Is infrastructure productive? Evaluating the effects of specific infrastructure projects on firm productivity within New Zealand

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Abstract

The paper investigates the feasibility of using a variant of the spatial equilibrium model to estimate the productivity effects of a specific infrastructure project in New Zealand. Policy makers are interested in the marginal effects of infrastructure investment on productivity and an evaluation of such effects would provide a useful check on the appropriateness and adequacy of current decision rules and institutions. To date, there appear to be no examples of using a spatial equilibrium model to estimate the productivity effects of a specific infrastructure project. However, the analysis in this paper suggests that such an approach is feasible. There is a range of data and estimation issues that needs to be addressed in the use of a spatial equilibrium model for this purpose, but we find that a reasonably useful range of data is available in New Zealand. The next step in determining feasibility is to select a particular infrastructure project, and to develop an empirical model based on available data.

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H54, R11, R23, R31

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Infrastructure, regional economics, land and labour markets.

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1 Introduction

Policy makers are interested in whether additions to the infrastructure stock will have positive effects on firm productivity and growth in per capita incomes. There is a considerable, but somewhat inconclusive, empirical literature that attempts to estimate the effects of infrastructure investment on productivity growth. The general conclusion from this literature is that productivity effects are contingent on a range of factors. These factors include the adequacy of the existing infrastructure stock and the existence or potential existence of complementary investments in physical and human capital (De la Fuente, 2000; O'Fallon, 2003).

A first question of interest to policy makers is whether at current margins the overall level of investment in infrastructure is optimal for productivity growth. A second perhaps more important question is whether a particular sort of infrastructure investment at a particular point of time and in a particular place is likely to have nett positive effects on productivity (whether in a particular region or in aggregate).

In practice, infrastructure investments are made with a variety of objectives according to decision rules that only imperfectly reflect those objectives. Depending on institutional arrangements, there is considerable scope for political judgment to influence decisions. There are many conceptual and operational problems in the methodologies used, and typically there is considerable uncertainty about the scope and size of the effects to be incorporated into the analysis.

Knowledge about whether current investments are having a positive effect on productivity could help guide decisions about the overall level of infrastructure investments. This knowledge could also guide decisions about which types of infrastructure to invest in and where to make those investments, and about whether decision rules might be amended to better reflect an interest in investment effects on productivity. However, the use of ex-post evaluation of the effect of a public infrastructure investment on firm productivity is rare in New Zealand.

The purpose of this study is to identify empirical methodologies that can help answer these questions, and to investigate the feasibility of applying them in New Zealand. In particular, ex-post evaluation offers the possibility of assessing whether the decision rules used and institutional arrangements are likely to lead to infrastructure provision that has nett positive effects on productivity and amenity values. It may also help clarify the extent to which decisions have favoured either productivity gains or the achievement of other objectives such as an increase in amenity values.

The remainder of this report is organised as follows. Section 2 summarises the decision rules used for making infrastructure investments within New Zealand and examines the extent to which infrastructure decisions focus on economic growth (productivity) objectives. Section 3 identifies the strengths and weaknesses of alternative ex-post methodologies for examining the effects on productivity of an infrastructure investment, and elaborates on the preferred spatial equilibrium methodology. Section 4 investigates the feasibility (e.g. availability of data) for measuring, ex-post, the productivity of an infrastructure investment within New Zealand, using the preferred methodology.

1.1 Scope

At the broadest level, infrastructure stocks can be divided into three types: economic, social, and institutional. Economic infrastructure relates to assets that provide services used in production and final consumption, social infrastructure supports a healthy workforce with adequate skills, and institutional infrastructure includes market operations and legal property rights (New Zealand Institute of Economic Research, 2004). Because the focus of this paper is on the relationship between physical infrastructure investment and firm productivity, we will focus our review on economic infrastructure stocks.

Following the definitions used in New Zealand Institute of Economic Research (2004) the distinguishing characteristics of infrastructure assets are taken to be:

1. Capacity can only be adjusted in large, ‘lumpy’ increments.
2. There are high initial fixed costs and risk of asset stranding as conditions (such as tastes and technology) change.

3. There are multiple users of the services, spanning production and final consumption.
4. Externalities are not reflected in service charges.
5. Scale and regulatory hurdles create long lead times for installing new capacity.

Again following official definitions,[1,2,3] we identify four main categories of infrastructure assets:

1. energy: all gas and electricity and petroleum assets (except retailing)
2. transport: roads, rail tracks and rolling stock, airport and dock facilities
3. water: supply and wastewater treatment including water capture, wastewater treatment, bulk distribution, local reticulation, irrigation, and flood protection
4. telecommunications: wireless and cellular transmission towers, transmission lines, local loops, and international connections.

2 Public infrastructure investment decision rules and methods

Public infrastructure investments are not random events. Planners (sensibly) assess the need for public infrastructure and direct investment to where they consider the need to be the greatest. The reasons that underlie a decision to invest in public infrastructure have important consequences for the benefits associated with the investment. For example, if the sole aim of investing in the road network is to reduce the accident rate, then it is possible that the productivity benefits from the project will be negligible. It is therefore important to understand the decision process that has shaped public infrastructure investments when evaluating their effect on firm productivity.

The purpose of this section is to examine the extent to which infrastructure investment decisions focus on economic growth (productivity) objectives and whether the decision rules adequately reflect the objectives. Table 1 lists the main New Zealand infrastructure stocks, that fall within the four main categories outlined in Section 1.1 (energy, transport, water, and

[1] Infrastructure stocktake report back, CAB M (04) 16/6.
[2] For a comprehensive review of New Zealand infrastructure stocks see PricewaterhouseCoopers, (2004).
[3] For this review we have also included oil assets (refinery and distribution) and flood protection.

telecommunications) and identifies the institutions that are involved in making the infrastructure investment decisions.

Table 1: Public infrastructure investment decision-making process

	Infrastructure Type	Institution(s) responsible for investment decisions
1	Electricity Generation	Private/SOEs
2	Electricity Transmission Grid	SOE (Transpower)
3	Electricity Line distribution	Private
4	Gas Supply and Transmission	Private
5	Local roads	Public (TLAs)
6	State highways	Public (Transit New Zealand)
7	Rail Passenger Services	Private/Public (RCs[1])
8	Rail Freight services	Private
9	Rail Track Network	SOE[2]
10	Sea/Air	Private/Public
11	Water Supply	Public (RC[1]/TLAs)
12	Sewage Treatment	Public (TLA)
13	Irrigation	Private
14	Flood protection	Public (RC[1]/TLAs)
15	Telecommunications	Private

Notes:
State owned enterprise (SOE), regional council (RC), territorial local authority (TLA)
1 Wellington and Auckland Regional Councils
2 The rail network was sold by the Government to Tranz Rail Holdings Limited in 1993. In December 2001 the Auckland rail corridor was sold back to the Government and the remaining rail network was sold back to the Government in July 2004.

Table 1 shows that infrastructure investment within New Zealand is conducted by a number of different types of organisations: private companies, state owned enterprises (SOEs), and central and local government authorities (Transit New Zealand, territorial local authorities (TLAs), and regional councils (RCs)). Privately operated companies and SOEs are responsible for investment in electricity and gas infrastructure services, irrigation, and telecommunications. Direct government involvement in public infrastructure investment, by central and local government authorities, is restricted to roads, the rail track network, and water infrastructure.

Private and public decisions to invest in infrastructure may also be influenced by regulation of prices and quantity of services, and regulation of access to networks, and by environmental regulation that may affect the cost of production or certainty of return on the costs of development.

