and S-CGE modelling results undertaken to date of both transport projects and other government interventions. This should consider the international literature as well as work undertaken in the UK.
ii. Commissioning research using S-CGE models in which a variety of transport projects can be tested. See for example the Norwegian PINGO model application to nine different transport projects where a welfare multiplier has been calculated as an example as to what could be done, though in a GDP context (Hansen and Johansen, 2017).

The first step of this research should be undertaken before any 'CBA Approach' to GDP modelling is included into TAG.

The absence of greenhouse gas costs from this calculus also warrants a mention. By taking the view that resources have to switch to a sector that abates carbon, so as to compensate for the additional carbon a transport project will produce, and then assuming no general equilibrium effects, we effectively imply that increasing greenhouse gases will not cause any detrimental impact to GDP. Of course, it will. If an impact pathway approach (as per safety, noise and air pollutants and their impact on health) were adopted this would be explicit. This also comes back to the counterfactual position that in the counterfactual we are reducing greenhouse gases, via the carbon budgets, to lower levels. Thus, the lack of GDP impact of increasing greenhouse gases is a function of both the assumption of no general equilibrium effects and the counterfactual in which greenhouse gases will be lower (by some unspecified method). It is also our view that this issue is subject to future research, to ensure that in an era of a 'climate emergency' the CBA Approach to modelling GDP impacts includes climate impacts.

For the modelling of employment impacts TAG includes an employment model, though this model has a rather narrow theoretical basis. Given how important employment impacts are to a GDP analysis, we would recommend that a review of alternative models is undertaken with a comparison against observed employment accessibility elasticities, to confirm the appropriateness of the model. It might be that the TAG model has a narrow theoretical basis, but its results are not that different from empirical observations, or what alternative (possibly more onerous) models may give.

A GDP estimate from a TAG Dependent Development would differ from the above framework only in that the development costs net of imports (primarily construction costs) would be added to the above GDP estimate. This is justified on the basis that the development is additional at the national level. As per the above framework residential rents from the development would be included, and commercial rents excluded. As a TAG Dependent Development appraisal does not include an estimate of business user benefits for the development traffic (to avoid double counting the LVU), this needs to be estimated and added back in.

Finally, it is important to recognise that GDP impacts may arise due to dynamic effects associated with induced private sector investment, government financing options, and construction stimuli. For appraisals in which the department's budget position is fixed, these would be excluded from a transport CBA and its comparable GDP analysis. This is likely to be the position for any project to which this approach to measuring GDP impacts is applied. Larger projects where the impacts of such considerations may be warranted would require the construction of specific models, for example S-CGE models[48]. A careful definition of the Do Minimum and Do Something counterfactuals is needed, and the same counterfactuals need to be used in the cost benefit analysis as well as the GDP analysis.

[48] Note, models are unlikely to capture longer-term effects on 'dynamic efficiency'

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APPENDIX

Notes to accompany Table 2-3 and the examples that follow the table.

1. The output of the 3 industries that make up the hypothetical economy, measured in £ per week
2. The final use of the 3 products that make up the hypothetical economy, measured in £ per week
3. The potato sector, which produces potatoes and marketing (when applied)
4. The marketing sector, which produces only marketing
5. The clothing sector, which produces only clothes (via importing)
6. Final consumption of the products, in this case only of clothes with marketing (when applied) embodied in clothes
7. Exports of products, in this case only of potatoes with marketing (when applied) embodied in potatoes
8. Imports of products, in this case only of clothing (and with an imported marketing component in Examples 3 and 3a)
9. The GDP per week of the hypothetical economy, calculated using 3 approaches
10. The product "potatoes" is only produced within the potato sector, with all products exported
11. The product "marketing" is produced within the potato and marketing sector, with all products then being embodied in exports or consumption
12. The product "clothes" is only produced within the clothes sector, with all products imported
13. Wages paid to employees (before tax)
14. Gross operating surplus of the firms (before tax), not used in these examples
15. Gross Value Added (GVA)
16. Output of the sector in basic prices (ie, before product taxes are applied)
17. VAT is a major product tax, not used in these examples
18. The GDP per week of the hypothetical economy, calculated using 3 approaches