Assessing new approaches to estimating the economic impact of transport interventions using the gross value added approach

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Executive summary

The project looked at the gross value added (GVA) approach to transport appraisal as used in the UK and a similar approach used in the USA. The commonality in the approaches was an attempt to measure the gross domestic product (GDP) elasticity to population (or employment) density based on observed differences in GDP (or similar), population mass and other explanatory variables, and then infer that a future transport-induced change in the accessible population mass would result in a GDP effect consistent with these elasticities.

The models used are effectively reduced form production functions, often taking into account labour inputs, sometimes also taking into account people attributes and infrequently taking into account capital inputs.

The advantages of these models are their relative simplicity and ability to isolate a productivity effect. This provides a useful complement to the standard transport appraisal benefits as this productivity gain will not be captured within a rule-of-half based appraisal.

However the accessible population elasticities can vary depending on the specification of the model. In particular, people attributes have been shown to be an important confounding influence on productivity. It is possible that other confounding effects also exist.

The term GVA gives away the essential focus of these models: they are typically applied to derive regional effects. GVA is simply GDP measured on the production side excluding taxes and subsidies on production, and is typically more readily available than GDP at a regional level.

In line with this regional focus, a second use of these models was to attempt an estimation of the spatial redistribution of employment and output that might result from a transport intervention but these approaches, while insightful, were not robust enough to provide non-judgemental forecasts.

Other models have also been applied elsewhere to the issue, including models of an input-output nature and the more sophisticated computable general equilibrium (CGE) models, both now being used with a spatial dimension. They also have problems. The multiplier approach implicit in input-output models has proved to be too simplistic in many appraisal situations. The CGE models come with more rigour but are also more costly to build and maintain and the outcomes are not necessarily readily understandable.

In all cases, the transmission mechanism between accessibility and GDP does not appear to be widely understood. Factors identified early on included the ability to increase specialised local providers, labour pooling and information dissemination but there is a lack of research showing exactly which factor or combination of factors gives rise to any productivity gain.

This project explored the usefulness of a two-stage least squares model of accessibility effects on GDP. The model chosen has been applied in the US and was easily adapted to data readily available in New Zealand, including people attributes at the territorial authority (TA) level. The two-stage nature of the model accepted the simultaneity and reduced the endogeneity bias that can result from the estimation of access effects from datasets where population densities have evolved along with employment and general economic activity in the region (rather than having formed independently). The model enabled investigation of nearby access, which is already included as a permissible wider economic benefit add-on within the NZ Transport Agency (2013) *Economic evaluation manual* (EEM), and also connectivity to people (a 'delivery zone' effect) and/or ports that are not necessarily nearby. Having derived the model coefficients using data across the 72 TA areas of New Zealand as at 2001 and 2006, the estimated access elasticities were applied to a proposed additional Waitemata Harbour crossing (AWHC) case study to derive estimates of GDP effects of such a crossing.

The results found in the New Zealand study were generally consistent with the offshore findings, in that productivity effects were identified but difficulties existed with any inference about spatial redistribution. The model provided an alternative measure to the EEM agglomeration effects, both confirming that the order of magnitude is likely to be large but also raising the prospect that a wider connectivity not picked up in the current methodology is important. This later finding was not put to the test very well in the case study, as the AWHC appeared to do little to enhance travel to/from the outer reaches of Auckland but the model which was estimated across New Zealand did point to the existence of a 'delivery zone' productivity effect.

This additional measured effect points to the GVA model being useful when a two to three hour drive time could be reduced significantly by a transport intervention. If the time savings are over shorter distances then the current EEM agglomeration methodology is likely to capture the effects that would otherwise be picked up within a GVA model.

That said, the GVA model did extend the current EEM approach in two further ways.

First, the elasticities derived before taking into account people-effects provided a useful indicator of the potential productivity gains that could be achieved if, not only accessibility were to change, but the mix of people skills and occupations were also to adapt, either by re-sorting of employees or by the training and development of current employees. In the case of the AWHC, an extra $105 million in present value was estimated as the potential GDP gain should people attributes re-align as well as access improve.

Second, the employment information provided some insights into possible spatial redistribution of activity and warned that employment would both increase and decrease within industries and places as a result of the improved accessibility. Unfortunately this GVA model – like others – did not predict what these changes would be but the employment elasticities derived were suggestive of the effects. The model can be used to illustrate potential net effects by way of scenario testing. The key point from this scenario testing was that the regional distribution of GDP changes need not be the same as the regional distribution of productivity changes – changing employment levels are also an important component of the net GDP effect.

In the end, the GVA model derived for New Zealand requires more work before it is suitable as a black-box tool to be used to blindly provide a quick appraisal. The model could be improved by changing from a fixed threshold measurement of population density to the type of distance-weighted measure of density currently employed in the EEM. The model could also be supplemented by a spatial CGE model to provide improved measures of spatial GDP distribution. Otherwise the model does provide a useful and readily available means to explore scenarios around a major transport intervention, and could be used in the Auckland project along with the existing land use transport interaction model to explore alternative scenarios of population and employment projections.

Abstract

Current transport appraisal methods, with their focus on the economic welfare benefits and costs of transport investment, are well grounded in theory and widely used, including by the NZ Transport Agency when it comes to prioritising transport interventions in New Zealand. However these methods do not provide estimates of extra gross domestic product and extra jobs, nor the spatial distribution of any economic gains and losses. Gross value added (GVA) models have recently been applied in the United Kingdom and variations also exist in the United States. This study developed a GVA model for New Zealand using 2001 and 2006 census data from the 72 sub-national TA areas, and applied the model to a proposed additional Waitemata Harbour crossing in Auckland. Promisingly the model revealed productivity gains from local agglomeration and pointed to some productivity gains from wider connectivity as well. However the building and use of the model also revealed shortcomings with the measurement of effective densities and the ability to reach inferences about regional distribution. Nonetheless the model did prove insightful in highlighting where the benefits of another harbour crossing would likely lie.

1 Introduction

1.1 Background

Current transport appraisal methods (NZ Transport Agency 2013) focus on the economic welfare benefits and costs of transport investment. This has been accepted practice in many countries[1] on the basis that the net benefit to society can be calculated by the gains made in the transport market, through such things as lower vehicle operating costs and time saved, when markets are fully employed and competitive. Under these conditions, and ignoring externalities at present, the remaining costs to society are the marginal capital and operating costs relating to the transport intervention. This equation between transport savings and general economic benefits enables an elegant solution, whereby a relatively straightforward calculation of benefit-cost ratios (BCRs) across a wide range of transport interventions can be made, and hence projects can thus be rationally and consistently prioritised; such is the appeal of the cost-benefit analysis (CBA) framework.

While this general approach has many strengths, increasingly in recent years and especially since the onset of the global financial crisis, decision makers have been interested in the question 'What will be the impact of an investment project on the economy, that is, on gross domestic product (GDP) or the similar gross value added (GVA)?' This is particularly the case when regional benefits and costs are of interest, rather than the benefits and costs to society as a whole. Such an analysis requires disentangling how the benefits and costs in the transport market become dispersed throughout the economy.

The purpose of this project was to investigate a GVA approach to the assessment of transport projects, either as a complement to the CBA framework or as a replacement for it.

First, a little about CBA and GVA.

The CBA approach is as described above. It has been refined in recent years to recognise the prevalence of imperfect markets and capture some benefits that would occur should the economy experience imperfect competition, particularly with add-on procedures to calculate agglomeration benefits. The approach is well grounded in microeconomic theory. It requires an extensive amount of data but a body of research and practice has provided this data and an efficient and consistent manner to apply the data and relationships. The challenge is, though, how to explain these benefits, often couched in the abstract notion of consumer surplus, and how to show where the benefits and costs will fall within society. Then there is the issue: are there benefits (and disbenefits) not currently recognised that lie beyond the wider economic benefits already added to the standard CBA analysis[2].

A GVA approach measures the change in activity that occurs throughout the economy, or within regions if that is the spatial foci, rather than in just the transport market. In fact, the change in the transport market may not be measured at all, with reliance being placed instead on more aggregated measures of change in economic activity. Unlike the CBA approach, the GVA approach does not have a standard set of data,

[1] In Western countries, with exceptions in parts of the USA, this framework has been the sector standard for many years and has progressively developed (Mackie and Worsley 2013; Douglas et al 2013).

[2] SACTRA (1999, table 4.2, p70) shows that depending on the economic conditions a classical transport CBA may overestimate or underestimate the economic impact of a transport quality improvement. A consensus has developed around this conceptual position (Venables 2007; Kanemoto 2013) and national transport cost benefit guidelines have been adjusted accordingly (eg DfT 2005; NZ Transport Agency 2013).

assumptions, equations and guidelines in place to enable consistent representation of the choices confronted by the decision maker. There are many models used. Outcomes are reported in different guises, whether they are jobs or wages or GDP or GVA. The results are reported for varying periods, sometimes a snapshot at one point in the future, sometimes a present value, with various durations and discount rates used. Often sums presented as benefits turn out actually to be costs (or disbenefits if you prefer). Unlike other types of economic intervention by government (eg support for a foreign direct investment) it is very difficult to identify the final beneficiaries of a transport project at a disaggregated level. Quite apart from the difficulty in identifying the true origins and destinations of long-distance traffic, there is also the issue that surpluses are bid away through competitive processes. It is little wonder therefore that GVA type approaches have struggled to get traction in the appraisal of transport schemes; though, with the advent of new modelling methods, this is changing.

Potentially, the GVA methods have much to offer. First, decision makers are demanding a richer description of the benefits and costs[3,4]. Fortunately, there is the ability to build or retro-fit welfare, environmental externalities and some agglomeration into GVA models such as those of the computable general equilibrium (CGE) kind. The partial nature of GVA analysis can be overcome by turning to CGE models, or at least by a more widespread understanding of what the partial analysis is measuring, and what it is not measuring. Wider use will bring with it a store of research and data, and a set of guidelines to enable consistent comparison of alternatives. But this is not the case at present. And the challenge will always remain that GVA benefits are described in future terms – this requires an ability to accurately model expected economic growth (Laird et al 2014); an issue unlikely to be resolved quickly.

This project specifically considers a group of UK papers and applications that have loosely been termed the ‘GVA approach’. These papers do not provide the alternative, elegant solution to oust CBA from its revered perch in project appraisal but they do show a way forward to improving the understanding of the spatial trade-off of winners and losers, and they do provide a more widely understood way to communicate the benefits and losses to a wide group of stakeholders. They therefore have the potential to be complementary to more conventional methods.

Limiting the focus to these UK GVA approaches is a judgement made by the project team, in part to match the project objectives and in part to ensure the project remained finite. To repeat from above, there are many models that can be considered ‘GVA models’. This literature review touches upon some of these models. It is the authors’ belief that the varied demands of decision makers will ultimately be met by a range of models, the model best matched to the situation at hand being employed. For large projects this is likely to be a model of the CGE variety, and improving CGE models will be a fruitful area of future research for the NZ Transport Agency (the Transport Agency). But the UK GVA models of focus in this study are reduced form models. We explore how these models might be of use in the New Zealand transport scene.

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[3] A number of commentators have found that investment decisions are only partially, if at all, influenced by CBA results (Nilsson 1991; Odeck 1996, 2010; Nyborg 1998; Eliasson and Lundberg 2012; Laird et al 2012). While economists typically view CBA results in a positive way, spatial planners and transport professionals are more sceptical about the role CBA should play in appraisal decision-making (Mouter et al 2013).

[4] The City Deal (HM Government 2012) has created a planning context in which decisions on transport investments have been devolved to city regions and has created an institutional environment in which economic growth has become a key indicator of worth. As a consequence city regions in England are now prioritising transport investments to maximise gross value added (for example Transport Committee (UK) 2011; Sheffield City Region Local Enterprise Partnership 2013; LCR 2012, p13).

1.2 Report objectives and structure

The key objectives of this study were to:

- set out the theoretical base of recent methods used in the UK for GVA modelling changes
- develop a similar GVA modelling methodology applicable to New Zealand, using New Zealand data
- determine the relationship between GVA benefits and conventional transport welfare benefits
- by using a case study, show how the GVA methodology can be applied.

The literature review in chapters 2 to 6 forms the first deliverable of the study setting the scene for the later work and specifically addressing the first objective described above. This is achieved by describing in chapter 2 what GVA is and how it varies by industry in New Zealand. We also briefly describe some of the GVA approaches to investment prioritisation in use in the UK. In chapter 3 we review the economic channels by which we would expect transport to influence both the size of the economy but also the spatial location of economic activity. In chapter 4 we introduce different methods for modelling how transport affects the size of an economy, before focusing on the wage equation method for assessing GVA gains. We then compare whether different methods of modelling transport and the economy lead to different GVA results. In chapter 5 we discuss some of the differences between the GVA approach and the CBA approach. To conclude the first phase of the project, in chapter 6 we present our conclusions and next steps. These next steps are taken up in chapters 7 to 9, where a GVA model is estimated for New Zealand (chapter 7), a case study is applied (chapter 8) and the results and difficulties with the model are discussed (chapter 9). Some concluding comments follow in chapter 10. Appendices contain details of key background papers (appendix A), the fitting of the GVA model in New Zealand (appendix B) and a glossary of terms and abbreviations used in this report (appendix C).

2 GVA and the GVA approach

- Change in GVA is very highly correlated with change in GDP, but change in GDP is only weakly correlated with changes in wages.
- Institutional change in the UK has led to studies bringing attention to the GVA impacts of transport.
- The KPMG (2010a) and Spatial Economics Research Centre (SERC) (Overman et al 2009) studies focus on the wage rate impact when commuting times are reduced between major centres.
- The GVA approach in entirety is three steps: building a GVA model; forming GVA forecasts; and applying these forecasts to provide project priority.

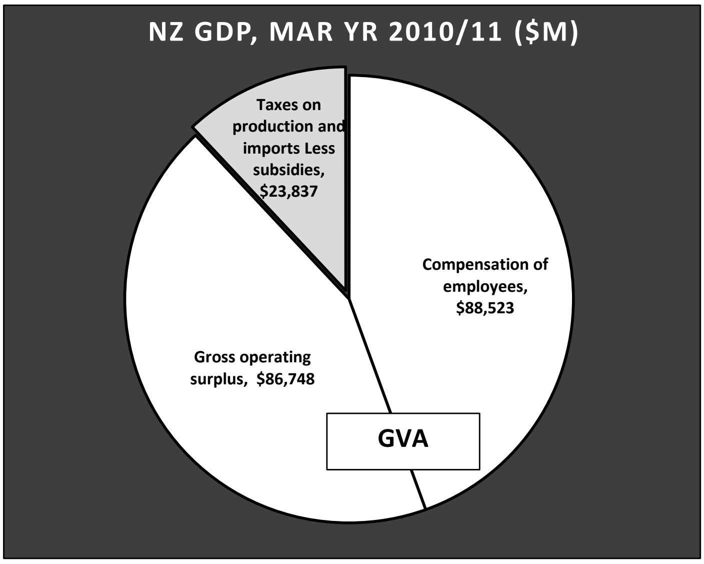
2.1 Gross value added (GVA)

GVA is GDP excluding taxes on production and export net of subsidies. The goods and service tax (GST) is the major component of taxes on production in New Zealand. GVA consists of two components:

- the compensation of employees (before-income tax), and
- the gross operating surplus, being the return to land and other forms of capital, both physical and non-physical[5].

For the year ending March 2011, New Zealand GDP totalled $199,108 million, of which GVA comprised $175,271 million. This in turn made up 51% gross operating surplus and 49% compensation of employees[6]. In the UK, GVA was £1,383,082 million in the year ending December 2012, comprising 39% gross operating surplus/mixed income and 61% compensation of employees[7].

Figure 2.1 New Zealand gross value added as component of GDP for the year ending March 2011 ($million)



Source of data: Statistics NZ

[5] and, in practice, labour income reported as profits by some self-employed

[6] Including costs such as ACC and superannuation payments

[7] www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-317145

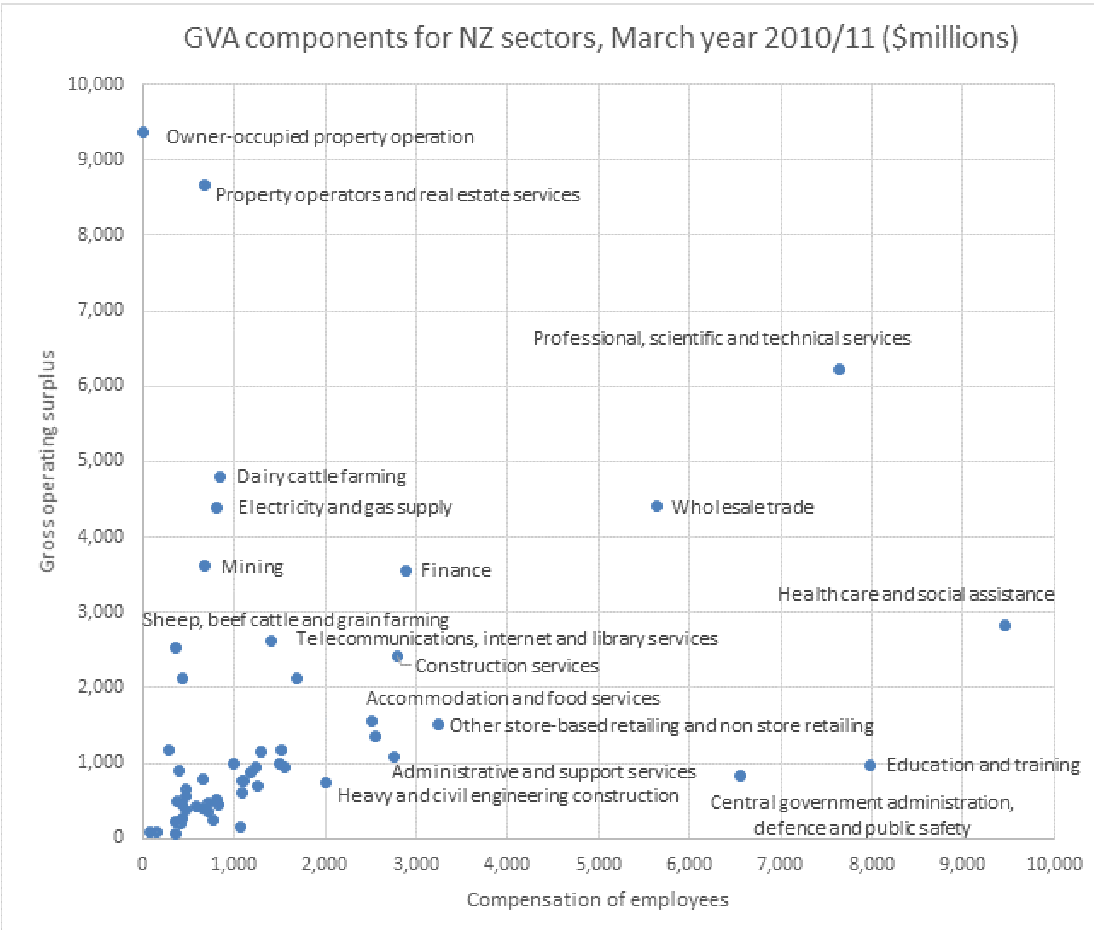
The relative significance of the two returns for different industries can be seen in figure 2.2, with land or capital intensive industries such as housing[8], property companies, farms and mines showing relatively large gross operating surpluses while labour intensive industries such as wholesale trade, health, education, government administration showing relatively large compensation of employees.

'Professional, scientific and technical services' is the largest industry in GVA terms and is also an industry showing a large and similar return to labour and capital (in dollar terms). It comprises (in order of sales):

- advertising, market research and management services
- scientific, architectural and engineering services
- computer system design and related services
- legal and accounting services
- veterinary and other professional services.

These entities combine skilled staff with office buildings and equipment, as often found in cities.

Figure 2.2 GVA components for New Zealand sectors as at year ending March 2011 ($millions)



Source of data: Statistics NZ

[8] Housing includes an inferred rental on owner-occupied housing

GDP is traditionally measured by three methods: via industry output (net of intermediate consumption), via expenditure (eg consumption, investment, net exports) and via incomes (ie the GVA method). Statistics NZ reports the same number for all three measures of GDP.

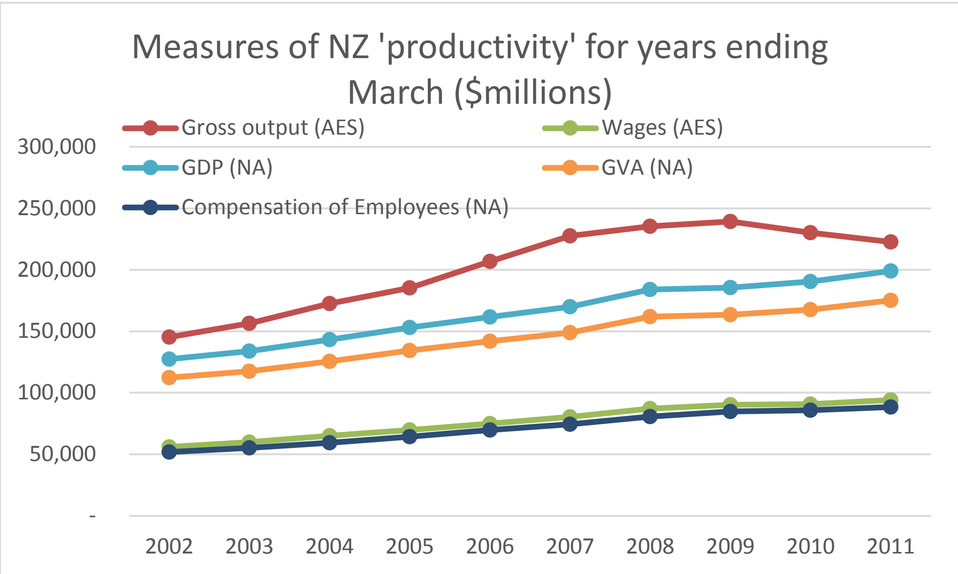
The output methodology builds the GDP measure by taking gross industry output ($396,030 million Mar 2011/12) and deducting intermediate consumption ($211,870 million) to give an industry contribution to GDP ($184,159), to which GST on production and import duties is added to derive GDP.

GVA is similar to the industry contribution to GDP measure, except that the second measure includes several indirect taxes that are excluded from GVA (such as road user charges and GST on imports).

GVA is not directly comparable with any expenditure subset of GDP. The income that GVA represents cannot be linked to any specific expenditure. All that can be said is that over half of GVA will likely be used by households for consumption, this being the major expenditure item in the economy (57% of GDP in 2010/11).

Another 'production' measure used in the literature is gross output (Mare and Graham 2009). Gross output deducts purchases of goods for resale from total revenue but, unlike GVA, does not deduct other intermediate goods purchased.

Figure 2.3 Measures used as New Zealand 'productivity'



Source of data: Statistics NZ (AES= annual enterprise survey, NA= national accounts)

Notably, annual percentage change in GVA is highly correlated with annual change in GDP (0.99). Likewise annual growth of wages, as measured from the annual enterprise survey, is highly correlated with growth of compensation of employees, as measured within the national accounts (0.95). The correlations between growth of GDP or GVA and growth of wages or compensation of employees is less (0.70–0.80), suggesting care should be taken in interpreting any wage effect as a proxy for a GDP effect.[9]

[9] The correlation in the UK between annual percentage change of GVA and annual percentage change of compensation of employees is 0.77 for the period 1998–2012

Table 2.1 Correlation matrix of annual New Zealand growth data for years ending March 2002–11

	Gross output (AES)	Wages (AES)	GDP (NA)	GVA (NA)	Compensation of employees (NA)
Gross output (AES)	1.00				
Wages (AES)	0.84	1.00			
GDP (NA)	0.49	0.81	1.00		
GVA (NA)	0.46	0.80	0.99	1.00	
Compensation of employees (NA)	0.84	0.95	0.70	0.70	1.00

Source of data: Statistics NZ (AES = annual enterprise survey, NA = national accounts)

2.2 The GVA approach

There are many transport models that could be termed GVA models. These models have a common feature in that the dependent variable is some change in economic activity, be it GDP, GVA, income or employment.

In some states in the US, an economic impact analysis is commonly used to analyse an investment impact. This would typically include an input-output analysis (eg RIMS, IMPLAN), with some multiplier effect, but can also include the more interdependent CGE model (eg REMI).

For the purposes of this research, the focus was on the UK 'GVA models'[10]. These models evolved out of an interest in regional investment. They, too, potentially, can take many forms but the form that has gained recent widespread attention is the reduced form equation of wages or GVA or employment density against economic mass; in particular, the approaches employed by KPMG and SERC to appraise the impact of high-speed rail. The regional issue is typically local growth and local funding, not necessarily the wider benefits and costs to society. The GVA approach evolved to meet this need.

The US also apply a similar model developed by Alstadt et al (2012) for middle-stage planning purposes, a model that was picked up in this project.

There are three steps to this GVA approach: a model, a forecast and then a prioritisation.

2.2.1 The model

The models have a common property, namely a focus on the correlation between GVA and accessibility to economic mass. Put aside are changes in economic output due to injuries or fatalities (safety), damage costs of crashes, carbon emissions and health.

The KPMG model (see appendix A for detail) is potentially the simplest model. In the form applied with Greengauge21, and earlier with Greater Manchester, the model takes an aggregate approach and equates sector wages to measures of surrounding economic mass (plus a residual term). There is no attempt to model the linkages between people and between firms and how they interact with land availability and the transport system. Rather, the model simply estimates the elasticity of wages to economic mass and

[10] Although it was a US model that was ultimately chosen as the basis of the New Zealand GVA model.

(independently) the elasticity of employment density to economic mass, and then applies these elasticities to derive a forecast, by region, of the impact of an effective increase in mass due to lower rail travel costs.

A model similar to Greengauge21 has also since been estimated and applied by (Heum 2013) in Norway.

The Overman et al (2009)[11] GVA model – or SERC model – developed for the Northern Way also bears some similarity to the KPMG wage model though it differs in terms of its econometric specification and in terms of the data to which it is estimated (see appendix A for detail).

Taking a different modelling tack, a more recent application (KPMG 2013) of the general approach has been developed to understand the impact of HS2 (a high-speed rail line from London to Manchester and Leeds via Birmingham). Here GVA is measured by GDP but the explanatory variables in the model are expanded to include labour input and an implied capital input. Also the density equation is made more sophisticated by including both changes in transport costs and changes in production as determinants of the relocation of labour (see appendix A for detail).

This KPMG 2013 model has attracted significant criticism (Peston 2013; Overman 2013), to which we will return in chapter 4.

These UK GVA models have presented the impact of transport investments in language (GDP and jobs) and focus (regions) that have enabled the impact – right or wrong – to be communicated easily.

2.2.2 The forecast

A forecast is required to assess the likely economic impact of a transport investment. More literally, two forecasts are required: the expected state of the economy after the investment; and the counterfactual without the investment. The difference between the two is a measure of the investment's impact.

KPMG chose to present their results as a difference at one point in time, sufficiently far ahead to be confident that the investment had been completed and its effects were being fully felt. In the two projects discussed, the forecast years were 2040 and 2037 respectively.

Overman et al (2009) presented some scenarios rather than forecasts. For example, should train travel time be reduced by 20 minutes between Leeds and Manchester then the average wage in Wakefield would increase by 0.50%, rising to 2.65% should the composition of the Wakefield economy also change.

The challenge with these forecasts are twofold: the future is unknown so uncertainty about both sets of forecasts creates large uncertainty about the impact of any investment; and a one-year snapshot does not adequately measure the cumulative benefits – and disbenefits – of any investment.

2.2.3 The prioritisation

Not a factor in the KPMG and Overman papers discussed above, but a natural extension of the process, and an extension already put into place in some instances, is to use the results of a GVA analysis to prioritise investment. The KPMG wage equation model applied in Greater Manchester was to be used as a

[11] The Overman et al (2009) paper employs two key models. This report primarily considers the chapter 5 model. Later in this report (see section 9.2.1) reference will be made to the GE model in chapter 6.

tool to prioritise projects. A similar process, albeit with different models, has also been applied in Sheffield City Region[12] and Leeds City Region[13] (see table 2.2).

Table 2.2 Examples of GVA-type approaches used for prioritisation in England

Location	Prioritisation method	The GVA model
Greater Manchester (a method also applied for Greengauge 21)	Schemes are ranked on the basis of their net impact on Greater Manchester's long-term economic potential (GVA) per £ of net cost [to Greater Manchester], subject to the programme as a whole delivering net positive returns on carbon, and a positive impact on accessibility to employment from the most deprived wards in Greater Manchester Major schemes that will be co-funded centrally from the Department of Transport need to have a CBA BCR of 2.0.	There are three models: (i) changes in earnings are related to changes in economic mass; (ii) employment density, eg in city centres, is affected by changes in accessibility to population leading to further increases in productivity (and earnings) due to agglomeration benefits; and (iii) a re-distribution of employment across the region is estimated. Changes in GVA are estimated by summing up the changes in earnings at the regional level.
Sheffield City Region	The primary objective is to maximise GVA in the Sheffield City Region (SCR) per pound of whole life cost spent from the investment fund (Sheffield City Region Investment Fund) subject to two constraints: (i) average connectivity/ accessibility to employment for the people in most need of support improves by at least the average for the whole of SCR; and (ii) the average % increase in employment connectivity/accessibility for each district across SCR is no less than 50% of the average % improvement for the whole of the SCR. Major schemes that will be co-funded centrally from the Department of Transport need to have a CBA BCR of 2.0.	The increase in GVA is calculated from output from a land-use transport interaction model, built using the DELTA software. The model forecasts changes in population and jobs by locality. The economic module has an input-output form, thus changes in jobs in the supply chain (indirect impact) and in industries that service workers (induced impact) are included along with jobs in transport using sectors of the economy (direct impact). The model explicitly accounts for re-distribution of employment and therefore economic activity. GVA is calculated from the earnings that the increased levels of employment within a region would bring plus both the changes in productivity from greater agglomeration and the direct transport cost savings of business and freight transport users.
Leeds City Region	The prioritisation criteria for the West Yorkshire Transport Fund are: • Primary objective: to maximise the increase in employment and productivity growth across West Yorkshire and York by the delivery of transport schemes. • Secondary objectives: to improve the ability of people in every West Yorkshire district and York to access jobs, with a particular focus on those living in the most deprived	The model used by the Leeds City region is known as the urban dynamic model. It uses a systems dynamic framework to simulate the interaction between transport, employment, land and people. It is calibrated to local demographic, employment and transport data. The increase in GVA is calculated in a similar way to that used in in the SCR, ie the sum of the earnings from the increased jobs plus changes in productivity from higher levels of

[12] The Sheffield City Region model is probably closest to a classical economic impact approach in its use of an input-output framework in the economic model, coupled with using transport benefits from business and freight as a measure of economic impact.

[13] The Leeds City Region GVA model has some similarities to Sheffield in the way they use the model outputs to estimate changes in GVA; however, its system dynamics approach gives it a very different functional form – with no direct representation of traded economic flows between industrial sectors.

Location	Prioritisation method	The GVA model
	communities, and to achieve a carbon neutral impact at the package level. Major schemes that will be co-funded centrally from the Department of Transport need a BCR of 2.0.	agglomeration and the direct transport cost savings of business and freight transport users.

Sources: Authors work compiled from TfGM (2012), KPMG (2010b), Laird and Mackie (2010), David Simmons Consultancy (2012), Roberts and Swanson (2011), West Yorkshire and York Local Transport Body (2013)

It can be seen in these approaches that transport schemes are ranked on their contribution to GVA per £ of investment costs subject to some minimum criteria. However the metrics of interest in the prioritisation process are the contribution to the *city region's GVA* and to the *cost to the city region*. Only scheme costs that are incurred by the city region are considered within the prioritisation – thus a scheme that is part funded by an external body (central government or the private sector) would be preferred to one that is wholly funded by the city region *ceteris paribus*. Similarly re-distributed employment/economic activity from outside the city region is treated as additional, while economic activity re-distributed within the region is treated as displaced. It is interesting to note that Greater Manchester and the Leeds and Sheffield City Regions – the focus of these GVA studies – are all neighbours and potentially their GVA gains are contingent on them being successful at displacing jobs from their neighbours. So, a study of the three regions together might not produce the same results as three separate studies.

Another interesting feature of the prioritisation process is the use of multiple criteria, especially the aim of assisting, or at least protecting, the least well-off in the regions. Estimating the impact on these groups of competing transport investments is made possible by having the spatial estimates provided by the GVA models.

3 Transport and economy linkages

- Improved transport enables greater specialisation and trade.
- The result can be higher output because transport costs previously inhibited trade.
- Production can also be re-organised to places where economies of scale can reduce production costs.
- There are various advantages to co-location such as access to larger and better matched input pools, and greater opportunity for knowledge spillover.
- The result can, but need not, be regional specialisation.
- Local conditions dictate where firms and people relocate to and from.
- Diminishing returns to agglomeration and further reductions in transport costs can in time lead to dispersion effects.
- The regional wage differentials that emerge largely reflect different people and skills rather than the place per se.
- To stimulate economic development, transport projects also require a ready labour force, willing investors and a supportive planning environment.

3.1 Introduction

Fundamentally, transport improvements enhance economic competitiveness by reducing the cost of doing business at particular locations. This can be seen historically in New Zealand by such major projects as Vogel's rail investments of the 1870s and Auckland and Tauranga harbour bridges (Grimes 2007), each project facilitating substantial nearby development. In this section we review the various linking mechanisms between improvements in accessibility due to transport infrastructure and changes in the rest of the economy outside the transport sector. We split the discussion into reorganisation effects and output effects and then discuss the spatial location aspects, which brings into the frame issues regarding the centralisation of economic activity and regional specialisations. We are not here discussing how these competitiveness effects are dealt with in appraisal.

3.2 Output effects

Lower transport costs can stimulate increases in output. Consider first an agricultural economy. Improved feeder roads both lower the cost of bringing fertiliser to the farms and lower the distribution cost of getting the product to market; there is both a supply side and a demand side effect. That is, input prices fall, delivered prices fall and output is enabled to rise. This can be a very marked effect in developing countries because transport costs can be a high proportion of delivered prices where transport infrastructure is poor. In the case of city economies, the effect is likely to be less marked but should nevertheless be there.

These output effects typically form the foundation of economic impact work based on interviews with businesses. Such work is easiest to undertake where the businesses affected by the transport infrastructure can be easily identified, as in rural areas.

Table 3.1 contains some examples from Scotland. For example, the removal of a toll on the bridge to Skye was estimated to generate a significant increase in tourism and hence employment within the tourism industry.

Table 3.1 Some regional output effects of rural transport schemes (ex ante predictions)

Scheme	GDP (regional impact)	Jobs (regional FTE impact)	Method
Berneray Causeway and Harris Ferry	+20% regional impact	+38.5 jobs	Micro surveys + multipliers
A82 upgrade (Tarbet to Fort William)	£152M regional impact of which £113M additional at the Scottish level (30-year discounted values)	+208 jobs (net +70 jobs nationally)	Micro surveys + multipliers
A9 dualling (Perth to Inverness)	£956M (30-year discounted)	Up to +4,500 jobs	Micro surveys + multipliers
Skye bridge de-tolling	£4.7M per annum	+256 jobs	Micro surveys + multipliers

Source: Laird et al (2013)

Other output effects also occur when the transport system is improved. With a transport improvement people are enabled to access employment at a lower generalised cost of travel so, assuming wages are held constant, wages net of transport costs rise and more people are willing to enter the labour market. Similarly, improved transport means that the cost incurred by the customer in accessing goods and services falls. In both situations output is enabled to rise.