The extent to which infrastructure investment promotes economic (productivity) growth may differ between private and public institutions. Private organisations will want to invest in infrastructure stocks to raise profits, whereas public organisations may have a range of economic, social, and environmental objectives. A complete review of the decision rules adopted by the institutions listed in Table 1 is not practical as part of this report. In some cases information about investment decisions is not easily available (e.g. private organisations) or the time required to compile the information is prohibitive. The remainder of this section will focus on road transport infrastructure and the investment decision rules used by the institutions involved. Investment in road infrastructure was chosen because the rules for investment are transparent, consistently applied to all road projects, and are easily accessible from Land Transport New Zealand's website.[4]

TLAs and Transit New Zealand are responsible for the identification and proposal of road maintenance and construction projects. Land Transport New Zealand (LTNZ) approves projects for funding by ensuring the project is economically viable[5] and meets the requirements of the Land Transport

[4] www.ltsa.govt.nz
[5] The benefits outweigh the cost of the project.

Management Act 2003 (LTMA).[6] The main objectives of the National Land Transport Programme (NLTP), administered by LTNZ, are to assist with economic development, assist with safety and personal security, improve access and mobility, protect and promote public health, and ensure environmental sustainability. The LTMA specifies that LTNZ should not prioritise any of the five key objectives and that all the objectives need to be considered equally in the planning process. The five key objectives, listed above, are applied at a macro level as individual road projects may focus on a couple of objectives. LTNZ uses a cost–benefit approach to assess whether the benefits from a road project outweigh the construction costs. Each decision rule does not focus on a particular objective (e.g. economic growth), but reflects the overall benefit to the community. For example, a reduction in travel times might be of benefit to firms by lowering their transport costs and to households by making the school run quicker. However, the decision rules are ambiguous in terms of how much a road project would contribute to each objective considered by LTNZ. For example, reducing accidents would probably make road travel safer, but a reduction in the accident rate could also have an economic growth effect by reducing transport costs because of fewer traffic delays caused by accidents.

Estimating, ex-ante, the economic (productivity) effects of a road transport investment using the current road transport decision rules is difficult for the following reasons. First, a decision to invest in a road improvement is motivated by a range of objectives (and not solely to promote economic growth), therefore, it is difficult to separate out the effect on economic growth from other effects (e.g. social and environmental). Second, the cost–benefit approach, used by LTNZ to estimate the ex-ante benefits of a road improvement, cannot fully capture the wider economic benefits of a road investment. The cost–benefit approach is a static model that ignores the effect a road project might have on the behaviour of firms and workers. For example, a road improvement may attract more firms and workers to an area, which may lead to productivity growth due to agglomeration effects. Ex-post evaluation would be better able to separately identify the specific economic (productivity) growth effects from an infrastructure

[6] Appendix A provides a detailed description of the objectives and assessment process of road investment within New Zealand.

investment, as well as capture the wider economic benefits associated with new infrastructure.

3 Ex-post evaluation of the effect of public infrastructure investment on productivity growth

The empirical literature assumes that public infrastructure stocks are a pure public good, available to all firms within some predefined geographic boundary. The ideal method of analysis of the role of infrastructure in production is to collect data on individual firms, calculate the marginal productivity of infrastructure for each firm, and then aggregate these individual productivities. In practice, sufficient data on individual firms is unavailable and researchers have turned to the analysis of aggregate outcomes.

Aggregate production functions (APFs) have been widely used in the literature to estimate the productivity of public infrastructure.[7] APFs assume that, for a given production technology, variation in aggregate firm production will be positively related to public infrastructure provision. An aggregate production function typically assumes that aggregate output is a function of private capital, employment and public capital. The coefficient on public capital is interpreted as the productivity of infrastructure. Another approach is to estimate the productivity of infrastructure using an aggregate cost function (ACF) model. [8] Both the APF and ACF models assume that factors of production (e.g. capital and labour) are immobile.

The assumption that either production quantities (APF) or prices (ACF) are fixed is unlikely to hold in the real world. If public infrastructure is productive then increasing infrastructure stocks within a region will raise the productivity of

[7] See De la Fuente (2000) for a comprehensive review of APF models and Appendix A for a brief summary of the issues raised in using them.

[8] The difference between the APF and ACF approaches is in the assumptions they make about individual firm behaviour. APF models assume that productive inputs are exogenously determined (i.e. firms do not alter their production technology in response to changes in available infrastructure stocks). Increasing a productive public infrastructure stock, within an APF model, raises the productivity of the available (fixed) inputs. ACF models assume that input decisions are endogenous to production decisions, whereas input prices in a competitive economy are exogenous. Under this scenario, firms respond to a costless increase in a productive public infrastructure stock by substituting more of the infrastructure service into their production technology (for other inputs) to reduce the marginal cost of production.

the existing firms and increase the attractiveness of the region as a production site.[9] If firms are assumed to be profit maximising then they will prefer (and want to move production to) locations that offer greater site-specific productivity gains.[10] Firm migration will increase demand for local production inputs and firms may alter their production technology to reflect changes in the relative prices of the production inputs. For example, if land is fixed within predefined boundaries, an increase in demand for production sites, within a region, will raise the price of land, and firms may substitute land for labour. Under the scenario of factor mobility, both production quantities and input prices cannot be treated as being exogenous to a region because public infrastructure investment may induce changes in regional factor prices. Aggregate models do not control for the fact that regional factor price differentials might reflect part of the value of public infrastructure stocks (Haughwout, 2002) and, therefore, cannot adequately estimate the marginal productivity of public capital (if factors of production are mobile).

A spatial equilibrium model assumes firms and households compete for sites across locations until profits, achievable by firms, and utility, achievable by households, are equal across all locations. This is the opposite to the assumption made by aggregate models, which assume that firms enjoy location-specific profits due to an increase in the productivity of inputs or lower costs of production. At equilibrium, firms and households have no incentive to move and differences in local factor prices (e.g. rents and wages), between locations, are fully explained by differences in unpriced and non-traded regional traits (e.g. public infrastructure stocks and climate). The following discussion of the basic spatial equilibrium model of firm and household behaviour is based on the

[9] This assumes that the productivity benefits do not spill over regional boundaries and that regions have a fixed geographical area.

[10] As long as the benefits of moving outweigh the cost of relocating. The theoretical models below assume zero relocation costs.

approach taken by Roback (1982) and expanded upon by Haughwout (2002). The model assumes a set of regions that vary only by the level of an endowed amenity (this could include public infrastructure stocks). It also assumes that any increase in infrastructure stocks is externally funded. Residents within a region consume and produce a composite good (X), whose price is determined by world markets. Private capital and labour are completely mobile. Workers face zero relocation costs between regions, commuting between regions is assumed prohibitive (too costly), and intra-city commuting is ignored. The land within a region is used for either production of a composite good or is consumed by households. Land use is mobile between the two users.

The model uses a production function for firms similar to the APF model and is given by:

$$x_j = \{G_j, n_j, m_j\}$$

where *x* is firm production in region *j*, *G* is the level of available infrastructure stocks, *n* is private employment, and *m* is land used by a firm in production.[11] A firm's demand for production inputs, labour, and land is a function of their relative prices. Firms minimise costs subject to the production function so that the (unit) cost of production equals the price of good X (under the assumption that profits are zero everywhere). As shown here:

$$c\{W_j, R_j, G_j\} = P_x$$

A firm's cost of production depends on wages (W), land prices (R), and infrastructure provision. A change in the infrastructure stock in a region is productive if it increases a firm's output or reduces its costs of production.