One exciting prospect of transport investment is the long-term nature of the benefit. In particular, when the transport investment unlocks an inaccessible region or site (think Canary Wharf in London), or simply lowers the costs of production, there is the possibility that the transport change may trigger further development.

An important caveat to transport leading to growth is that in the favoured locations, land (and more generally all factors of production) is assumed to be available. In simple models, the land market is assumed to be competitive so that the cost changes in the transport sector, possibly amplified by economies of scale, are fully passed through into the product market. In the real world this may not be the case; accessibility improvements may pass partially into increased land rents which then mute the final output effects. Different results occur depending on the relative competitiveness of the urban land, labour and product markets.

3.3 Reorganisation effects

In a world of all round perfect competition with constant returns to scale, there is no reason why transport improvements should lead to any commercial reorganisation. The number of hairdressers in Auckland and the price of a haircut are unlikely to be influenced by the quality of the transport system. The proposition is that there are some sectors which are subject to economies of scale but which cannot be fully exploited because of transport costs. This leads to a form of imperfect competition or possibly spatial monopoly in which market areas are served from different locations. With improvements reducing transport costs, the balance between production costs and distribution costs is shifted in favour of fewer but larger lower cost production locations and a more transport intensive form of production. Mohring and Williamson (1969) use the example of steel production but the argument applies also to physical distribution and logistics, cement, oil distribution, beer and other transport intensive products. The ability to better exploit economies of scale in production also raises total factor productivity. In New Zealand, the move from many local milk processing plants to several giant plants over recent decades is an example of regional specialisation, particularly in Hawke's Bay where milk is produced but is no longer processed, an innovation closely linked to transportation costs.

The interesting question is whether a similar effect might occur in office employment or other sectors characteristic of city centre locations. If transport quality was really very poor, the limiting factor might be the ability to assemble the necessary volume of qualified labour in one place; thus firms might operate with branch offices partly to be attractive in the labour market and partly to serve the customers. A much improved transport system might then be expected to encourage centralisation so as to exploit economies of scale in office functions. For high value added activities, the likely location would be in the city centre so as to maximise accessibility to workers, visitors and customers. Notoriously, however, in car dominated societies, the natural advantage of the city centre can break down in favour of satellite locations, classically at points around the city ring road(s).

The important point about reorganisation effects is that in the pure case, economic output remains fixed but output is produced at lower cost. At the aggregate level there will be economic benefits but within that aggregate there will be gainers and losers from the economic adjustments.

Compared with output effects it is hard to identify re-organisation effects unless the transport cost changes are substantial – such as estuary crossings or fixed links to islands. Mackie and Simon (1986) find evidence of internal firm re-organisation in response to the construction of the Humber Bridge and Reference Economics et al (2011) also found scope for significant re-organisation in the provision of local authority services with the construction of four sub-sea tunnels in the Shetland Islands.

3.4 Location effects

There is a spatial dimension to both the reorganisation and output effects. Looking at it from the perspective of a region, such as Auckland, there are three categories to consider:

1 Relocation of activity within the city/region. This is likely to be the largest category. Changes in relative accessibility shift the location of production within the city/region.

2 Relocation of activity between cities/regions. Obviously this only applies for activities where there is competition between cities/regions.

3 Relocation of activity between countries.

These categories are useful for considering the different perspectives of regional and national government. For the first and third categories the perspective is essentially the same: the first is a redistribution within the area while the third is an unambiguous effect on national output. However, the second will be viewed differently by the two tiers of government and is one reason why the regional tier can be more enthusiastic than the national tier about infrastructure investment.

3.4.1 Centralisation and dispersion

It is important to understand the mechanisms that give rise to these spatial changes. These are varied and multi-faceted. First there are competition effects. Reduced transport costs in one region reduce input and output prices in that region compared with other regions allowing them to out-compete businesses located elsewhere. This is related to the output effects discussed above. Output in the benefiting regions will increase *ceteris paribus*, while output in the competing regions will fall (as their markets are now served by the benefiting region). Total factor productivity in the whole economy increases and net total output at the economy wide level also increases – but there will be both gains and losses at a regional or sub-regional level.

The story is similar with re-organisation effects. Lower transport costs allow the better exploitation of economies of scale allowing production to concentrate in fewer locations – and this of course has a spatial dimension. Output will expand for the regions where production concentrates, while it will fall elsewhere. Total factor productivity across the economy increases, but again there will be gains and losses in output at a regional/sub-regional level.

As transport infrastructure facilitates travel and trade in two directions, it typically does not benefit a single region or sub-region. All regions and sub-regions connected to the improved transport link can benefit. Where economic activity finally concentrates is a matter of some debate – as transport links facilitate trade in both directions of travel (the two-way road effect). Ultimately where economic activity concentrates is determined by underlying economic conditions and geography. However, a number of insights regarding the role of transport costs in determining the final location of economic activity can be inferred from the theoretical and empirical contributions of the new economic geography literature. This field of study indicates the existence of centripetal forces that pull mobile economic activity towards 'centres' and centrifugal forces that push mobile activity away. Classically the primary sector (agriculture, fisheries and mining) is regarded as immobile forms of production while manufacturing and services are mobile. Tourism too is often immobile. Quoting from Krugman (1998):

> *The centripetal forces listed on the left of* [table 3.2] *are the three classic Marshallian sources of external economies. A large local market creates both 'backward linkages'—sites with good access to large markets are preferred locations for the production of goods subject to economies of scale—and 'forward linkages'—a large local market supports the local production of intermediate goods, lowering costs for downstream producers. An industrial concentration supports a thick local labour market, especially for specialized skills, so that employees find it easier to find employers and vice versa. And a local concentration of economic activity may create more or less pure external economies via information spillovers. (In Marshall's words: 'The mysteries of the trade become no mystery, but are, as it were, in the air.')*
>
> *The centrifugal forces listed on the right-hand side of the table are a bit less standard, but represent a useful breakdown. Immobile factors—certainly land and natural resources, and, in an international context, people as well—militate against concentration of production, both from the supply side (some production must go to where the workers are) and from the demand side (dispersed factors create a dispersed market, and some production will have an incentive to locate close to the consumers). Concentrations of economic activity generate increased demand for local land, driving up land rents and thereby providing a disincentive for further concentration. And concentrations of activity can generate more or less pure external diseconomies such as congestion.*

Table 3.2 Forces affecting geographical concentration

Centripetal forces	Centrifugal forces
Market-size effects (linkages)	Immobile factors
Thick labour markets	Land rents
Pure external economies	Pure external diseconomies

Source: Krugman (1998)

When transport costs are very high, every region is in effect isolated from all other regions and production occurs evenly throughout the economy. In such a situation transport costs are too prohibitive to serve one region's market from another region, ie there is no inter-regional trade. A lowering in inter-regional transport costs induces the competitive and reorganisation effects discussed previously, leading to a centralisation of (mobile) economic activity.

This centralisation process is re-enforced through the centripetal forces which make the regions in which activity centralises even more competitive[14]. Lowering transport costs assists businesses located in the core who are more efficient due to the presence of large external economies of scale in the core (agglomeration economies) but also because of the market size effects and the thicker labour markets.

With lower transport costs economic activity will continue to centralise until the point that supply side constraints cause land rents, wages and diseconomies of scale[15] to become sufficiently large to make locating outside of the core region attractive. This gives rise to the bell-shaped curve of economic development (Venables 1996; Lafourcade and Thisse 2011). That is, as transport costs decrease, economic activity begins to concentrate in a few locations, but, as costs continue to fall, economic activity begins to disperse. The smaller transport costs are, the more sensitive businesses are to small regional differences in land rents and wages. This is because with low transport costs it is no longer quite so important to be located in or close to the largest market. This bell-shaped curve of economic development was observed empirically by Combes et al (2011) for the French manufacturing sector, which concentrated in a few regions up until 1930 and has since dispersed across more regions[16]. The southern migration of the US automotive manufacturing industry from its heartlands in the states of Michigan, Indiana, and Ohio (Platzer and Harrison 2009, pp28–33) also reflects this trend. Also reflecting this trend is that the peak level of concentration in US manufacturing occurred in the 1950s (Kim 1998) and since the mid-1970s the spatial concentration of manufacturing in Europe has been falling (Brülhart and Traeger 2005). At a more micro-level of analysis Strauss-Kahn and Vives (2009) found that US businesses re-locating their headquarters increasingly chose locations in medium-sized service-oriented metropolitan areas – with relatively low wages and good transport links. Dixon and Freebairn (2009) found evidence of industry spread in Australia.

Clearly all the centripetal and centrifugal forces influence the rate of agglomeration and then dispersal of economic activity. Many of these forces are common (or at least correlated) between industries within a locality/region/agglomeration; however, the influence of pure external economies varies by industry (Rosenthal and Strange 2004; Melo et al 2009). Graham (2007) found diminishing returns to agglomeration for five out of the nine sectors he analysed – the other four sectors experienced constant returns to agglomeration. Manufacturing is one of the sectors experiencing diminishing returns, while business services and banking, finance and insurance are among the sectors experiencing constant returns. The implication is that the centripetal force to agglomerate is less strong for manufacturing than it is for service sector industries that we typically find in city centres. We therefore expect manufacturing industries to disperse from an economy's core before service sector industries. This is consistent with the

[14] In the 21st century there already exists cores and peripheries to regional, national and international economies – and as we are interested in how changes in modern transport costs alter the balance between regions we do not discuss here what the literature says about where economic activity will first begin to concentrate, see eg Lafourcade and Thisse (2011)

[15] Congestion costs on the transport network but also on other networks – telecommunications, water, sewage, energy, etc.

[16] This dispersal is also known as *convergence* as regions become more similar, in an economic context, through dispersal of economic activity away from the core.

findings of Combes et al (2011). It is important to note that these effects are played out both at a regional level but also at an international level – if international trade is relatively unrestricted.

There are few examples in the literature of the modelling of the GDP impacts of transport schemes using methods that are consistent with the new economic geography concepts discussed above. Such a model requires incorporation of imperfect competition, location decisions, economies of scale and agglomeration effects and is likely to be a CGE model. A brief overview of such models is discussed in section 4.2.

3.4.2 Regional specialisation

The agglomeration and later dispersal of economic activity as transport costs fall is not the only effect that transport costs have on the location of economic activity. Falling transport costs can also lead to a change in the type of industries located in a particular region. This is because falling transport costs can lead to regional specialisation. Krugman and Venables (1996) show that, with lower transport costs and economies of scale in production, it is more efficient for regions to specialise in a particular industry/sector and trade with other regions, than it is for them to maintain a little bit of every industry.

As an example of specialisation, Krugman and Venables cite the Detroit car manufacturing cluster, the New York garment industry, and the modern high technology clusters in Silicon Valley and Route 128 as examples of such regional specialisation within the US. The 'Wall Street' financial sector is another US example. Regional specialisation can also occur at an international level – with a few financial centres serving the world market (eg London, Tokyo and New York) and the growth in manufacturing in Asia and business services/financial services in the developed economies.

Venables (2013) extends this further and sets out a framework in which (city) specialisation occurs at the task level rather than the sector level. That is, certain business functions are carried out in certain cities – thus headquarters are located in certain cities, and back office functions in other cities. Inter-city communications are essential to allow such city task specialisation to occur. In the service sector some of this communication will be purely by telecommunications, which for example facilitates the offshoring of certain tasks (Grossman and Rossi-Hansberg 2008) but other tasks will rely on both telecommunications and occasional business travel. Task specialisation is still possible here. For example recent 'near-shoring' investments in new offices have been made by international law firms in the UK, where skilled client facing legal functions are retained in London, while skilled back office legal functions are 'near-shored' to lower wage cities. For example international law firm Ashurst is opening an office in Glasgow, Scotland where the main client base is not expected to be in Scotland and 'the legal work will initially focus on matters which involve recurring activity' (Ashurst 2013). Empirical work in this field is challenging due to difficulties in obtaining sufficiently disaggregate data to identify tasks, but also in controlling for the endogeneity present between structural economic changes and changes in transport costs. Early work does however indicate that city specialisation at the task level is occurring (in addition to at the industrial sector level) and transport cost reductions have influenced that specialisation (Michaels et al 2013). It would not be too surprising if investment in inter-urban connectivity such as high-speed rail and high-speed broadband strengthened this trend.

We are not aware of any transport analyses that include task specialisation in estimating GVA impacts.

3.4.3 Productive people or productive places

It is clear from the above discussion that changing transport costs influences productivity: through output effects (essentially producing more output with fewer inputs), through re-organisation benefits and through productivity gains as a result of agglomeration and task specialisation. The spatial reorganisation of economic activity that transport therefore brings about has the corollary effect that we observe the highest levels of productivity in the largest cities. How much of this arises due to the inherent productivity of the place (through market size effects, thicker labour markets and pure external economies) and how much arises due to the most productive people in the economy clustering or sorting themselves towards (large) urban areas, the people-based or Dick Whittington effect, is an important issue. It is relevant as transport schemes can directly influence the place-based effect, but have only an indirect influence over people-based effects (eg through migration).

This issue has only been investigated recently and the empirical evidence shows that the majority of the observed spatial variations in labour productivity are due to people-based effects – that is, the way those with the highest skills and the most ability spatially sort themselves into the largest urban agglomerations (Combes et al 2008; Mion and Naticchioni 2009; D'Costa and Overman 2013; Gibbons et al 2014). For the UK; for example; Gibbons et al (2014) find that 'the contribution of individual characteristics to variation in wages is between 100 to 850 times larger than the contribution of area effects [ie place-based effects]'.

This distinction between how the influence of people and places differs in the role they play in determining the underlying observed productivity of workers in different regions has important implications when estimating the size of the agglomeration economies – as not controlling for the heterogeneity of workers means that biased estimates of agglomeration economies will be obtained (Combes et al 2008; Graham and van Dender 2011; Melo et al 2009; Overman et al 2009). In their meta-analysis Melo et al (2009) for example find that the use of panel data (to control for heterogeneity of workers) on average reduces the agglomeration elasticity by 0.03 points. Given that the mean elasticity in their dataset is 0.058 this is a quite substantial reduction. Overman et al (2009) find that the agglomeration accessibility elasticities reduce far more for train accessibility than they do for car accessibility once worker heterogeneity is taken into account.

It is relevant to note here that the agglomeration elasticities used in transport appraisal in New Zealand (Mare and Graham 2011) and the UK (Graham and Van Dender 2011) reflect place-based gains in productivity only. As such they will produce lower estimates of productivity gain than ones that allow the mix of workers to change in response to a transport investment (ie an elasticity that includes people-based effects on productivity).

3.4.4 Agglomeration assessment in Australia and New Zealand

In an Australian study, Hensher et al (2012) reports five mechanisms through which agglomeration might lead to improved productivity:

1 Closer proximity of intermediate good suppliers allows for cost savings.

2 A larger pool of labour enables finer division of labour and incentives to invest in skills development.

3 Knowledge can spill over to nearby workers and firms.

4 Resources can be shared.

5 Skill requirements can be better matched.

Picking up on the earlier work by Venables (2007), Hensher et al (2012) went on to estimate the elasticity of wages to changes in employment density amongst 14 zones and 19 sectors of the Sydney metropolitan area, and conservatively estimated elasticities ranging from -0.09 (transport, post and warehouse) to +0.29 (arts and recreation services). That is, a 10% increase in employment per square kilometre, with employment weighted by distance from each zone, produced an average 2.9% increase in wages within the arts and recreation services sector above that resulting from factors such as changes in occupation mix.

When it came to applying these estimated elasticities to a proposed Sydney rail investment, a pure agglomeration effect (due to increased density) was distinguished from a wage effect resulting from a rearrangement of employment. The former was around 16% to 23% of the latter (depending on assumptions about elasticity).

In New Zealand, Mare and Graham (2009) modelled annual firm gross output on factors of production (labour, capital, intermediates) and a measure of employment mass to estimate employment density elasticities for 15 New Zealand industry groups. These elasticities, ranging from +0.032 (agriculture, forestry and fishing) to +0.87 (finance and insurance), were similar to those estimated for the UK and were later adopted by the Transport Agency for the EEM.

3.4.5 The shifting transport demand curve

The above discussion has highlighted how transport costs induce land use change both in terms of shifting the locations of production (the bell shaped curve of economic development) and in terms of what is reproduced where (regional specialisation). Both of these land use effects stimulate inter-regional trade (above and beyond what would be expected from the reduction in transport costs alone). In transport terms this means that the transport demand curve shifts outwards. This has implications for transport CBA as the benefits of simultaneous changes in land use and transport quality cannot be evaluated within the rule-of-half framework (Neuberger 1971; Martinez and Araya 2000).

3.5 Transport and economy frictions

We have set out above the channels by which transport is expected to and has been shown to influence the broader economy. However, such a one sided discussion may create an impression that transport is the lynchpin to economic growth. Such an impression requires tempering as its role in shaping a modern economy remains the subject of debate. On the one hand there are the arguments set out in the preceding parts to this chapter, while on the other hand there is a view that while transport has undoubtedly shaped our economic geography, its role in the continued shaping of economies is more relevant to that of high growth developing nations (Krugman 2011). There is also the case that empirically our estimates of the importance of accessibility in shaping the urban agglomerations (the elasticities related to the place-based effects referred to above) may be overstated due to estimation issues (Graham and van Dender 2011). Finally economic growth is contingent on not only transport linkages but on other supply side factors: the availability of land, a workforce with suitable skills and the ability and willingness of economic actors to invest. If any of these conditions are not present transport benefits will not be wholly passed through – that is not to say that there will be no benefits but that transport cost reductions will be partially retained by the users (including businesses), and as such they may not stimulate the full reorganisation and spatial changes that we have discussed at some length. A new road in a desert will remain without traffic if there is no workforce willing to work in the desert and no business willing to invest in the desert land. Transport investment in declining regional economies may not stem that decline if there are other underlying structural weaknesses to the regional economy (eg a workforce with inappropriate skills) – as in such a situation even local businesses wanting to expand will be unable to – as a result of supply side labour constraints. Drawing from Banister's and Berechman's (2003) studies:

> *…in developed countries where there is already a well-connected transportation infrastructure network of a high quality, further investment in that infrastructure will not on its own result in economic growth. Transport infrastructure investment acts as a complement to other more important underlying conditions, which must also be met if economic development is to take place. Additional transport investment is not a necessary condition, but acts in a supporting role when other factors are at work.* (Bannister and Berechman 2003, p318)

The conditions for growth are generally viewed as economic regarding labour, investment (eg availability of finance and role and timing of the investment) and political and institutional (including supportive planning policies and institutional conditions). Successful transport projects that stimulate economic development exhibit all these characteristics: a ready labour force, willing investors and a supportive planning environment. For example a feature of the Jubilee Line underground rail line extension in London was that the Canary Wharf development that it serves was a high growth area and the object of a strong preferential planning regime through the London Docklands Development Corporation.

While seemingly obvious it also needs to be said that the driver to the economic change is the transport user benefits. Transport investment will only facilitate economic growth if the investment generates primary transport benefits which enhance accessibility now and in the future. Transport schemes that do not generate significant user benefits are unlikely to grow the economy significantly as there is no stimulus to the growth.

4 Predicting the GVA impact of transport schemes

- At the inter-regional level, transport models on the economy typically fall within three genres: spatial CGE models, multi-regional input-output models and regional production functions.
- At the intra-regional level, economic location models use either trade flows from input-output tables to predict locations, or use bid-rent location models or use utility-based location models.
- Recent innovations are to use estimates of travel cost savings as inputs into regional models.
- Also to model forms of GDP on common explanatory variables plus a measure of accessibility, including so-called GVA models in the UK.
- Models have produced a wide and at times inconsistent set of results.

4.1 Transport-economy modelling methods

There exist a large range of models that model the impacts of regional policy, including transport investment, on the economy (Vickerman 1991; Rietveld and Bruinisma 1998; Oosterhaven and Knaap 2003). Potentially all of these could be considered 'GVA' models, in the sense that they focus on changes in economic activity. This plethora of modelling methods and the rapid advances that are being made in the field gives rise to a variety of different modelling method categorisations. From the perspective of this paper, Wegener's (2011) classification is useful as it focuses specifically on the modelling of economic development in a spatial sense. Wegener identifies six modelling genres operating at two different spatial scales – the inter-regional level and the intra-regional level. At the inter-regional level he identifies three modelling genres:

- **Spatial computable general equilibrium (SCGE) models**. These models follow the ideas of new economic geography introducing economies of scale and imperfect competition to an input-output framework. They also differ from multi-regional input-output models as economic growth is endogenous to the model, and prices adjust to reflect supply side constraints that can crowd out economic growth.
- **Multi-regional input-output (MRIO) models.** These use the classic Leontif (1966) multi-regional input-output framework, where inter-industry and inter-regional trade flows are a function of technical input-output coefficients and transport costs. Models that utilise this framework will often treat final demand as exogenous (that is transport investment cannot grow the overall size of the economy), instead transport investment affects growth at a regional level (ie it affects the spatial distribution of economic growth).
- **Regional production function models.** In classic production function models the inputs are capital, labour and land. To these, other location specific factors have since been added such as infrastructure (as in Aschauer's (1989) seminal work and in Mera (1973)), and in more recent applications accessibility and other 'soft' location factors have been added. This project widened the genre to include all reduced form models whereby a production measure, be it GVA or wages or some other statistic, is modelled against a general set of explanatory variables; regional production functions form a subset of this wider genre.

At the intra-regional level Wegener (2011) also identifies three genres for modelling industry location: spatial interaction location models which take changes in trade flows from an input-output framework as an indicator of changes in industry location; bid-rent location models that have firms acting as profit maximisers choosing locations given land prices (where land prices are endogenous to the model); and utility-based location models which are similar to bid-rent models, but include multiple location factors and convert them to a utility scale, with firms choosing locations to maximise utility.

Bespoke model applications or proprietary modelling software may often mix and match different approaches meaning any particular modelling method may simply not fit into one of the identified modelling genres. Furthermore some model applications may incorporate both inter-regional and intra-regional modelling. There are also differences in the treatment of dynamics with some models taking a static analysis (MRIO, SCGE, spatial interaction and bid rent models) and others taking a dynamic approach (regional production function models and utility based location models). It is also clear that the models operate at very different spatial scales – this is implicit in Wegener's distinction between inter-regional and intra-regional location models, but even within these categories models operate at very different scales with, for example, some location models simulating the actions of individual firms through microsimulation, and others taking a much broader spatial perspective. The field is also rapidly evolving, which to a certain extent is a reflection of the difficulties associated with the state of practice in regional economic modelling. For example, the interface between the transport model and the regional economic model can introduce complications to the modelling process particularly in the treatment of personal travel (as opposed to freight costs) (Bröcker and Mercenier 2011; Tavasszy et al 2011), and this of course is an area of particular interest to transport economists.

The following section considers briefly the first two model genres, largely to provide context, and then expands in detail on the wage equation model that is a subset of 'reduced form models'. It is these wage equations and more generally the reduced form income and/or employment equations that are the focus of this report. Estimations for and applications of these wage equation models to a transport context include those by:

1 KPMG for Greater Manchester Passenger Transport Executive (GMPTE) (see table 4.2) and Greengauge (KPMG 2010a)

2 The Spatial Economics Research Centre at the London School of Economics for Northern Way (Overman et al 2009)

3 Institute for Research in Economics and Business Administration for the Norwegian Roads Administration (Heum 2013).

We then go on to ask the question as to whether the choice of the modelling method can influence the results and, if so, why.

4.2 MRIO and CGE models

Multi-regional input-output models aim to provide a picture of the industry and household interactions on economic activity; that is, the models consider not just the initial impact on regional quantities but go on to consider the ripple effect that any change may trigger within the whole economy.

Some of these model types have been applied in New Zealand to transport interventions. Auckland has a land use transport interaction (LUTI) model built using the DELTA software. DELTA uses a utility-based location model. When DELTA is used in a multi-regional capacity it uses a multi-regional input-output model to model inter-regional economic impacts, but this has not been utilised in the Auckland application.

CGE models aim to provide a more complete picture of the impacts of intervention than MRIO. CGE models consider not just the impact on demand but also on prices and, importantly, on supply side constraints. CGE models also provide outputs broken down by expenditure type, such as consumption.

A recent example is the analysis of transportation shocks by King (2012) who shows that the effect of reduced transports costs can be moderated by responses within the economy, and that effects on sectors can vary. Considering a 10% reduction in shipping costs, the modelling showed higher New Zealand export volumes and higher New Zealand consumption spending emerged but also higher inflation and more importing, reducing the net GDP impact to +0.1%. Export sectors with relatively high transport costs (eg wood and paper) increased output while dairy, with its relatively low transport cost for milk powders, experienced an output decline under some scenarios as a result of competition for inputs leading to higher input prices. The study employed the CGE model which was built by the NZ Institute of Economic Research (NZIER) using the ORANI-G CGE model design, developed at Monash University for the Australian economy and updated with New Zealand data and equations.

Infometrics (2010) used another CGE model to study the impact of the New Zealand Roads of National Significance (RoNS) projects, showing that total benefits could be 80% above user benefits if investment in other industries was to be undertaken in response to the higher expected rate of return. By way of comparison, a study by Paling (2010), employing add-on techniques to the standard CBA analysis to capture agglomeration and labour supply effects, estimated the wider economic benefits of RoNS to be 40% of the user benefits. Note these two estimates not only vary in magnitude but they measure different impacts: the CGE model picks up allocative efficiencies, namely the re-balancing of consumption choices to better match consumer preferences – there are no agglomeration effects calculated in this model and any employment impact comes through wage changes; whereas Paling picked up higher productivity arising from agglomeration and higher employment.

A general equilibrium model has been used in the UK, incorporating some of the new economic geography ideas such as imperfect competition, location decisions, economies of scale and agglomeration effects. Overman et al (2009, chapter 6) use a structural equation model and find 30-year discounted present value of £2.7 billion (2006 prices) by reducing train journey times between Leeds and Manchester by 20 minutes and a 30-year present value of GDP benefits of £7 billion by reducing train times from Leeds and Manchester to London by 40 minutes.

Some of the similarities and differences between a CGE approach and a CBA approach have been discussed by Layman (2004) and Forsyth (2011). Both models are well grounded in economic theory. Both models are data hungry. CGE models tend to be at a high level of aggregation and have typically excluded location-specific effects, but this need not be the case. Likewise, welfare gains, typically excluded, can be added to CGE models. Agglomeration effects are not handled easily but can be included. One key issue is the variety of specifications and assumptions that can make understanding and comparison challenging. Conversely, the CBA approach is only a partial analysis (that works if the economy is fully employed, fully competitive and has no economies of scale) and provides outcomes that can be difficult to quantify in real output terms which is typically the metric of interest to wider stakeholders. The suggestion of Forsyth (2011) was that both models could be employed to approach the answer from two directions, with key insights gained in developing a concordance.

4.3 Reduced form GVA models

Reduced form models come in many forms but at the heart of each model is a single equation of the form:

$$Y_t = f(X_t\, A_t,) \qquad \text{(Equation 4.1)}$$

Where Y_t is some outcome for the economy measured at time t

X_t is a set of attributes that normally shape Y_t, typically including factors of production

A_t is a measure of the variable of interest.

An early example was the output elasticity equation estimated by Aschauer (1989), where Y_t was US annual output, X_t were the factors of production, labour and capital, combined in a Cobb-Douglas function and A_t was a measure of public capital.

Examples in New Zealand include Mare and Graham (2009) estimating the elasticity of gross economic output by industry (Y_t) to employment mass (A_t), with other explanatory variables being the number of employees and the cost of capital services (the X_t).

Both equations are production functions in the sense that production output is regressed against production inputs; both equations can become regional production functions by dropping measurement back to a sub-national level.

An example of a more general reduced form model is Schiff and Small (2013), where the elasticity of international tourist arrivals to New Zealand (Y_t), along with other measures, was regressed against an Air Liberalisation Index (A_t), with other explanatory variables being foreign GDP, exchange rates, oil prices, New Zealand GDP, New Zealand terms of trade and jet fuel prices (the X_t).

The relevant form of the general equation recently applied to transport investment in the UK has the dependent variable as some measure of GVA, including in some cases wages, the accessibility variable being some measure of local population or employment density and the explanatory variables being measures typically associated with wage impacts, sometimes excluding the labour and/or capital input variables found in production functions.

Unlike MRIO and CGE models, these reduced form models, including the production model subset, do not have an explicit representation of trade flows.

4.3.1 The wage equation and what it implies

The wage equation is worth special mention, as it was a core equation used in the KPMG (2010b) and SERC (Overman et al 2009) studies. Wage equation models, in the transport context, aim to capture the outcome of changes in accessibility on the economic performance of a region/country as measured by wages.[17] As discussed in chapter 2, wages only comprise one aspect of GVA and therefore a wage equation model will only give a partial estimate of the change in GVA of a transport scheme. The wage equation models typically have the form:

$$Wage_i = f(X_i, A_i) \qquad \text{(Equation 4.2)}$$

Where i is an individual or a locality (depending on application)

X is a set of attributes about the individual/region (eg skills)

A is an accessibility measure.

These models do not attempt to replicate or capture in any way the underlying transport–economy linkages that we have discussed in chapter 3. The wage equation model therefore contains no direct link

[17] A reminder that wage equations only measure the effect on the wage level and that the change in total wages (and hence GDP) will differ depending on whether higher wages attract employment or whether, as will happen in some cases, higher wages will cause a shift in business location to a lower wage location.

between the transport outcomes (eg transport cost reductions experienced by individual firms) and the predicted economic outcome. In particular, not modelled is any change in location of employment due to some of the factors discussed in chapter 3 such as specialisation or changes in input prices such as rents and wages themselves. They are therefore very different from the CGE and MRIO models. Instead wage equation models can be viewed as explaining the spatial variation in wages – an obvious feature of which is the urban wage premium. The models can then be used to predict how the spatial variations in wages will alter should any of the independent parameters (the Xs and As in equation 4.2) alter.

This lack of a direct relationship between the transport 'shock' and the final economic outcome effectively means that the derived relationships implied in the wage equation are invariant to the transport shock – in particular that there are no supply side constraints that will prevent wages rising (falling) in response to changes in the Xs and As. It is worth examining this more closely. The discussion in section 3.4.3 on productive people and productive places identifies that the majority of the spatial variation in wages arises from differences in the quality of labour. The remainder is due to variations in the productivity of different locations. It is therefore clear that, for an improvement to deliver the full wage gain predicted by a wage equation model, the supply side of the labour market needs to be able to deliver a better quality labour force, in terms of observable attributes such as qualifications and unobservable attributes such as ability. Potentially some of these changes could be fulfilled through migration of highly skilled, high-ability workers to the area which has received the accessibility improvement. This will raise average skill levels in the locality, though obviously such migration has no impact on skill levels nationally[18] and has a detrimental effect on the areas they migrate from. Whether the local economy can therefore upskill the local workforce and whether the local workforce wants to be upskilled is fundamental to whether the full GVA gain (through increased wages) as predicted by the wage equation model will be delivered. As discussed in section 3.5 an appropriately skilled labour force is regarded as a fundamental condition for economic development. Thus if supply side frictions prevent this upskilling then only the place based productivity gain will be realised. Even if an upskilling process did occur one would expect that this would take time to occur and therefore there could be a considerable lag before the full GVA gain of the transport intervention is felt.

With respect to the three noted studies, only Overman et al (2009) distinguish between the people and place-based effects. KPMG (2010b) and Heum (2013) take it that both people-based and productivity-based effects will occur. Overman et al (2009) find that the wage elasticity to changes in accessibility reduces by about a fifth for car-based accessibility and four fifths for rail-based accessibility if people-based productivity effects are excluded[19, 20]. As noted earlier, Melo et al (2009) in their meta-analysis found that controlling for time invariant unobserved worker characteristics through fixed effects on average reduces the wage elasticity by two percentage points, while controlling for time invariant human capital reduces the elasticity by between five and six percentage points. The aforementioned Mare and Graham (2009) study could not control for people skills directly but did find that controlling for between-

[18] Unless by international immigration

[19] The car accessibility elasticity reduces from 0.084 to 0.069 and the rail accessibility elasticity decreases from 0.258 to 0.049 (Overman et al 2009, table 7 p46 and table 8 p49).

[20] As in the UK the road network is universal, while the rail network either serves an intercity function or an urban metropolitan function it is possible that the rail-based elasticity is picking up a metropolitan type effect of accessibility.

enterprise variation reduced the elasticity of output to employment density by nearly three percentage points[21].

As the accessibility of a location increases, a wage equation model including people-based effects would suggest that that location becomes increasingly like other locations with similar levels of accessibility. For the most accessible location the derived relationship is extrapolated. In the New Zealand context, the most accessible location is Auckland – thus improving accessibility in other locations effectively makes them become more and more like Auckland in terms of the sectorial composition of industries and the skills sets of workers. We have already mentioned that this would require some re-training or relocation of workers, which in itself would incur costs additional to the transport investment costs, but it also has strong implications for the industrial structure of the national economy if taken to its extreme. As the largest agglomerations in developed economies specialise in service sector industries the wage equation model implies that the economy would increasingly specialise in the service sector and manufacturing and primary sector needs would be served through world trade. How realistic this is will vary on a case-by-case basis, but one would expect some limits to the level of possible structural change. This again implies a degree of caution in interpreting the economic gain predicted by a wage equation model that includes people-based productivity effects.

It is also important to realise that a wage equation does not model migration or re-distribution of economic activity in the way that the intra-regional location models presented briefly in section 4.1 will. Furthermore wage equation models do not capture an increase in labour supply that would arise with any increase in the real wage. All the model does is explain the spatial variation in wages, and how that may alter with a change in accessibility *ceteris paribus*. A spatial variation in wages is indicative of a change in productivity and therefore the wage equation model also shows how labour productivity would be expected to vary spatially as a consequence of a transport investment.

4.3.2 Simultaneous output and employment equations

Returning to the more general equation 4.1, a variation of this model has been fitted in the US by Alstadt et al (2012)[22] Recognising that output and employment are likely to be jointly determined, these authors fitted a simultaneous model that estimates employment and output, in this case taken to be sales, and added in export revenue as a third endogenous variable, and modelled these against population and various measures of accessibility and connectivity. This model aims to reduce the heterogeneity bias around the estimates of the accessibility variables, a bias that arises because employment is likely to be endogenous.

4.3.3 Measuring accessibility

The three cited studies use different accessibility measures, though all are similar in that they attempt to capture the effective size of the market. Heum (2013) uses the size of the regional labour market defined by travel time, while KPMG (2010b) estimates the number of people[23] willing to travel to a particular location as an indicator of market size – this is based on an observed trip length distribution. Overman et

[21] It should be noted that the 'within enterprise' estimates of elasticity were not chosen as the preferred estimates due to fears of downward bias and instead elasticities were derived from equations that controlled for variation between 'industry sector per area unit'.

[22] This model subsequently became the basis of the New Zealand GVA model, for reasons discussed in chapter 7.

[23] People were measured as working age population willing to travel by train to a destination (as a measure of potential labour force) and people employed in a destination (as a measure of business market size).

al (2009) use a more traditional accessibility measure based on equation 4.3. Here the accessibility of an area *i* is the sum of employment in all other areas *j* weighted by a decay function in travel costs[24] (*GTC*). Essentially these different accessibility measures all do one thing – they capture the size of the urban area surrounding any particular locality. Of the three, the accessibility measure used by Heum (size of regional labour market defined by travel time) is the coarsest and is the most difficult to utilise in predictive capacity, due to issues of linked/overlapping labour markets in densely populated parts of a country. This shortcoming was subsequently confirmed in the case study as the New Zealand GVA model adopted used a drive time defined measure of density.

$$Accessibility\ (A_i) = \Sigma employment_j \times GTC_{ij}^{-1} \qquad \text{(Equation 4.3)}$$

Where: A_i is the accessibility of area i

$Employment_j$ is the level of employment in area j

GTC_{ij} is the generalised travel cost (travel time plus cost) of travelling from area i to area j

In New Zealand and Australia, Hensher (2012) and Mare and Graham (2009) simply weighted nearby employment by the straight line distance between areas. This is a variation of equation 4.3, but with crow fly distance as the denominator.

In a broader assessment of accessibility, Alstadt et al (2012) calculate seven access measures, in response to unreferenced past research studies indicating that different access affects clustering and agglomeration. The seven access variables used to enter a system of three independent activity equations were (1) population within 40-minute travel time as a proxy for the local labour market, (2) employment within a three-hour drive time as a proxy for the delivery market, (3) average ground time to nearest domestic airport weighted by number of landings and takeoffs, (4) average drive time to rail terminal, (5) average drive time to sea port weighted by tonnage exported, (6) average drive time to major air cargo gateway weighted by value of exports and (7) drive time to local border weighted by export value. The first labour market proxy suffers from the arbitrary boundary problem discussed above.

4.3.4 Estimation challenges

In estimating a wage equation GVA model a number of challenges exist. First and foremost is the need to separate out the people and place-based productivity effects. Thus the *X's* in equation 4.2 need to include as many personal determinants of wages as is possible (qualifications, experience/age, gender, etc). Additionally, and even with the most complete dataset, there will be a number of unobserved attributes that affect wages – such as ability[25]. To control for such unobserved attributes a panel dataset is required and a fixed effects model can then be estimated. Related to this are problems of endogeneity. Endogeneity may be present for a number of reasons: higher skilled workers may migrate to the larger agglomerations as that is where the jobs they undertake are located; workers in general may migrate to the most productive locations thus increasing the size and mass of those locations and transport investment may be concentrated in the most productive locations as that is where incomes are highest and travel demand is highest. In such a situation instrumental variables or fixed effects estimation methods can be used. We have already mentioned the effects of controlling for human capital and unobserved fixed effects above, which have a strong impact on the empirical findings. In contrast to this, the evidence is that controlling

[24] Two accessibility measures were calculated, for travel by train and travel by car.

[25] A reminder that model mis-specification, including the omittance of important explanatory variables, can lead to biased estimates of elasticities.

for reverse causality between productivity and the accessibility measure (ie economic mass) has no significant effect on the elasticities estimated (Melo et al 2009).

There also exists a choice as to whether to estimate a model to data on individuals or to grouped data at eg a regional level. The evidence for this from Melo et al's meta-analysis is that there is no significant impact on the estimates. We do, however, note that if we merge aggregate data with data on individual units; for example attributing the effects of a particular geographic location to all those who reside in that location, then an ordinary least squares (OLS) estimation will lead to downwardly biased standard errors due to a failure to take into account non-independent errors. This latter issue is known as group effects.

The final challenge in estimating such a model is in defining the accessibility measure. Ideally we would wish to be able to understand the individual impacts of the different modes, traffic types (freight vs people) and even time periods on wages. Invariably, however, these accessibility measures are heavily correlated leading to a confounding problem – this is acutely the case in the UK where the economic and transport geography naturally leads to a high degree of correlation. However, Alstadt et al (2012) find in the US that modal accessibility measures, while exhibiting a degree of correlation, are not overly correlated, thus it may be possible in some regions/countries to identify the different contributions to labour productivity of the different modes (car, train, air and access to international destinations).

4.4 Variation in GVA forecasts by modelling method

The literature demonstrates that different economy models can give very different predictions of the effect of transport schemes on the economy (eg Lakshamanan 2011). Our survey of transport-economy studies confirms this. We illustrate this in tables 4.1 and 4.2.

It is rare that two transport-economy modelling methodologies are employed simultaneously for the same set of projects using exactly the same set of inputs. The only study we have identified where this is the case is the IASON research study (Bröcker et al 2004). The results from the comparison between the economy modelling of these trans-European projects using a regional production function model (SASI) and a spatial computable general equilibrium model are reported in table 4.1 for 13 different investment and transport policy scenarios. The second column represents the degree of correlation between the two models' results for changes in GDP/capita at a NUTS3 regional level[26]. As can be seen this is not particularly high, but they do show broad agreement in terms of the direction and spatial location of change. The right-hand column represents the average difference between GDP/capita changes forecast by the two models. Taking scenario A1, implementation of all Trans-European Network (TEN) priority projects (Essen list), a value of 5.05 means that the SASI model suggests GDP/capita growth 5.05 times that predicted by CGEurope. However, it is clear that there is no consistency between the scenarios with SASI predicting a 9.1 times larger GDP/capita growth in one scenario, and at the other extreme CGEurope predicting a GDP/capita growth 3.3 times that predicted by SASI (=1/0.30). Without further research it is difficult to say exactly why these differences occur but Bröcker et al (2004, pp168–175) identify a number of factors. These include the specification of trade costs (including transport costs) across borders, the neglect of mobile capital in SASI and mobile labour in CGEurope, and that CGEurope is a static model directed primarily at short-term responses, while SASI is a quasi-dynamic model which includes self re-inforcing cumulative effects.

[26] There are 1,324 NUTS3 areas in the EU (28 countries).

Table 4.1 A comparison of GDP/capita impacts between a regional production function model (SASI) and a spatial computable general equilibrium model (CGEurope) across multiple European transport investment scenarios

Scenario		Relative change of GDP per capita	
		Coefficient of correlation between SASI and CGEurope results	Regression coefficient of SASI results on CGEurope results
A1	Implementation of all Trans-European Network (TEN) priority projects (Essen list)	0.47	5.05
A21	Implementation of all high-speed rail priority projects (Essen list)	0.70	9.10
A22	Implementation of all conventional rail priority projects (Essen list)	0.68	4.64
A23	Implementation of all road priority projects (Essen list)	0.80	1.76
A24	Implementation of all rail priority projects (Essen list)	0.62	8.17
A3	Implementation of all TEN and TINA projects	0.50	5.62
A4	Implementation of all TEN projects	0.56	5.10
B1	Social marginal cost pricing applied to road freight	0.08	0.30
B2	Social marginal cost pricing applied to all modes (travel and freight)	0.73	2.36
C1	Implementation of all TEN priority projects (Essen list) plus social marginal cost pricing applied to all modes (travel and freight)	0.69	1.87
D1	Dedicated rail freight network	0.46	3.64
E1	TIPMAC business-as-usual scenario	0.52	5.80
E2	TIPMAC fast implementation scenario	0.70	0.89

Source: Bröcker et al (2004, table 5.1 p168)

The results in table 4.2 are drawn from UK ex ante project reports identified through a search of the literature. The sample is not large as it is hard to identify projects where two different methods are applied and the results are publicly available, but they are once again indicative of the general view that there is little correspondence between the results from different modelling methods. Typically we found that even when we identified where two different methods had been applied to the same transport improvement (and not different variants of a transport improvement) the comparison remained difficult as the results were reported differently – in terms of price base, single year vs present value and even the period over which the present value was calculated. Notwithstanding this it is apparent from table 4.2 that the results can differ quite significantly between methods. We attribute this principally to the following three reasons:

1 *Perspective/geography.* The geography over which the economic impact is reported is relevant to the size of the impact. This is because the redistribution of economic activity can result in substantial transfers of GVA at a local or sub-national level. The partial equilibrium method which uses output from a CBA would therefore be associated with net gains at a national level, while at the other extreme business and household surveys would only report local impacts. The local perspective is therefore a

significant explanator of the disparity between the results from partial equilibrium and other GVA approaches.

2 *Economic potential.* What we mean by economic potential is the ability of a transport project to stimulate a number of structural changes to the economy, which would be accompanied by complementary investment in skills training, business premises, etc. This complementary investment would often be private sector developer driven, and would in turn generate further changes in output and employment. The wage equation models in table 4.2 in which people-based productivity changes are included would be regarded as models of economic potential. Similarly KPMG's regional production function model (in table 4.2) and the SASI model (referred to in table 4.1) could be viewed as models of economic potential. The business and household survey approach would also be regarded as an economic potential method – as the growth forecast by these methods would typically require additional private sector investment. Static equilibrium models such as the partial equilibrium methods which are based on user benefits (as in table 4.2) and the CGEurope model (referred to in table 4.1) do not account for these ancillary investments and as such produce lower estimates of economic growth.

3 *Use of local economic data.* CBAs often use standard values of time across the country despite wage rates and incomes varying significantly. This is often done on equity grounds. The user benefits in table 4.2 are therefore estimated using these standard values, while the other GVA methods would typically use local data on, for example, earnings.

There also exists an extensive literature on the effect of transport infrastructure on private output, stemming from Aschauer's (1989; 1990) seminal work. Melo et al (2013) present an international meta-analysis from this literature. They find for example an elasticity of private output to road investment of 0.088. Thus a 10% increase in the stock of roads would increase private output by 0.88%. They find lower elasticities for other modes (0.0277). These estimates, they find, are also biased upwards by the presence in the dataset of early estimates of elasticities that do not correct for omitted variables and unobserved heterogeneity. Of course the meta-analysis data represents an average and returns from transport infrastructure investments would be expected to alter with local characteristics – including the stage of economic development of the region/country, the extensiveness of the existing transport infrastructure, the quality of the new infrastructure vis a vis existing infrastructure, and due to the manner that transport affects the spatial location of activity whether regional or national output is of interest. Notwithstanding this, the application of such elasticities is straightforward, and we therefore find it surprising that our literature search has not identified any studies that have used the elasticities from this part of the literature to estimate changes in GVA – even as a benchmarking exercise or as a validation for other model results.

Table 4.2 Comparison between user benefits and transport-economy modelling results for selected transport schemes in the UK

Scheme	User benefits[a]	Wage equation model	Regional production function model	New economic geography consistent model	Business and household surveys plus input-output multipliers
UK high-speed rail lines (full national network)[b]	£117 billion (60-year PV in 2002 prices) [business and leisure] (MVA-SYSTRA 2009)	£29 billion (2040 in 2010 prices) (KPMG 2010b)			,
High speed 2 (HS2) (UK high speed rail line)[c]	£34.3 billion (60-year PV) [business] £15.4 billion (60-year PV) [WEBs] (DfT 2012)		£15 billion (2037 in 2013 prices) (KPMG 2013)	£7 billion (30-year PV in 2006 prices)[d] (Overman et al 2009, chapter 6)	
Northern Hub rail capacity and service improvements (Manchester, England)	£12.7 billion (60-year PV in 2002 prices) [business and leisure] (SDG 2009, p76)	£2.8 billion (2021 local impact) £0.9 billion (2021 national impact) (GMPTE 2010)			
A82 upgrade, Scotland	£52.5M [business] (60-year PV) £41.3M [leisure] (60-year PV) (Scott Wilson 2006)				£152M(30-year PV) (Tribal 2005, tables 2 , 4 & 6)
A96 bypasses, Scotland	£13.5M [business] (single year) £8.0M [leisure] (single year) (Scott Wilson 2008a)				£134.5M (single year) (Scott Wilson 2008a)
A9 dualling, Scotland	£594M [business] (60-year PV) £582M [leisure] (60-year PV) (Scott Wilson 2008b)				£956M (30-year PV) (Scott Wilson 2007)

Notes: [(a)] the partial equilibrium method for estimating GVA impacts as discussed in chapter 4 is the sum of business user benefits, earnings due to increased employment and increased earnings due to agglomeration. For these studies this GVA estimate is not available, however we have presented the user benefits as a guide. [(b)] full network links London, Birmingham, Manchester, Leeds, Sheffield, Newcastle, Edinburgh, Glasgow and Cardiff); [(c)] HS2 is a proposed UK high-speed rail line linking London to Birmingham, Manchester and Leeds; [(d)] This is only for 40-minute journey time reductions from Manchester/Leeds to London. Therefore excludes benefits to Birmingham and benefits from increased trains services on the released capacity.

Abbreviations used in table: PV = present value; WEB = wider economic benefits; M = million

5 On the relationship between changes in GVA and transport user benefits

- GVA and CBA measurements have conceptual and practical differences.
- More recently CBA guidelines frequently allow for adjustments for agglomeration gains, lower prices resulting in imperfect markets and increased labour supply, but:
  - CBA may miss the benefits of land use change if calculated using the rule-of-half.
- GVA measurements can – and often do – incorporate land use change.
- Some GVA models provide estimates of macroeconomic impacts at a regional level, but:
  - GVA models ignore non-market welfare gains and many overlook opportunity cost.

5.1 Introduction

A number of authors have set out the different impacts of transport and whether they affect only GDP/GVA or welfare or both (Lindberg 1992; DfT 2005). Our intention in this chapter is to review these areas of overlap with a particular interest on the relationship between changes in GVA and user benefits. We note at this stage that safety, noise, air pollution and carbon externalities all have an economic impact as well as a welfare impact, but we do not delve into this further. Our interest primarily is in the relationship between user benefits and changes in GVA. To do this we first of all re-visit the principles of transport CBA under perfect competition and also under imperfect competition with agglomeration externalities and a labour tax.

5.2 Can GVA equate to CBA?

The equivalence of transport benefits to the ultimate societal benefit in a fully employed and competitive economy has been shown by numerous authors, and revisited in Mackie et al (2011). The logic is shown in figure 5.1. The user benefits for a transport related intervention are given by area A in the top panel (ie in the transport market). Under perfect competition everywhere outside of the transport market, that is with constant returns to scale and no environmental or safety externalities, this represents the total welfare gain. Under this scenario, the gain in the transport market is passed directly to the end user in the goods market as a lower price or to the employee in the labour market as a higher wage (in lieu of the increased supply afforded by the otherwise lower cost of production). In terms of the supply and demand diagrams, area A is equivalent to area B (goods market, middle panel) and area C (labour market, bottom panel) under conditions of perfect competition. It is greater than either areas B or C if the supply of goods or labour is elastic – this is the situation depicted in figure 5.1. Should either of these benefits be added to the surplus in the transport market, there would double counting of the user benefits. This holds for all types of transport interventions – and not just for the case of a freight improvement as illustrated in figure 5.1. This is the rationale behind the widespread use of transport market savings to calculate the benefit to society from a transport intervention, thus avoiding the need to calculate the varied and at times widespread benefits within other markets[27].

That it is difficult to equate the CBA benefits with changes in other markets is illustrated by considering the example in figure 5.1. Take, first, the goods market. Ultimately there has been an increase in real production of (Q_1-Q_0), in volume terms. This can be shown by example to be approximately equal to the CBA welfare benefit, ie most of the welfare benefit is transferred into extra production in this example. So, at face value, the calculation is relatively simple, and it would be if it were one person receiving the extra wage and the goods price reduction was using the 'spare' cash to fund the extra purchases (a real income gain)[28]. In fact if all factors are fixed (ie in the short run), there are no terms of trade effects (ie a closed economy) and no externalities and non-priced goods, then the user benefit measure would be exactly equal to the GDP impact (Forsyth 2014, p12).

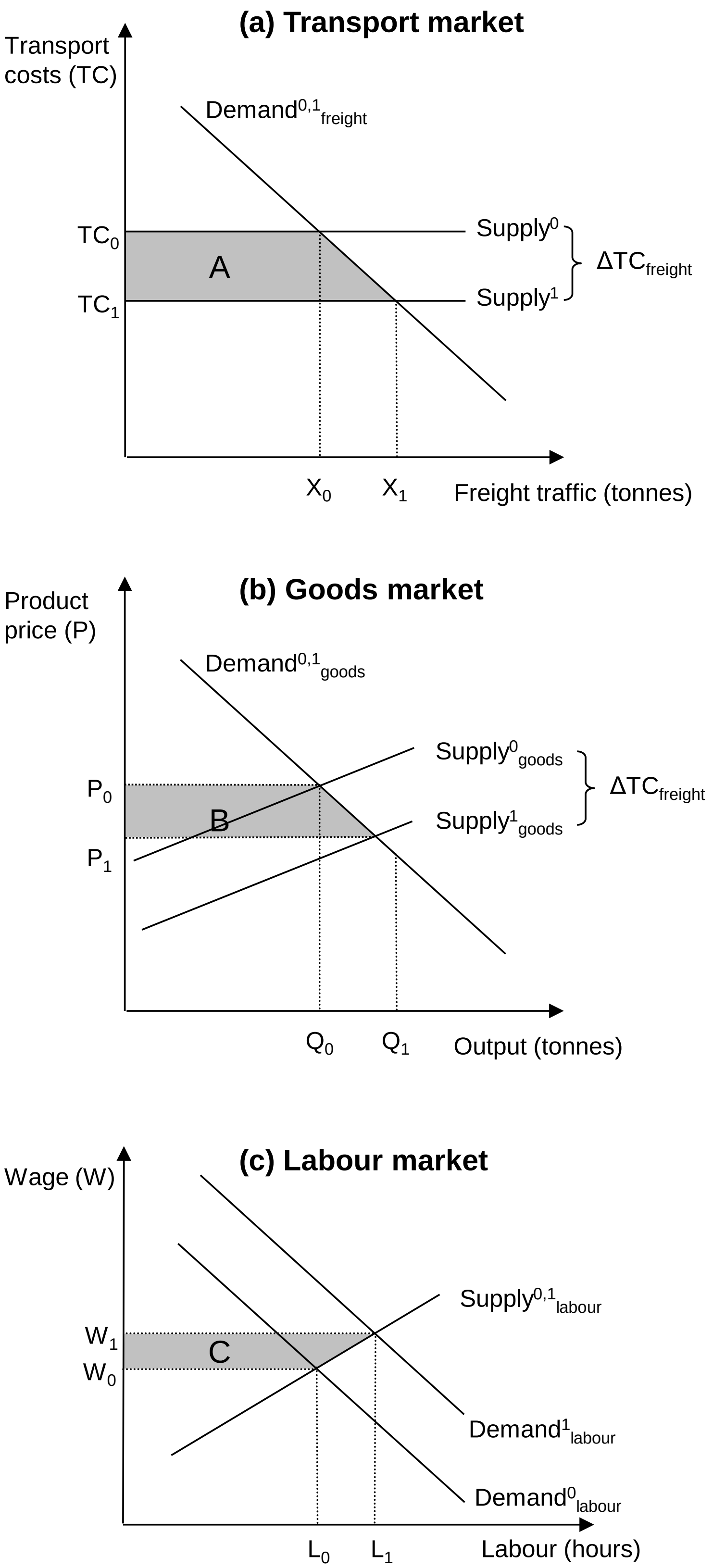
However, with multiple goods and multiple consumers this framework does not capture the benefits of improvements in allocative efficiency that result from consumers reallocating expenditure in response to the positive income effect brought about the lower transport costs,

The situation gets even more complicated as assumptions about perfect competition are relaxed and economies of scale are permitted. Economies of scale allow imperfect competition in the goods market to persist. In this situation output is not at competitive levels and therefore any output expansion will generate surpluses additional to transport user benefits. The above equivalence between GDP impacts and CBA user benefits is then lost. The same outcome occurs if labour taxes or agglomeration externalities exist. These additional CBA surpluses are illustrated by areas D, E and F in figure 5.2. Arguably other market failures can also exist creating additional surpluses (Venables et al 2014), but these figures – particularly figure 5.2 – represents the state of practice in transport cost benefit analysis CBA in the appraisal of wider economic benefits.

[27] Equivalence (or almost equivalence) between transport user benefits and total economic welfare with undistorted secondary markets (eg an undistorted goods market and labour market) also requires that the demand curve in the transport market should be empirically measured (ie it is the demand curve measured with prices allowed to change as a result of the intervention). The price changes are small and income effects are also small (Boardman 2011, pp121 and 131).

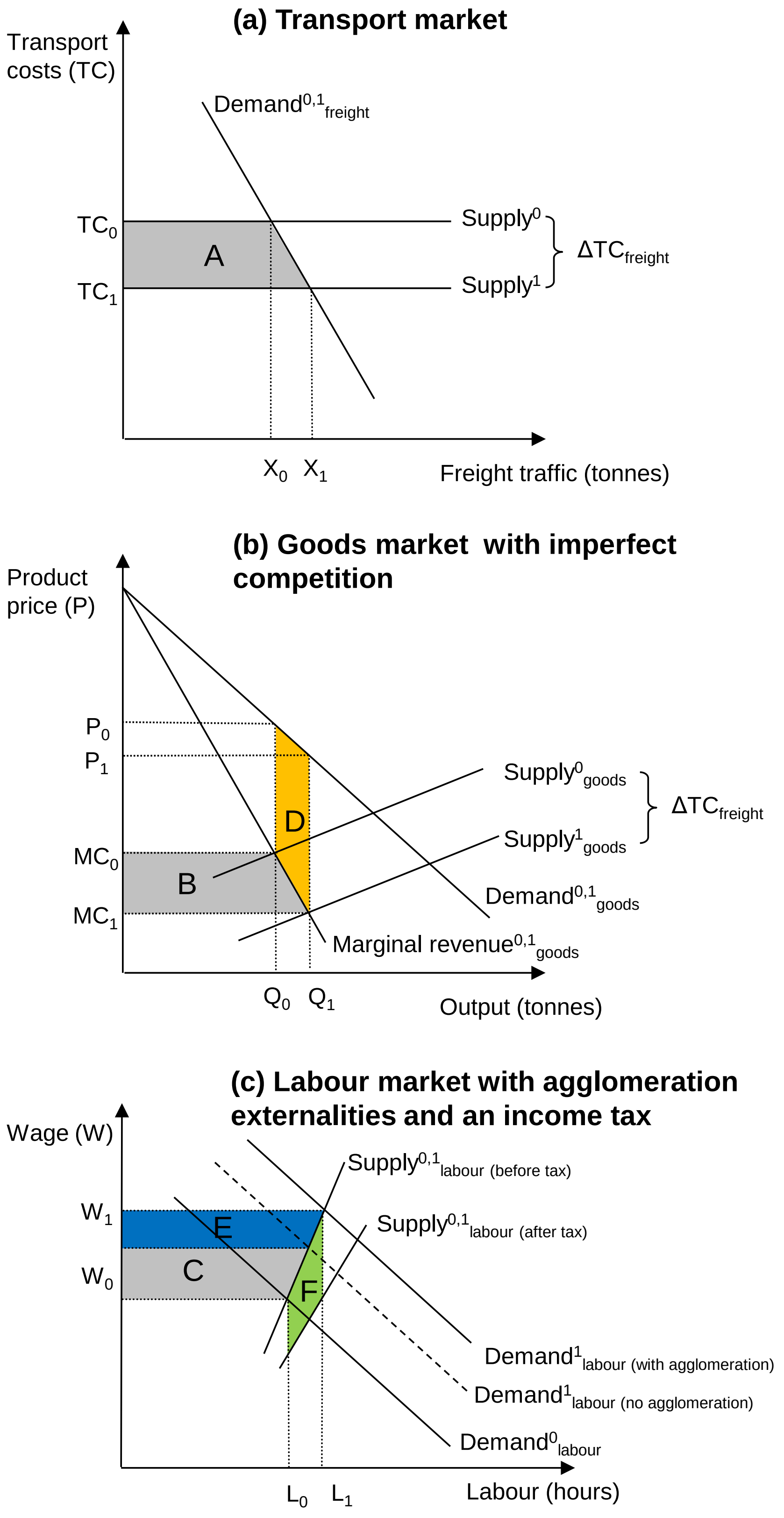
[28] Note that this equivalence between welfare gains and extra GDP will not hold where the travel saving relates to a commuter time saving that, in turn, is applied to leisure.

Figure 5.1 Direct and indirect benefits of a freight-related transport quality improvement in competitive conditions



Source: Mackie et al (2011)

Figure 5.2 Direct and indirect benefits of a freight-related transport quality improvement with market failures in the product and labour markets



Source: Mackie et al (2011)

It has further been established that a technological externality associated with land use exists which affects the calculation of social surpluses when land uses change. The benefits felt by users from a transport improvement in this situation can no longer be calculated using the rule-of-half (Martinez and Arraya 2000; Bates 2006; Parker 2013). The social benefits need to be estimated within some land use modelling framework. There has been very little research on this subject, but embryonic evidence suggests that the error of omitting measuring this externality is less than that of holding land use fixed (Borjesson et al 2014). At the moment it is Transport Agency policy to hold land use fixed between the do minimum (DM) and do something (DS) scenarios.

Ultimately, in the real world economies are open, externalities and market failures exist, some goods are unpriced (particularly time in respect of transport services), there are many people interacting over many goods and there are many changes occurring at any one time. Coming from the macro angle, dissecting changes in aggregate GDP to find the impact of a particular transport intervention presents a huge identification problem. Coming from the micro angle, modelling the correct pathway of exchange is equalling challenging. Either way though it is clear that welfare benefits will diverge from GDP impacts under normal conditions for an economy.

Besides these conceptual differences, there are also differences of practice. First, there are differences associated with computational methods. CBA relies on surplus measures associated with changes in generalised costs computed at zone pair level and aggregated across some appropriate combination of origins and destinations, modes, routes and times of day. There is no reason why changes in GVA should not be computed in exactly the same way, but in practice they are derived in a variety of ways which are not necessarily so closely tied up to the travel demand model outputs. Another example of inconsistencies, which potentially could be resolved, is that GVA methods use behavioural values at sub-market level, whereas in some countries CBA appraisal values are based on standard average values.

However, more fundamental differences also exist. CBA is normally taken from a national or supra-national measurement whereas GVA methods are used to provide estimates at a city region level; the approaches differ in their treatment of relocation of economic activity between regions within the country. Put another way, regional analysis is possible with GVA models but not possible with the CBA approach unless a zero value is associated with benefits accruing to beneficiaries in other jurisdictions[29].

Finally, the CBA approach is quite strongly an equilibrium approach. Benefits are computed as the difference in a move from one equilibrium to another initiated by a single or package of stated (and costed) interventions. GVA methods can tacitly adopt a more dynamic approach to the economy and rely on estimates of responses in the urban labour and land markets which yield changes in the *potential* output of zones whose accessibility is improved. None of these practical points are inherent in the GVA method but they can account for some of the very significant difference in results which can arise in practical work.

5.3 What CBA does not do

Before addressing the question of what CBA does not do, it is worth recording a further conclusion of SACTRA (1999) about what CBA could do. Three conceptual definitions which practical CBA work might approach to a greater or lesser extent are:

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[29] A CBA is undertaken from the perspective of a stakeholder. That stakeholder may ascribe zero value to benefits accruing to certain actors, eg foreign countries if undertaken from the perspective of a national government or other businesses if undertaken from the perspective of a business.

- a fully specified correct transport demand and supply model but with fixed land use, out of which come correct estimates of transport user benefits and producer surpluses
- as above, but allowing for induced land use change and feedback between the transport and land uses
- again as above, but considering relevant additional impacts, positive and negative in the rest of the economy outside the transport sector. SACTRA and previous authors demonstrate that these wider economy impacts have been shown to depend upon the presence of market imperfections or external economies of various kinds.[30] The effect of the railroads on the American West and indeed the world economy is a famous example of the proposition that these spillovers can be very important.

The above are conceptual ideals; practical work inevitably falls short in various respects because data, models and forecasts are incomplete or imperfect. Over the last 15 years, practice has in our view not changed greatly in terms of the treatment of transport benefits and costs and induced land use change, but has moved forward appreciably in trying to estimate the additional wider economy impacts within the CBA umbrella.[31]

In New Zealand, following the research of Mare and Graham (2009) and Kenohan and Rognlien (2011), the Transport Agency (EEM, pp2–7, 5–406, 5–412, 5–413) now allows wider economic benefit add-ons to the standard CBA for 'agglomeration where firms and workers cluster for some activities that are more efficient when spatially concentrated', 'imperfect competition where a transport improvement causes output to increase in sectors where there are price cost margins' and 'increased labour supply where a reduction in commuting costs removes a barrier for new workers entering the workforce'. Plus there is the ability to consider 'national strategic factors' (p5–414).

Other wider economic benefits considered by Kernohan and Rognlien (2011) and dismissed for inclusion in current guidance by the Transport Agency, were 'increased competition' and 'job relocations'.

Returning to the more general point, CBA approaches often take a very constrained view of land uses (though as we have noted above government guidance requires a highly constrained approach with fixed land uses).

This is where the GVA models enter the fray. The KPMG GVA model is structured to measure the potential impact of improved accessibility. Their 2010 Greengauge21 study showed that wages could increase by 0.11% if the accessible economic mass could be increased by 1% as a result of a transport improvement – the key word here is *could*. This result is premised on the benefiting local economy changing so it has the characteristics of the previously higher paying areas that already have higher levels of accessible economic mass. This may involve changes in capital, changes in occupation and changes in industries within the benefiting area – it will almost certainly require an upskilling of the workforce, either by training, commuting or immigration. This is the major contribution of the Overman et al (2009) study: remove all the composition effects and the wage elasticity to accessible economics mass reduces from 0.258 to 0.049 for train travel.

The challenge, then, for decision makers is to assess whether these compositional changes will indeed occur after the transport intervention: Will people change? Will business invest (preferably with embodied technology)? Will other policy makers accommodate the change? Is there capacity for greater activity? It

[30] In all three of these cases, environmental externalities would also need to be represented in the appraisal framework. The treatment of these is not a source of difference between these approaches and is not discussed further.

[31] The valuation of particular elements of cost and benefit such as reliability has progressed significantly however (see Mackie and Worsley 2013).

may well be that the answer to these questions is not discrete; change will come to be described in probabilistic terms. A risk analysis will thus be needed.

A summary of the key differences between CBA and GVA methods is given in table 5.1.

Table 5.1 A comparison of CBA and GVA methods

	Transport CBA	**GVA**
Perspective	National or supra-national.	City or regional level typically, though displacement and additionality should be identified.
Unit of account	Market prices or factor prices depending on appraisal system (the Transport Agency uses market prices).	Observed prices and wages.
Values	Shadow prices minus opportunity costs are used. Thus for example labour is valued at the wage rate (ideally adjusted by shadow pricing in the presence of structural unemployment) minus the opportunity costs of lost leisure time. It is also often common practice in transport appraisal to use standard or average values for a whole country (as in New Zealand).	Only goods that are traded are valued. The values used are the observed prices and wages. Price data local to the city/region are used.
The do something counterfactual	CBA analyses are often conducted by trying to analyse the impact of the transport intervention in isolation. It is accepted that the intervention will lead to other changes in the economy, but these are not costed and therefore the analysis is typically constrained to the costed initiatives. Furthermore it is common, but not necessary, for land uses to be held fixed in a transport CBA – this is a reflection of current state of practice/ knowledge rather than a requirement of CBA.	GVA analyses typically assume a more dynamic approach to economic growth. The transport investment will stimulate further investment, which will in itself have a positive return. Some of these investments will be government initiatives with respect to for example re-development of city centres and/or skills training. The final GVA prediction is a culmination of all the investments – both private and public sector. Implicit in almost all GVA analyses will be that land uses will change. A good GVA analysis would undertake a risk assessment of the probability of these additional investments and land uses occurring.

6 Conclusions drawn from the literature reviewed

6.1 Summary

There are many models that could be termed GVA models, in the sense that they model the impact of a transport intervention on economic activity. This study has chosen to focus on the subset of GVA models recently employed in the UK to examine regional impacts of transport interventions.

Therein lies one of the key differences – and advantage – of the GVA approach: the changes in regional activity can be estimated, and the winners and losers identified (at least this is the intention). This is not only required due to the regional funding arrangements in the UK now, but it is also useful additional information to that offered within a CBA. For example, not only does, say, Sheffield City Council want to know whether their region will benefit from a transport investment (as opposed to the nation), they are also keen to ensure investment creates the potential for the least well-off to benefit. In other words, Sheffield City wishes to apply multi-criteria in its investment prioritisation.

This approach presents two major challenges: to get accurate forecasts of future impacts on the local economy and to understand the likelihood of the sequence of events required to make the expected change a reality; and to correctly identify what are benefits and what are costs within the various measures of macroeconomic change. A further important pre-requisite, besides getting the above two assessments right, is to have a consistent approach so as to enable consistent application of decision rules.

These challenges are substantial. For now, a safety net exists for Sheffield City in the form of the BCR hurdle also imposed. This co-existence of CBA and GVA is likely to remain for a long time. At the end of the day, the approaches measure different things. There is much rigour and lore surrounding the CBA approach but it does not show spatial and macroeconomic changes well, and it is possible that some (probable) development is overlooked. The GVA approach can conceptually be just as rigorous but application to date has been variable (especially thinking in terms of use of input-output multipliers). The two together provide both improved understanding amongst a wider stakeholder group and the assurance gained from past experience – indeed working during the analysis stage to find congruence between the two approaches will undoubtedly increase understanding.

A key insight from the GVA modelling work in the UK is that people matter (as if we needed to be told this). It is possible that productivity will increase with economic mass but taking full advantage of improved access to an economic mass will require people to upskill, and possibly to change occupation and sector; transformation is many dimensioned.

As part of meeting the first challenge above, ie accurate forecasts, GVA modelling is likely to evolve in two ways: the simplicity of reduced form models will appeal to some at least at an aggregate level, but wider understanding of their limitations and suitable purposes will be required; and CGE models will likely evolve to include spatial analysis, welfare and environment impacts but there will always remain a ‘black box’ element to this approach.

6.2 Next steps

The Transport Agency has a CBA framework in place at present to assess day-to-day transport projects, including taking into account some wider economic benefits. We found little in our literature review to suggest that a GVA approach could replace this system.

That said, the GVA approach does offer further insights that would be of value, especially when it comes to applying multiple criteria to an investment decision, or when the regional and/or community breakdown of the effects is of high importance, or when the transport investment does materially change the probability of local transformation, or when there is simply a need for better understanding by the wider group of stakeholders.

Research into GVA methods could follow one of these paths:

1. A panel data of individuals' wage income over time is studied to separate the effect of economic density on productivity due simply to place and the effect of economic density on productivity due to changes in composition of firms and people. A key issue in the GVA approaches is whether the impact of a transport intervention should be estimated with or without the people effect. This research would both aid refinement of the current agglomeration elasticity applied in the EEM, and provide an input into decision making based on GVA models.
2. A regional production model is built, with the aim of (a) testing the more commonly used accessibility variables plus those relating to sea and air travel and (b) applying the resulting parameters to a known transport investment to explore the differences between a CBA approach and a GVA approach. It is possible to construct this model employing production outputs and inputs (ie move beyond the pure wage equation), and extend the analysis to other accessibility of importance, but data and time limitations imply this model will not include a fixed person (or firm) parameter. This shortcoming can be partially addressed by the inclusion of people characteristics at a TA area level or by using the same technique as in Mare and Graham (2009) to create industry fixed effects in each region.
3. An existing CGE model is adapted to include agglomeration effects (perhaps as per the EEM) and to show the spatial distribution of economic impacts, again with the aim of testing against a known CBA analysis (of a large project) to build insight into how the investment could lead to transformation.