Households are assumed to be identical in tastes and skills. Leisure is ignored and households supply a single unit of labour independently of the wage rate. Households choose between the consumption of land, within a region, and the composite good (X) subject to their wage income (other income is ignored). Household utility is a function of wages, rents, and public infrastructure provision,

[11] Exclusion of private capital has no effect on regional economic equilibrium, as long as it is freely mobile and its price is nationally determined. Returns from private capital are constant across locations and are not influenced by infrastructure, but could be related to relative prices of land and labour, which are affected by public infrastructure provision.

subject to a given utility value (equal across locations). Households require an equilibrium wage that, given local land prices and infrastructure stocks, enables them to achieve a utility level equal to levels elsewhere. A household's wage (income) is given by:

$$W_j = e(R_j, G_j, P_x, \overline{V})$$

where a household's wages (*W*) are equal to household expenditure (*e(.)*) at a nationally determined utility level ($\overline{V}$). A household's expenses depend on land prices, the level of public infrastructure stocks, the price of the composite good, and utility. Public capital is directly valuable as a consumption good if a change in infrastructure stocks increases utility, or equivalently decreases household expenditure.

The firm cost and household expenditure functions show that rents and wages can be determined as functions of public infrastructure stocks for a given level of utility (Roback, 1982). At equilibrium (equal profit rate and utility across all locations), rents and wages can be defined as:

$$R_j^* = R(P_x, G_j, \overline{V})$$
$$W_j^* = W(P_x, G_j, \overline{V})$$

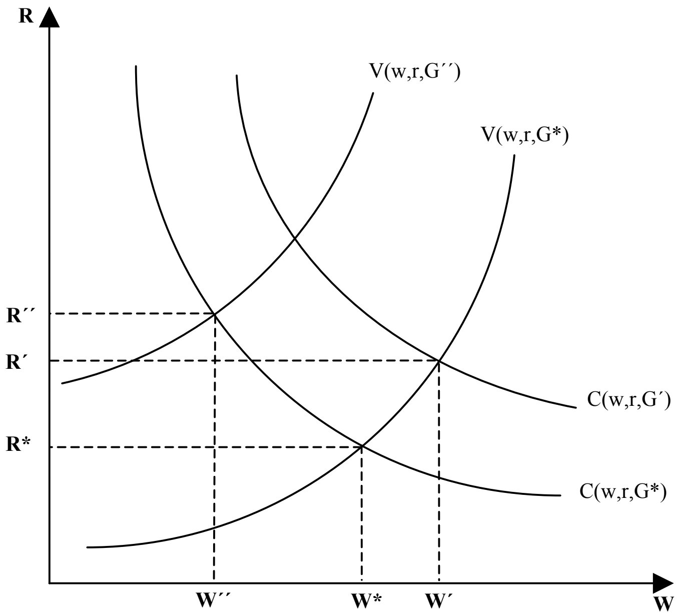
Rents and wages are determined by the price of the composite good X, local infrastructure provision, and national utility. Since P_x and $\overline{V}$ are exogenously determined, G is the only location-specific parameter and therefore fully explains rent and wage differentials between locations. Households and firms divide themselves across regions based on the variation in levels of site-specific amenities and the relative marginal benefit of public infrastructure stocks to households and firms.

When production factors are mobile, the relationship between aggregate output and the provision of public goods will represent a combination of the effect of public infrastructure on productivity, local prices (that reflect the valuation of locations as production or residential sites), and the response of firms and households (workers) to these local price changes (Haughwout, 1998).

Local prices adjust following a change in demand for land and labour for firms and land for households following an exogenous (costless) increase in public infrastructure stocks. The size and magnitude of these differentials depends on the relative value of a site-specific infrastructure stock to firms and households. Figure 1 illustrates three types of public capital investments and their effect on equilibrium rents and wages. The first investment is purely productive and households are indifferent, the second investment is a pure amenity that firms are indifferent to, and the third is an investment where both firms and households place some value on the investment.

The downward sloping curves represent a firm's cost function (C(.)), where unit costs of production are equal at all points along the curve. The upward sloping curves plot equal household utility levels (V(.)). If an increase in the level of public infrastructure stocks (G* to G′) is purely productive to firms (households are indifferent), then the iso-cost curve will shift out. Firms will increase their demand for land and labour in the location with more productive infrastructure stocks, which will push up rents (R* to R′) and wages (W* to W′). (Households, to remain indifferent, have to be compensated for an increase in rents with higher wages.) Rents and wages will stop increasing when there is no longer an incentive for firms to move production to the region because the greater site-specific productivity gains equal the additional costs of rent and wages. If an increase in infrastructure stocks is amenity positive (firms are indifferent) then the iso-utility curve will shift upwards (from G* to G′′). Households will increase their demand for land (R* to R′′) in amenity-rich locations and firms will be compensated with lower wages (W* to W′′). When a public capital investment is both productive and amenity positive, rents will always increase, whereas the change in the wage rate is ambiguous and will depend on the relative valuation of the infrastructure investment to firms and households.

Figure 1: Infrastructure, wages, and rents equilibrium



Firms and households react to a change in the relative prices of land and labour by changing their production technology (in the case of firms) and consumption behaviour (in the case of households). For example, if rents become relatively more expensive compared with wages, both firms and households economise on land. Firms produce using more labour and households consume more of the region's composite good (X). Therefore, the region can support more firms and workers earning the equilibrium profit and utility wages, which results in an increase in the region's output irrespective of whether the public good is purely productive or is of value only to households (an amenity). How much the price of land and labour changes, within a particular region, will depend on the shape of the firms' production technology (C(.)) and households' preferences (V(.)), shown in Figure 1. Haughwout (1998) shows algebraically that, without knowing the functional forms of a firm's production technology and a household's preferences, the sign of the effect of public infrastructure investment on aggregate productivity is ambiguous. Under some conditions, increases in marginal productivity due to a rise in the provision of public goods can reduce aggregate output, even if households are indifferent to the public good, whereas a zero marginal productivity effect does not imply that aggregate productivity will also be zero. Haughwout (2002) concludes that it is not possible to use aggregate output and local factor prices to uncover the true productivity of infrastructure. The only solution is to directly observe changes in local factor prices (wages and rents) to measure the communities' 'willingness to pay'. By including employment and land use data it is possible to disaggregate a communities willingness to pay into those benefits that go to firms and the gains to households from an infrastructure investment.

The aggregate models discussed at the beginning of this section assume a static world where a firm's production technology (APF) or a firm's input prices (ACF) are fixed and will not adjust following an infrastructure investment. On the other hand, if factors of production are mobile, a productive infrastructure investment would increase demand for production inputs, raising prices and inducing firms to adjust their production technology in response to the change in prices. The spatial equilibrium model is able to control for adjustments in input prices and production technologies following an infrastructure investment. Therefore, the spatial equilibrium model would be the preferred model for estimating the ex-post productivity effects of an infrastructure project.