It was recommended that the model built for this project should follow the second option above, for the following reasons:

- Option 1 was beyond the scope of the project as initially outlined and would involve considerable data collection.
- Likewise option 3 was seen as an extension of this 'GVA project'. A CGE model was employed in the Overman (2009) project but the common element of the KPMG (2010b) and Overman et al (2009) projects was the use of a reduced form production function type equation.
- Option 2 fitted closely with the GVA research initially referenced in the project outline. It also enabled some validation of the current EEM agglomeration method, with people effects taken into account, plus it enabled connectivity to be extended beyond the commute zone. This model would only provide limited information on spatial effects but would be a stepping stone to a more sophisticated CGE model.

7 GVA model

7.1 Introduction

Phase II of the project was the development of a model to explore the findings of the literature review described in chapters 2 to 6. The following sections describe the data used within, and the findings from, a New Zealand GVA model. The 'UK GVA' models are primarily wage equations and, as discussed in chapter 2, changes in GVA only partially correlate with changes in wages. As also discussed in chapter 2, changes in GVA are very highly correlated with changes in GDP. The opportunity existed for this project to explore more directly the relationship between GDP and accessibility between New Zealand TA areas. Hence the terms GDP and GVA have been used interchangeably, including the use of GDP data for a 'GVA model'. Also a model used in the US was chosen as the basis of the New Zealand GVA model, for reasons discussed below. The fact that the model used in this project was applied in the US rather than the UK is not considered to be a fundamental divergence from the 'UK GVA approach' but rather a refinement of the underlying model. Last, it should be pointed out that the model aimed to capture the ongoing GDP impacts of a transport innovation and not any initial construction activity directly related to a transport investment.

7.2 Method

A common feature of the GVA models discussed in chapter 4 is the modelling of some measure of productivity against measures of accessibility (equation 4.1 is repeated below as equation 7.1).

$$Y_t = f(X_t, A_t,) \qquad \text{(Equation 7.1)}$$

Where Y_t is some outcome for the economy measured at time t

X_t is a set of attributes that normally shape Y_t, typically including factors of production

A_t is a measure of the variable(s) of interest.

The KPMG (2010b) UK study reports that local wages (one measure of Y) are positively associated with the size of the local labour market (one A) and to the size of the wider business market (another A).

The Alstadt et al (2012) US study also reports a positive association between sales (another measure of Y) and accessibility – or connectivity to use the term applied – to airports and seaports (further As), believed to result from freight efficiency gains.

The Alstadt et al (2012) model was considered appropriate for this project as it (a) would allow accessibility effects beyond commuting to be considered, with these wider effects being of particular interest to New Zealand with its dispersed population centres and (b) it would bring together the estimation of the employment and GDP/worker effects, thus reducing a potential estimation bias.

The study began by considering four measures of accessibility or connectivity, namely access to labour, access to goods/services markets, access to international destinations by air, and access to international markets by ship.

The model chosen followed closely that of Alstadt et al (2012), with some exceptions. Alstadt et al (2012) fitted three simultaneous equations of employment, domestic sales and export revenue against population, population skill level and seven measures of accessibility within 3,141 US counties, repeated for 54 industry sectors.

$$Employ_t = f(Pop_t\ Skill_t\ Access40_t, Access180_t, AccessRail_t, AccessDomAir_t, AccessInterAir_t, AccessSea_t, AccessBorder_t) \quad \text{(Equation 7.2)}$$

$$Sales_t = g(Employ_t\ Skill_t\ Access40_t, Access180_t, AccessRail_t, AccessDomAir_t, AccessInterAir_t, AccessSea_t, AccessBorder_t)$$

$$Exports_t = h(Sales_t\ AccessDomAir_t, AccessInterAir_t, AccessSea_t, AccessBorder_t)$$

Where $employ_t$ $sales_t$ and $exports_t$ are vectors of number employed, sales revenue and international export revenue by county at time t for an industry sector

$skill_t$ is a vector of percent of worker in each county with college degrees at time t (across all sectors)

the seven access vectors are as defined in table 7.1 (also the same across all sectors).

The model chosen for this project was dictated by data constraints, and influenced by differences between the US and New Zealand. A set of two simultaneous equations were fitted (see equation 7.3). Employment and GDP were regressed against working age population, population skill level, several other variables chosen to isolate people differences between TA areas and four measures of accessibility within 73 New Zealand TA areas, repeated for 55 industry sectors. A lack of sufficient New Zealand export data restricted the ability to model local and export sales separately – these were combined into a single measure and one equation. A further innovation was to use GDP, instead of sales revenue, to address more directly the impact of accessibility on productivity. Of the accessibility measures, the US access to a land border was irrelevant, the US access to an intermodal rail terminal was not included due to the limited range of freight moved by rail in New Zealand and the two US airport access variables – one for domestic commercial and one for international freight – were replaced by one New Zealand airport access variable, with emphasis placed on passenger travel due to the predominance of passenger over freight transport by air in New Zealand. Retained in the New Zealand model were the remaining three US access measures of size of local labour and goods/service markets and proximity to major marine ports, albeit with some data modifications (see table 7.1).

$$Employ_t = f(Pop_t\ XVAR_t\ A40_t, A180_t, AAir_t, ASea_t) \quad \text{(Equation 7.3)}$$
$$GDP_t = g(Employ_t\ XVAR_t\ A40_t, A180_t, AAir_t, ASea_t)$$

Where $employ_t$ and GDP_t are vectors of number employed and real GDP by TA area at time t for an industry sector

$XVAR_t$ is a matrix of people attributes associated with each TA area at time t

the 4 access vectors (the As) are as defined in table 7.1.

This model is also an extension of the earlier mentioned[32] agglomeration models, in two ways. First, access to air and sea ports is explicitly taken into account. Second, the effect of wider populations is less restricted by the form of the model: for example, in the Mare and Graham (2009) model, a change in employment within one sector 100km away is restricted to have an effect on local output of 1/100 of the effect of a change in population only 1km away, based on the premise that people further away are less likely than those closer to mingle with local businesses. This may be correct from a commuting

[32] Recall KPMG (2010b; 2013) models employed for the Greengauge and HS2 projects where wages were fitted against local labour market catchment and local business market catchment for industry sectors and zones of the UK, with some double counting of effects as the two access variables were fitted in different models; Overman et al (2009) modelled wages against GTC-weighted surrounding employment for UK individuals; Mare and Graham (2009) modelled gross output against distance-weighted surrounding employment for New Zealand businesses.

perspective but not necessarily from the delivery market point of view. However, imposing an arbitrary 180-minute travel time cut-off[33] also imposes restrictions such as limiting all mass within the area to have the same effect and any mass beyond the cut-off to have no effect.

The sensitivity to this restriction was tested by also examining the effect of 120- and 150-minute travel time cut-offs.[34] That said, the sensitivity around the threshold point was likely to be a weakness with this model but the project provided an opportunity to test the sensitivity of results to different measures of drive time.[35]

One further feature of the measures of accessibility is that the measurements revolve around drive time, as per Alstadt et al (2012). Two points are relevant. It would be preferable to use a generalised cost of travel, as opposed to simply time, to measure accessible masses but this data was not available across New Zealand. Second, whether derived from GTC or simply travel time, the use of accessibility variables of this nature introduces time (or travel cost) directly into the regression model. This means that any estimated elasticities will include the effect of time, and hence will include effects explicitly calculated in a standard transport CBA, eg the elasticities will pick up any improvement in GDP due to a reduction in travel time (or cost) for existing travellers plus any improvement in GDP due to more travel plus any improvement in GDP due to more people ‘connecting’ but not necessarily travelling.

When it comes to ports, the ‘mass’ to which connection applies is not immediately obvious. The US study used the number of operations at the domestic airport as a proxy for mass and divided this by travel time. For other ports, drive time to port was simply used to measure connectivity although personal communication revealed that measures of scale were also being sought for the other ports. In other international studies of connectivity, Smyth and Pearce (2007) used the weighted global share of passenger seats to international destinations as a measure of connectivity. We, the authors, made the judgement in this study that access to frequency of planes and ships was likely to be more important than the access to scale, so measures of connectivity were chosen to reflect the frequency of plane and ship visits to a port. This judgement was not tested.

As with many models of this nature, capital was not explicitly included. Our model starts from the standard production function where GDP is a function of labour supply, the stock of capital and technology but capital was excluded as no measure of the stock of capital by sector and territory was available. Instead it was assumed that the relationship between GDP and labour supply adequately captured the effect of capital as well. This assumption is significant as any observed association between GDP and accessibility may in fact arise due to higher capital stock being applied in the more accessible locations.[36] The risk of this potential bias from an omitted variable was addressed by estimating the

[33] It is also noted that the travel time was imprecisely measured as travel time for all years was taken to be equivalent to current travel time, ie no account was taken of different roads and speeds in earlier years.

[34] Note the 180 minute variable was initially fitted as the working age population within that travel time *minus* the population of the study territory. When considered together, the 180 minute variable was the working age population within that travel time *minus* the 150 minute working age population, the 150 minute variable differenced to the 120 minute mass, and the 120 minute variable differenced to the 40 minute commute zone. The differencing reduces correlation between the 40 minute, 120 minute, 150 minute and 180 minute variables but correlation will still exist to the extent that populations in adjoining areas are related.

[35] No sensitivity to the 40 minute threshold was tested across different sized TA areas.

[36] If capital stock does correlate with accessibility then there is the issue of causation: did accessibility cause the investment and hence any higher GDP can be attributed to accessibility (in which case higher GDP would reasonably be expected to require improved access and more investment), or did improved accessibility follow or coincide with capital investment?

model within sectors, hence implicitly acknowledging the varying capital-labour-technology relationships between sectors but assuming a fixed relationship across regions for each sector.

Returning to the simultaneous nature of the model, both the accessibility effect on employment and the effect on GDP can be estimated directly[37]. That is, the model allows for increased accessibility to lead to higher or lower[38] levels of local employment than would be typical for the number of local residents, implying either higher (lower) labour participation rates or more (less) commuting into the area. The model also allows for GDP/worker to increase as a result of increased accessibility. Note, there is a third channel which was not modelled, being the possibility that increased accessibility also leads to a higher local population from immigration into the area.

7.3 Data

The effect of accessibility was measured on two variables at a TA area level, namely employment and GDP. Three variables were used to take account of differing populations between regions, more 'people' variables than used by Alstadt et al (2012) and Overman et al (2009) due to the significance placed on people-effects in UK agglomeration research. Four access variables were tested for the effect on employment and GDP.

The study considered data for 72 TA areas. There was some amalgamation of TA areas during the study period but this project used the 2006 definitions, which comprised 65 of the current 67[39] TA areas plus the seven cities/districts that combined to form Auckland City. Christchurch City included data for Banks Peninsular District prior to amalgamation. Data unless specified was drawn from the results of the 2001 Census and 2006 Census, both conducted in March, with data available at www.stats.govt.nz.

Distances and travel times were generally calculated from population weighted centroids using the ESRI ArcGIS platform, with travel calculated from the road nearest to the centroid (centroids were not necessarily adjacent to a road).

Details of each variable, and any differences from the Alstadt et al (2012) study, are given in table 7.1. GDP and employment were measured within 55 industry sectors[40]. The other variables were not broken down by industry sector.

[37] Previously KPMG (2010b) had estimated these two effects independently. Note, though, that KPMG regressed employment density on accessibility, allowing for the possibility of people shifting their place of employment, whereas this model restricts the employment density effect to changes in commuting only.

[38] Higher productivity may lead to less employment due to (a) no need for as much labour with higher labour productivity and (b) some crowding out of city centre locations for some industries due to higher land rents/wage rates.

[39] Not included within the 67 TA areas is 'the area outside a territorial authority' and Chatham Islands while 'Auckland' is replaced by its components.

[40] An 'unallocated' amount for each TA area was ignored by this study plus, within the 55 sectors, four sectors had low employment coverage across TA areas that prevented some regressions.

Table 7.1 Data used within US and New Zealand models

Variable	Alstadt et al (2012)	This project (with code used)
Employment	Employment by county and industry	EMPL – Number of persons employed by territory and industry.
Output	Sales by county and industry	GDP – GDP by territory and industry was already held by the Transport Agency so was used as a direct measure of output. GDP had previously been estimated by Infometrics Limited, derived from the Statistics NZ GDP by region dataset for the years ending March 2001 and 2006 (see appendix B, section B1 for methodology).
Populations	Population by county	POP – Population aged 15–64 by territory as at March 2001 and 2006.
Skill	Percentage of workers with a college degree	QDEG – Proportion of the usually resident population aged 15 or older in each territory with a bachelor degree or higher qualification.
Age	Not used	AGE – Proportion of the usually resident population aged between 15 and 64.
Occupation	Not used	OCCUP – Proportion of usually resident employed persons in each territory who worked as legislators, administrators, managers or professionals (these being the occupations with higher average wages).
Dummy for year	Not used.	Z2006 – 1 if 2006 and 0 if 2001.
Dummy for Taranaki	Not used.	ZTAR – 1 if territory within Taranaki, 0 otherwise.
Local labour market	Proxy of population within a 40-minute drive (being 80th percentile for US commute time) from population centroid less county population.	A40 – Proxy of working age population within 40-minute drive of population centroid. The drive time calculated using 2014 roads and speeds but using 2001 or 2006 populations by meshblock. The population of the meshblock was included in the drive time total if the meshblock centroid was within the 40-minute polygon[41].
Regional delivery market	Proxy of employment within 180-minute drive from population centroid less 40-minute population total from above (the 180-minute limit approximately captures same-day deliveries).	A180 (and A120, A150, A180c) – Proxy of working age population within 180-minute drive of population centroid, calculated in same manner as above, less A40 working age population. This was further broken down into working age population within a drive of 40–120 minutes (A120), 120–150 minutes (A150) and 150–180 minutes (A180c). A further variable (A120all) was calculated that measured all working age population within 120 minutes (ie without deduction of A40).
Access to domestic airport	Number of annual operations at nearest commercial airport to the county divided by drive time to nearest airport	AAIR – Drive time to port divided by average number of flights between New Zealand airport and Australian ports per month, where New Zealand port was closest airport with flights to Australia (except Auckland used in place of Hamilton airport north of New Plymouth). 2006 flights were for the year ending March 2006 and

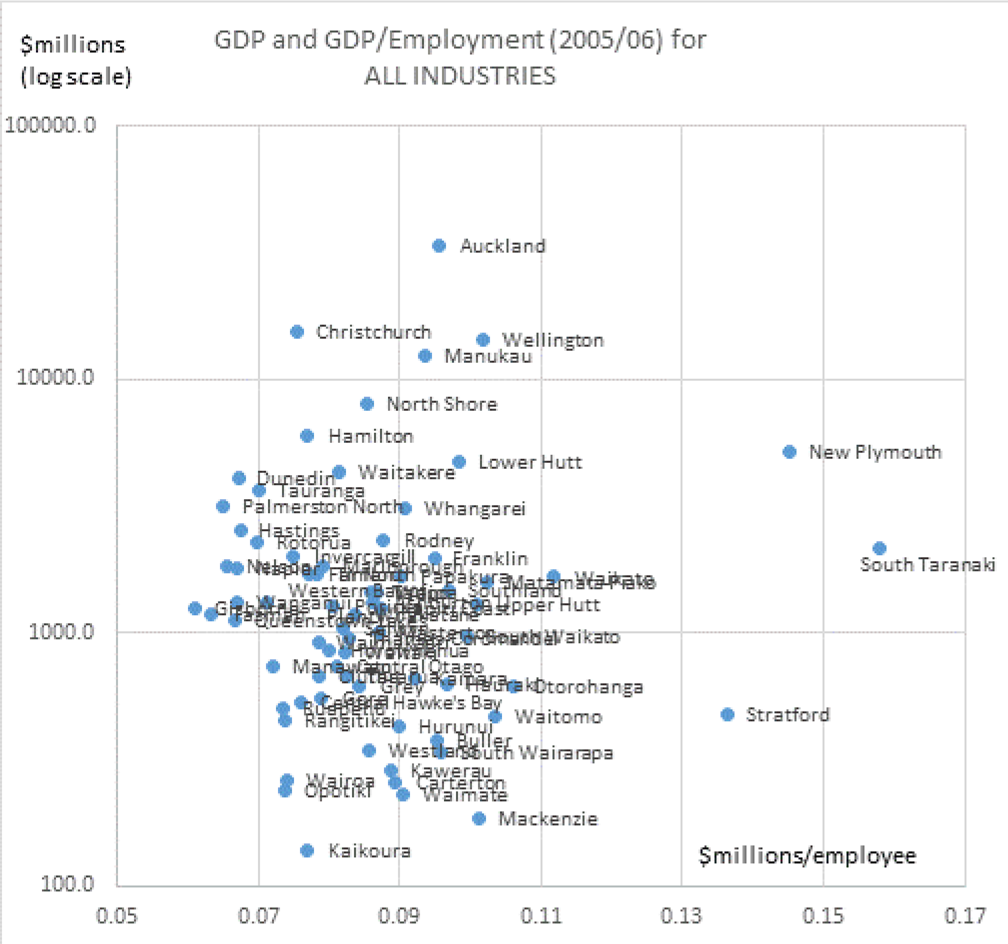
[41] Less than 20% of people commuting to work in 2006 travelled more than 20km, a distance that can be reached within 40 minutes travelling at 30km/hour.

Variable	Alstadt et al (2012)	This project (with code used)
		2001 were for the year ending June 2004 (the earliest available data). Flight data was sourced from www.bitre.gov.au/publications/ongoing/airport_traffic_data.aspx Drive time was as at 2014.
Access to seaport	Drive time to closest marine port (weighted by size of operation at port in subsequent research – personal correspondence)	ASEA – Drive time to seaport divided by number of port visits during 2013, where port was closest seaport with international visits. Visits data was sourced from www.transport.govt.nz/ourwork/sea/figs/ Drive time was as at 2014.
Access to major international freight airport	Drive time to closest major international freight airport.	Not used.
Access to intermodal rail facility	Drive time to closest intermodal rail terminal.	Not used.
Access to international border	Drive time to closest border to Canada or Mexico.	Not used.

Data for the 2013 Census was unavailable at the time of writing but could be included in future work.

A graph (see figure 7.1) of the 2006 data subset shows (a) a wide range in GDP per territory, ranging from high GDP for the cities of the Auckland region (including Auckland City, Manukau and North Shore), Wellington region (Wellington City and Lower Hutt) and Christchurch to small districts such as Kaikoura and Mackenzie, and (b) three TA areas that have a markedly larger GDP and number of employees than the rest.

Figure 7.1 2005/06 GDP by territory



Three highly productive A areas form the region of Taranaki. The high productivity is in part due to the capital-intensive mining sector but Taranaki also ranks number 1 in 10 of 55 sectors. To ease estimation within multiple regressions, a dummy variable was used to provide for a fixed Taranaki effect in all models.

For reasons to be discussed below, the data for 2001 and 2006 was considered within the same model[42] but a dummy variable was also created to provide for a fixed year effect in all models.[43]

Using the combined 2001 and 2006 census data, the following correlations (see table 7.2) exist between the variables to be used as the 'independent' explanatory variables. In particular, local working age population is highly correlated with the A40 people mass, and also with other TA area characteristics such as the percentage of people in managerial and professional jobs. Both correlations should be kept in mind when it comes to interpreting the modelling results as they create difficulties isolating what effect accessibility might have on GDP as opposed to the effect of the sheer number of people and how those people might choose to sort themselves between TA areas.

[42] Thus providing 144 observations for sectors that were present in all 72 territorial authorities.

[43] It should also be pointed out that drive times were not available for either year and that effective densities for both 2001 and 2006 were based on current drive times.

Other correlations are those between the access variables, including between air access, sea access and A40 people mass. These correlations create challenges differentiating between the effects of each variable.

Last the three statistics used to describe the people mix of the TA areas – the proportion of working age, of those highly qualified and those in high-paying occupations – are also correlated. This was not of major concern to the modelling as they would typically be used as a block to help 'explain' a TA area's GDP, which was of little interest to our project.

Table 7.2 Correlations between variables to be used as explanatory variables in models

	QDEG	OCCUP	AGE	A40	A180	AAIR	ASEA	POP	A120	A150	A180c
QDEG	1.00										
OCCUP	0.88	1.00									
AGE	0.75	0.57	1.00								
A40	0.48	0.55	0.29	1.00							
A180	-0.15	-0.07	-0.32	0.08	1.00						
AAIR	-0.38	-0.53	-0.22	-0.59	-0.31	1.00					
ASEA	-0.43	-0.53	-0.20	-0.66	-0.17	0.64	1.00				
POP	0.64	0.75	0.42	0.74	-0.07	-0.50	-0.60	1.00			
A120	0.00	0.01	-0.22	0.35	0.77	-0.41	-0.30	0.11	1.00		
A150	-0.10	-0.04	-0.15	0.03	0.66	-0.07	-0.10	-0.05	0.30	1.00	
A180c	-0.22	-0.07	-0.31	-0.16	0.64	-0.18	-0.01	-0.15	0.18	0.45	1.00

Note: POP and access variables are in natural log form

7.4 Results

The following sections proceed in a stepwise fashion to match the sequence of analysis and to allow the reader to more readily align this analysis with previous GVA model building. The procedure leads to the application of the model presented in the previous section, and a consideration of how this model might be adjusted to provide robust results for New Zealand.

7.4.1 Ordinary least square GDP models

The first thing to note is that the number of people with the 40-minute 'commute zone' does affect GDP. This is hardly surprising as it is a matter of scale: more people enable more work and output.

There are some immediate features to note about the association, shown in the figures 7.2 to 7.4 using the 2006 data only. First, the relationship appears linear on a log scale. All model estimation has used the natural log transformation for variables that were not proportions or dummy variables. Second, there is a wide range of GDP at each level of commuting mass. Third, there continues to be wide variation when GDP/employee is also measured for TA areas (figure 7.3), including the exceptional Taranaki effect previously noted. Fourth, the GDP elasticity to A40 mass ranges from -0.33 to +1.04 between sectors, and the GDP/employee elasticity (figure 7.4) ranges from -0.12 to +0.13. (The elasticities are measured as the coefficient in an ordinary least square (OLS) regression of ln(GDP) or ln(GDP/Employee) against a constant term and ln(A40)).The association is strongest amongst the service sectors and weakest amongst the primary sectors.

Figure 7.2 2005/06 GDP and commuting mass

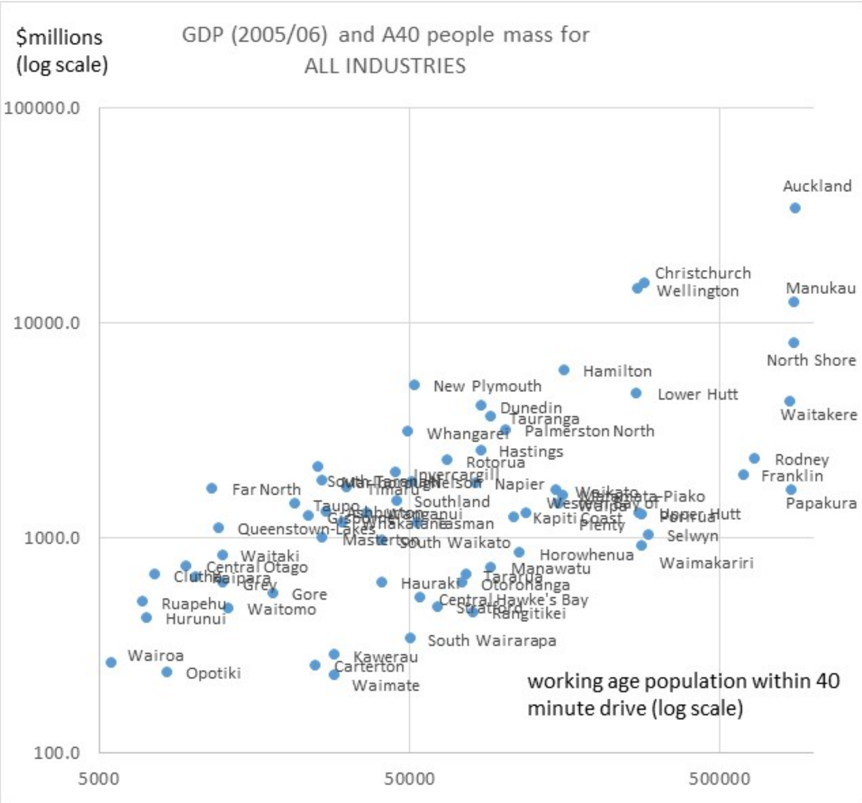


Figure 7.3 2005/06 GDP per employee and commuting mass

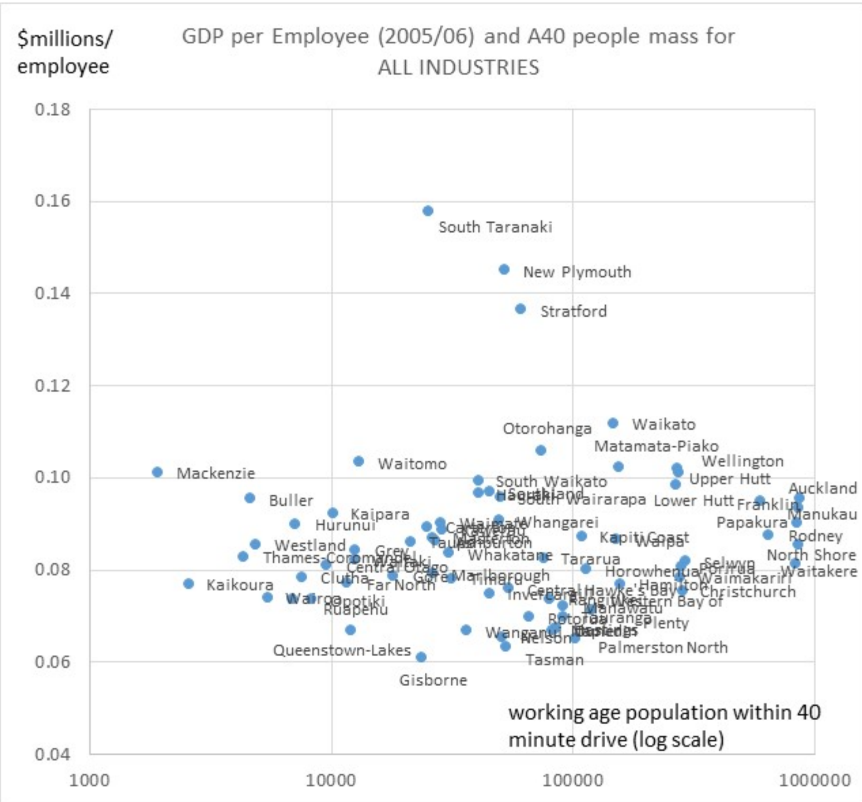
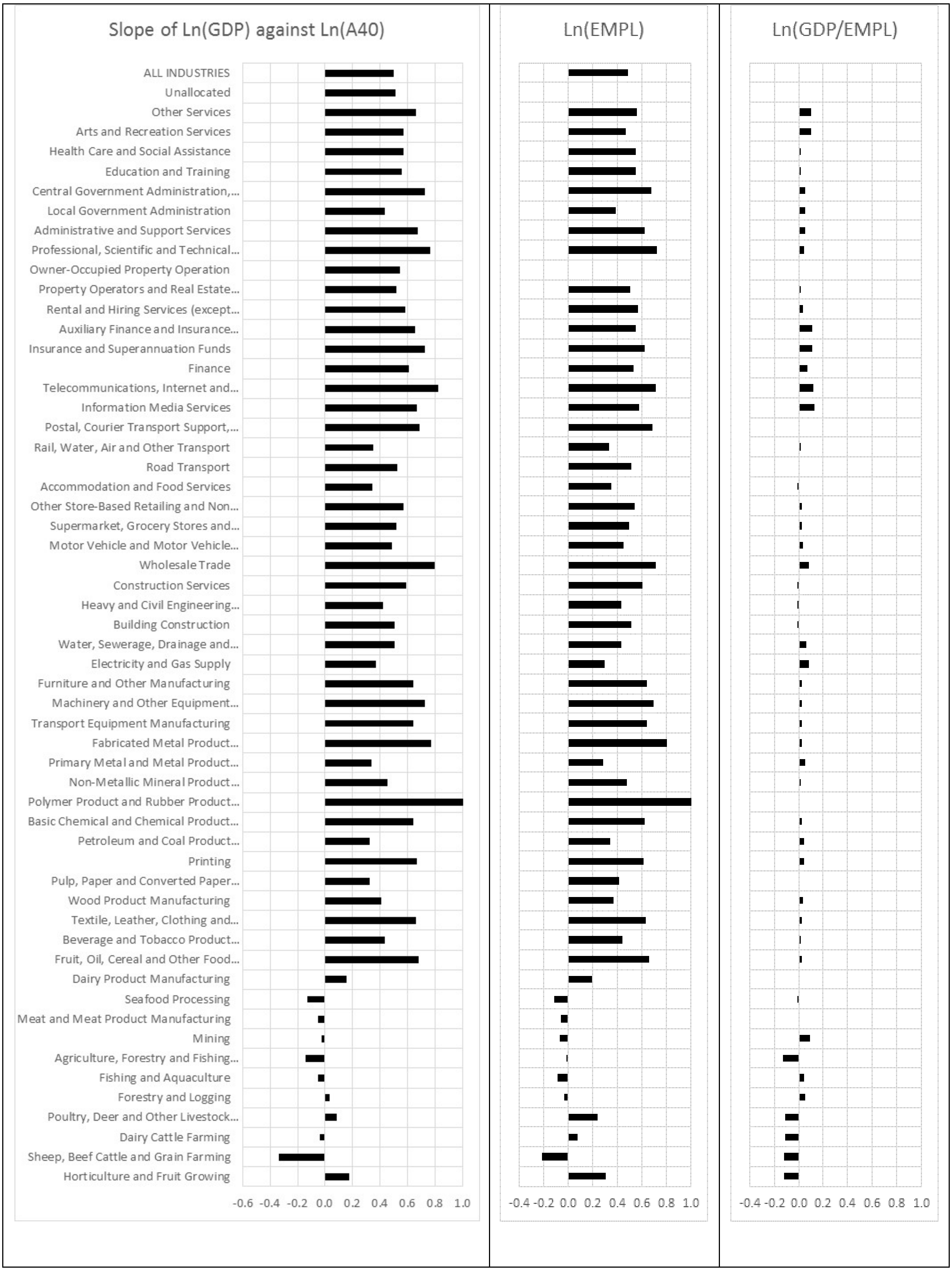


Figure 7.4 Elasticity between GDP, EMPL and GDP/EMPL and A40 in 2006



While the all industries GDP to A40 elasticity was 0.50 in 2006, it is well known that this statistic cannot be used to infer that a 1% increase in the working age population within a 40-minute drive will necessarily increase GDP by 0.50%. What is being observed is that a 1% higher working age population within a 40-minute drive time in 2006 was associated with GDP that, on average, was 0.50% higher. The observed higher GDP is likely to have been the consequence of many influences, including the reasons why people moved to within this 40-minute zone over prior years, who these people were and what type of activities they were undertaking.

The next step in the analysis was to build up the model to differentiate some of these effects.

But first, we need to consider if the GDP and accessibility relationship changed between 2001 and 2006? A look at various statistics suggests there was no significant change, other than a potential stepwise increase in GDP. This lack of change in elasticities may be due to the relatively small period – five years – that elapsed. The lack of discernible difference may also be a consequence of not having measured drive times using 2001 roads and speed limits. Without delving further into the reason, all further analysis was undertaken by combining the 2001 and 2006 data, thereby doubling the observations, and thereby also introducing an element of autocorrelation in the analysis[44].

The second data issue was how to treat the obvious sector differences in the GDP-A40 relationship? To address this issue and to match the intended model, the following analysis was undertaken within sectors or sector groupings.[45]

Returning to isolating the effects, progressively adding explanatory variables to an OLS regression of GDP against A40 for the finance sector illustrates how estimates of the GDP-A40 elasticity change as other factors are taken into account. This was a major point made by Overman et al (2009).

A regression of GDP against A40 over all TA areas and two periods shows (see step 1 in table 7.3) an A40 elasticity of 0.593 (with the two dummy variables also included). It may be that increasing accessibility will increase GDP but it is also clear that an increase of this magnitude would require an inducement of more employment. Without the induced employment, the A40 elasticity reduces to 0.083 (step 2 in table 7.3, being the estimated coefficient when EMPL is added to the model as an explanatory variable). Taking account of other potential differentiators of the people within each territory further reduces the elasticity to 0.063 (see step 5 in table 7.3). That is, the previous larger GDP effect of a change in A40 mass also requires changes in the age structure, qualifications and occupations of the local population. This 'people effect' is less than that observed by Overman et al (2009) (where the car accessibility impact on wages dropped from 0.084 to 0.054 when age, education and occupation were included in the model) but this is to be expected as the New Zealand data is aggregated over a TA area and the age, qualification and occupation measures relate to the residents of this area who are not necessarily employees there, plus the analysis is being undertaken within a sector (Overman et al (2009) fitted a sector effect later). What this analysis does confirm is that there are people effects that should be taken into account if the pure accessibility elasticity is sought (which it is). Not doing so risks biasing the elasticity estimate.[46]

[44] Spatial correlation between observations also exists.

[45] See section B2 in appendix B for statistical test of sector differences.

[46] A fault with the KPMG (2010b) Greengauge study.

Another insight from this stepwise analysis is that other forms of accessibility may also matter. The inclusion of A180 had little effect for this sector but adding AAIR did reduce the A40 elasticity estimate (from 0.063 to 0.038) and produced a significant flight effect.[47]

Table 7.3 Coefficients as variables (rows) are added incrementally to eight OLS models of GDP – finance sector

Variable added:	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
	ln(A40)	Ln(EMPL)	AGE	QDEG	OCCUP	A180	AAIR	ASEA
ln(A40)	0.593	0.083	0.082	0.070	0.063	0.062	0.038	0.048
ln(EMPL)		0.968	0.952	0.911	0.890	0.890	0.899	0.907
AGE			1.699	-0.831	0.052	0.156	-0.367	-0.642
QDEG				3.263	0.482	0.476	1.290	1.528
OCCUP					2.570	2.564	1.534	1.460
ln(A180)						0.009	-0.021	-0.020
ln(AAIR)							-0.060	-0.073
ln(ASEA)								0.033
R-square	0.413	0.973	0.974	0.977	0.978	0.978	0.980	0.980

Note: shading indicates that the coefficient was significantly different from zero at 5% level

To illustrate more closely the challenges in estimating which accessibility is influencing GDP, table 7.4 reports what each estimated access elasticity would be within the above GVA model if only one access variable were to be included in a model that otherwise already included the variables EMPL, AGE, QDEG and OCCUP, and the two dummy variables (Z2006 and ZTAR).

Table 7.4 Coefficients as each access variable (column) is added singly to OLS models of GDP – finance sector

Variable	Step 5	Step 9	Step 10	Step 11	Step 8
ln(A40)	0.063				0.048
ln(A180)		0.023			-0.020
ln(AAIR)			-0.072		-0.073
ln(ASEA)				-0.026	0.033
R-square	0.978	0.976	0.979	0.976	0.980

Note: shading indicates that the coefficient was significantly different from zero at 5% level

Each access variable shows the expected effect on GDP when it is the only access variable in the model, albeit only two are significantly different from zero. Of the four, the AAIR access provides the best fit for this sector (ie marginally higher R^2). Putting all four in the model shows a combination of A40 and AAIR accessibility has a significant association with GDP within the finance sector.

Thus far it would appear that accessibility beyond the commute zones does matter.