However, some of the assumptions made by the spatial equilibrium model require careful consideration (and are discussed in more detail in the next section). First, if workers are able to commute between regions, then the benefits from a public infrastructure investment may spill over into the adjacent regions. Therefore, it is important to carefully define the region to eliminate inter-regional commuting of workers. A similar point applies if the amenity value of infrastructure spills across regions. Second, the spatial equilibrium model assumes that the supply of land to firms and households is inelastic. If the supply of land is neither elastic nor inelastic, then the adjustment in land rents and wages may be mitigated by an increase in housing and worker supply. Third, it is unlikely that land will be completely mobile between users (firms and households), as local authorities often restrict land use to designated zones. Fourth, the spatial equilibrium model assumes that firms are identical (they produce a single good using the same production technology); therefore, the productivity effect of an infrastructure investment will be the same for all firms. However, if firms produce different goods (using different production technologies), the productivity effect of an infrastructure improvement may vary across firms due to different production technologies.[12] An infrastructure investment within a particular region may change the industry composition of production by attracting industries that are intensive users of the services provided by the infrastructure improvement. A change in the industry composition of producers, following an infrastructure investment, would be partially reflected in a change in a region's mean wage if wage rates vary across industries. Finally, if infrastructure is funded from within the region, then the effect on firms and households of taxes and loans raised will be different from that if it is externally funded (as assumed by the model).

4 Feasibility of using the spatial equilibrium model to estimate marginal productivity effects of infrastructure in New Zealand

The spatial equilibrium model described above provides a theoretical link between public infrastructure stocks, firm costs, and household expenditure to determine the value of a marginal infrastructure project to firms and households using adjustment in wages and land prices. A marginal infrastructure project is of positive value to a community (of firms and households) if it raises aggregate land prices. However, land prices alone are not sufficient to determine whether a marginal increase in public infrastructure stocks are valued more by firms than households, or vice versa. By including wages it is possible to determine whether the gains from a marginal infrastructure project are (overall) greater for firms (increase in wages) or households (decrease in wages).

The basic spatial equilibrium model has been implemented empirically in a variety of ways to estimate the effects of factors such as infrastructure, industrial concentration, and urban agglomeration on productivity and amenity values. For instance, Haughwout (2002) and Rudd (2000) examined the effect of aggregate infrastructure investment on wages and house prices within US cities to determine the overall value of a marginal increase in infrastructure provision to firms and households. Gibbons and Machin (2005)[13] and McMillen and McDonald (2004) examined the impact of a new commuter rail transport route on

[12] Fernald (1999) found that increases in the stock of roads lead to faster productivity growth in those industries that are more intensive users of road transport infrastructure.

[13] An application of the Gibbons and Machin (2005) study is to compare the ex-post shadow price of walking with the ex-ante prediction used as part of the project's cost–benefit analysis.

house prices in London and Chicago respectively, as a way of estimating the value that commuters placed on the new infrastructure. A related literature (e.g. Glaeser et al, 2005) uses similar models to estimate the determinants of house prices and supply.

While each of these examples is clearly relevant to our interest in estimating the productivity effects of specific infrastructure projects, the empirical models used address somewhat different questions. Haughwout (2002) and Rudd (2000) are interested in the effects on productivity and amenity values of changes in the comprehensively measured aggregate stock of infrastructure across selected urban locations.[14] Gibbons and Machin (2005) and McMillen and McDonald (2004) do not attempt to estimate the productivity effects per se of the particular infrastructure projects they investigate, but rather their value to the affected households. We are not aware of any studies that use a spatial equilibrium model to estimate the productivity effects of particular infrastructure projects.

The purpose of this section is to discuss the elaborations on the basic model, the empirical strategies and identification issues, the broad data requirements, and the availability of data in New Zealand that would be required to implement such a study. The section also briefly discusses the characteristics of infrastructure projects that would be most amenable to a study of this sort, and tentatively suggests possible projects that may be worth further investigation.

Section 4.1 outlines a broad conceptual model that would form the basis for specifying an empirical model to estimate the productivity effects of a specific infrastructure project. It identifies a range of variables that are relevant to such a model, identification issues, and briefly discusses strategies to address these

[14] Even if this was the question of prime interest to policy, the requirements for comprehensive measures of the infrastructure stock in particular locations over time would preclude its implementation in New Zealand. An audit of current public infrastructure stocks has been conducted by the Ministry of Economic Development (see PWC report), but the report provides an overview for the whole country and does not measure stocks by geographic region and across time.

issues. Section 4.2 reviews and draws lessons from the empirical strategies and identification issues addressed in the four studies referred to above. Section 4.3 reviews New Zealand data available for estimating such a model. Section 4.4 discusses criteria for selecting a specific infrastructure project for analysis and tentatively suggests some projects that may be worth further investigation. Section 4.5 concludes with an outline of the next steps required to establish the feasibility of a full-scale study.

4.1 Elaborating on the basic conceptual model

In order to obtain an unbiased estimate of the relationship between wages, land prices, population growth, and public infrastructure stocks, the empirical model has to separate out the effect of a rise in infrastructure services from all other effects that may explain differences in wages, land rents, and population growth between locations (dependent variables in Table 2, panel A). Wage rates, land prices, and population growth will differ across locations due to public infrastructure provision and other location-specific amenities (e.g. warmer climate).

Individual characteristics

In addition the average wage rate can be expected to vary between locations due to differences in the workforce, for example, some regions may have a relatively large share of younger inexperienced workers compared with other regions. Panel B in Table 2 outlines the main factors that explain wage rate differences between individuals. High-skilled workers, on average, can be expected to have a higher wage rate compared with low-skilled workers. A worker can acquire skills from attending school and from on-the-job training.[15] An individual's level of work experience will depend on their age minus the time spent not in employment (e.g. education, unemployment spells, and childcare).[16] Some individuals may acquire additional skills from their family or community group (e.g. religious training) or belong to a large community that increases the number of potential job contacts and leads to better job matching prospects. Wage rates may also differ between industry sectors and occupations for reasons

[15] The marginal effect of an additional year at school or on-the-job training may diminish with each additional year.
[16] Including gender may control for most of the difference in wage rates due to childcare responsibilities.

unrelated to skill levels.[17] Central city workers may be able to achieve a higher wage rate due to a greater range of job opportunities (better job matching), compared to workers within rural locations with fewer job opportunities.[18]

Table 2: Estimation variables (dependent and controls)

A Dependent variables • Hourly wages rate • Land prices – by residential, commercial, industrial and agricultural land • Population B Individual characteristics • Years of completed schooling/Academic achievement • Work experience (number of years in employment) • Community group • Industry sector • Occupation • Urban location	C Property characteristics • Type (e.g. house/apartment) • Lot size • No. of units on same lot • Building area • Number of floors • Age • Quality • No. of rooms • No. of bedrooms • No. of bathrooms • Basement • Attic • Elevator • Central heating/air conditioning • Garage (single/double) • Reticulated water and sewage
D Unproduced local amenities • Sunshine hours • Rainfall • Annual temperature • Number of heating days • Mean distance to beaches and national parks E Produced local amenities • Level of local infrastructure stocks • Local taxes • Quality of schools • Crime level	F Other • Transport costs – wages, fuel, new cars, public transport • Housing stock and changes in housing stock • Housing density • Zoning restrictions and changes in zoning restrictions

[17] Including information on industry sector and occupation will control for any variation in the wage rate caused by changes in the (industry) composition of producers following an infrastructure investment.
[18] Workers may earn a higher wage rate due to their natural ability (e.g. physical characteristics), which is difficult to capture.

Property characteristics

The price of a parcel of land is used within the spatial equilibrium model as a proxy measure to value the stream of services generated from a particular location. However, when properties are sold or rented,[19] the price usually combines the value of the land parcel with any improvements (e.g. buildings). Improvements to a land parcel are usually durable, making them expensive to remove and replace. Therefore the prospective buyer or renter makes a bid that reflects the value of the property's location and any improvements that have already been made. A property's sale or rental price will vary across locations due to the location-specific amenities and the mix of improvements that have been made to the land parcel (e.g. size, type, and quality of buildings). The value of the land improvements will depend on their characteristics. For residential buyers and renters their preferences are easier to model, for example, larger properties are preferred to smaller properties. However, the preferences of buyers and renters of properties for commercial use will vary depending on the type of business they intend to use the property for. For example, an insurance company would require a different building from a car repair business.

The spatial equilibrium model assumes that a firm and a household can compete for the same location (land use is freely interchangeable between users). Therefore, firms and households will be exposed to the same change in land rents due to a change in the level of public infrastructure services. The assumption that land is freely interchangeable between users (firms and households) might not hold if a local government authority divided their administration region into residential and commercial zones. Under this scenario firms and households would compete in separate land markets over the short term (because they do not compete for the same locations). Land use would change between residential and commercial use only when the local authority amended the zones. Therefore, it would not be possible to measure only changes in the price of land used for residential purposes as a proxy for the average change in land prices experienced by firms and households. Under the assumption that land use is freely

[19] The rental price should exclude utility costs (e.g. heating) as it makes it difficult to assess the effect of location-specific amenities on the rental price if they also influence the expenditure on utilities. For example, households in locations that have a relatively high average annual temperature will spend less on heating than households in locations where annual temperatures are lower.

interchangeable, panel C of Table 2 lists the characteristics of a residential property that are most likely to be related to its price.[20] The property characteristics define the type and size of the property, the condition and age of the property, and the types of accommodation services the property supplies.

Alternatively, if available, data on prices for different types of land—residential, commercial, industrial, agricultural—may assist in identifying the incidence of benefits.

Local amenities

The next part of the estimation model is contained within panels D and E of Table 2 and captures the effect of local amenities on the wage rate, land price, and population growth. Local amenities can be characterised as either unproduced (panel D) or produced (panel E). Unproduced local amenities are those that are exogenous to a region, whereas produced amenities can be either exogenous or endogenous to a region. Unproduced amenities include the local climate (e.g. number of sunshine hours, level of rainfall and mean annual temperature) and proximity to the coastline (beaches), national parks, and rivers. Produced amenities might include the quality of local schools, regional crime levels, taxes, and public infrastructure provision.

In relation to local taxes, the magnitude of the effect on wages, land prices and population growth from a public infrastructure investment may depend on whether the infrastructure investment is funded from outside (e.g. central government) or from within (e.g. local government) a location. If an infrastructure project is funded wholly or partly from the local purse, then it is possible that the productivity and amenity gains will be offset by an increase in local taxes (i.e. wages, land prices, and population growth may not adjust as much as if the investment was exogenously funded).

[20] The assumption that firms and households are exposed to the same land market is a common approach adopted within the literature.

Elasticity of housing supply

The basic spatial equilibrium model and the four studies reviewed in the next section assume that the value to firms and households in a community of raising public infrastructure stocks will be fully capitalised into adjustments in land prices. However, Glaeser et al (2005) argue that if the supply of housing within a location is elastic, then a rise in public infrastructure stocks may lead to an increase in the supply of housing. If housing supply is not inelastic or elastic, then productivity and amenity effects caused by an increase in infrastructure will not be fully reflected in prices.

Glaeser et al (2005) assume that the supply of new housing will be a function of the cost of construction, which in turn is related to local building regulations and the current density of housing. (The authors assume that building high-rise accommodation is more expensive than building single residential units). For a particular location that has few barriers to new construction and/or low housing density, housing supply will be relatively elastic compared with locations where barriers to construction and/or housing density are higher.[21] If housing supply within a location is relatively elastic (e.g. a new subdivision), then land prices may still rise in line with construction (which will increase with housing density), but at a lower rate compared with a location with relatively inelastic supply. Elastic housing supply will also mitigate a rise in wages and labour demand will be met by an increase in the number of workers.

Glaeser et al (2005) find strong evidence that differences in elasticity of housing supply are positively related to measures of housing density and restrictiveness of regulation. In turn, differences in the elasticity of supply have the predicted effect on the extent to which house prices rise in response to productivity shocks.

If housing supply is elastic, and housing price responses are to be used to identify the productivity effects of infrastructure, then housing supply responses need to be accommodated in the model. This is likely to be a particular issue for a New Zealand study, as the supply of housing in New Zealand cities is

[21] Glaeser et al (2005) find that, for US metropolitan regions, where building regulation is limited and population density is low, growth is likely to take the form of higher population levels. For regions with restrictive building regulations and a higher population density, growth is predominantly reflected in higher wages and house prices.

almost certainly more elastic than in the majority of the cities covered in the four studies referred to above and reviewed in Section 4.2. In these studies, which cover mature central city locations, the issue of housing supply is effectively ignored, reflecting an assumption of inelastic supply.

Direct measures of housing supply (changes in the stock of houses) or population increase, or proxies for elasticity in the form of housing density measures, and measures of the restrictiveness of regulation (together with measures of house price rises) may help identify the effects of additional infrastructure provision in a particular location.

Transport costs

The spatial equilibrium model predicts that changes in transport costs will affect outcomes across space. Transport costs incorporate changes in wages, but also petrol costs and the price of new cars (including depreciation), and also include, where relevant, public transport. Changes in any of these may be useful in identifying incidence of the benefits of infrastructural innovation.

As noted in the next section, the conceptual model outlined above has been specified in two distinct ways (depending on the question of interest) and econometric estimation techniques have been used to address the problem of unobserved variables.

Panel F in Table 2 incorporates variables to address elasticity of housing supply and changes in transport costs.

4.2 Lessons from studies using a spatial equilibrium model to estimate the benefits of infrastructure

Haughwout (2002) uses comprehensive data on infrastructure stocks in selected US cities over time to estimate the marginal effects of infrastructure on house prices and thus the benefits to households and firms combined.[22] He uses data on wage changes to estimate how many of these benefits are due to productivity increases, and how many are due to an increase in amenities of value to households. He calculates whether an average city's willingness to pay for a marginal increase in aggregate infrastructure stocks (as measured by the movement in house prices due to the increase) is outweighed by its cost.

One problem with using geographic regions is that the boundaries are often predefined (e.g. city administration boundaries) and may not capture the total benefits created by infrastructure investment. Haughwout (2002) used central city boundaries and found that the estimated benefit to firms and households from aggregate infrastructure investment is, on average, lower than the cost of the investment. However, Haughwout suggests that this could be due to some of the benefits from a city infrastructure investment spilling over into the adjacent suburbs.

The ideal (geographic) unit of analysis for this type of study is one that encompasses both the local labour and housing markets, so that any adjustments in wages and house prices that occur due to a rise in the infrastructure stock are captured within the region. For example, Rudd (2000) used the larger US metropolitan regions that include a city's central business district and the adjacent suburbs, and were designed to include the entire labour market (and housing market) associated with a city.[23]

Gibbons and Machin (2005) and McMillen and McDonald (2004) examined the impact of a new commuter rail transport route on house prices in

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[22] Haughwout (2002) estimates two hedonic regression equations with two second-stage regression equations. The first-stage regression models control for variation in wages and house prices that is explained by differences in human capital levels and housing characteristics. The unexplained variation in wages and house prices across different regions and time periods (estimated by the first-stage models) is then regressed on factors that are specific to a region and point in time and include: local taxes, debt conditions, infrastructure stocks, and amenities. A problem with the two-stage approach, adopted by Haughwout, is that the model assumes that housing characteristics and human capital variables are not correlated with region-time specific variables (e.g. infrastructure levels). For example, houses in poor infrastructure areas many be in a worse condition compared with houses in other areas because there is a reduced incentive to add value to a house where infrastructure levels are relatively low. Therefore, it may be more appropriate to include the region-time specific variables in the first-stage regression models. Another issue is that the shadow price of a characteristic (e.g. off-street parking, view of the sea) may vary across regions and time. A possible solution to this problem is discussed below.