Repeating the above regression on all sectors shows the accessibility effects do differ by sector. Each model is the sector GDP (logged) fitted using OLS against EMPL and the four access variables (also logged), the

[47] The negative AAIR elasticity implies more GDP was associated with less drive time per international flight.

three people variables and the two dummy variables. Table 7.5 reports the estimated coefficients for the four access variables only for selected sectors while all results for all sectors are shown in table B.2 of appendix B.

Table 7.5 GDP-Access elasticities for selected sectors from OLS model (other coefficients not shown) and test for endogeneity

Industry sector	Ln(A40)	Ln(A180)	Ln(AAIR)	Ln(ASEA)	Wu-Hausman t-test
Dairy cattle farming	-0.094	-0.003	0.024	0.027	1.69
Fabricated metal product manufacturing	-0.006	0.032	-0.015	-0.005	0.73
Wholesale trade	0.083	0.040	-0.064	0.016	2.07
Finance	0.048	-0.021	-0.073	0.033	2.97
Professional, scientific and technical services	0.039	-0.051	-0.041	-0.023	0.03

There is a wide range of estimates with some coefficients being negative. The elasticity that more consistently shows the expected association with GDP is the AAIR measure (see appendix B, table B.2).

Table 7.5 does not include any estimates of standard errors. While these are readily available from the standard OLS statistical package output, it is important to note that the endogeneity of employment, an included explanatory variable, does raise the risk that the tabled estimates are biased. Thus while the estimated standard error may provide information about the precision of the elasticity estimate, the estimated coefficient and standard error tell us little of the accuracy of the estimate.

A Wu-Hausman test for endogeneity is shown in the last column of table 7.5 (and for all sectors in appendix B, table B.2). A t-value above 1.96 – indicative of endogeneity within the model – exists for the wholesale trade and finance sectors in table 7.5, and for over one-third of all sectors.

7.4.2 Two-stage least squares GDP models

The standard econometric method to deal with endogeneity is to undertake a two-stage least squares (2SLS) analysis, effectively regressing employment first against the other explanatory variables and then using the fitted employment in the GDP equation. We have now come to the simultaneous equation model presented as equation 7.3 in section 7.2. The 2SLS does not entirely remove bias due to endogeneity, especially when the first-stage equation provides a poor fit, but does produce estimates that are more consistent with the actual coefficients when large samples are used.

A further test revealed that residual terms in many of these models were heteroscedastic, contrary to the standard model assumption. To overcome this shortcoming, the option was taken to estimate White's heteroscedastic consistent standard errors.[48] This adjustment does not change the coefficient estimates (which remain unbiased despite heteroscedasticity) but does provide unbiased estimates of the standard errors so we can properly assess statistical significance.

The results of fitting this model for the five selected sectors in table 7.5 are shown in table 7.6. Only the estimated access coefficients within the GDP equation are reported. There is no change in the coefficients estimates within the professional services sector, given there was little evidence of endogeneity to begin with; the impact of the 2SLS was greater within the wholesale trade and finance sectors where the endogeneity was also greater.

[48] Within the Eviews software package – it is not known whether this adjustment was made in Alstadt et al (2012).

Table 7.6 GDP-access elasticities for selected sectors from 2SLS model vs OLS

Industry sector	Ln(A40) – 2SLS	Ln(A40) – OLS	Ln(A180) – 2SLS	Ln(A180) – OLS	Ln(AAIR) – 2SLS	Ln(AAIR) – OLS	Ln(ASEA) – 2SLS	Ln(ASEA) – OLS
Dairy cattle farming	-0.065	-0.094	0.048	-0.003	0.034	0.024	0.012	0.027
Fabricated metal product manufacturing	0.000	-0.006	0.033	0.032	-0.013	-0.015	-0.007	-0.005
Wholesale trade	0.093	0.083	0.039	0.040	-0.061	-0.064	0.012	0.016
Finance	0.056	0.048	-0.020	-0.021	-0.066	-0.073	0.027	0.033
Professional, scientific and technical services	0.039	0.039	-0.051	-0.051	-0.041	-0.041	-0.023	-0.023

The results of fitting this model for the 55 sectors are also shown in appendix B, table B.2. Table 7.7 is a summary of these results where only those coefficients significantly different from zero at the 90% level (95% significance in bold) are reported[49], plus shaded cells indicate where Alstadt et al (2012) estimated high sensitivity of GDP to connectivity.

Before considering the elasticity estimates, it is appropriate to point out that 2SLS estimates can also be biased when the first-stage equation is not a good fit. The squared correlation between the fitted EMPL and the actual EMPL is reported in appendix B, table B.2. The low correlation within the primary and some of the manufacturing sector is a warning that the elasticity estimates for these sectors may be unreliable. There is also the possibility that the employment equation suffers from endogeneity given that the accessible working age population for a TA area and the working age population within a TA area have co-evolved over time.

That said, it is interesting to note that the accessibility effect of apparent significance in these sectors is typically that beyond the commute zone. This seems logical as primary and manufacturing activity are often located in rural settings.

The results are similar to Alstadt et al (2012) in that significant access effects only occur within some sectors, access beyond the commute zone can matter and the significant effects are more common among the service sector. However, the sectors with sensitivity to access are different in the US and New Zealand studies.

Looking at the A40 coefficients, those estimates which are significantly different from zero include positive effects within the utility, trade and many of the service sectors, ranging from 0.020 (education and training) to 0.126 (water services).

Three manufacturing sectors are included amongst those sectors with significant positive effects from the wider 40–180 minutes working age population mass (A180), albeit only two at the 95% significance level.

Twenty-seven of the 28 sectors below the agriculture and manufacturing sectors (in appendix B, table B.2) show a direct negative association between GDP and drive time per flight (AAIR), with half being significant. Generally the magnitude of the direct GDP elasticity decreased between the OLS and 2SLS estimations.

[49] Probability tests are now appropriate given the adjustments undertaken for endogeneity and heteroscedasticity.

There is little evidence of effects from seaport accessibility, with only three elasticity estimates showing as possibly significant. One sector (health services) showing a significant association with GDP directly is worth mention: the reasons for this association, ie more productivity in the health sector when better connected to shipping, are not immediately apparent and are likely to be coincidental.

Table 7.7 Estimated access elasticities for each sector, with estimation by two-stage least squares using White's heteroscedasticity consistent standard errors (a) (b)

Industry sector	Ln(A40)	ln(A180)	Ln(AAIR)	Ln(ASEA)
Horticulture and fruit growing	**-0.071**			
Sheep, beef cattle and grain farming	**-0.083**			
Dairy cattle farming	-0.064			
Poultry, deer and other livestock farming				
Forestry and logging				
Fishing and aquaculture			0.087	-0.076
Agriculture, forestry and fishing support services and hunting	**-0.082**			
Mining	0.071			
Meat and meat product manufacturing	-0.053	**0.057**		
Seafood processing				
Dairy product manufacturing				
Fruit, oil, cereal and other food product manufacturing				
Beverage and tobacco product manufacturing			**-0.102**	
Textile, leather, clothing and footwear manufacturing				
Wood product manufacturing		0.040		
Pulp, paper and converted paper product manufacturing				
Printing				
Petroleum and coal product manufacturing				
Basic chemical and chemical product manufacturing			-0.049	
Polymer product and rubber product manufacturing				
Non-metallic mineral product manufacturing				
Primary metal and metal product manufacturing				
Fabricated metal product manufacturing				
Transport equipment manufacturing				
Machinery and other equipment manufacturing		0.044		
Furniture and other manufacturing				
Electricity and gas supply		0.130		
Water, sewerage, drainage and waste services	**0.126**	**0.139**		
Building construction				
Heavy and civil engineering construction				
Construction services				
Wholesale trade	**0.090**	**0.040**	**-0.061**	
Motor vehicle and motor vehicle parts and fuel retailing	**0.024**		**-0.040**	
Supermarket, grocery stores and specialised food retailing	**0.026**		**-0.039**	

Industry sector	Ln(A40)	ln(A180)	Ln(AAIR)	Ln(ASEA)
Other store-based retailing and non-store retailing	**0.025**		**-0.038**	
Accommodation and food services			**-0.041**	
Road transport		**-0.068**		
Rail, water, air and other transport		**-0.063**		
Postal, courier transport support, and warehousing services.		**-0.057**		
Information media services	**0.104**			**0.070**
Telecommunications, internet and library services	**0.123**		-0.054	
Finance	**0.056**		**-0.066**	
Insurance and superannuation funds	**0.055**		**-0.060**	
Auxiliary finance and insurance services	**0.061**		**-0.052**	
Rental and hiring services (except real estate)			**-0.063**	
Property operators and real estate services			**-0.068**	
Owner-occupied property operation				
Professional, scientific and technical services	**0.038**	**-0.050**	**-0.039**	-0.025
Administrative and support services	0.047			
Local government administration	**0.053**			
Central government administration, defence and public safety	**0.084**			
Education and training	**0.020**		**-0.038**	**0.036**
Health care and social assistance		**0.031**		-0.029
Arts and recreation services	**0.110**		**-0.086**	**0.093**
Other services	**0.100**		**-0.088**	

[(a)] Only coefficients significantly different from zero at 90% level reported (95% in bold red)

[(b)] Shaded cells are coefficients scored with high sensitivity (6–10) by Alstadt et al (2012). Note: US sectors are not an exact match to New Zealand.

So where does this leave us?

We have shown that elasticity estimates differ if 2SLS is used instead of OLS. Take wholesale trade: with 2SLS, A40 has a larger effect on GDP than the OLS estimate while the other three access coefficients were dampened.

We have also confirmed that accessibility effects vary by sector, with the primary and manufacturing sectors exhibiting quite different coefficients from the service sectors.

Finally, we have shown that access beyond the commute zone also matters. In some sectors above, a lower drive time to international flights (AAIR) was associated with higher GDP while the effect of the wider working age population base (A180) was mixed.

7.4.3 Further refinements to the New Zealand model

While these results are broadly consistent with Alstadt et al (2012), a closer examination of the results is appropriate. This section explores further the consistency of results across different sized TA area and the effect of breaking down the 180-minute travel time.

As measured at present, the A180 variable is very broad, being the working age population accessible beyond the commute zone (taken as 40 minutes) but within a three-hour drive. The 2006 numbers range from 1.38 million for the South Waikato District (low local population but within proximity to Auckland) to 0.39 million for Tasman District (with its long drive to either Christchurch or Wellington (via ferry)). The approach taken was to break down the working age population mass within a 40–180 minute drive time to 40–120 minutes, 120–150 minutes and 150–180 minutes.

The TA area size effect was considered by splitting the 72 TA areas into two groups: 'large' and 'other'.[50]

A number of further regressions were run with different variations of the model above, and with different samples of TA areas. These regressions are summarised below using three sectors as an example of the process and the results. A full set of results are shown in appendix B, table B.3.

First, take the finance sector. This was a sector where commute and flight effects were identified in New Zealand and the US (the first column in table 7.8 – recall US sensitivity shown as shading). If the larger regions are excluded from the sample then the significant A40 effect is no longer identifiable and the AAIR effect is dampened; in other words, the larger TA areas were a big part of the previously noted effect and the relationship was much smaller amongst the rest of the TA areas. The next step was to exclude the shipping access variable from the model, given there was little evident effect. As a result of this change, the previously noted AAIR effect no longer existed. The ASEA effect had been a small but opposite effect to the AAIR effect – remove the first and the second effect also disappeared. The next steps were to remove the AAIR variable from the model – this made little incremental difference – and to replace the A180 variable with the A120 variable. In this sector, this also had a minor incremental effect. The last step was to add the large regions back into the model that now contained only two (A40 and A120) access variables: the first noted A40 effect is still picked up but this is the only access variable of significance in this sector.

Table 7.8 Estimated access elasticities for the finance sector from stepwise changes to base 2-stage least squares model

Finance	Alstadt et al (2012)	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas
Ln(A40)	**0.056**				**0.065**
Ln(A180) or Ln(A120)					
Ln(AAIR)	**-0.066**	-0.030		NA	NA
Ln(ASEA)			NA	NA	NA

Take another sector, the wholesale trade sector (see table 7.9). The A40 effect is evident in all aforementioned regressions. The delivery zone effect is also always significant but appears better captured by the A120 measurement rather than by the A180. As above, the AAIR effect is heavily weighted towards the larger TA areas and to the presence in the model of the otherwise ineffectual ASEA variable.

[50] The 'large' TA areas consist of the seven TA areas of Auckland, Hamilton, the five TA areas of Wellington and Christchurch (14 in total leaving 58 others).

Table 7.9 Estimated access elasticities for wholesale trade sector from stepwise changes to base 2-stage least squares model

Wholesale trade	Alstadt et al (2012)	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas
Ln(A40)	0.090	0.051	0.049	0.046	0.087
Ln(A180) or Ln(A120)	0.040	0.067	0.067	0.078	0.070
Ln(AAIR)	-0.061	-0.044	-0.042	NA	NA
Ln(ASEA)			NA	NA	NA

We now look at a third sector – fabricated metal product manufacturing (see table 7.10). In the Alstadt et al (2012) model, a significant effect was found of the A40 mass in the US but no significant effect was identified in any access variable in New Zealand. Excluding the large TA areas reveals an association between this manufacturing sector's GDP and the working age population in the 40–120 minute drive zone. Exclude the AAIR and ASEA variables from the model and this effect persists when the large TA areas are returned to the model. A similar change occurred for other manufacturing sectors when this stepwise change in model and samples was undertaken.

Table 7.10 Estimated access elasticities for the fabricated metal product manufacturing sector from stepwise changes to base 2-stage least squares model

Fabricated metal product manufacturing	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas
Ln(A40)					
Ln(A180) or Ln(A120)		0.054	0.055	0.068	0.063
Ln(AAIR)				NA	NA
Ln(ASEA)			NA	NA	NA

Where do these analyses leave us? The air and flight effects appear largely associated with the larger TA areas and much of the variation explained by these two variables can be explained by a simpler model that only has two access variables, namely A40 and A120. Reducing the model to the two access variables has the advantages of parsimony and improved consistency across TA areas.

In sum, the outcome of this procedure – and the preferred estimates for further application outside of the large TA areas – is shown in the first two columns of coefficients in table 7.11, with the result for all sectors in appendix B, table B.4. The model remains a 2SLS model with employment estimated in the first stage and GDP in the second; with fixed effect dummy variables for Taranaki and 2006; but with only two access variables, namely A40 and A120. The resulting estimates are less sensitive to the size of the TA area and appear to capture most – if not all – of the effects found in the fuller model.

A variation of this model was also fitted, primarily the result of shortcomings revealed in the subsequent case study phase of the project. A new access variable was calculated as the working age population within the 0–120 minute drive area, ie the equivalent of A40 plus A120 (recall A120 is 40–120 minute density). The last model fitted included both A40 and A120all. This model suffers from increased correlation between the right-hand side variables but was of practical interest, for reasons that will become evident in the case study.

The estimated coefficients for the two models are shown in table 7.11.

A last column has been added to the table showing the agglomeration elasticities applied in the EEM.

Table 7.11 Preferred GDP-to-access coefficients for further application

Industry sector	Ln(A40)	Ln(A120)	Ln(A40)	Ln(A120all)	EEM
	Initial model		Variant model		
Horticulture and fruit growing	-0.070		-0.069		0.032
Sheep, beef cattle and grain farming	-0.085		-0.081		
Dairy cattle farming	-0.078		-0.081		
Poultry, deer and other livestock farming					
Forestry and logging					
Fishing and aquaculture					
Agriculture, forestry and fishing support services and hunting	-0.087		-0.085		
Mining					0.035
Meat and meat product manufacturing	-0.061	0.070	-0.093	0.102	0.061
Seafood processing					
Dairy product manufacturing					
Fruit, oil, cereal and other food product manufacturing		0.048		0.070	
Beverage and tobacco product manufacturing					
Textile, leather, clothing and footwear manufacturing		0.052		0.084	
Wood product manufacturing		0.059		0.085	
Pulp, paper and converted paper product manufacturing					
Printing		0.058		0.095	
Petroleum and coal product manufacturing					
Basic chemical and chemical product manufacturing		0.065	-0.070	0.101	
Polymer product and rubber product manufacturing					
Non-metallic mineral product manufacturing		0.068	-0.074	0.108	
Primary metal and metal product manufacturing					
Fabricated metal product manufacturing		0.063		0.093	
Transport equipment manufacturing		0.068	-0.062	0.104	
Machinery and other equipment manufacturing		0.067		0.100	
Furniture and other manufacturing		0.061		0.095	

Industry sector	Ln(A40)	Ln(A120)	Ln(A40)	Ln(A120all)	EEM
	Initial model		Variant model		
Electricity and gas supply					0.035
Water, sewerage, drainage and waste services	**0.085**	0.083			
Building construction					0.056
Heavy and civil engineering construction					
Construction services					
Wholesale trade	**0.087**	**0.070**	**0.057**	**0.099**	0.086
Motor vehicle and motor vehicle parts and fuel retailing	**0.028**	**0.021**		**0.030**	0.086
Supermarket, grocery stores and specialised food retailing	**0.031**	0.018		**0.025**	
Other store-based retailing and non-store retailing	**0.029**	0.019		**0.026**	
Accommodation and food services					0.056
Road transport		**-0.044**	**0.027**	**-0.061**	0.057
Rail, water, air and other transport		**-0.038**	**0.029**	**-0.052**	
Postal, courier transport support, and warehousing services.		**-0.033**	**0.025**	**-0.047**	
Information media services	**0.077**				0.068
Telecommunications, internet and library services	**0.107**		**0.079**		
Finance	**0.065**		**0.061**		0.087
Insurance and superannuation funds	**0.077**		**0.051**	**0.060**	
Auxiliary finance and insurance services	**0.070**		**0.053**		
Rental and hiring services (except real estate)					0.079
Property operators and real estate services					
Owner-occupied property operation					
Professional, scientific and technical services	**0.061**		**0.054**		0.087
Administrative and support services	**0.051**		**0.056**		0.087
Local government administration	**0.056**		**0.040**		
Central government administration, defence and public safety	**0.081**		**0.068**		
Education and training		**0.026**		**0.041**	0.076
Health care and social assistance		**0.043**		**0.062**	0.083
Arts and recreation services	**0.089**		**0.062**	**0.067**	0.053
Other services	**0.096**	**0.069**	**0.053**	**0.119**	

Notes:

Only coefficients significantly different from zero at 90% level are reported (95% in bold red)

Shaded cells are coefficients scored with high sensitivity (6-10) by Alstadt et al (2012). US sectors are not an exact match to New Zealand.

The results of the access effect on employment are shown in appendix B, table B.5.

This completes the analysis of the data. The next step is to consider how to use this information.

7.5 Discussion and extension of study

The GVA method as applied by KPMG (2010b; 2013) in the UK involved three steps[51]:

1 Estimate the GVA elasticity to accessibility, where accessibility can be measured in various – often confounding – ways.

2 Apply this elasticity to a proposed transport intervention to show the GVA impact in one future year (say 20 years).

3 Estimate how the GVA effect is distributed amongst regions.

7.5.1 Model estimation

The results of this chapter have focused on the first step. Estimates of elasticities have been developed using and extending similar methods to previous GVA and agglomeration studies.

The results confirm the commuting mass effect on GDP, providing elasticities to A40 that are similar to those derived by Mare and Graham (2009) for some sectors. The results also show that there is a wider dimension to accessibility effects on GDP than just access to commuting labour. For example, the Transport Agency currently use the 0.086 elasticity estimated by Mare and Graham (2009) for the wholesale trade sector to calculate the likely extra GDP impact of having a higher effective mass. The above analyses imply that the accessibility effect is broader than that and instead the GDP increase resulting from an improvement in travel time can be estimated by applying two estimated elasticities to the improved access variables, namely a 0.087 ‘commute zone’ effect and a 0.070 ‘delivery zone’ effect (see table 7.12).

Table 7.12 Elasticity estimates for accessibility

Industry sector	Mare and Graham (2009)	Ln(A40) OLS	Ln(A40) 2SLS	Ln(A120) 2SLS
Wholesale trade	0.086	0.118	0.087	0.070

One immediate way to test and improve these results would be to extend the data to the 2013 Census.

7.5.2 Use of model for forecasting

The second step in the GVA analysis was to adapt an existing forecast to take into account the changes likely from a transport project, the difference in forecast GDP being a benefit from the project. This step became phase III of this project (after the literature review and model fitting). It was during the case study phase that a number of issues could also be addressed.

First, the model fitting phase revealed a large number of elasticities. From a practical perspective, some grouping of effects might be preferred. This would be better done alongside consideration of how these results could be applied to project appraisal[52].

[51] Overman et al (2009) and Alstadt et al (2012) did not take the third step.

When it comes to applying the elasticities to forecasts, there are issues of whether the effects are persistent over a long period and whether the estimated GDP is inclusive or exclusive of the traditionally measured travel cost savings.

The UK GVA methodology simply applies the forecasts to one period and assumes this GDP gain accumulates slowly and then persists. At the least, the sensitivity of results can be tested to this assumption.

The UK applications also treat the model as an ancillary to the standard CBA model, with the two results presented side by side; the implication being that the GDP effects will include travel cost savings. In the US, elasticities of this sort have been used to estimate add-ons to the standard CBA. Mare and Graham's (2007) agglomeration elasticities for the UK and New Zealand are also treated in this way. Under what circumstances these GDP effects might be considered additional to traditional transport benefits requires further investigation.

There is also the fundamental issue of whether it is appropriate to measure benefits that may be several steps removed from the transport intervention. The elasticities derived after taking people-based effects, sector-based effects and employment effects into account can be used to measure the direct effects to be expected from a transport investment. That is the conservative approach. But it may be that a transport investment is pivotal to the transformation of activity in an area, with the ultimate benefits requiring both the transport investment and supporting investment, either by the private or public sector, and either in real or human capital. The model developed here has the potential to consider wider benefits such as changing skills and changing employment levels, thus providing an even greater assessment of 'wider economic benefits'.

Three reasons are typically offered for ignoring any expected changes in people's skills or business activities.

1 These improvements will require further investment by the people and/or businesses so that any estimated GVA impact due to skill or activity change would be a gross benefit and not a net benefit to society (more precisely, the other costs of change are required to be included in the cost side of the CBA).
2 It is difficult to differentiate the historic GVA effect of transport from other influences, including showing that previous transport interventions have caused GVA changes (as opposed to higher GVA prompted more transport investment), although KPMG (2013) reports that 'where time series data is available some other studies have been able to detect a causal link between transport and infrastructure investment and economic output, however the transferability of these results is uncertain'.
3 It is questionable that the accompanying investment and hence GVA effect will occur.

In other words, there is uncertainty about the wider benefits of a transport intervention whereas there is confidence that the travel-saving benefits, and the direct capital and operating costs of the transport intervention, will occur and, even if not exactly as modelled, the estimated benefits will be biased in a consistent manner across standardised project assessments. The difficulty with this approach to appraisal is that the BCR can potentially filter out a transport intervention that could initiate a path of action by people, businesses and governments that generates large extra benefits relative to the extra costs. Picking

[52] Groupings were not suggested in the case study where it was considered more flexibility was offered by retaining the original sector elasticities.

up such projects is left to the judgement of a few decision makers outside of the BCR filtering process. Put another way, it is not obvious that the transformation effect of any project is always correlated with the travel-saving derived BCR for a project, and a more specific study of wider benefits may be required. To truly understand the net wider benefits of a project requires some understanding of the distribution of the benefits and disbenefits, eg jobs being relocated from one territory to another.

The model developed here, as with the Alstadt et al (2012) US model but unlike the UK GVA models, can be used to explore employment effects. Unfortunately, though, the model does not take into account the competing forces for resources that exist in reality. This is where the third step in the GVA analysis is relevant.

7.5.3 Estimating regional redistribution effects

The aforementioned discussion of the model and its merits ignores the third dimension to the GVA approach, namely the estimation of regional effects. How this assessment is done has not received the same public attention as the contested magnitude of national benefits but there has also been no consistent method applied to estimate the regional effects.

The starting point for the regional assessment, ie beyond the net productivity gains estimated in the previous section, has been to assume that the change in productivity will change the relative attractiveness of locations and that, in a world of fixed labour supply, the change in relative attractiveness will cause people to shift from the relatively less attractive to the relatively more attractive locations. As an example, an accountant in Wanganui, may experience no change in connectivity following an investment into Waikato roads and hence will not receive a one-off change in wages, but he/she may move to Hamilton if the wages in Hamilton increase as a result of improved connectivity for Hamilton.

It is also possible that the higher Hamilton income attracts migration from overseas. This potential international migration effect has been ignored in the UK studies and has also been ignored here, largely due to scope of the projects. There is unlikely to be a new immigrant effect in New Zealand given the quota system for immigration in operation but it is possible that higher Hamilton wages do attract New Zealanders to return from abroad and, to a lesser extent, prompt Australians to emigrate.

The three core GVA papers use three different methods to assess the effect of the estimated relative GVA change.

1 KPMG (2010b) in the Greengauge assessment estimated the elasticity of employment density to accessibility by running a regression analysis on employment density in a similar but separate manner to the regression for wages.[53] The next step was to multiply the estimated elasticity by the forecast changes in the effective working age population mass (the ‘labour market’) and the wider effective employment mass (the ‘business market’), as at 2040, to derive the relative one-year employment gain expected at each district.[54] Working within a constraint of a zero national employment change[55], the relative employment gain was engineered by shifting ‘mobile’ employment between districts where

[53] The separate estimation does create the potential for bias, most likely an estimated elasticity greater than the true parameter.

[54] Again a bias potentially was created by arbitrarily choosing to use the ‘labour’ elasticity and to apply this to a change in accessibility calculated as 60% of the change in ‘labour’ mass and 40% of the ‘business’ mass.

[55] KPMG (2010b) in a separate step calculated a net national employment gain (25,200) equal to 0.1 times the average wage gain, being an estimate of those enticed into the national labour market by the higher average wage available after the transport intervention.

mobility was assessed as that proportion of local employment not within sectors that primarily serve the local district or region (eg not hairdressers or mechanics). The movement of employment to the districts with relatively improved connectivity has the regional effect of increasing the number of people employed (with an offsetting decrease in other districts) and has the national effect of increasing the wage by the pre-intervention difference in regional wages within the sector (ie a wage premium already exists between regions but it is only after the transport intervention and the further widening of the wage differential that the shift occurs between districts[56]).

2 KPMG (2013) in the HS2 study applied a trade model to estimate the extent of shifting between districts, again subject to a zero national employment gain constraint. The competition component of the model has the market share of any sector in a district being a function of the sum of the local cost per output, the weighted cost of car travel to other districts and the weighted cost of rail travel to other districts relative to the sum of these costs across all districts for the sector. That is, a district will have a relatively high share of national output for a sector if their production costs are relatively low and/or the cost of travelling by car or rail to other districts is relatively low. The consumer component of the model estimates consumption for each sector and district from input-output tables. Applying the model, changes in transport costs, and hence the number of trips, will lead to changes in sector market shares. Again it appears that the movement within a sector from a low-wage location to a high-wage location creates both a regional employment effect on regional GVA and a national wage effect on national GVA (as people shift from low-wage areas to high-wage areas).

3 Overman et al (2009, chapter 6) do not explicitly forecast a change in effective density but instead consider various counterfactuals within a trade model with heterogeneous firms. Different firms have different productivities and decreasing transport costs allows the more productive firms to widen their sales market, and in the process forcing less productive firms to change activities. Note neither model measures the shift in population that would occur as a result of these dynamics but it is possible to consider within the model what an exogenous shift in population would do to regional wages (eg what would be the average wage effect of a 10% increase in the Manchester population resulting from a shift from elsewhere in the UK in proportion to local population).

There has been criticism of the KPMG approaches while the Overman approach did not provide a forecast of regional distribution. How regional redistribution effects are estimated in New Zealand requires further investigation.

To sum up, a model has been fitted that considers the relationship between accessibility and GDP, taking into account that accessibility affects both employment and productivity. The data confirms that accessibility does matter and that the influence may go beyond the commute zone. Elasticities were derived that can form the basis of project appraisal. The estimates of these elasticities and how the estimates are applied can be refined by considering a real project appraisal example. It is possible to use the model to estimate productivity gains. It is also possible to use the model to consider wider impacts via change in employment and activity at the more accessible locations. However, the model does not take into account effects at other locations, where accessibility may not have changed in absolute terms but where relative effects may occur. Selecting a method for estimating regional redistribution may be helpful if impact analysis is limited to productivity effects; it will be essential if changes in people and activity at a more accessible location are also to be assessed.

[56] Implicitly this analysis acknowledges that there exists a cost to shifting (otherwise why had the shift not already occurred?) but this cost is overlooked in any subsequent benefit assessment.

8 Case study

8.1 Introduction

The GVA approach measures the effect of changing populations on GDP productivity. Specifically, the early stages of our GVA project found a relationship within some industry sectors between the working age population within a 40-minute drive of the territory centroid (considered the commute zone) and the level of GDP in the territory, and between the working age population within 40–120 minutes of the territory centroid (considered the delivery zone) and industry sector GDP.

The methodology contrasts with the EEM agglomeration benefits that relate industry sector GDP to distance-weighted populations surrounding the territory centroid.

A case study was chosen to test the application of the model, namely to examine the GDP effects of an additional Waitemata Harbour Crossing (AWHC). The 2010 Preliminary Business Case (NZ Transport Agency 2010) for AWHC estimated a 2026 agglomeration benefit[57] from an additional harbour crossing of around $60 million, rising to $110 million in 2041. The present value of the 30-year benefit stream, at 8% pa, was estimated to be up to $250 million. All sums are in 2010 dollars.

The study considered the GVA effect of an AWHC using the model and methodology explored in this report. The analysis revealed a range of estimated GVA effects, depending on the time of day the travel was modelled. This presentation may seem confusing but the results are presented for the different travel times as it is unknown in theory or practice which travel period is the major contributor[58] to the productivity gains. Applying the elasticities from the model in the previous chapter in a similar manner to that used in the US and aligning the analysis period and discount rate to the preliminary AWHC study revealed a range of candidates for the 'GVA effect' from $1,401 million (present value in 2010 dollars) if the time saving was measured at the AM peak to $103 million if the time saving was measured at the interpeak period. The present value of a weighted average daily time saving was $425 million.

The positive effect largely comes from more people with a 40-minute commute with an AWHC and hence measures a similar agglomeration to the earlier study, albeit the resulting number is different. The AWHC does increase the delivery density in some zones but the effect is not large and is sometimes offset by declines in delivery densities elsewhere. The net effect of the delivery zone changes is negative when a weighted average drive time is used.

8.2 Description of the case study

The AWHC is a proposal to build a second crossing across the Waitemata Harbour, a little to the east of the current harbour bridge (opened 1959). The options are a tunnel or bridge, expected to cost around $3–5 billion for construction (in 2010 dollars) or $1.16–1.57 billion for all costs in present value terms. A preliminary business case prepared by PWC and NZIER (NZ Transport Agency 2010) estimated the following benefits (in 2010 present value terms) by applying the methodology in the EEM, including the wider economic benefits related to agglomeration:

[57] Using EEM methodology, with elasticities derived by Mare and Graham (2009).

[58] One argument is that the interpeak drive time saving is appropriate because the model estimated in the previous chapter was based on a general GIS-derived drive time.

- $300 million in travel time savings
- $80 million in decongestion benefits
- $9 million in travel time reliability benefits
- $250 million agglomeration benefits.

Kernohan and Rognlien (2011) in a similar calculation put the agglomeration benefits for the AWHC at $18m in 2026, $28m in 2041 and $72m in present value terms.

8.3 Steps in the analysis

This case study GVA analysis first required calculation of effective densities based on drive times and population forecasts from the Auckland Transport Model (ATM2)[59] run used in the preliminary business case. This model also provided the employment and GDP forecasts used to translate the changes in densities (that are likely to result from an AWHC) to changes in GDP by applying the previously estimated density elasticities. The difference between the do-minimum (DM, ie base case) and do-something (DS, ie the AWHC) were estimated at two time periods (2026 and 2041) and the benefits were extrapolated over a 25-year period (2029 to 2053), again consistent with the preliminary business case.

8.3.1 Change in densities

The following steps were taken to calculate effective densities:

- Estimate working age population forecasts for 2026 and 2041 based on population forecasts provided.
- Extend beyond the Auckland regional transport model (ART3) area (512 zones) to capture potential destinations within two hours travel of each ART3 zone.
- Estimate working age populations at 2026 and 2041 for the census area units (CAUs) within these outer TA areas.
- Estimate drive time from the edge of the ART3 zone to centroids of outer CAUs and add these times to intra-ART3 drive times to complete the drive time matrix (687 x 687 matrix).
- Calculate A40 and A120 for DM and DS scenarios as at 2026 and 2041, based on drive times[60] for DM and DS scenarios – densities derived separately using AM (7–9am), PM (4–6pm) and interpeak (9am–4pm) workday drive times.
- Also calculate A40 and A120 densities based on a weighted average workday drive time, using weights of 20%, 20% and 60% for AM, PM and interpeak respectively.[61]
- Select zone or CAU containing the territory centroid as the estimate of the A40 and A120 densities (DM and DS) for the 15 TA areas included in the case study.[62]

[59] The ATM2 project integrates population and land use projections from the Auckland strategic planning model (ASP3) and routes and travel costs from the Auckland regional transport model (ART3). This LUTI model works within demographic and economic assumptions and within planning policy constraints to (a) fill up the available area and (b) optimise route selection in an integrated manner.

[60] Drive times are for all trip purposes for a typical working day.

[61] Subsequent investigation suggests these weights are inappropriate and hence the magnitude of the net benefit will differ to what is reported here but the general conclusions are still valid.

8.3.2 Changes in employment and GDP

The following steps were taken to translate density changes into changes in GDP productivity:

- Estimate employment by sector by territory for 2026 and 2041 for 55 sectors based on projections for six larger sectors provided within ART3.
- Estimate GDP by sector by territory for 2026 and 2041 for the 55 sectors based on the above employment projections and assume 1.8% pa real GDP growth rate (same for all sectors).
- Apply change in densities per territory and estimated sector elasticities to calculate estimated change in employment and GDP due to change in drive times, by sector and territory – effects available for AM, PM, interpeak and weighted average drive times at 2026 and 2041.
- Sum direct GDP effects over sectors and TA areas to derive total productivity gain in GDP in 2026 and 2041.
- Extrapolate benefits over the period 2026 to 2070, using the average per annum change in benefit between 2026 and 2041, and discount the benefits between 2029 and 2053 back to 2010 at an 8% pa real discount rate.

8.4 Results

The variation within the results can be illustrated by building up the net effect from the individual year and travel time periods. For example, take the travel during the AM period in 2026.

The change in drive times varies between zones. A trip from Takapuna to Greenlane[63] in the 2026 AM reduces from 35.03 minutes to 29.58 minutes (ie down by 5.45 minutes) under the DS scenario, but a trip between Warkworth and Takapuna[64] increases from 67.60 minutes to 71.1 minutes (ie up by 3.5 minutes). In other words, the new crossing induces both higher and lower drive times.

A mix of increases[65] and decreases in drive time combines with forecast populations to produce a range of population density rises and falls. These are shown for the TA areas in and around Auckland in table 8.1. For the 2026 year and AM travel period (as above), the A40 density increases for North Shore City (+15.6%) and Auckland City (+8.5%), being the TA areas immediately north and south of the AWHC, but the A40 density declines further north for Rodney trips (-5.0%) as traffic slows above North Shore.

A difficulty arises when it comes to what 'A120 density' to use. The model was initially estimated using the 40–120 minute drive time to define the A120 effective density. With the AWHC, there is a slight widening of the 40-minute drive time polygon for zones near the crossing but often little change in the 120 minute drive time polygon for TA areas. The working age population within 120 minutes of any zone does not change much as most of the large population bases are already within 120 minutes' drive time. Thus an increase in the A40 density is mirrored in many cases by a decrease in the 40–120 minute density. The difficulty this presents is that the model was not estimated with data created under these circumstances. That is, the initial model data contained few if any instances where the population within

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[62] A sensitivity test, reported below, was also applied with change in density calculated on the basis of the sum of all zones within a TA area rather than just the centroid zone.

[63] A trip from Takapuna to Greenlane is moving south, using the AWHC (or the existing bridge).

[64] A trip from Warkworth to Takapuna is moving south but does not reach the AWHC.

[65] Drive times did increase for some routes in the network beyond the AWHC.

40 minutes increased while simultaneously the population within 40–120 minutes decreased as a result of investment in transport infrastructure. Applying the elasticities from the above model to changes in 40–120 minute densities would result in the illogical situation where a rise in GDP due to a 1,000 people 'transferring' into the A40 density of Auckland City, say, and producing some percentage increase in A40, can be more than offset by these same 1,000 'transferring' out of the A120 density and producing a larger percentage decline, with the net effect that people being more accessible to firms and to other people can lead to lower GDP. This mirroring effect is evident in table 8.1, showing the change in densities using the 2026 AM travel period (although there are also some A120 increases due to a widening of the A120 polygon TA areas outside of Auckland), eg the Auckland City A40 density rises by 70,447 people or 8.5% while the A120 density falls by 55,687 or 13.7%.

Table 8.1 Change in A40 and A120 densities using 2026 AM drive times

Territory	∆A40 people	∆A40 %	∆A120 people (40–120 min)	∆A120 %	∆A120all people (0–120 min)	∆A120all %
Whangarei District	0	0.0%	-8,231	-10.1%	-8,231	-5.9%
Kaipara District	0	0.0%	51,519	12.6%	51,519	10.7%
Rodney District	-3,398	-5.0%	7,683	0.7%	4,284	0.4%
North Shore City	106,023	15.6%	-101,758	-19.4%	4,265	0.4%
Waitakere City	-5,055	-0.7%	11,780	2.4%	6,725	0.6%
Auckland City	70,447	8.5%	-55,687	-13.7%	14,760	1.2%
Manukau City	12,873	2.0%	-11,148	-1.5%	1,725	0.1%
Papakura District	59,800	14.9%	-59,800	-6.2%	0	0.0%
Franklin District	1,213	0.5%	12,776	1.1%	13,989	1.0%
Thames-Coromandel District	0	0.0%	4,635	3.2%	4,635	1.3%
Hauraki District	0	0.0%	13,775	4.4%	13,775	2.6%
Waikato District	0	0.0%	38,451	4.8%	38,451	3.8%
Matamata-Piako District	0	0.0%	14,816	4.4%	14,816	2.7%
Hamilton City	0	0.0%	65,006	15.0%	65,006	10.1%
Waipa District	0	0.0%	7,406	6.1%	7,406	2.3%

The US analysts have addressed this issue by simply *estimating* the elasticity with 40–120 minute densities but then *applying* the elasticity to changes in 0–120 minute densities. This practical solution does produce an unbiased A40 coefficient estimate and results that appear reasonable across a wide number of situations. It is also suited to situations where the effect is largely a density shift towards the inner drive time zone. In particular, it means the situation described above leads to an estimated increase in GDP due to a greater A40 density and no offsetting decline. But, in general, the A120 coefficient will be biased and therefore not suitable in all situations.

Following the US lead, the results reported in table 8.2 use the elasticities reported in chapter 7 but applied to changes in the 0–120 minute density (plus changes in the A40 density as per usual). That is not to say, at this stage, that this provides the correct estimate of the GDP effect of the AWHC. Other means to derive an estimate are also provided in table 8.6.

Applying the elasticities from the model with A40 and A40–120 elasticities to the changes in A40 density provide an estimate of an A40 effect of around $282 million extra GDP, based on the 2026 AM drive time savings.

The elasticities for the delivery zone (taken to be 0–120 minutes) are mixed and the changes in densities are also varied but there is a moderate increase in productivity expected from delivery zone densities, resulting in a total delivery zone GDP effect of $34 million.

The combination of the A40 and A120all density direct effects on GDP is modelled to be $316 million or +0.2% on the DM scenario.

Table 8.2 Model run: 2026 unrestricted, origin=CENTROID and drive times= maximum of to/from AM trip[(a)]

0–120							
AM							
Centroid	2026	Change	Change	Change	Change	Change	Change
Sensitivity off		WA POP	GDP$mill	WA POP	GDP$mill	GDP$mill	GDP
Territorial authority area	GDP ($millions)	ΔA40	A40 effect	ΔA120all	A120all effect	A40 + A120all	% change
Whangarei District	6,537	0.0%	$0.0	-5.9%	-$6.3	-$6.3	-0.1%
Kaipara District	1,389	0.0%	$0.0	10.7%	$1.9	$1.9	0.1%
Rodney District	6,493	-5.0%	-$4.3	0.4%	$0.3	-$4.0	-0.1%
North Shore City	16,043	15.6%	$77.9	0.4%	$0.9	$78.8	0.5%
Waitakere City	10,277	-0.7%	-$1.5	0.6%	$1.0	-$0.5	0.0%
Auckland City	65,914	8.5%	$190.9	1.2%	$10.9	$201.8	0.3%
Manukau City	24,627	2.0%	$10.2	0.1%	$0.5	$10.7	0.0%
Papakura District	3,412	14.9%	$8.4	0.0%	$0.0	$8.4	0.2%
Franklin District	4,806	0.5%	$0.3	1.0%	$0.6	$0.9	0.0%
Thames-Coromandel District	2,010	0.0%	$0.0	1.3%	$0.3	$0.3	0.0%
Hauraki District	1,308	0.0%	$0.0	2.6%	$0.3	$0.3	0.0%
Waikato District	3,488	0.0%	$0.0	3.8%	$0.8	$0.8	0.0%
Matamata-Piako District	3,331	0.0%	$0.0	2.7%	$1.2	$1.2	0.0%
Hamilton City	12,649	0.0%	$0.0	10.1%	$21.2	$21.2	0.2%
Waipa District	3,019	0.0%	$0.0	2.3%	$0.8	$0.8	0.0%
SUB-TOTAL	165,303		$281.8		$34.4	$316.2	0.2%

[(a)] The A40 and A120all represent the change in effective density of working age population. Note that the actual working age population and employment level are fixed, ie this is a fixed land use assessment.

A similar exercise repeated for the 2026 PM and interpeak travel period, and AM, PM and interpeak repeated for 2041, is summarised in the table 8.3. The access effect is not always positive. This is particularly noticeable for travel during the interpeak period when the effect of many drive time increases leads to a net decrease in accessibility and a potential productivity decline (except the A40 density effect in 2041).

The present value of these benefits extrapolated over 45 years at 8% pa real discount rate[66] is $1,401 million if productivity gains were to result from AM drive time savings, or $103 million and $1,705 million if based on the interpeak and PM drive time savings.

[66] As used in the earlier preliminary AWHC business case.

Applying a 20%/60%/20% weighting to drive times and reworking the density changes using these weighted average workday drive times results in a GDP productivity gain of $425 million in present value terms[67]. This estimate is higher than the estimate derived using the EEM agglomeration methodology of $250 million.

Table 8.3 Summary of annual and cumulative effects on GDP of changing accessibility ($m)

Time of day	AM	Interpeak	PM	WGTAVE	EEM agglomeration
Density measured from:	**Centroid**	**Centroid**	**Centroid**	**Centroid**	**ART3 zones only**
A40 GDP effect 2026	$281.8	-$17.7	$137.4	$36.74	$60.0
A120all GDP effect 2026	$34.4	-$15.4	-$6.1	$0.5	na
A40 GDP effect 2041	$571.7	$71.1	$811.1	$203.3	$110.0
A120all GDP effect 2041	$23.1	-$8.1	-$2.1	-$3.0	na
PV of extra GDP	$1,401.6	$103.6	$1,705.6	$425.5	$250.0

What can be said about these various estimates of GDP productivity effects?

- First, the positive effect is primarily from short trips, suggesting the benefit of the AWHC is largely for trips restricted to Auckland.
- The agglomeration effect, as measured by the A40 effect, is larger than previously estimated elsewhere for the AWHC. This is likely to be the result of the different weighting applied to drive time savings around the 20–40 minute trips. For example, a drive time savings of a few minutes that brings, say, 1,000 people within the 40-minute polygon increases the density in this study by 1,000 people. A similar change in the EEM appraisals would increase density by around 40 people assuming that the increased population of 1,000 people is 25km away (hence a weight of 1/25 is applied).
- Effectively this part of the analysis has measured the same agglomeration effect in a different way. The EEM appraisal method is widely accepted as the norm. This study draws attention to the impact of downplaying drive time savings of lesser proportion but there is no strong reason to favour the threshold method used here over the EEM GTC-weighted method.
- Another aspect of the benefit analysis brought to attention by this study is the difference in drive time savings, and hence productivity estimates, during different times of day. Some of this effect is due to only slight drive time increases that push the drive time above the 40-minute threshold. Be that as it may, the general lack of drive time improvement in the interpeak period warns that, should business-to-business travel during the day be a key determinant of the density effect, the productivity gains may indeed be modest (or conversely if the AM commute is of primary importance then the productivity gains are large).
- The net GDP effect in present value terms is heavily influenced by the high 2041 A40 effect, which in turn results from some large threshold effects (see more on threshold effects below). A large number of trips drop from 40–45 minutes to 30–40 minutes with the DS. In 2026 all these trips (DM and DS) are less than 40 minutes.
- The A120all effect is negative in the weighted average estimate, largely due to a few small increases in drive time from under to above 120 minutes.

[67] A subsequent analysis using traffic demand as weights provided a present value of $515 million.

- Unfortunately the lack of growth in population within 120 minutes resulting from the DS means that this wider delivery zone effect was not well tested within the case study. In the weighted travel time 2041 run, the 0–120 minute density was unchanged in four of the 15 TA areas and decreased in eight (albeit due to small drive time increases).
- That said, should travel time at the AM peak – where a positive effect on A120all was picked up – be of importance to the wider accessibility effect then potentially improved access to people far away around these times could have a significant productivity effect.

The following tables look more closely at the nature of the A40 productivity increase in 2041 and the A120all productivity decreases discussed above, based on the weighted average drive time changes.

Some patterns are evident from tables 8.4 and 8.5.

- There would be strong productivity gains near the AWHC but little A40 effect beyond the inner suburbs.[68]
- Large productivity gains occur in four sectors in the two inner city TA areas: wholesale trade, telecommunications, internet and library services, finance and professional, scientific and technical services (shaded in table 8.5).
- There are general productivity declines south of the CBD, due to both slower short trips and slower longer trips. It is possible that information such as this may lead to some other investment to improve the southern flow but, taking the project as standalone, this slowing of traffic does dampen the net productivity gains to be expected from the AWHC.

Table 8.4 Model run: 2041 unrestricted, origin=centroid, drive times= maximum of to/from WGTAVE trip[(a)]

0–120							
WGTAVE							
Centroid	**2041**	**Change**	**Change**	**Change**	**Change**	**Change**	**Change**
Sensitivity off	**:**	**WA POP**	**GDP$mill**	**WA POP**	**GDP$mill**	**GDP$mill**	**GDP**
Territorial authority area	**GDP ($million)**	**ΔA40**	**A40 effect**	**ΔA120all**	**A120all effect**	**A40 + A120all**	**% change**
Whangarei District	10,387	0.0%	$0.0	0.0%	$0.0	$0.0	0.0%
Kaipara District	2,206	0.0%	$0.0	23.3%	$6.1	$6.1	0.3%
Rodney District	9,825	0.0%	$0.0	0.2%	$0.2	$0.2	0.0%
North Shore City	22,718	5.3%	$39.8	0.3%	$0.9	$40.8	0.2%
Waitakere City	17,926	6.0%	$22.6	0.0%	$0.0	$22.6	0.1%
Auckland City	105,237	4.3%	$159.1	-0.2%	-$3.2	$155.9	0.1%
Manukau City	34,723	-2.0%	-$15.2	-0.1%	-$0.4	-$15.6	0.0%
Papakura District	7,804	0.0%	$0.0	0.0%	$0.0	$0.0	0.0%
Franklin District	6,887	-3.6%	-$3.0	0.0%	$0.0	-$3.0	0.0%
Thames-Coromandel District	3,194	0.0%	$0.0	-2.6%	-$1.0	-$1.0	0.0%
Hauraki District	2,078	0.0%	$0.0	-2.5%	-$0.5	-$0.5	0.0%

[68] Note that this is a productivity gain in the district listed that could accrue to persons travelling into the district to work as well as to resident workers

0–120							
WGTAVE							
Centroid	2041	Change	Change	Change	Change	Change	Change
Sensitivity off	:	WA POP	GDP$mill	WA POP	GDP$mill	GDP$mill	GDP
Territorial authority area	GDP ($million)	∆A40	A40 effect	∆A120all	A120all effect	A40 + A120all	% change
Waikato District	5,543	0.0%	$0.0	-3.7%	-$1.2	-$1.2	0.0%
Matamata-Piako District	5,292	0.0%	$0.0	-3.5%	-$2.5	-$2.5	0.0%
Hamilton City	20,099	0.0%	$0.0	-0.3%	-$1.1	-$1.1	0.0%
Waipa District	4,798	0.0%	$0.0	-0.7%	-$0.4	-$0.4	0.0%
Sub-total	258,718		$203.3		-$3.0	$200.3	0.1%

[(a)] The A40 and A120all represent the change in effective density of working age population. Note that the actual working age population and employment level are fixed, ie this is a fixed land use assessment.

Table 8.5 Access effect on GDP in Auckland City and North Shore City for model run: 2041 WGTAVE ($million)

Industry sector	North Shore		Auckland City	
	A40-2-GDP	A120all-2-GDP	A40-2-GDP	A120all-2-GDP
Horticulture and fruit growing	$0.0	$0.0	-$0.1	$0.0
Sheep, beef cattle and grain farming	$0.0	$0.0	-$0.1	$0.0
Dairy cattle farming	$0.0	$0.0	$0.0	$0.0
Poultry, deer and other livestock farming	$0.0	$0.0	$0.0	$0.0
Forestry and logging	$0.0	$0.0	$0.0	$0.0
Fishing and aquaculture	$0.0	$0.0	$0.0	$0.0
Agriculture, forestry and fishing support services and hunting	$0.0	$0.0	$0.0	$0.0
Mining	$0.0	$0.0	$0.0	$0.0
Meat and meat product manufacturing	$0.0	$0.0	-$0.5	$0.0
Seafood processing	$0.0	$0.0	$0.0	$0.0
Dairy product manufacturing	$0.0	$0.0	$0.0	$0.0
Fruit, oil, cereal and other food product manufacturing	$0.0	$0.0	$0.0	-$0.1
Beverage and tobacco product manufacturing	$0.0	$0.0	$0.0	$0.0
Textile, leather, clothing and footwear manufacturing	$0.0	$0.0	$0.0	$0.0
Wood product manufacturing	$0.0	$0.0	$0.0	$0.0
Pulp, paper and converted paper product manufacturing	$0.0	$0.0	$0.0	$0.0
Printing	$0.0	$0.0	$0.0	-$0.1
Petroleum and coal product manufacturing	$0.0	$0.0	$0.0	$0.0
Basic chemical and chemical product manufacturing	$0.0	$0.0	$0.0	-$0.3
Polymer product and rubber product manufacturing	$0.0	$0.0	$0.0	$0.0
Non-metallic mineral product manufacturing	$0.0	$0.0	$0.0	-$0.1
Primary metal and metal product manufacturing	$0.0	$0.0	$0.0	$0.0

Industry sector	North Shore		Auckland City	
Fabricated metal product manufacturing	$0.0	$0.0	$0.0	-$0.2
Transport equipment manufacturing	$0.0	$0.0	$0.0	-$0.1
Machinery and other equipment manufacturing	$0.0	$0.1	$0.0	-$0.2
Furniture and other manufacturing	$0.0	$0.0	$0.0	-$0.1
Electricity and gas supply	$0.0	$0.0	$0.0	$0.0
Water, sewerage, drainage and waste services	$0.2	$0.0	$1.5	$0.0
Building construction	$0.0	$0.0	$0.0	$0.0
Heavy and civil engineering construction	$0.0	$0.0	$0.0	$0.0
Construction services	$0.0	$0.0	$0.0	$0.0
Wholesale trade	$11.9	$0.5	$39.5	-$1.6
Motor vehicle and motor vehicle parts and fuel retailing	$0.5	$0.0	$0.7	$0.0
Supermarket, grocery stores and specialised food retailing	$1.0	$0.0	$1.0	$0.0
Other store-based retailing and non-store retailing	$2.0	$0.0	$2.5	$0.0
Accommodation and food services	$0.0	$0.0	$0.0	$0.0
Road transport	$0.0	$0.0	$0.0	$0.1
Rail, water, air and other transport	$0.0	$0.0	$0.0	$0.1
Postal, courier transport support, and warehousing services.	$0.0	$0.0	$0.0	$0.1
Information media services	$0.8	$0.0	$6.6	$0.0
Telecommunications, internet and library services	$3.5	$0.0	$15.3	$0.0
Finance	$1.8	$0.0	$19.1	$0.0
Insurance and superannuation funds	$2.0	$0.0	$7.4	$0.0
Auxiliary finance and insurance services	$1.3	$0.0	$5.8	$0.0
Rental and hiring services (except real estate)	$0.0	$0.0	$0.0	$0.0
Property operators and real estate services	$0.0	$0.0	$0.0	$0.0
Owner-occupied property operation	$0.0	$0.0	$0.0	$0.0
Professional, scientific and technical services	$6.5	$0.0	$34.0	$0.0
Administrative and support services	$1.4	$0.0	$7.2	$0.0
Local government administration	$0.1	$0.0	$0.4	$0.0
Central government administration, defence and public safety	$2.3	$0.0	$4.1	$0.0
Education and training	$0.0	$0.1	$0.0	-$0.2
Health care and social assistance	$0.0	$0.1	$0.0	-$0.3
Arts and recreation services	$1.8	$0.0	$6.9	$0.0
Other services	$2.7	$0.1	$7.7	-$0.3
Unallocated	$0.0	$0.0	$0.0	$0.0
Total	$39.8	$0.9	$159.1	-$3.2

One interesting feature of the above estimated effects is the similar direction of benefits to both the North Shore and Auckland City. Both will benefit from improved drive times – relative to DM – but the nature of the model implies that both are estimated to achieve productivity benefits in a similar manner. This may not be the case in reality. The model simply estimates a positive productivity effect to scale and does not take into account that there are likely to be competing forces and existing specialisation which mean that the productivity gain in any one sector may accrue to one rather than both of the TA areas.

Other runs of the model produced other insights. Six runs are reported in the table 8.6.

1 The first run has already been discussed in section 8.4. To recap, the model includes two access variables, A40 measuring the 0–40 minute density and A120all measuring the 0–120 minute density, but the elasticity applied to A120all was estimated in a model using a 40–120 minute density. The densities were calculated using a weighted average drive time from the zone containing the population-weighted centroid for the territory. Densities changed if the drive time change pushed people in or out of the 40 minute and 120 minute drive zones, irrespective of how small any drive time change might be. Coefficients in the employment and GDP equations were applied if they were significantly different from zero at 5% confidence. The estimated productivity gain is $425 million.

2 The second run tested the sensitivity of the results to small changes in drive times. Effectively any drive time changes less than 2% of the DM drive time were treated as zero. Thus a density change required at least a time saving (or increase) of 2%. The net effect was that the estimated productivity gain was $52m greater than (1) at $477 million. Note that the A120all density tended to increase now, although still only marginally, as threshold effects around 120 minutes were reduced.

3 The third run tested the sensitivity to the exclusion of non-significant coefficients. When all coefficients in the model were applied – positive and negative, big and little – the net effect was a $15m larger net gain, estimated at $440m. It is encouraging to see the exclusion of non-significant terms was of little effect.

4 The fourth run reverted to the 5% significance level and used the same densities as per model (1) but this time the elasticities applied were derived from a model that had an A40 access variable and a A120all access variable[69] (ie coefficients estimated in a consistent manner with the densities being applied). This had the effect of reducing the estimated productivity gain by $179 million to $246 million. We will return to this point in section 9.2.9.

5 The fifth run was again the same as (1) but with the elasticities now derived from a model that excluded the people-effect variables of OCCUP, AGE and QDEG. As revealed in chapter 3, taking account of people effects does reduce the effect otherwise ascribed erroneously to population density. However, that does not preclude the possibility that people can retrain or re-sort themselves, enabling the higher productivity to be gained. The model suggests the potential effect of such restructuring would be an extra $105 million on the initial estimate, providing a total productivity gain of $530 million (in 2010 present value terms).

6 The sixth run shows the outcome if the delivery zone density was measured as the working age population within 40–120 minutes. The A40 effect is the same as run (1) but now there are large negative effects coming through the A120 effect, with the net effect being a GDP decline of $83.7 million. This declining A120 density occurs because people 'shift' into the A40 area, causing some proportionally large negative declines in A120 density. These in turn imply large negative GDP effects.

[69] In effect GDP is now modelled, still as 2SLS, as a function of A40 and (A40+A120) since A120all is equal to the population within 0–40 minutes (defined as A40) plus within 40–120 minutes (defined as A120).

Table 8.6 Runs using three different models

Run	1	2	3	4	5	6
Significance level	0.05	0.05	1.00	0.05	0.05	0.05
Model used to derive elasticities	e=40-120	e=40-120	e=40-120	e=0-120	e=no XVAR	e=40-120
Measure of A120 applied	0-120	0-120	0-120	0-120	0-120	40-120
Apply 2% tolerance	Sensitivity off	Sensitivity on	Sensitivity off	Sensitivity off	Sensitivity off	Sensitivity off
A40 GDP effect 2026	$36.74	$50.89	$38.99	$20.80	$44.77	$36.74
A120all GDP effect 2026	$0.5	$1.7	$3.1	$1.0	$0.0	-$35.5[(a)]
A40 GDP effect 2041	$203.3	$214.8	$218.0	$120.9	$253.0	$203.3
A120all GDP effect 2041	-$3.0	$6.6	-$11.9	-$5.1	-$2.8	-$245.6(a)
PV of extra GDP	$425.5	$477.8	$440.1	$246.1	$530.4	-$83.7

[(a)] Now A120 in this run (ie 40–120 effective mass)

The differences between runs (1), (4) and (5) can be largely attributed to the different A40 coefficients in the GDP equation, especially for the key sectors at the heart of the productivity gains likely in the AWHC (see table 8.7).

The second model (run 4 in tables 8.6 and 8.7) dampens the A40 effect. This occurs because the A40 density is included within both the A40 variable and the A120 variable. Essentially, some of the A40 effect is shared between the two estimated coefficients. This may be appropriate in other situations but with A40 effects being dominant in this project, a more accurate estimate of the A40 coefficient is required. This is believed to be provided by the model applied in run (1), and discussed initially.

The third model (run 5) has A40 coefficients, not surprisingly, higher than in the initial model. These coefficients do not measure the effect of density as factors are known to explain the apparent 'density' effect but the coefficients do imply a potential effect, if people skills could be changed also.

Table 8.7 The A40 coefficient for selected sectors in runs 1, 4 and 5

Run	1	4	5
Industry sector	e=40-120	e=0-120	e=no XVAR
Information media services	0.077	0.063	0.146
Telecommunications, internet and library services	0.107	0.079	0.145
Finance	0.065	0.061	0.093
Insurance and superannuation funds	0.077	0.051	0.112
Health care and social assistance	0.016	-0.004	0.024
Arts and recreation services	0.089	0.062	0.140
Other services	0.096	0.053	0.123

9 Discussion of the case study

9.1 Introduction

The preceding chapter presented the key results from applying the GVA approach to the proposed AWHC. The estimated productivity effect varied depending on how elasticity and density were modelled but the results largely confirmed that agglomeration effects are likely to result from faster commute zone trips – relative to DM – and showed that effects beyond Auckland were likely to be small. The analysis raised a number of issues, discussed below, both about the model and about appraisal of the AWHC. For the model, there are insights gained into potential benefits but the threshold method used to measure density is unsuitable. For the AWHC, the analysis does highlight the emphasis on the commute time savings – and probably reliability and resilience – rather than transformational change as the most likely reasons to support an AWHC business case. The analysis also demonstrates the weakness of considering the benefit of the AWHC independently of alternative land use changes and alternative infrastructure investments if agglomeration effects are a key objective.

9.2 Issues

The model, the data and the approach each have shortcomings. But first, there is an element of the model not yet discussed – the employment equation. It would be useful to know the distribution of employment effects, so the model was examined to determine what could be said about employment.

9.2.1 Induced employment changes

The change in commute and delivery densities implies changes in employment as well as the changes in GDP that are tabled in the previous chapter; that much is clear. In particular, higher commute densities generally accompany a lower employment requirement (relative to the working age population in the territory). This change in employment is not explicitly considered in a traditional CBA appraisal although the net effect may be included in the travel time benefits.

The GVA model was initially proposed as a method for looking more closely at the employment effects of infrastructure investments (ie employment effects beyond the initial construction effects). Employment effects were identified in the GVA model and applied here. Unfortunately the methodology has so far come up short as an estimator of net employment effects.

The challenges in this study highlight some of the issues.

First, there is an employment effect but just how big it is, how it is distributed and how much of the net GDP effect is already measured by the rule-of-half is unknown. But the model applied here does illustrate that an employment effect is likely and that, as a result, the spatial distribution of GDP effects will likely differ from the spatial mix of productivity gains. In fact, some of the productivity gains in some industries and/or locations could manifest as employment reductions.

Second, the GVA 2SLS model does provide some insight into potential employment changes but falls short of providing an estimate of the likely net effects when all factors are taken into account.

The changes of employment that would result from simply applying the access coefficients from the core GVA model discussed in the previous chapter (ie run (1)) are set out in table 9.1. The table shows a 6776 reduction in employment in 2026 should the AM time savings of the AWHC be the influential transmission mechanism. The general fall in employment due to a rising A40 is the result of many negative coefficients to A40 access amongst the sectors. Conversely many employment coefficients on A120all were positive. However these numbers are not what they first seem.

Table 9.1 Employment effect. Model run: 2026, Origin=centroid, drive times= max to/from AM trip

0–120				
AM				
Centroid	**2026**	**Change**	**Change**	**Change**
Sensitivity off		**EMPL**	**EMPL**	**EMPL**
Territorial authority area	**Employment (people)**	**A40 effect**	**A120all effect**	**A40 + A120all effect**
Whangarei District	50,781	0	-83	-83
Kaipara District	10,603	0	81	81
Rodney District	48,801	229	3	232
North Shore City	135,452	-2,129	4	-2,125
Waitakere City	84,166	55	7	62
Auckland City	476,686	-4,294	29	-4,265
Manukau City	179,196	-386	1	-385
Papakura District	25,677	-236	0	-236
Franklin District	33,413	-15	8	-7
Thames-Coromandel District	17,104	0	3	3
Hauraki District	9,537	0	15	15
Waikato District	21,980	0	45	45
Matamata-Piako District	22,936	0	57	57
Hamilton City	115,802	0	154	154
Waipa District	24,558	0	32	32
Sub-total	1,256,690	-6,776	356	-6,420

The GVA model – and many similar models created to examine agglomeration effects – are typically estimated using the current spatial distribution of GDP, employment and population and/or measures of how these have changed over time. The key point is that observations of differences in GDP, differences in employment and differences in densities, measured either spatially or over time, are the result, in whole or in large part, of changes in population. That is, the populations differ either spatially and/or over time and modellers ascribe differences related to accessibility created by population changes as an independent effect. Forecasters then predict GDP effects (or employment effects) that might result from changes in density that are expected to occur for reasons other than population change (eg a bridge or tunnel improves accessibility). The underlying shortcoming is that the effects observed may be interdependent with population changes. This shortcoming is evident when considering the employment effects derived in this model.

The first stage employment equation provides the above estimates of employment changes, which can be expected from a change in density alone (ie without a change in population). The initial inference is that greater accessibility will decrease employment in the greater Auckland area. Furthermore the implied GDP effect of the drop in employment outweighs the previously tabled estimated increases in GDP from productivity gains. This is clearly an incorrect inference. Simply improving accessibility (and no other changes) is unlikely to reduce aggregate employment and is thus also unlikely to decrease GDP in total. It seems that the missing ingredient is the population change that typically accompanies the changes in GDP, employment and densities that we have observed.

In fact the issue is more subtle. The second equation in the 2SLS model is used to identify the pure effect of agglomeration-induced productivity changes on GDP with any other required changes to employment, occupation, education etc assumed implicitly to occur. The first equation identifies the 'shock' to labour productivity, effectively measuring how much employment could fall if there were no reactions by producers or consumers to the gain in productivity. These notional negative employment effects should not be interpreted as the likely actual effect of the infrastructure project on employment. A traditional CBA analysis is subject to the same effect: travel time savings are not interpreted as causing unemployment.

Accordingly, provided one is happy with the assumption that infrastructure projects do not of themselves reduce total employment, the net employment effects predicted by the first equation in the 2SLS model should be not be viewed as an estimate of the employment effect. Their only real value is as a guide to how the spatial distribution of employment might change as a result of the infrastructure project.

It is worthwhile considering the underlying process of the data creation. The model is based on data that typically shows population rising in the current or adjoining territory and employment growing in total, but also shifting and sometimes not growing by as much as the population, either due to shifts between industries and TA areas or economies of scale. Take away the endogenous population growth and the apparent negative effect of accessibility on employment produces the unreasonable inference that improved accessibility will decrease employment and GDP.

This insight gained from considering the detail of the model raises two issues.

1 There is the risk that the endogeneity in the employment equation – introduced to reduce endogeneity in the (second) GDP equation – risks biasing the results of all equations. This is an artifice of such models.

2 The access coefficients for employment, even if possibly unbiased, are not suitable to predict employment changes that would result from an AWHC. To make such a prediction would require either an accompanying population effect of the AWHC or some other variable to identify how a zero-gain population scenario would redistribute employment.

An attempt of this nature is the business location model used by KPMG (2013) in their HS2 study, a model that has been criticised for its judgement-based nature (ie there is no evidence to support the assumption made that business location is determined by the calculated competitive index).

An alternative approach was that of Overman et al (2009)[70], who used a CGE model to estimate the potential spatial effects on GDP of various scenarios including travel time savings of 20 and 40 minutes. This is much more sophisticated modelling than is within the scope of this project but is a potential next step.

In the interim, some insight into possible spatial effects can be gained by testing 'what if' scenarios with the GVA model. Note, these are not estimates of employment effects but rather different scenarios that could occur.

Two such scenarios are tabled below. The starting point for the first scenario was to consider what population growth would be required to produce employment growth equivalent to the implied A40 induced employment fall in the above table (ie 6,776). This, after all, is how the original observed data

[70] See also Hensher et al (2012) where a CGE model is also employed to model spatial effects, plus gains from redistribution of labour

would have evolved – via population changes. Unfortunately we do not know the equivalent pattern but a credible scenario is that the population change was in proportion to the local density change. This provides a pattern of employment changes to offset that implied by the density change, the net effect being zero employment growth. These employment changes, in turn, have a GDP effect that is modelled via the EMPL variable in the GDP equation. The constraint imposed in this scenario on the equivalent population growth was that it should produce a net zero GDP impact from employment changes (rather than a net zero employment change). The resulting mix of GDP distribution would see the largest gains go to North Shore and Papakura (ie column 7 in table 9.2, which in turn is the sum of effects on GDP of employment redistribution (column 5) and productivity (column 6)).

An alternative scenario is to consider the estimated change in effective densities resulting from a growth in population that occurred only in Auckland City (ie the pre-amalgamation Auckland City). This shows Auckland to gain strongly in GDP terms (ie more employment and higher GDP/worker) and declining GDP in North Shore and Papakura (see net effect in column 8 of table 9.2 – composition not provided).

Table 9.2 Equivalent scenarios to achieve zero GDP effect with (1) population growth in proportion to A40 density change in 2026 AM run and (2) population growth in Auckland City only (only net GDP result shown for (2))

Column 1	**Col 2**	**Col 3**	**Col 4**	**Col 5**	**Col 6**	**Col 7**	**Col 8**
Territorial authority area	**EMPL effect of A40 change (1)**	**Equivalent EMPL resorting to population increase (1)**	**Net EMPL change (1)**	**GDP effect of EMPL change (1)**	**GDP effect of A40 change[(a)] (1)**	**Net GDP effect of A40 change (1)**	**Net GDP effect of A40 change (2)**
Whangarei District	0	0	0	$0.0	$0.0	**$0.0**	**$0.0**
Kaipara District	0	0	0	$0.0	$0.0	**$0.0**	**$0.0**
Rodney District	229	-59	170	$17.4	-$4.3	**$13.0**	**$19.5**
North Shore City	-2,129	2,232	103	$32.5	$77.9	**$110.4**	**-$107.8**
Waitakere City	55	-73	-18	-$2.4	-$1.5	**-$3.9**	**$3.3**
Auckland City	-4,294	2,837	-1,457	-$157.9	$190.9	**$33.0**	**$415.9**
Manukau City	-386	268	-117	-$12.3	$10.2	**-$2.1**	**-$32.5**
Papakura District	-236	1,316	1,080	$121.8	$8.4	**$130.2**	**-$15.2**
Franklin District	-15	23	8	$0.9	$0.3	**$1.2**	**-$1.5**
Thames-Coromandel District	0	0	0	$0.0	$0.0	**$0.0**	**$0.0**
Hauraki District	0	0	0	$0.0	$0.0	**$0.0**	**$0.0**
Waikato District	0	0	0	$0.0	$0.0	**$0.0**	**$0.0**
Matamata-Piako District	0	0	0	$0.0	$0.0	**$0.0**	**$0.0**
Hamilton City	0	0	0	$0.0	$0.0	**$0.0**	**$0.0**
Waipa District	0	0	0	$0.0	$0.0	**$0.0**	**$0.0**
Sub-total	**-6,776**	**6,545**	**-232**	**$0.0**	**$281.8**	**$281.8**	**$281.8**

[(a)] As reported in table 8.2

Unfortunately these are only two of many possible outcomes. The point is that the productivity gain estimated in stage 2 GDP equation (see equation 7.3) is derived from an implicit decline in employment. A net decline will not occur under full employment conditions. The implied unemployed people will take up other work – just what and where that work will be is unknown. The net GDP effect per territory will depend on just where employees do relocate. Further investigation is required to identify another variable to include in a model that might predict employment distribution under a zero-gain population scenario.

Nonetheless, the modelling does confirm that many other GDP distributions are possible other than that implied by productivity gains; in other words, the distribution of productivity gains does not necessarily represent the distribution of GDP growth for each TA area.

9.2.2 Delivery zone effects

A key differentiating element of the GVA model estimated in the earlier phase was the significance of a delivery zone that captured GDP effects beyond the nearby commute effects (already captured within the EEM agglomeration method).

It turned out for this case study that these delivery zone effects were difficult to isolate and were most likely moderate, unless high store was put on small drive time savings around the AM and PM peak periods.