[23] New Zealand local labour markets have been created using census data and are defined by maximising the proportion of residents that live and work in the same geographic region (Newell and Papps, 2001).

London and Chicago respectively. Instead of estimating the average adjustment in house prices before and after the new transport route became operational, both studies focused on how much property prices changed with increasing distance from the new transit stations. Incorporating information about the distance between households and transit stations in the estimation model makes it possible to determine the geographic extent of the impact of a specific infrastructure project on house prices. For example, Gibbons and Machin (2005) find that the effect of new commuter rail stations is highly valuable to households within 2 kilometres of the station, after which the effect becomes very small.

The estimated effect of explanatory variables in a spatial equilibrium model will be biased if unobserved characteristics of the location are correlated with any of them. This is most likely to occur with distance from the infrastructure project. The problem is that new transport stations (or infrastructure projects in general) may be located near other amenities that households value independently of access to public transport. For example, stations are often located in high street locations that offer retail outlets and entertainment centres. The location of stations may also be associated with negative characteristics, for example, higher crime and noise levels.

Haughwout (2002), McMillen and McDonald (2004) and Gibbons and Machin (2005) used information on households for more than one time period and used panel estimation techniques to control for unobserved effects on house prices and wages that are specific to locations, but do not vary over time, and effects specific to a time period, but common to all locations.[24] For example, while some regions may have more hours of sunshine or some households may have a view of a park, the effect of the business cycle on house prices may vary across time, but remain constant across all locations.

To control for pre-existing local area characteristics that may be correlated with distance to railway stations, McMillen and McDonald (2004) and Gibbons and Machin (2005) measured house prices in differences instead of levels. Measuring house prices in terms of differences controls for initial local area characteristics, but does not control for changes in local area characteristics

[24] Rudd used only a single year cross section of regions and therefore could not control for unobserved location-specific and time-specific differences.

due to the opening of a transport stations (e.g. more restaurants or a rise in crime rates). Therefore, the models are able to capture the nett benefit to the local residential community from a transport improvement. Gibbons and Machin show that cross-sectional estimates of the effect of the new infrastructure are considerably larger than those from their preferred 'differences-in-differences' methodology.

However, a problem will still remain if there are unobserved characteristics of locations not caused by changes in infrastructure, whose effect on prices and wages varies over time. For instance, households may place an increasing premium on locations with a warm climate, beaches, and water views over the period in which the effects of infrastructure are estimated. One possible strategy is to use movement in house prices in other locations with these same amenities, to control for their effects in the location under study. (This strategy assumes that the movements in the two locations due to changes in the relative value of amenities are correlated.)

Another important factor is identifying the time period over which wages, land prices, and population are likely to adjust. McMillen and McDonald (2004) detected house price adjustment, in anticipation of the opening of a new transit line in Chicago, up to 6 years before the actual opening of the line, which coincided with the announcement of the route for the proposed transit line.[25] The level of adjustment in land prices prior to a public infrastructure project may depend on the composition of household ownership. Gibbons and Machin (2005) ignore the possibility of anticipation effects. They examine house prices shortly before and after the infrastructure investment event on the basis that owner-occupiers outnumber landlords by around 5 to 1 in the study area and have a shorter time horizon than landlords. (Landlords will invest early in the anticipation of capturing increased rents, whereas home owners are motivated to move by the availability of an amenity.)

4.3 New Zealand data sources

Section 4.1 set out a conceptual model for estimating the relationship between public infrastructure provision, wages, land prices, and population levels.

[25] McMillen and McDonald (2004) found that house prices tended to overshoot and then adjust downwards once the transit line was in operation.

Section 4.2 briefly reviewed particular studies. This section examines whether existing datasets are available within New Zealand to estimate a spatial equilibrium model.

Table 3 summarises the variables required to estimate the effect on firm productivity of a specific infrastructure project. The variables can be divided into three groups. The first group includes the independent variables of wages and land rents. The second group includes the dependent variables of interest: level (value) of infrastructure provision (monetary value) and distance of the household from the infrastructure project. The third group includes the control variables and is divided into time-variant and time-invariant effects. Time-variant variables measure location-specific factors that are likely to change over time (e.g. the quality of local schools). Time-invariant factors are location-specific effects that are not expected to change throughout the period of study. The measurement of time-invariant factors (location-specific characteristics) is not necessary if a panel of observations across more than one time period is available, as location- and time-specific fixed effects can be used to control for unobserved effects. Similarly, the measurement of time-variant variables that are common across locations is not necessary if a differences-in-differences approach to estimation is used. Essentially, the effect of changes in these variables on locations that are not influenced by the change in infrastructure controls for their effect in the locations that are.

Wage and income data is available for New Zealand from three datasets. The New Zealand Census of Population and Dwellings records the total income of individuals, aged 15 years and older, every 5 years. The last four censuses (1986, 1991, 1996, and 2001) are available aggregated to small geographical areas called meshblocks (MBs).[26] The New Zealand Income Survey (NZIS) and Household Economic Survey (HES), conducted annually and every 3 years respectively, contain information on labour and non-labour income for individuals. However, the geographic resolution of the survey datasets is not as good as that of the census (main urban areas and the rest of New Zealand) and the time period covered by the two surveys is restricted to the 1990s to the present.

[26] A meshblock is equivalent to a city block and contains on average 100 people.

All three datasets contain demographic information about individuals that would be suitable to control for most of the differences in wages between individuals.

Unit record house price data is available from the early 1980s to the present from Quotable Value Limited (QV). As the dataset is drawn from an administrative database, individual house sales can be aggregated to customisable geographical zones and time periods. QV data exist that break down the capital value of properties into both their land component and their improvements component. If this breakdown is reliable (and there is no reason to presume that it is not), it could be useful in disentangling some of the effects being measured. Data also exist on vacant land values, which can be used as a cross-check on the other data. Additionally, data exist on a valuation basis for all properties in a meshblock as well as for sales prices (where the latter applies only to those properties that are sold). The main disadvantage of the QV database is that the characteristics of properties (e.g. lot size, number of bedrooms) are poorly recorded. This will make it difficult, in cross-sectional estimation, to control for differences in property sale prices between locations that are accounted for by differences in the housing stock.[27] However, it may be reasonable to assume that relative quality of the housing stock in different locations changes only slowly over time.

Each property can be located in a particular land parcel to calculate the distance between a land parcel and a specific infrastructure project. Gibbons and Machin (2005) and McMillen and McDonald (2004) measured distance between postcode regions (slightly smaller than MBs) to the infrastructure project (railway stations).[28]

It may be reasonable to assume that the effect of many unproduced regional amenities (e.g. climate) will not vary over time and could thus be controlled for by using location-specific fixed effects in the estimation model. Nevertheless, as discussed in Section 4.2, it is possible that the value of these to households or firms does change over time, and it may be necessary to use data on

[27] Unit record property sales data is available also from other sources (e.g. DTZ, www.dtz.co.nz) with apparently reliable detail on individual property characteristics.

[28] Both these studies used Euclidean distances between properties (meshblocks) and railway stations. Checks were made to control for trips that were impossible, e.g. across rivers. Road distance would be more appropriate, but within New Zealand the road network data is incomplete.

house price movements from other regions with similar amenities to control for effects in the location with new infrastructure.