One problem was the transfer of those beyond the 40-minute drive (but within 120 minutes) to within 40 minutes as a second crossing is added. In other words, commuting becomes easier but the wider delivery zone, if considered as the 40–120 minute zone, actually declines. This need not be a problem if the model is derived from data of this nature but it was not. The interim solution was to measure the delivery zone density as the 0–120 minute working age population.

Also noticeable in this study is that there are few increases in the total 0–120 minute working age population. This does occur for Hamilton in the 2026 AM run as the population around the west and central isthmus becomes more accessible but the actual change in drive time is low (around three minutes of a two-hour journey), suggesting the effect in this example is overstated. The Hamilton-Auckland drive time saving is even less during the PM peak and interpeak.

More generally these results show that the AWHC, considered in line with population and land use changes envisaged within the ART3 model, is largely about reductions in commuter times – and possibly increased resilience – rather than large changes in travel times that might produce transformational change in the wider economy.

That said, it may be that the population growth envisaged on the northern side of the crossing may not actually occur given the increase in commute times without an AWHC. Indeed this may still be the case even with the AWHC given that commute times are still projected to increase significantly (eg AM Greenlane to Takapuna goes from 23.08 minutes in 2006 to 34.37 minutes in 2041 with the second crossing, although this is better than the 40.64 minute trip otherwise). This point is picked up again in section 9.2.6.

9.2.3 Population projections

The DM scenarios are based on population projections within the ART3 zones as used within the preliminary AWHC business case study, plus the average of the Statistics NZ low and medium projections for TA areas outside the ART3 zones (the ART3 projections are broadly consistent with the average of the low and medium projections for the total area). No attempt has been made to raise population growth rates to levels considered more likely by Statistics NZ, nor nearer recent growth trends.

9.2.4 Employment projections

Likewise the DM scenarios are based on employment projections within the ART3 zones as used within the preliminary AWHC business case study, plus assumed employment growth rates for TA areas and sectors outside the ART3 zones of 50% over 2006–2026 and 20% over 2026–2041, these growth rates being similar to the rates averaged within the ART3 zones. No attempt has been made to reconcile or update employment projections within the ART3 model that appear unusual, eg government/defence/ medical/education growing by 3.4% only within the ART3 zones between 2006 and 2026 or the participation rate rising from 54.7% in 2006 to 69.1% in 2041.

9.2.5 Industry sector composition

More generally, the use of employment projections by industry and zone does not allow the opportunity for industry growth rates to evolve according to supply and demand forces, as would be the case under a general equilibrium model. Thus the GDP effects estimated in this case study are contingent on the employment and GDP projections proving correct; the likelihood of this being so has not been assessed.

9.2.6 Land use

In a similar vein, land use had been projected using a LUTI model but this in turn is constrained by initial assumptions so, for instance, the GDP effects of a second crossing are contingent on accommodating large population growth on the northern side of the crossing. It is not known at this stage whether the interaction between population growth, traffic congestion and infrastructure costs has been fully taken into account. In other words, the differing land use assumption/derivation raises another missing element in the GVA model, namely the extent to which building a second crossing is interdependent with residential and business expansion north of the crossing. Building the crossing in part enables northern residential development. The counterfactual is presumably southern residential expansion. The 'benefit' of northern versus southern expansion might potentially be (a) the lower cost of sub-division/building in the north plus (b) any extra pleasure that people derive by living further north plus or minus (c) the difference in agglomeration potential around northern and southern growth. This study has not explored these potential benefits. A similar discussion of interdependent benefits not included in the traditional CBA or this GVA approach is discussed in Parker (2013).

9.2.7 Threshold effects

The use of a 40-minute and 120-minute threshold to define commute and delivery zone densities is a serious weakness with the model. It does create some changes in densities that result from minor changes in travel time. Furthermore, whether the drive time changes are small or not, the time changes are given high weighting even though they may be a small proportion of the total drive (and travel) time. The latter effect has been discussed in section 9.2.2.

An example of the former is the 2006 AM drive time from Whangarei to zone 53 increasing from 119.8 minutes to 121.4 minutes with the AWHC and hence leading to a reduction in the A120 density of Whangarei. Likewise Whangarei to zone 15 increases from 119.4 to 121.4 (zones 53 and 15 are north of AWHC). These two small changes in time and the implied change in A120 density produced a $12.5m GDP reduction for Whangarei according to the model.

Kaipara experienced some decrease in A120 densities due to slightly higher drive times to zones north of the AWHC but also experienced some gains in A120 densities with a slight drop in the drive time to zones south of the AWHC.

To test the sensitivity of the results to small drive time changes near the threshold, the initial analysis was rerun with the restriction that no change in density would be recorded should the change in drive time be less than 2%. The results of this constrained analysis are tabled as run (2) in table 8.6. The net effect was the total GDP effect, in present value terms, increased from the original $425 million to $477 million.

However, without a good reason to select a tolerance, and given the modest change in benefit (relative to cost), the results are being reported for the unconstrained model.

A variation of this threshold effect is the large – and counter-intuitive – difference that can take place should the significant time savings occur on a 40-minute trip rather than a 30-minute trip. The GVA method applied here defines the commute zone to be the working age population within a 40-minute drive. This has the disadvantage of putting emphasis on time savings around the 40-minute threshold. This was the case for 2041 when, for example, the drive time south reduced from just over 40 minutes to 30–35 minutes for many paired zones on the North Shore. This had the effect of increasing the A40 density for the North Shore by around 50%, with a resulting large GDP effect estimated. Conversely, a similar time saving was achieved in 2026 but both the DM and DS trips were often within 40 minutes so there was little change in the A40 density, and hence only a moderate implied GDP effect. This apparent inconsistency in the GDP effect of similar drive time savings points to a weakness in using thresholds, and is reason to believe the GVA figures reported here probably overstate the likely agglomeration effect for savings related to short trips.

A sensitivity test on a different threshold for the commute zone only further weakens the case for a threshold. The 40-minute cut-off was replaced by limits of 20, 25, 30, 35 and 45 minutes for a 2041 AM run of the model. The implied GDP effect, using the A40 elasticity, spanned a range of over $400m.

There are two elements to these problematic threshold effects: the results from this case study are well above results previously reported for reasons to do with a large weight being put on proportionally small drive time savings; and, second, the result produced can be very sensitive to the cut-off time chosen. For consistency of application alone, changing to distance or cost-weighted densities is appealing.

9.2.8 Measurement of densities

The method for estimating GVA coefficients uses working age population densities based on travel time from the 2006 (or 2001) working age population centroid for the TLA. That is, drive time from this central point defines the densities for all parts of the territory.

The case study data was recorded on a zone or CAU basis. The results given in this report are based on densities defined by travel from the zone or a CAU that contains the 2006 centroid. As in the model derivation, the central zone is used as a proxy for the whole territory.

The effect of defining densities differently was tested by calculating the density of the TA area as the sum of the (overlapping) densities for all zones in the area and, as per usual, re-calculating the combined density for each area under the DS scenario. While the densities now were much larger, the change in density – the key component in the analysis – was similar. In total, applying changes in the 'all zones' density produces results that are similar but with a present value effect of around $90–150 million higher than otherwise reported here.

9.2.9 Elasticity coefficients

The coefficients used to convert the density changes into GDP changes are those estimated from the earlier phase that passed a 5% significantly different from zero test. There was no preference shown for positive or negative coefficients – both were accepted if significantly different from zero.

A range of elasticity estimates were presented. Just which set of elasticity estimates are appropriate will depend on how the elasticities are to be applied.

If people effects are also expected to occur then the access elasticities with XVARS dropped (run 5 in table 8.7) are appropriate. These provide an estimate of potential productivity gains. Otherwise the direct effect of the transport intervention can be estimated by using elasticities estimated with XVARS in the model.

As currently measured, the A40 and A120 density create difficulties for inferring effect. This paper has followed the US approach and presented the results using a biased estimate of the A120 effect (ie run 1 in table 8.7). This approach is judged to be appropriate for this case study as the A120 effect is small and this leaves the A40 effect estimated in an unbiased manner. However this approach need not be the most appropriate in other situations. In other cases, the model used in run 4 (table 8.7) may be appropriate. More generally, a preferred approach would be to move away from the threshold-defined densities.

9.2.10 Travel time period.

The GDP effect was estimated from the three key travel periods that had been previously modelled. The earlier literature has not revealed what travel is important to the agglomeration effect. There is good reason to believe that commuters during the AM and PM periods are important. Equally, though, the inter-firm connectivity benefits that have been postulated (see chapter 3 for discussion of transmission mechanisms) are likely to be more sensitive to interpeak travel time savings.

Unfortunately, resolution of this issue matters for the GVA approach as the net GDP effect differs considerably depending on what travel period is used to measure the time saving and hence density of people accessible.

The results in this report have, unless stated otherwise, used a weighted average of the effects derived for the three time periods with weights of 20%, 60% and 20% for the respective AM, interpeak and PM drive times[71]. The earlier EEM-based agglomeration effects were derived from a travel volume weighted average travel time per workday.

It should also be mentioned that the drive times used in each period are an amalgamation of trips for several purposes including home work, home education, home shopping, home other and business to business, using light, medium and heavy vehicles.

[71] As per earlier footnote, a subsequent analysis using traffic demand as weights provided a present value of $515 million.

10 Conclusions, further research and recommendations

10.1 Conclusions

The project has looked at the GVA transport appraisal approach as used in the UK and a similar approach used in the US. A 2SLS model of GDP versus various measures of accessibility was chosen and fitted using 2001 and 2006 census data for the 72 TA areas of New Zealand. This model chosen was similar to the GVA models cited in the project outline but was also readily fitted using available New Zealand data and was able to address the endogeneity between employment and accessible population mass. The derived elasticities were applied as a case study to the proposed AWHC, a project that already had other appraisal results available, which gave further insights into the model. In application the model gave a range of GDP estimates of the AWHC ranging from $246.1 million to $530.4 million. This is a substantial range. The higher end of the range is associated with the model including people based effects – that is, the characteristics of workers change through either upskilling, re-training or migration. The lower end of the range is associated with one of the several ways in which accessibility effects can be defined in the model. We found the model quite sensitive to how accessibility is defined and to how the elasticities are applied; this to some extent reflects the current uncertainty regarding what are the micro drivers to productivity growth.

The development and application of the model has highlighted two issues that are not taken into account in current appraisal methods. First, there appears to be a GDP effect of access beyond that captured within the current agglomeration effect. And second, the model highlights that the spatial distribution of GDP effects depends not just on the distribution of productivity effects but also on how employment re-distributes.

There were also three further insights gained while investigating GVA models and the case for an AWHC.

1 A more sophisticated model is required if robust estimates of the ultimate spatial distribution of GDP are required.

2 US appraisals also take into account connectivity and reliability effects as supplementary to the standard transport benefits and access effects. First, connectivity is a more sophisticated measure of the ASEA and AAIR access variables tested within this study. There was a hint of some port effects in New Zealand but in this project any effect appeared to be confounded with A120 density, so it was excluded in the case study model. Possibly a more sophisticated measure of connectivity and a longer dataset may have revealed a connectivity effect here in New Zealand. This is likely to be important for longer journeys in New Zealand. Second, the benefit of more reliable travel times is likely to also be of general importance and is likely to be very relevant to the AWHC business case. Reliability is measured within the EEM at present but could be expanded.

3 Not part of the GVA approach but an issue that was raised within the case study is the interdependence of the transport intervention – in this case a bridge or tunnel – and the assumed population and business growth in the surrounding districts. The anticipated increase in drive times within the wider vicinity of the AWHC does raise the possibility that the spatial growth forecast within the DM scenario may not eventuate if people believe drive times will remain high (ie there will be no bridge or tunnel). From this perspective, the development of the city is interdependent with the AWHC and the benefits of an AWHC would include a proportion of the development otherwise assumed. Besides trying to put a dollar value on this proportion, any further research would also require an

investigation into what extent these benefits were independent of rule-of-half benefits so that benefits were not to be double-counted in an appraisal.

We also found that the New Zealand GVA model suffered from a simplistic measurement of population mass, with the estimated GDP effect for the AWHC appearing to be too high and, just as importantly from a consistent appraisal point of view, the estimated GDP was very sensitive to small changes in definitions of density. A change to using distance- or cost-weighted measures of density would improve the model.

10.1.1 Overview of findings about a GVA model

This project fitted in New Zealand a version of a US model that was similar to that used within GVA studies in the UK. The project:

- confirmed the significance of people-based effects (ie full productivity benefits require a change in the skills of the employee, either via re-skilling or job transfer)
- confirmed employment is endogenous and provided consistent estimates of the productivity elasticities to near-term density
- showed there exists a delivery zone effect on productivity, an effect that is not presently taken into account in the EEM.

The project also applied the model to the AWHC, using the same spatial projections of population growth by TA area, employment growth by sector and drive time savings as used in the preliminary business case. The project:

- confirmed the order of magnitude of previously estimated agglomeration effects (although these appear overstated by this model due to threshold effects).
- showed also that a wider density effect can apply but it was not large, and was sometimes negative in this case study – nonetheless a reminder that effects can be widely felt.
- confirmed that spatial GDP distribution could be different from the distribution of productivity gains.

One issue that was not fully resolved was whether the benefits measured are additional or inclusive of the rule-of-half benefits measured within the standard transport appraisal. In the UK, the GVA benefits have been applied as an ancillary to the standard transport appraisal, partly due to the regional nature of the GVA estimates whereas the standard transport benefits are measured on a national scale. In the US, the GVA benefits have been applied as additional benefits, akin to the wider economic benefits currently used by the Transport Agency.

At present the ‘commute zone’ and ‘delivery zone’ GDP effects are estimated from models similar to that employed to estimate the agglomeration effect but in general it cannot be shown that the GVA estimates preclude rule-of-half benefits. Hence at this stage it is recommended that the GVA approach be used alongside the EEM, rather than as an additive effect.

10.1.1.1 Pros and cons of method

The project has identified the following pros and cons of the GVA methodology.

Table 10.1 Pros and cons of GVA methodology

Pros	Cons
• The GVA model captures some of the wider benefits of transport investments that are not captured in the traditional CBA, notably those stemming from agglomeration and from wider connectivity. • Furthermore, once estimated, the model can be easily applied to give a measure of GVA or GDP. For reasons discussed in chapter 5, CBA does not give this measure. GDP and GVA are of direct interest to policymakers. • Different models can be used to compare how GDP will alter if person composition is allowed to change with accessibility (the people-based effect and the place-based effect). • Scenario testing with the models can provide a guide to the spatial composition of effects (but does not actually forecast these effects). • The model brings focus on issues to do with the transmission of benefits, eg is time of day important? • The model produces estimates of changes in productivity by industry that could be incorporated into a general equilibrium model that, in turn, would be able to more closely estimate spatial effects.	• The GVA approach is not consistently defined across different studies. Likewise density measures also differ across studies. These inconsistencies reduce the ability to compare model outcomes and calibrate model parameters. • The model and access variables as currently defined have econometric shortcomings that reduce credibility in the results. • The model parameters have been estimated from data that has evolved in a different way from the intention of the model (ie the data is about population change while the application of the model is about travel time change). • Frictions and constraints are not represented in the model (we assume accessibility gains are passed directly through into the economy). • The GVA model does not track which resources (labour) in which locations and in which industries that might initially be displaced by higher productivity are eventually re-employed. • The GVA model omits welfare effects that are not part of GDP, eg savings in leisure travel time.

10.1.1.2 Situations suited or unsuited to the GVA method

The project team suggests the following situations would suit GVA methodology, and conversely suggest some situations where the GVA method has little more (or even less) to offer than other currently used approaches.

Table 10.2 Situations that would suit or not suit a GVA analysis

GVA suitable for	GVA not suitable for
• Inter-urban projects where accessibility beyond the already measured agglomeration effect is expected. • Projects where the spatial distribution of economic effects are important – the GVA approach cannot forecast these changes but the scenario testing can highlight potential redistribution. • Strategic analysis of large projects where a quick overview of effects can be estimated and what-if questions can be explored – in the US this type of approach is used as ‘middle stage’ analysis with a ‘late stage’ analysis possibly using a more sophisticated modelling tool.	• Projects which are likely to lead to small time savings for a large volume of traffic – the current appraisal methods can already measure the components that a GVA would also pick up. • An off-the-shelf toolbox for final BCR calculation.

10.2 Further research

The project has identified a number of lines of research, to both enhance the GVA methodology and to broaden appraisal of transport projects. These are listed below, not in any particular order within each section.

10.2.1 Issues to do with refinement of current model

1. Test the connectivity effect. Use the model on an inter-urban project (ie a project that connects places rather than enlarges a place), to examine whether the model is good at picking up the gains from trade effects predicted by new economic geography.
2. Refine the accessibility variables. Use a gravity-like equation with a distance or generalised cost decay parameter to calculate effective density, rather than assuming boundaries at times such as 40 minutes and 120 minutes.
3. Improve data. Extend the analysis to include 2013 Census data. The 2013 data was unavailable at the start of the study. Inclusion of the 2013 data would both add further observations and hence improve estimation efficiency and would enable estimation of the response of GDP to changes in density between 2001 and 2013 (a more reasonable period apart from 2001 and 2006 in which to assess change).
4. Improve data. If possible, refine the measures of effective density to include changes in travel time (between 2001, 2006 and 2013) rather than just changes in population within given travel times (this study used the same travel time for both 2001 and 2006 population sets). This would enable better understanding of the dynamics of agglomeration gains.
5. Improve model structure. Develop an unbiased employment model, both to improve the 2SLS GDP estimation but also to examine the spatial distribution of employment and GDP. Two improvements are suggested:
    a. The sign of the link between employment and effective density is theoretically ambiguous. For a small area that is close to a large area, jobs in certain industries may flow from the small to the large area as commuting time falls (people may not necessarily move house). For other industries – those for which a presence in the CBD and surrounding area is not essential – the reverse flow of jobs may apply. If this hypothesis is true it is unhelpful to expect the same sign on variables such as A40 for all locations. For example, if finance is an industry that benefits from agglomeration effects in the CBD, the sign on A40 in an equation that explains employment as a function of A40 (and other variables) would be positive for Wellington city, but negative for surrounding areas such as Lower Hutt and Porirua; conversely perhaps for an industry such as warehousing. Accordingly the analysis in this report could usefully be re-done, still industry by industry, with a distinction between areas that are likely to attract/lose jobs when access improves and areas that are likely to lose/attract jobs.
    b. Currently most of the A40 effects in the employment equations are negative, implying a net negative employment effect overall. This is an implausible result: while some industries and some areas may lose jobs from improved transport infrastructure, an aggregate negative employment effect is most unlikely. A model that differentiates between the effect of changes in travel time on A40 and the effect historical changes in population on A40 should produce different results. It would also be possible to test a restriction across the estimated employment equations that the total net effect of introducing travel time improvement (via A40) is zero.

6 Improve data. It would be useful to assess the benefits of the second Sydney crossing, along with other such projects. This enables data to be drawn from large transport interventions that lead to accessibility changes rather than the traditionally used observations on population induced changes in access.

7 Apply the results from (5) above to an innovation such as the AWHC and ascertain whether changes in effective density (A40) still produce a net negative effect on employment. Identify which areas that gain and lose overall.

10.2.2 Issues to do with extension of current model

1 Determine the journeys of significance. Explore the nature of the journey that is producing the agglomeration effect, eg test whether one or more travel time periods are more important than others; consider estimating time savings by journey purpose.

2 Link the connectivity measure to ports. This project did reveal some correlation between activities at sea and air ports and GDP but this effect was largely confounded with wider population densities. Irrespective of how the A120 density measure is improved, bringing into the model the ports connection would be of valuable insight to future projects.

3 Distinguish between localisation and urbanisation effects. With the model data already available it would be possible to look at the industrial diversity/concentration of an area as a guide to whether an industry tends to favour growth and diversification of industry (ie urbanisation) or concentration of an industry (ie localisation). Better still would be to observe how diversity/concentration had changed in response to a change in accessibility.

10.2.3 Issues to do with other models and appraisal in general

1 Move to a more sophisticated model to address interactions. Agglomeration effects are essentially (labour) productivity effects generated by changes in effective demographic density. In contrast general equilibrium effects change the distribution of workers between industries, thereby raising average incomes. Wage rates do not necessarily change, but may do if there are changes in the overall demand for and supply of labour. Thus a spatial general equilibrium analysis is the logical extension of agglomeration analysis.

2 Estimate the interdependence of development and infrastructure provision. A large benefit of a project such as the AWHC is likely to be in the development that takes place in anticipation that the infrastructure will be put in place to resolve any potential bottlenecks or supply constraints. An analysis such as this project is based on the assumption that the DM outcomes are certain when more likely they are probable and this probability is linked with expectations about the AWHC.

3 Improve reliability effects. It was suggested in the process of gathering information on the AWHC that a key issue was consistency of travel time in Auckland. It would be of value if the AWHC were to improve reliability of travel times and/or costs. The US 'middle stage' analysis looks at the traditional travel benefits plus the wider economic benefits that accrue from (a) reliability (b) accessibility and (c) connectivity.

10.3 Last word

The big question is, is this a tool that can be applied by the Transport Agency to measure the potential benefits of transport interventions? In its current state, the tool could not be used as an off-the-shelf estimate of benefits, either those ancillary to or intersecting with current benefits measured within the EEM.

However it could be improved to eventually provide another way to measure the agglomeration benefit from 'commute zone' effects and the productivity gain from the 'delivery zone' effects. Given that the latter is currently not available, this innovation is likely to be useful. This would require a closer look at how connectivity is measured (other than the 0–120 minute drive time population). The correlation between productivity and port access presents a promising line of research, a line of research that is being currently undertaken in the US.

Another use of the tool is for strategic analysis. It does enable large projects to be assessed easily and in terms that are more readily understandable than 'travel benefits' and more transparently than within a CGE model. However, rather than provide an outcome that can be blindly accepted, the model in a sense provides 'null hypotheses' that can be investigated and tested using various techniques. For example, in this case study, the model implies there are very little benefits in connectivity to TA areas outside of Auckland. Unless proven otherwise, this puts the emphasis back on travel and activity within Auckland as the cause of benefits. This in itself has potential implications for funding. The model confirms there are advantages around agglomeration but does raise issues: (a) will the relatively small time saving during the interpeak period compromise expected agglomeration benefits? and (b) will both Auckland City and North Shore both benefit or is there other reason to believe that one will benefit more? The model also creates some hypotheses around benefit distribution, eg are businesses and people in Papakura likely to be major beneficiaries of the AWHC and, if so, what is the transmission mechanism? And another question: what would the productivity gains look like if some of the planning constraints and demographic forecasts within the ASP3/ART3 model were adjusted, especially showing more and less population growth south and north of the potential crossing. While the model does not answer these questions, it has provided a focus and perspective that might not otherwise have eventuated.

In other projects, the hypotheses are likely to relate to different matters. In particular, it will be interesting to see what the model reveals about changes in inter-urban travel times, especially near ports.

This raises the point that the model will improve with iterations. In time it could provide a measure of connectivity gains to add as another wider economic benefit in the EEM. In the meantime, the model could be providing insight into the issues around large projects.

Ultimately, though, this is likely to be as far as the model can go. A more sophisticated model such as a CGE model is required if the fuller economic benefits, and the spatial distribution of these benefits, are to be estimated.

10.4 Recommendations

In sum, the following recommendations are made.

1. Use weighted populations in any density measure.
2. Further investigate a wider connectivity effect on productivity.
3. Further investigate the interaction between population growth forecasts and agglomeration effects in the AWHC.
4. Further investigate the reliability benefits, both in general and with the AWHC.
5. Further investigate a spatial CGE model.

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Appendix A: Detail of key papers

Notes on key models used.

A1 Greengauge21 (KPMG)

The KPMG approach combined (a) estimating wage and employment elasticities to people mass and (b) applying these elasticities to adjust forecasts for 2040 previously formed.

A1.1 Elasticities (see KMPG 2010a)

Elasticities were derived from single equation models of form (some with beta or gamma set to zero)

$\ln(y) = \alpha + \beta * \ln(\text{business market catchment}) + \gamma * \ln(\text{labour market catchment})$

with 376 districts and one time period (2007).

Equations were calculated for sectors (nine sectors, 376 observations per sector) and regions (nine regions, average 42 observations per region).

Variables used (separately) as independent variables (the y's):

1 Estimate of wage income by district for nine business sectors (the difference between sectors in regional gross annual pay per region was applied to the district average wage rate for each sector).

2 Estimate of wage income by district, with each district assumed to have the same sectorial employment mix.

3 Estimate of wage income by district, with each district assumed to have wages within each sector equivalent to the national average for the sector.

4 Employment density per district.

Catchments (the x's) measured:

- Catchment of business employment – employment in each other district (the destination zone) times an (unknown) measure of trip propensity times a proportion according to rail generalised journey times.
- Catchment of labour – as working age population in each other district (the origin zone) times an (unknown) measure of trip propensity times a proportion according to rail generalised journey times:
  - The generalised journey times between 376 rail stations were sourced from the national rail network model (times include allowance for in-vehicle time, inconvenience of waiting and inconvenience of interchange), to which were added ticket prices and access to station time (from a population weighted centroid), all expressed in minutes.
  - The share of trips by generalised journey time was derived from 'demand data'.

Challenges of the analysis:

- The analysis picks up the well-known correlation between mass and wages but does not prove that rail connection has any role in play in the correlation (it may be spurious).
- The direction of causation is unclear. Even if the correlation is not spurious, the analysis does not prove that changes in rail connection between, say, a large urban mass and a remote area will necessarily increase wages in the remote area.

- There are known missing explanatory variables (eg capital, people skills) that create the risk of bias in the parameters estimates. In particular, there is no explicit account of a person effect, ie different qualifications and occupations of the people employed in each sector within each district.
- The missing explanatory variable shows as low R-squareds, especially for primary production and utility sectors.
- The analysis provides a snapshot of the productivity-employment density relationship for one period (2007). This relationship may change over time.
- It may be that density of own-industry employment is more important than general employment density, as measured here. This is yet to be tested.
- Wages within sectors at a district level were unknown and required estimation, increasing uncertainty around parameter estimates.
- Wages are only one component of GVA.

A1.2 Forecasts (see KPMG (2010b)

The impact of rail investment was presented as changes to 2040 forecasts for regional employment, wage income and GVA arising from the investment.

The following exogenous forecasts were made:

- Employment and population by district, based on 2007 data and using growth rates derived from a currently used model.
- Wages, using a UK Treasury estimate of real productivity growth of 2.25% pa.
- Generalised travel costs.
- Generalised travel costs after rail investment.

Other forecasts derived were:

- Change in wages within sectors (ie does not calculate any change in share of sectors within district), using elasticities from above.
- Change in national employment, applying an elasticity of 0.1 to the change in wages from above (the 0.1 being that recommended by the DfT).
- Change in employment density by region (with no change in national total employment beyond the previous step), using elasticities from above.
- The sum of these effects (the 'base case' of £16,800m) were further scaled up by 1.7 to take account of potentially less train overcrowding and more frequent train services (see KPMG's table 7) to give a total one-year GVA impact of £29,400m.
- Within this GVA impact, an estimate of the extra tax revenue component was provided as 35% of the GVA impact, and a present value of tax benefits was calculated of £87b (base) or £150b (additional services) assuming the extra tax revenue accumulates between 2021 and 2040 and thereafter grows at the rate of real GDP and a discount rate as per the UK Treasury's *Green book* (HM Treasury 2013).

Challenges of the forecasts:

- The impact of the rail investment is dependent on the counter-factual forecasts, albeit these forecasts were chosen to be consistent with other Greengauge 21 analysis (but not necessarily consistent with other transport investment analysis).
- A number of effects (following a rail investment) were explicitly excluded: freight impacts; change in sector composition within a district; change in international migration; changes in employment due to improved commuter journeys; feedback changes on agglomeration effects from increased business density; any response by other transport operators (eg airlines) when rail share rises; multiplier effects arising from the extra income created.
- It is assumed that a large proportion of people are willing to shift or commute between districts (ie the behavioural patterns observed for current commuters will apply to a large group of new commuters and/or people will be willing to relocate).
- It is assumed that other personal (eg re-training), business (eg capital investment) and political (eg planning changes) will occur to give effect to the increase wages.

A2 HS2 (KPMG)

The HS2 model was similar to that described for KPMG above but with several refinements, as described below.

A2.1 Elasticities (see KPMG 2013)

Single equation model expanded to include measure of capital and labour as explanatory variables:

$$\ln(Y_i) = A_0 + A_1\ln(C_1) + A_2\ln(C_2) + A_3\ln(C_3) + A_4\ln(C_4) + \text{alpha} * \ln(\text{Labour}_i) + (1\text{-alpha}) * \ln(\text{Capital}_i)$$

Reduction of 376 districts into 234 zones (the i's) and time period changed to 2010 (for estimation and the forecast base) and forecast year changed to 2037.

Equations were calculated for sectors (four sectors, 234 observations per sector) and regions (seven regions, average 33 observations per region).

y-variables now is production (rather than wages as a proxy for GVA):

- Estimate of GDP per sector was derived by multiplying GDP per worker by employment by sector, with both data provided by the DfT's wider impacts dataset.

x-variables expanded to include the C's being the two catchments as in Greengauge21, plus catchments for business weighted by car journeys, and catchments for labour weighted by car journeys

- Labour is measured as zone employment and capital is assumed to be a fixed ratio of labour (differing by sector and zone), dependent on a fixed cost of capital (r) and a fixed share of labour input (alpha), with alpha fixed in the final analysis used by KPMG:
  - An adjusted labour variable was also used in some regressions with only minor effects, zone employment being scaled up (or down) according to a factor that captured the weighted average wage of 'high' and 'low' occupation groups within a sector.
- Dummy constants were added for zones in Scotland and Wales (to allow for productivity differences between England, Scotland and Wales).

- The x-variables in the economic density equation were replaced by a set of variables that captured both changes in transport costs and changes in production costs (resulting from changed transport costs).

Challenges of the analysis:

- Same challenges as above with the Greengauge21 study plus those listed below.
- The labour and capital measures introduce another potential source of bias, due to mis-measurement errors (both are estimated).
- The model assumes output changes occur through the productivity parameters (the A's) rather than affecting the productivity of labour or capital (ie it is Hicks neutral), and that capital and labour will remain in a fixed ratio.
- It is not clear that the adjustment to labour supply tested in the model adequately captures the skill effect of people given that other studies, eg Overman et al (2009) found relatively large skill effects on wage rates.
- KPMG acknowledges other explanatory variables that might improve the analysis, such as fixed effects for typologies (eg urban vs rural), the standard of the built environment and past public investment, but concede data difficulties prevented their use.
- KPMG uses an unconventional weighting process to derive estimates for the four connection elasticities in lieu of multicollinearity, providing estimates that Overman (2013) claims are wrong.

A2.2 Forecasts (see KPMG 2013)

The impact of rail investment was presented as changes to 2037 forecasts for regional employment, wage income and GVA arising from the investment.

A3 Northern Way (SERC/Overman)

SERC undertook several analyses to explore the relationship between economic activity measures and economic mass, including a reduced form equation (below) and a CGE model.

A3.1 Elasticities (see Overman et al 2009)

The general reduced form equation was:

$$\ln(y_{it}) = \alpha_t + \theta * \ln(A_{it}) + \beta * X_{it} + \lambda_i$$

Approximately 250,000 individuals (the i's) x up to 10 annual observations (1998–2007).

Variables used as independent variables (the y's):

1 Basic hourly wage each year

2 Annual average percentage change in basic hourly wage (period within 1998–2007 varied by individual)

Identifiers per person (the X's):

1 Age and aged-squared

2 Gender

3 Years of education (estimate)

4 Occupation

5 Industry

6 Plus individual constant (λ_i)

Density measure by:

- Car accessibility – access to economic mass (A_{it}) for Ward i at time t is sum of employment in adjoining wards (j) weighted by generalised transport costs (GTC), where GTC_{ij} is fuel costs + non-fuel vehicle operating costs + value of time x travel time (as per DfT)
- Train accessibility - access to economic mass (A_{it}) for Ward i at time t is sum of employment in adjoining wards (j) weighted by generalised transport costs (GTC), where GTC_{ij} is waiting costs + access costs + value of time x travel time (as per DfT)

$$A_{it} = \frac{\sum employment_{jt}}{GTC_{ij}}$$

Challenges of the analysis:

- The extensive range of explanatory variables reduced the risk of biased elasticity estimates but the low R2 recorded in the change in wages equations shows that other unexplained factors are affecting wages, so the risk of bias remains.
- The elasticity measures are correlated so the standard errors are inflated (but otherwise are unbiased).

A3.2 Forecasts (see Overman et al 2009)

SERC did not make forecasts but rather presented the results for areas within Leeds and Manchester of various scenarios, including, for example, a 20-minute reduction in the train time between Leeds and Manchester that resulted in a 4.12–10.26% range of increase in economic mass accessible by train amongst the districts and, in turn, a range of 0.20–0.50% range of average wage increases amongst the districts, rising to 1.06–2.65% average wage increases if the composition of workers were also to change.

The elasticity to train accessibility applied was 0.049 (while the unapplied elasticity to car elasticity was 0.069).

Challenge of the forecasts:

- To achieve the higher impact, there would have to be considerable change in either the people employed in an area or a rapid upskilling.

A4 New Zealand agglomeration (Mare and Graham)

Single equation production function (Hicks neutral, ie density does not alter labour-capital ratio)

Approximately 100,000 enterprises x 9 annual observations

Variables used as independent variables:

- Sales and revenue less purchases and stock adjustment (from annual business survey)

Identifiers per enterprise (drawn from longitudinal business database):

- Count of employees (including working proprietor, NB enables use of many firms with zero employment).
- Capital (input is measured as the cost of capital services rather than as the stock of capital).

- Intermediate consumption
- Employment density (within area unit)
- Year
- Area unit
- Industry code
- Region x industry (two-digit) dummy variable.

Density measured by:

- Access to economic mass (A_{it}) for area unit i at time t is sum of employment in adjoining area units (j) weighted by distance (d_{ij})

$$A_{it} = \frac{\sum employment_{jt}}{d_{ij}}$$

Challenges of the analysis:

- There is no explicit account of a person effect (instead people are grouped within enterprises or within industry-areas).
- The analysis provides a snapshot of the productivity-employment density relationship for one period (1999-2006). This relationship may change over time, as may the relationship between gross output and the factors of production. In particular, Mare and Graham (2009) refer to the possibility that the benefits of density may accrue over time, ie there may be productivity benefits that have yet to materialise.
- The density parameters are dependent on correct specification of the production function. It is noted that the same dataset was used to estimate concurrently the parameters of the production function and the density parameters, rather than use fully specified production functions.
- More generally, the measurement errors that exist with the explanatory variables risk biasing the parameter estimates: capital was proxied by the reported cost of capital services (rather than capital itself), which, in turn, was itself partially derived; the true form of the individual production function is unknown – it could well vary by firms, independent of any density effect – and hence above-average productivity of a firm may be confounded with the surrounding density of employment.
- The within enterprise density elasticity, estimated at only 0.010, was rejected as potentially biased downward, due to endogeneity between the enterprise parameter and the density parameter. Mare and Graham (2009) suggest exploring a control-function approach (Ackerberg et al 2006) to address this issue.
- It may be that density of own-industry employment is more important than general employment density, as measured here. This is yet to be tested.
- The weight applied to employment in the access to mass variable was distance between area units, largely due to a lack of other data at the time. More refined weighting – using either generalised transport costs or a distance decay parameter – could change the density estimates and hence the elasticities estimates also.

That said, the parameter estimates derived (centred on 0.069) are broadly consistent with elasticities estimated in other parts of the world.