Produced amenities could be expected to change over time and it is important to control for these. Local authorities collect property rates to pay for local services. Motu Economic and Public Policy Research has put together a rates database for New Zealand TLAs from 1991 to the present. Information about the relative quality of schools in terms of academic outcomes has only recently been collected for all of New Zealand. The New Zealand Police regularly publish crime figures across New Zealand.

Table 3: New Zealand data

Measure	**Variable name/description**	**New Zealand data sources**
Dependent variables		
Wages	Income/wages	Census (5 yearly, annual income), NZIS, HES (annual, hourly and weekly salary rates)
Land prices	Valuations and sale price (land and improved)	Unit record continuous house price data (1981-present) QV database. Also includes commercial property prices. Data available from other commercial sources (DTZ)
Population levels	Usually resident population	Census of population and dwellings, NZIS and HES
Individual characteristics		
Human capital characteristics	Years of completed schooling/Academic achievement Work experience (number of years in employment) Community group Industry sector Occupation Urban location	Census, NZIS, HES
Property characteristics		
Housing characteristics	Bedrooms, bathrooms, floor area, age of property, central heating, garage, property type	Floor area and property type available from QV database. Other commercially available data (e.g. DTZ) have data on individual property characteristics
Distance to infrastructure investment	Euclidean/road distance between firms and households	LINZ topographic database
Unproduced regional characteristics		
Sunshine hours Rainfall Annual temperature Number of heating days Mean distance to beaches and		NIWA LINZ topographic database

national parks		
Produced regional characteristics		
Level of local infrastructure stocks Local taxes Quality of schools Crime level		TLA and RC local rates database, Motu: Economic and Public Policy Research Trust, Wellington, New Zealand
Aggregate infrastructure levels/values	Value of public infrastructure stock for different types (e.g. roads)	TLA annual reporting of assets (from 1991), Central government agencies (e.g. Land Transport New Zealand) and Private companies responsible for public infrastructure assets.

Notes: Household Labour Force Survey (HLFS), New Zealand Income Survey (NZIS), Household Economic Survey (HES), Linked Employer Employee Database (LEED), DTZ (www.dtz.co.nz)

4.4 Identification of a specific infrastructure project

The discussion in the previous three sections helps identify the sort of infrastructure project for which a variant of the spatial equilibrium model may usefully be used to measure productivity effects. Briefly, the infrastructure project needs, first, to have effects on productivity that vary across geographic space. In particular, there should be some expectation that a public infrastructure project will provide a sufficient incentive for firms and households to want to change their location. For example, investments in the national (electricity) grid will probably benefit all firms and households within New Zealand (nationwide effect), whereas the effect of investing in the local distribution of electricity within a region will only affect the firms and households located within the region and can be compared with other regions where local electricity lines investment may be lower or higher.

Second, the infrastructure project will need to have large enough effects to be detectable given noisy data and other factors influencing variation in house prices and wages.

A panel-based ‘differences-in-differences’ approach is likely to produce estimates that are less biased by omitted variables, and will in any case reduce the need for data on time-invariant characteristics of locations. The data thus needs to encompass the relevant geographic range of the effects and the period of time over which wages, land prices, and population levels may adjust.

The most obvious candidates for a study of this sort would be additions to road and rail networks that have geographically concentrated benefits. Given the lack of investment in additions to the rail network in New Zealand, the most likely projects are significant additions to roading. Possible candidates include projects such as the Tauranga Harbour bridge, the Auckland south-west motorway link, or the extension to Auckland's northern motorway. Water supply projects (such as the Waikato River pipeline to Auckland) or local electricity transmission projects (such as the renovation of Auckland's transmission infrastructure) might also have measurable effects.

As noted above, the level of spatial aggregation used in estimation may be important in deriving the results. For some purposes, labour market areas (LMAs) may be the best unit of analysis. In some areas, the LMA and territorial local authority (TLA) may coincide. However, in other cases (e.g. Auckland) it is very likely that the LMA will include a number of different TLAs. This could be very useful in disentangling effects—especially relating to new residential construction—since regulatory regimes may differ across TLAs within the same LMA.

4.5 Recommendations on the feasibility of implementing a spatial equilibrium model within New Zealand

This report has identified a range of issues that will bear on the feasibility of implementing a spatial equilibrium model to estimate the productivity effects of a specific infrastructure project in New Zealand. Some of the most salient issues are:

- the availability of data with an appropriate range over time and space to implement a differences in differences estimation methodology
- the feasibility of addressing the issue of elastic housing supply (unless it is reasonable to assume that this is not an issue in the particular case)
- the reasonableness of assumptions of unchanging relative quality across locations (given poor data on housing quality)
- the feasibility of controlling for time-varying characteristics of locations (such as the changing value put on amenities such as beaches and climate)

- the need or otherwise to control for other time-varying characteristics of locations—such as school quality and crime rates—that may change only slightly over the relevant time period.

Judgements on these issues can be made only in relation to an identified infrastructure project. However, at this point it looks feasible to explain regional property values (especially of different types of property), wages, population, housing stock, and stock of other structures in a region affected by a new infrastructure project by reference to (inter alia): TLA zoning regulations, local commodity prices, (instrumented) value of certain amenities, direct measures of certain amenities (e.g. crime levels and school quality), transport costs, and other national effects (such as changing industry patterns).

We recommend that in the next phase of this study, an empirical model be specified aimed at estimating the productivity effects of an identified infrastructure project. This will then inform a decision to proceed to a full-scale study.

5 Conclusion

This paper has investigated the feasibility of using a variant of the spatial equilibrium model to estimate the productivity effects of a specific infrastructure project in New Zealand. The paper highlights that there are a variety of objectives that infrastructure investments are designed to achieve, and decisions are also subject to other competing objectives being taken into account. It is not obvious that the decision rules used in infrastructure investment will necessarily lead to projects that have nett positive effects on productivity. Policy makers are interested in the marginal effects of infrastructure investment on productivity. An evaluation of such effects would provide a useful check on the appropriateness and adequacy of current decision rules and institutions.

Aggregate cost and production function approaches have been used in the literature to estimate the effects of changes in the stock of infrastructure on productivity. These approaches entail unrealistic assumptions about either unchanging costs or unchanging prices. In contrast, a spatial equilibrium approach takes into account the effects of factor mobility on costs and prices. It assumes that the nett amenity and productivity benefits of infrastructure investments are fully reflected in land rents, and that the distribution of benefits between firms and households is reflected in wage movements. Data on land rents (property values) and wages may therefore be used to estimate the productivity effects of changes in the stock of infrastructure, and of specific infrastructure projects.

There are examples in the literature of a spatial equilibrium approach to estimating the productivity effects of changes in the stock of infrastructure. There are also examples of the approach being used to estimate the benefits to commuters of particular infrastructure projects. To date, there appear to be no examples of using a spatial equilibrium model to estimate the productivity effects of a specific infrastructure project. However, the analysis in this paper suggests that such an approach is feasible.

There are a range of data and estimation issues that need to be addressed in the use of a spatial equilibrium model for this purpose. These include the ability to control for time-varying and time-invariant characteristics of locations that may be correlated with changes in land values and wages; and the availability of data to cover the relevant geographic and time span of productivity effects. A reasonably useful range of data is available in New Zealand for this purpose. The next steps in determining feasibility are to select a particular infrastructure project, and to develop an empirical model based on available data.