Appendix B: GVA model

B1 Methodology for GDP measurement

In the mid-2000s Statistics NZ investigated the establishment and maintenance of an official data source that would present GDP for a limited number of industries across all regional councils in New Zealand. This effort yielded a set of time series for 1 digit industries in the ANZSIC96 classification, covering each regional council and the period 2000–2003. This series was updated for the period 2007–2010 using a different industry classification (the data remains only available in current prices). Infometrics applied the following method to further disaggregate the dataset, providing:

- two variables, GDP in constant prices and employment
- the 31 national accounts industries disaggregated to 56 industries using data from the New Zealand nominal GDP series and then further disaggregated to 12 regional councils and 72 TA areas (ie with Auckland local authorities prior to amalgamation in 2010).

B1.1 National GDP

1. GDP for 31 national accounts industries in constant prices is available at quarterly frequency. For March years, the 31 industries are disaggregated to 56 industries using intra-31 industry shares of double deflated nominal GDP. The latter is obtained by taking the difference between gross output and intermediate input series which are deflated by the Producer Price Index output and input prices respectively.

   This can be achieved for the periods from 1988 onwards, but only up to the last annual observation for the nominal GDP series at the more disaggregated level. This is two years behind the reference March year release of GDP. The gap between the nominal and real GDP reference quarter is initially estimated by using the intra-31 industry shares of the 56 nominal GDP series (for example horticulture as a share of agriculture) of the latest observation. In other words, the intra-31 industry structure is assumed not to change in the last two years.

   Special attention is paid to the disaggregation of agriculture. Discussions with Statistics NZ after recent revisions of GDP (September 2012 quarter) suggest that 90% of the change in GDP of agriculture as a whole since 2010 can be attributed to dairy cattle farming and 10% to sheep and beef farming with no increases for horticulture and poultry and other farming. More recently Infometrics looked at changes in production volumes and prices in 2012 and 2013 and made further adjustment to this allocation of the change in agriculture over the last two years based on output and price changes in these sub industries.

   The result is a set of annual series of real GDP estimates for 56 industries up to the GDP reference quarter.

2. Quarterly estimates are obtained by using the LEED employment data for four digit ANZSIC06 industries which have been aggregated up to the 56 nominal GDP industries. For each quarter, Infometrics multiplies the deviation from the March year annual average with the results from the previous step. For the quarters prior to the start of the LEED series and beyond the LEED reference quarter we use the average quarterly deviations for the period as a whole. The working hypothesis is that the LEED employment data is a good proxy for seasonal movement in real GDP for the intra-31 national accounts industries.

The series for beverages is replaced with one where using the difference between deflated sales and purchases and operating expenses of the manufacturing survey. Moreover, due to volatility introduced by transfer pricing in the dairy product manufacturing industry, GDP is derived for this industry as the residual of the five sub-industries of food and beverages (since a benchmark series from the national accounts is available for the latter).

The result is a set of quarterly series of real GDP estimates for 56 industries up to the Household Labour Force Survey reference quarter to be used as a national benchmark for TA area level regional disaggregation at the same level of industry detail.

B1.2 Regional GDP

1 Using the results of (2) above, the next step is to disaggregate the national level estimates for 54 industries to the TA regional area level:

   a Regional GDP at 16 industries for 2007–2010 in current prices is disaggregated to 53 industries using LEED employment data and turned into constant prices using New Zealand level constant and current price GDP for 32 national accounts industries.

   b GDP for Tasman–Nelson is disaggregated into the respective regional councils using LEED employment.

   c Regional GDP is then disaggregated from regional council to TA areas using industry specific earnings shares at the one digit ANZSIC level, with employment data used to disaggregate the number of industries to 53. There is no employment associated with LL21 (owner occupation GDP, imputed rent), so it is distributed according to total employment across the territorial authorities in a regional council. LL21 is available from Statistics NZ regional GDP data.

   d Holes in the earnings data have been plugged by using employment shares. Note also that the wages earnings shares are measured in current prices and are then applied to constant price GDP.

B2 Test of sector differences

The access coefficient estimates have been shown in various studies to vary by sector, and such was the case with the data in this project. However, regressions were run to test whether sectors showed similar coefficients within natural groupings such as agriculture, manufacturing or service sectors. In all three cases, an F-test based on the change in the residual sum of squares rejected equivalence of coefficients within each group (see table below for results).

Table B.1 F-tests of equivalent coefficients within groupings of sectors within 2SLS GDP model including all XVARS and access variables

Model	A. All sectors with unique coefficients	B. Model A but with 7 agricultural sectors having same coefficients	C. Model B but with 18 manufacturing sectors having same coefficients	D. Model C but with 16 service sectors having same coefficients
System r^2	0.9705	0.9473	0.8869	0.7569
Eqn 1 r^2	0.8094	0.7675	0.6769	0.5215
Eqn 2 r^2	0.9682	0.9542		0.8953
n	6670	6670	6670	6670
RHS (k)	921	819	530	292
Exogenous	487	433	280	154

Model	A. All sectors with unique coefficients	B. Model A but with 7 agricultural sectors having same coefficients	C. Model B but with 18 manufacturing sectors having same coefficients	D. Model C but with 16 service sectors having same coefficients
Test:		**B v A**	**C v B**	**D v C**
$r^2(u)$		0.9705	0.9473	0.8869
$r^2(r)$		0.9473	0.8869	0.7569
df(u)		5,749	5,851	6,140
df(r)		5,851	6,140	6,378
q		102	289	238
F		44.326	23.204	29.653
df1		102	289	238
df2		5,749	5,851	6,140
Verdict		Reject that coefficients same within sector grouping	Reject that coefficients same within sector grouping	Reject that coefficients same within sector grouping

Conclusion: Estimate the model within each sector, unless there are strong a priori reasons to group sectors.

B2 Tests of heteroscedasticity

Each model fitted was tested to see whether the assumption of equal residual variance was appropriate. The following tests for heteroscedasticity were undertaken in Shazam, where e denotes the residuals, y the dependent variable and x the explanatory variables:

- e^2 on predicted y
- e^2 on predicted y^2
- e^2 on lag
- |e| on x.

Results were mixed so robust estimation was used for all equations. This entailed selecting the option to estimate White's heteroscedastic consistent standard errors within Eviews when running each regression.

B3 OLS and 2SLS estimates and endogeneity test

The following table lists the coefficients estimates for all sectors, estimated individually using first OLS and then 2SLS.

The Wu-Hausman statistic provides a t-test for endogeneity, with a high value indicating the presence of endogeneity (eg finance). Effectively it tests whether the residuals from the first-stage equation (ie the employment equation) have a significant coefficient when entered into the second-stage equation (ie the GDP equation); the usual t-test of H_0: coefficient=0 provides the test of endogeneity.

The F-stat is a measure of variation explained within the first-stage equation (ie the employment equation) of the two-stage GDP model. A high value indicates that the explanatory variables do provide some explanatory power. The R^2 value indicates goodness of fit of the first-stage equation, being the squared correlation of the fitted employment values and the observed employment values.

Table B.2 Estimates for access coefficients in base 2SLS and OLS models, plus tests for endogeneity and first-stage fit

Industry sector	Ln(A40) - 2SLS	Ln(A40) - OLS	Ln(A180) - 2SLS	Ln(A180) - OLS	Ln(AAIR) - 2SLS	Ln(AAIR) - OLS	Ln(ASEA) - 2SLS	Ln(ASEA) - OLS	Wu-Hausman t-test	F-stat of 1st stage	R^2 observed and predicted 1st stage
Horticulture and fruit growing	-0.072	-0.069	-0.011	-0.014	0.017	0.017	-0.007	-0.008	0.14	249.4	0.33
Sheep, beef cattle and grain farming	-0.088	-0.089	0.013	0.013	0.006	0.005	0.013	0.011	0.14	406.0	0.38
Dairy cattle farming	-0.065	-0.094	0.048	-0.003	0.034	0.024	0.012	0.027	1.69	412.8	0.42
Poultry, deer and other livestock farming	-0.057	-0.107	0.015	0.026	0.020	0.019	0.005	0.003	2.11	371.6	0.31
Forestry and logging	0.010	0.052	0.083	0.101	0.011	0.003	-0.010	0.031	2.30	185.1	0.33
Fishing and aquaculture	-0.030	0.002	-0.048	0.041	0.086	0.048	-0.079	-0.021	2.46	126.3	0.53
Agriculture, forestry and fishing support services and hunting	-0.085	-0.092	0.035	0.030	0.020	0.009	0.003	0.010	1.05	606.0	0.46
Mining	0.068	0.087	0.070	0.077	0.011	0.024	0.018	0.022	1.10	82.6	0.12
Meat and meat product manufacturing	-0.052	-0.056	0.060	0.058	-0.024	-0.026	-0.018	-0.012	1.10	138.2	0.28
Seafood processing	0.001	-0.019	0.122	0.048	-0.018	-0.010	0.050	0.004	1.41	106.7	0.63
Dairy product manufacturing	-0.036	0.006	-0.022	0.016	0.033	-0.015	-0.009	0.036	1.65	62.7	0.17
Fruit, oil, cereal and other food product manufacturing	-0.005	-0.002	0.023	0.021	-0.017	-0.016	-0.001	-0.002	0.34	498.3	0.76

Industry sector	**Ln(A40) - 2SLS**	**Ln(A40) - OLS**	**Ln(A180) - 2SLS**	**Ln(A180) - OLS**	**Ln(AAIR) - 2SLS**	**Ln(AAIR) - OLS**	**Ln(ASEA) - 2SLS**	**Ln(ASEA) - OLS**	**Wu-Hausman t-test**	**F-stat of 1st stage**	**R^2 observed and predicted 1st stage**
Beverage and tobacco product manufacturing	-0.050	-0.067	-0.008	0.026	-0.101	-0.107	-0.001	0.021	0.87	52.4	0.35
Textile, leather, clothing and footwear manufacturing	-0.007	0.005	0.032	0.030	-0.018	-0.015	-0.012	-0.014	1.02	313.2	0.69
Wood product manufacturing	0.008	-0.001	0.041	0.041	-0.006	-0.009	0.008	0.013	1.23	576.5	0.56
Pulp, paper and converted paper product manufacturing[(a)]											
Printing	-0.007	-0.006	0.037	0.037	-0.011	-0.010	-0.027	-0.028	0.20	274.3	0.74
Petroleum and coal product manufacturing[(a)]											
Basic chemical and chemical product manufacturing	-0.045	-0.059	0.021	0.022	-0.051	-0.059	-0.028	-0.009	2.04	125.2	0.65
Polymer product and rubber product manufacturing	-0.034	-0.031	-0.025	-0.026	-0.068	-0.071	0.003	0.004	0.18	119.0	0.69
Non-metallic mineral product manufacturing	-0.028	-0.036	0.037	0.037	-0.035	-0.033	-0.009	-0.006	1.26	311.8	0.59
Primary metal and metal product manufacturing	0.047	0.008	0.026	-0.017	0.002	-0.029	-0.039	-0.023	3.91	39.2	0.42
Fabricated metal product manufacturing	0.000	-0.006	0.033	0.032	-0.013	-0.015	-0.007	-0.005	0.73	734.4	0.87
Transport equipment manufacturing	-0.019	-0.019	0.038	0.038	-0.026	-0.025	-0.006	-0.007	0.06	262.4	0.72
Machinery and other equipment manufacturing	-0.004	0.006	0.044	0.046	-0.011	-0.009	-0.007	-0.014	1.03	689.5	0.79
Furniture and other manufacturing	-0.015	-0.036	0.017	0.024	-0.019	-0.022	-0.024	-0.008	2.15	453.3	0.75
Electricity and gas supply	0.101	0.093	0.129	0.101	-0.050	-0.030	0.097	0.078	1.61	103.1	0.38
Water, sewerage, drainage and waste services	0.139	0.114	0.138	0.131	-0.001	0.002	0.064	0.069	2.33	505.4	0.77
Building construction	-0.010	-0.012	-0.008	-0.008	-0.014	-0.015	-0.005	-0.005	0.54	2708.7	0.91
Heavy and civil engineering construction	-0.012	-0.017	-0.007	-0.005	-0.016	-0.018	-0.004	-0.004	1.25	864.9	0.73
Construction services	-0.010	-0.020	-0.006	-0.007	-0.015	-0.019	-0.005	-0.002	2.58	5910.5	0.95
Wholesale trade	0.093	0.083	0.039	0.040	-0.061	-0.064	0.012	0.016	2.07	2059.6	0.91

Industry sector	Ln(A40) - 2SLS	Ln(A40) - OLS	Ln(A180) - 2SLS	Ln(A180) - OLS	Ln(AAIR) - 2SLS	Ln(AAIR) - OLS	Ln(ASEA) - 2SLS	Ln(ASEA) - OLS	Wu-Hausman t-test	F-stat of 1st stage	R^2 observed and predicted 1st stage
Motor vehicle and motor vehicle parts and fuel retailing	0.023	0.022	0.010	0.010	-0.042	-0.043	0.013	0.014	0.50	2552.3	0.89
Supermarket, grocery stores and specialised food retailing	0.026	0.019	0.010	0.012	-0.040	-0.042	0.014	0.016	2.86	7116.5	0.94
Other store-based retailing and non-store retailing	0.026	0.024	0.011	0.011	-0.039	-0.040	0.014	0.014	0.90	5321.8	0.94
Accommodation and food services	-0.012	-0.012	-0.018	-0.018	-0.042	-0.043	0.011	0.011	1.44	6550.4	0.93
Road transport	-0.005	0.000	-0.068	-0.068	-0.007	-0.005	-0.001	-0.002	1.53	3275.6	0.90
Rail, water, air and other transport	-0.006	-0.010	-0.071	-0.076	-0.009	-0.005	-0.003	-0.009	1.11	158.5	0.61
Postal, courier transport support, and warehousing services.	-0.003	-0.002	-0.059	-0.059	-0.010	-0.009	-0.004	-0.005	0.65	1216.5	0.90
Information media services	0.117	0.112	-0.013	-0.014	-0.031	-0.044	0.078	0.076	3.86	570.9	0.84
Telecommunications, internet and library services	0.129	0.082	-0.054	-0.033	-0.038	-0.065	0.035	0.057	4.39	476.5	0.87
Finance	0.056	0.048	-0.020	-0.021	-0.066	-0.073	0.027	0.033	2.97	1450.4	0.89
Insurance and superannuation funds	0.062	0.064	-0.018	-0.022	-0.063	-0.068	0.012	0.027	2.10	208.4	0.85
Auxiliary finance and insurance services	0.067	0.067	-0.030	-0.026	-0.044	-0.057	0.005	0.023	3.49	627.8	0.88
Rental and hiring services (except real estate)	-0.013	-0.024	0.013	0.013	-0.065	-0.074	-0.034	-0.022	3.79	1163.8	0.90
Property operators and real estate services	0.005	0.008	0.017	0.017	-0.068	-0.067	-0.021	-0.023	0.67	3538.1	0.92
Owner-occupied property operation[(a)]											
Professional, scientific and technical services	0.039	0.039	-0.051	-0.051	-0.041	-0.041	-0.023	-0.023	0.03	4287.6	0.95
Administrative and support services	0.049	0.044	-0.006	-0.005	0.011	0.001	-0.014	0.001	1.96	1486.8	0.90
Local government administration	0.053	0.040	-0.013	-0.008	-0.024	-0.028	0.002	0.007	3.77	1735.2	0.84
Central government administration, defence and public safety	0.087	0.056	-0.008	-0.004	-0.019	-0.023	0.018	0.015	3.99	638.5	0.77

Industry sector	Ln(A40) - 2SLS	Ln(A40) - OLS	Ln(A180) - 2SLS	Ln(A180) - OLS	Ln(AAIR) - 2SLS	Ln(AAIR) - OLS	Ln(ASEA) - 2SLS	Ln(ASEA) - OLS	Wu-Hausman t-test	F-stat of 1st stage	R^2 observed and predicted 1st stage
Education and training	0.020	0.023	0.015	0.015	-0.038	-0.038	0.036	0.035	1.35	9130.1	0.95
Health care and social assistance	0.005	0.003	0.031	0.032	-0.026	-0.027	-0.029	-0.028	0.82	3826.2	0.92
Arts and recreation services	0.112	0.105	0.005	0.003	-0.086	-0.086	0.096	0.095	1.75	2057.2	0.90
Other services	0.102	0.088	0.008	0.009	-0.087	-0.095	0.030	0.038	3.39	6342.4	0.95

(a) Low or no observations so estimates not made

B4 Process for deriving preferred access model

A full description of the significant coefficients for the models tested beyond the Alstadt model is presented in table B.3 (note that only those coefficients with a positive sign are included).

Table B.3 Estimated access elasticities for all sectors from stepwise changes to base two-stage least squares model (NB table in two parts) (1) (2)

Industry sector	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas
	A40 coefficient					A180 (or A120) coefficient				
Horticulture and fruit growing	-0.071				-0.070					
Sheep, beef cattle and grain farming	-0.083				-0.085					
Dairy cattle farming	-0.064				-0.078		0.092	0.092		
Poultry, deer and other livestock farming										
Forestry and logging							0.111	0.112		
Fishing and aquaculture		-0.136								
Agriculture, forestry and fishing support services and hunting	-0.082				-0.087		0.052	0.052		
Mining	0.071						0.170	0.170	0.074	

Industry sector	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas
	A40 coefficient					A180 (or A120) coefficient				
Meat and meat product manufacturing	-0.053			**-0.075**	**-0.061**	**0.057**	**0.068**	**0.068**	**0.084**	**0.070**
Seafood processing										
Dairy product manufacturing										
Fruit, oil, cereal and other food product manufacturing							**0.053**	**0.053**	**0.063**	**0.048**
Beverage and tobacco product manufacturing										
Textile, leather, clothing and footwear manufacturing							**0.058**	**0.061**	**0.062**	0.052
Wood product manufacturing						0.040	**0.062**	**0.062**	**0.070**	**0.059**
Pulp, paper and converted paper product manufacturing*										
Printing							0.060	**0.062**	**0.072**	**0.058**
Petroleum and coal product manufacturing*										
Basic chemical and chemical product manufacturing		**-0.085**	**-0.091**	**-0.090**					**0.075**	**0.065**
Polymer product and rubber product manufacturing										
Non-metallic mineral product manufacturing				**-0.066**			**0.056**	**0.056**	**0.075**	**0.068**
Primary metal and metal product manufacturing										
Fabricated metal product manufacturing							**0.054**	**0.055**	**0.068**	**0.063**
Transport equipment manufacturing				-0.059					0.061	**0.068**
Machinery and other equipment manufacturing						0.044	**0.064**	**0.064**	**0.074**	**0.067**

Industry sector	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas
	A40 coefficient					A180 (or A120) coefficient				
Furniture and other manufacturing							0.051	0.052	0.071	0.061
Electricity and gas supply		0.172				0.130	0.202	0.234	0.153	
Water, sewerage, drainage and waste services	0.126	0.145	0.125		0.085	0.139	0.203	0.199	0.106	0.083
Building construction										
Heavy and civil engineering construction									-0.024	
Construction services										
Wholesale trade	0.090	0.051	0.049	0.046	0.087	0.040	0.067	0.067	0.078	0.070
Motor vehicle and motor vehicle parts and fuel retailing	0.024				0.028					0.021
Supermarket, grocery stores and specialised food retailing	0.026				0.031					0.018
Other store-based retailing and non store retailing	0.025				0.029					0.019
Accommodation and food services		-0.036	-0.038	-0.036						
Road transport						-0.068	-0.078	-0.078	-0.047	-0.044
Rail, water, air and other transport						-0.063	-0.072	-0.072	-0.039	-0.038
Postal, courier transport support, and warehousing services.						-0.057	-0.065	-0.065	-0.032	-0.033
Information media services	0.104				0.077					
Telecommunications, internet and library services	0.123	0.049			0.107					
Finance	0.056				0.065					
Insurance and superannuation funds	0.055				0.077				0.040	
Auxiliary finance and insurance services	0.061				0.070					

Industry sector	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas
	A40 coefficient					A180 (or A120) coefficient				
Rental and hiring services (except real estate)										
Property operators and real estate services										
Owner-occupied property operation*										
Professional, scientific and technical services	**0.038**				**0.061**	**-0.050**	**-0.041**	**-0.041**		
Administrative and support services	0.047				**0.051**					
Local government administration	**0.053**	**0.052**	**0.053**	**0.052**	**0.056**					
Central government administration, defence and public safety	**0.084**	**0.084**	**0.077**	**0.077**	**0.081**					
Education and training	**0.020**								**0.023**	**0.026**
Health care and social assistance						**0.031**	**0.038**	**0.038**	**0.038**	**0.043**
Arts and recreation services	**0.110**				**0.089**		0.059	0.061	0.041	
Other services	**0.100**				**0.096**		**0.050**	**0.050**	**0.078**	**0.069**

Industry sector	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas
	AAIR coefficient					ASEA coefficient				
Horticulture and fruit growing										
Sheep, beef cattle and grain farming										
Dairy cattle farming										
Poultry, deer and other livestock farming										
Forestry and logging										
Fishing and aquaculture	0.087	**0.203**	**0.159**			-0.076	**-0.123**			

Industry sector	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas
	AAIR coefficient					ASEA coefficient				
Agriculture, forestry and fishing support services and hunting										
Mining		**0.067**	**0.068**							
Meat and meat product manufacturing										
Seafood processing										
Dairy product manufacturing										
Fruit, oil, cereal and other food product manufacturing										
Beverage and tobacco product manufacturing	**-0.102**									
Textile, leather, clothing and footwear manufacturing										
Wood product manufacturing										
Pulp, paper and converted paper product manufacturing*										
Printing										
Petroleum and coal product manufacturing*										
Basic chemical and chemical product manufacturing	-0.049	-0.064	**-0.058**							
Polymer product and rubber product manufacturing										
Non-metallic mineral product manufacturing										
Primary metal and metal product manufacturing										
Fabricated metal product manufacturing										

Industry sector	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas
	AAIR coefficient					ASEA coefficient				
Transport equipment manufacturing										
Machinery and other equipment manufacturing										
Furniture and other manufacturing										
Electricity and gas supply										
Water, sewerage, drainage and waste services			0.100							
Building construction										
Heavy and civil engineering construction										
Construction services										
Wholesale trade	**-0.061**	-0.044	-0.042							
Motor vehicle and motor vehicle parts and fuel retailing	**-0.040**									
Supermarket, grocery stores and specialised food retailing	**-0.039**									
Other store-based retailing and non store retailing	**-0.038**									
Accommodation and food services	**-0.041**									
Road transport										
Rail, water, air and other transport										
Postal, courier transport support, and warehousing services.			-0.027							
Information media services						**0.070**				
Telecommunications, internet and library services	-0.054									
Finance	**-0.066**	-0.030								

Industry sector	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas	Alstadt	Excl large TA areas	Excl ASEA also	Excl AAIR, use A120 for A180	Same with all TA areas
	AAIR coefficient					ASEA coefficient				
Insurance and superannuation funds	**-0.060**									
Auxiliary finance and insurance services	**-0.052**									
Rental and hiring services (except real estate)	**-0.063**						-0.050			
Property operators and real estate services	**-0.068**	-0.063	**-0.074**							
Owner-occupied property operation*										
Professional, scientific and technical services	**-0.039**		-0.036			-0.025	-0.029			
Administrative and support services										
Local government administration										
Central government administration, defence and public safety										
Education and training	**-0.038**					**0.036**	**0.028**			
Health care and social assistance						-0.029	**-0.038**			
Arts and recreation services	**-0.086**					**0.093**	**0.065**			
Other services	**-0.088**									

(1) Only coefficients significantly different from zero at 90% level reported with 95% significance in bold

(2) Shaded cells are coefficients scored with high sensitivity (6-10) by Alstadt, NB US sectors not exact match to New Zealand

B5 GDP models

The results from the GDP equation within the 2SLS are tabled below (and for the 1st-stage employment equation in the next section).

Table B.4 Coefficients in GDP model when both A40 and A120 included in model

Industry sector	C	ln(EMPL)	Z2006	ZTARA	QDEG	OCCUP	AGE	ln(A40)	ln(A120)	N	R2
Horticulture and fruit growing		0.938	0.118	0.437		-1.655		-0.070		134	0.956
Sheep, beef cattle and grain farming		0.889	0.233	0.335	5.534	-5.213		-0.085		143	0.928
Dairy cattle farming		0.963	0.162	0.476				-0.078		130	0.957
Poultry, deer and other livestock farming	-1.877	0.904	0.328	0.436		-1.944				136	0.904
Forestry and logging	3.324	0.759		1.647	6.420		-7.980			122	0.890
Fishing and aquaculture	4.223	0.743	-0.431	1.754	9.358		-8.768			93	0.918
Agriculture, forestry and fishing support services and hunting		0.946		0.441		-2.076		-0.087		143	0.925
Mining		0.797	-0.691	2.038	6.173		-4.065			119	0.932
Meat and meat product manufacturing	-4.908	0.977	0.144	0.218				-0.061	0.070	112	0.975
Seafood processing										0	
Dairy product manufacturing	-3.982	1.243	0.583							77	0.940
Fruit, oil, cereal and other food product manufacturing	-2.440	0.969		0.194					0.048	138	0.973
Beverage and tobacco product manufacturing		0.955	-0.152							78	0.980
Textile, leather, clothing and footwear manufacturing	-2.875	0.951		0.164					0.052	122	0.971
Wood product manufacturing	-3.439	0.975	0.124	0.232		2.599			0.059	143	0.946
Pulp, paper and converted paper product manufacturing										0	
Printing	-2.842	0.966		0.189					0.058	112	0.973
Petroleum and coal product manufacturing										0	0.000
Basic chemical and chemical product manufacturing		0.971	-0.163	0.295		3.370			0.065	102	0.985
Polymer product and rubber product manufacturing	-2.963	0.956		0.219						83	0.984
Non-metallic mineral product manufacturing	-2.787	0.946	0.109	0.173					0.068	127	0.953

Industry sector	C	ln(EMPL)	Z2006	ZTARA	QDEG	OCCUP	AGE	ln(A40)	ln(A120)	N	R2
Primary metal and metal product manufacturing										0	
Fabricated metal product manufacturing	-2.460	0.970		0.242					0.063	137	0.977
Transport equipment manufacturing	-2.433	0.988	0.179	0.202					0.068	126	0.975
Machinery and other equipment manufacturing	-3.516	0.961		0.266		3.133			0.067	141	0.968
Furniture and other manufacturing	-3.403	0.924		0.232		3.469			0.061	127	0.964
Electricity and gas supply		0.787		2.292						93	0.861
Water, sewerage, drainage and waste services		0.651	-0.172	2.123	4.482		-6.124	0.085	0.083	126	0.842
Building construction	-2.681	0.990	-0.376			-1.242				144	0.985
Heavy and civil engineering construction	-1.865	0.991	0.115			-1.314				143	0.984
Construction services	-2.746	0.990	0.084			-1.269				144	0.986
Wholesale trade	-4.406	0.923		0.072		2.570		0.087	0.070	144	0.986
Motor vehicle and motor vehicle parts and fuel retailing	-3.802	0.978	0.233					0.028	0.021	144	0.985
Supermarket, grocery stores and specialised food retailing	-3.938	0.975	0.068					0.031	0.018	144	0.984
Other store-based retailing and non store retailing	-3.977	0.978	0.176					0.029	0.019	144	0.989
Accommodation and food services	-4.386	0.945					1.544			144	0.979
Road transport	-1.066	1.024			1.516		-1.825		-0.044	144	0.981
Rail, water, air and other transport		1.011	0.131		1.396		-2.354		-0.038	125	0.995
Postal, courier transport support, and warehousing services.	-1.628	1.009	0.166		1.078		-1.108		-0.033	136	0.993
Information media services	-4.880	0.834	-0.125			4.878		0.077		131	0.960
Telecommunications, internet and library services	-6.095	0.771	0.297			5.657		0.107		141	0.962
Finance	-2.964	0.861				3.032		0.065		144	0.978
Insurance and superannuation funds	-3.531	0.904	0.271		2.243	1.526		0.077		97	0.991
Auxiliary finance and insurance services	-3.242	0.897	-0.324			2.982		0.070		117	0.988
Rental and hiring services (except real estate)	-3.508	0.913	0.472			2.201				136	0.961
Property operators and real estate services	-2.212	0.940	0.136	-0.177						144	0.941
Owner-occupied property operation										0	

Industry sector	C	ln(EMPL)	Z2006	ZTARA	QDEG	OCCUP	AGE	ln(A40)	ln(A120)	N	R2
Professional, scientific and technical services	-2.221	**0.921**		**0.268**	**1.865**		**-1.679**	**0.061**		144	0.986
Administrative and support services	-2.711	**0.963**		**0.243**			**-2.303**	**0.051**		142	0.963
Local government administration	-1.721	**0.787**			**2.384**	**2.054**	**-2.852**	**0.056**		144	0.947
Central government administration, defence and public safety	-2.386	**0.865**						**0.081**		144	0.979
Education and training	-3.410	**0.962**	**-0.109**						**0.026**	144	0.983
Health care and social assistance	-3.185	**0.956**							**0.043**	144	0.982
Arts and recreation services	-5.009	**0.744**	**-0.121**			**3.948**		**0.089**		144	0.947
Other services	-4.990	**0.766**		**-0.125**		**4.379**		**0.096**	**0.069**	144	0.960

B6 Employment models

The results from the employment equation within the 2SLS are set out in table B.5.

In 26 of the 55 sectors there was a negative A40 effect. That is, generally a territory with a large working age population within the 40-minute commute zone has lower employment relative to the resident working age population. As with GDP, the association between employment and the A40 access was more common amongst the services sectors. The negative effect ranged from -0.505 (fishing and aquaculture) to -0.063 (education and training). In 1 of the 55 sectors, the access effect on employment was positive. There was no significant effect in the remaining sectors.

The association with the A120 delivery zone was more mixed, being a negative association with employment (relative to population) in some sectors, positive in others and of no significant effect in over half the sectors.

In all sectors where the 2SLS model were fitted, the employment coefficient in the second-stage GDP model was significantly different from zero, ranging from 0.651 (water, sewerage, drainage and waste services) to 1.243 (dairy product manufacturing).

The net effect of access on GDP that comes through an employment effect is found by multiplying the access coefficient in the employment model by the employment coefficient in the GDP model. For example, within the fishing and aquaculture sector, A40 access has a net effect on GDP of -0.375 (ie -0.505 x 0.743) and the A120 has a net effect on GDP of -0.269 (ie -0.362 x 0.743). That is, a 1% increase in A40 access is associated with a 0.505% reduction in employment relative to the local resident working age population, which in turn has a 0.375% reduction in GDP. Within the finance sector, the only access effect through employment comes via the A40 variable, providing a net effect on GDP of -0.171 (ie -0.199 x 0.861).

Table B.5 Access coefficients in EMPL model, plus EMPL coefficient in GDP model

Industry sector	Ln(A40)	Ln(A120)	Ln(EMPL)
Horticulture and fruit growing		-0.181	0.938
Sheep, beef cattle and grain farming	-0.308		0.889
Dairy cattle farming		0.376	0.963
Poultry, deer and other livestock farming			0.904
Forestry and logging	-0.387		0.759
Fishing and aquaculture	-0.505	-0.362	0.743
Agriculture, forestry and fishing support services and hunting	-0.164		0.946
Mining	-0.260		0.797
Meat and meat product manufacturing			0.977
Seafood processing			
Dairy product manufacturing		0.381	1.243
Fruit, oil, cereal and other food product manufacturing		-0.112	0.969
Beverage and tobacco product manufacturing	0.327	-0.402	0.955
Textile, leather, clothing and footwear manufacturing			0.951
Wood product manufacturing	-0.110		0.975
Pulp, paper and converted paper product manufacturing			
Printing			0.966

Industry sector	Ln(A40)	Ln(A120)	Ln(EMPL)
Petroleum and coal product manufacturing			
Basic chemical and chemical product manufacturing			0.971
Polymer product and rubber product manufacturing			0.956
Non-metallic mineral product manufacturing			0.946
Primary metal and metal product manufacturing			
Fabricated metal product manufacturing		0.161	0.970
Transport equipment manufacturing	-0.210	0.320	0.988
Machinery and other equipment manufacturing		0.101	0.961
Furniture and other manufacturing			0.924
Electricity and gas supply	-0.376	0.310	0.787
Water, sewerage, drainage and waste services	-0.191	0.140	0.651
Building construction	-0.085		0.990
Heavy and civil engineering construction		-0.114	0.991
Construction services		0.050	0.990
Wholesale trade			0.923
Motor vehicle and motor vehicle parts and fuel retailing	-0.176	0.111	0.978
Supermarket, grocery stores and specialised food retailing	-0.072		0.975
Other store-based retailing and non store retailing	-0.174		0.978
Accommodation and food services	-0.312		0.945
Road transport			1.024
Rail, water, air and other transport	-0.444	-0.219	1.011
Postal, courier transport support, and warehousing services.	-0.168		1.009
Information media services	-0.433		0.834
Telecommunications, internet and library services			0.771
Finance	-0.199		0.861
Insurance and superannuation funds	-0.397		0.904
Auxiliary finance and insurance services	-0.264		0.897
Rental and hiring services (except real estate)	-0.148		0.913
Property operators and real estate services	-0.114	0.105	0.940
Owner-occupied property operation			
Professional, scientific and technical services			0.921
Administrative and support services	-0.263		0.963
Local government administration	-0.150		0.787
Central government administration, defence and public safety			0.865
Education and training	-0.063		0.962
Health care and social assistance	-0.207		0.956
Arts and recreation services	-0.237	0.057	0.744
Other services	-0.070		0.766

Appendix C: Glossary

2SLS	two-stage least squares
A40	working age population within a 40-minute drive
A120	working age population within a 40–120 minute drive
A120all	working age population within a 0–120 minute drive
AADT	average annual daily traffic
AES	annual enterprise survey
ANZSIC	Australian and New Zealand Standard Industrial Classification
AWHC	Additional Waitemata Harbour Crossing
ART3	Auckland Regional Transport Model (of Auckland Council)
ASP3	Auckland Strategic Planning Model (of Auckland Council)
ATM2	Auckland Transport Model (of Auckland Council)
BCR	benefit-cost ratio
CAU	census area unit
CBA	cost-benefit analysis
CBD	central business district
CGE	Computable General Equilibrium Model
DfT	Department for Transport (UK)
DM	do minimum (scenario within an appraisal)
DS	do something (scenario within an appraisal)
EEM	*Economic evaluation manual* (NZ Transport Agency)
GDP	gross domestic product
GIS	geographic information systems
GMPTE	Greater Manchester Passenger Transport Executive
GST	goods and services tax
GTC	generalised travel cost
GVA	gross value added
HS2	company responsible for developing and promoting the UK's new high speed rail network
IMPLAN	impact analysis for planning (an input-output software package)
LEED	linked employer-employee dataset
LUTI	land use transport interaction (model)
MRIO	multi-regional input-output (models)

NA	national accounts
NPV	net present value
OLS	ordinary least squares
PV	present value
REMI	Regional Economic Models, Inc
RIMS	regional input-output modelling system (of the US Bureau of Economic Analysis)
RoNS	roads of national significance
SERC	Spatial Economics Research Centre (within London School of Economics)
TA	territorial authority (the second tier of local government in New Zealand, after regional councils)
Transport Agency	New Zealand Transport Agency
WGTAVE	weighted average (of effects estimated at different times of day)