6 Appendix A: Road infrastructure investment within New Zealand

Road transport policy within New Zealand is the responsibility of central government and is contained within the Land Transport Management Act 2003 (LTMA). The LTMA shifted the policy of land transport management from providing a safe and efficient road network to one that is integrated, safe, responsive, and sustainable. Land Transport New Zealand (LTNZ) is the central government agency responsible for implementing the LTMA through the development of the National Land Transport Programme (NLTP). The key objectives of the NLTP are:

- assisting economic development
- assisting safety and personal security
- improving access and mobility
- protecting and promoting public health
- ensuring environmental sustainability.

Before the introduction of the LTMA, land transport projects were developed to provide a safe and efficient roading system as their first priority, with additional objectives of mitigating public health and environmental concerns. However, the LTMA specifies that LTNZ should not prioritise any of the five key objectives and that all the objectives need to be considered equally in the planning process. The five key objectives, listed above, are applied at a macro level while individual road projects often focus on just a couple of objectives.

The NLTP sets out a programme of road maintenance and construction projects that Land Transport New Zealand jointly funds with approved organisations. Approved organisations are responsible for the identification and proposal of road maintenance and construction projects. LTNZ approves projects for funding by ensuring the project is economically viable[29] and meets the requirements of the LTMA.[30] The NLTP is funded by the National Land Transport Fund (NLTF), which receives funds from road user charges, motor

[29] The benefits outweigh the cost of the project.
[30] It is assumed that NLTP has to collectively meet the requirements of LTMA and not individual road projects.

vehicle registration, fuel excise, and licensing.[31] Differences between the projected revenue and revenue received by the NLTF are accommodated by changes in NLTP (number of projects funded). In addition to the maintenance and construction of roads the NLTF covers a range of land transport issues, including safety (Land Transport Safety Authority), enforcement (police), public transport, and the promotion of walking and cycling.

The identification of a need for road infrastructure investment is the responsibility of territorial local authorities (TLAs) and Transit New Zealand. TLAs[32] are responsible for the maintenance and construction of local roads within their jurisdiction. Transit New Zealand, a central government agency, is in charge of managing the state highway network. Transit New Zealand receives 100% of its funding from LTNZ, whereas TLAs receive, on average, 50% of maintenance costs and 60% of construction costs,[33] with the remainder coming from locally generated revenues and/or supplementary funds.[34]

LTNZ is responsible for aiding an approved authority in formulating a proposal for road funding, providing the framework for assessing the benefits and costs of an investment, and approving or declining the application for funds.[35] The following steps are involved in obtaining LTNZ approval for funding for road projects:

1	Formulation	Approved authorities submit proposals in accordance with the LTMA (and with guidance from LTNZ).
2	Assessment	Approved authorities conduct an assessment of the proposal using LTNZ's assessment framework.
3	Prioritisation	Proposals are ranked and funds provisionally allocated.
4	Programming	The NTLP is created from the ranked proposals and lined up with available finance.
5	Approval	Reassessment of stage 2 before approval is granted.
6	Monitoring	Feedback to proposing authorities.

[31] Additional funding is provided by the Crown Account (specific funding for Auckland land transport) and from miscellaneous sources ($33 million).
[32] New Zealand has 74 TLAs (including the Chatham Islands).
[33] With the exception of Northland and Tairawhiti who receive 100% of their regional road programme funding from Land Transport New Zealand as part of the Regional Transport Fund, which is designed to assist 'acute' regions that cannot meet their funding contribution requirement.
[34] Supplementary funds can include toll revenues, capital sums borrowed against tolling revenue, concession agreement payments, and developer contributions.
[35] The decision not to grant funding often, but not always, stops a road project from proceeding.

6.1 Assessment process

The aim of the assessment process is to evaluate the total costs and benefits of a proposed road project to the local community. If the benefit-to-cost ratio of the proposed road project is greater than one, then the road project is regarded as economically viable and eligible for funding from LTNZ. If the proposal includes several alternative scenarios, the incremental costs and benefits of adopting a larger scheme with higher costs or a smaller scheme with lower costs are assessed.

The major effects of a proposed road project considered within the economic assessment are on road users, principally travel time savings, changes in vehicle operating costs, and changes in the accident rate. For effects on non-road users, or externalities, LTNZ divides the effects of road projects into tangibles—effects that are easily converted into monetary terms such as travel time savings—and intangibles—non-traded effects that have no established market price. For some intangible effects, quantitative values have been calculated (indicative value), whereas for other intangible effects, qualitative measures have been adopted (e.g. preference rankings).

For each effect, the benefit (or cost) to the community is compared to a benchmark scenario, referred to by Land Transport New Zealand as the 'do minimum' option. The 'do minimum' option is the level of investment required to maintain the current level of service. A proposed road project has a positive benefit if the effect is greater than the 'do minimum'.

6.1.1 Tangible benefits

Travel time

The cost of travel time savings is calculated from a mix of direct site-level observations and assumptions of traffic flow. The key factors in determining changes in travel costs are traffic composition, vehicle occupancy and travel purpose (work, commuting or leisure), current traffic volumes, expected traffic growth rates, future traffic volumes (created by the adoption of the proposed road project), average travel times, and average speeds.

Traffic composition, vehicle occupancy, and travel purpose are calculated for different road categories and time periods and are determined using average values for New Zealand. However, if the project is fiscally large or the site has unusual traffic characteristics, then traffic composition, vehicle occupancy, and travel purpose are observed directly. Traffic volume data is collected using sample counts to produce an average daily traffic volume (AADT) and adjusted using concurrent axle counts (or national level averages for urban and rural roads if local counts are not available). The AADT is adjusted to provide weekday and weekend/holiday daily flows either from direct measurements or using Transit New Zealand's traffic counting guidelines if local counts are not available. Depending on the type of road project additional estimates are made for hourly traffic flows (e.g. rush hour periods).

Growth rates in traffic flows are predicted for the current road network, using regression models, from count data or taken from estimated regional averages (predicted using 1980–2000 data) if local counts are not available. The growth rate models take into consideration population growth, gross domestic product and car ownership[36]. Future traffic volumes differ from growth rates because they incorporate the proposed changes to the road network. The assessment of future traffic volumes takes into consideration predicted traffic growth (as above), the effect the road project might have on diverting existing traffic, inducing additional traffic (the null hypothesis being that new projects do not induce additional traffic or redistribute trips), and the effect of intermittent traffic. Average travel times and average vehicle speeds are measured using survey techniques or default values (which are nationally or regionally estimated).

The cost of transport (in terms of time) is estimated by road category and time period using the road composition tables described above. The additional cost of congestion (i.e. what an individual would be willing to pay to avoid sitting in traffic) is also calculated. In addition it is assumed that users are also prepared to pay for improvements in trip reliability (i.e. more consistent travel times).

Vehicle operating costs

Vehicle operating costs (VOC) are calculated from fuel, oil, and tyre costs and the cost of maintenance, repairs, and depreciation for different vehicles and road types. The base running costs are adjusted by site-specific factors,

[36] Evidence suggests that growth rates are reasonably stable and only major events have any effect (e.g. doubling of fuel prices during the 1973 oil crisis).

including traffic composition, travel speed, road gradient, road conditions (surface quality), and congestion costs (cost of decelerating and accelerating).

Accident rates

There are three methods for measuring site-specific accident rates depending on the availability of site data. Accident-by-accident analysis (using site-specific historical accident data) is conducted if the site has accident data with at least five accidents recorded over the last 5 years. Accident rate analysis is used if no accident data is available and the accident rate is interpolated using similar site data. Weighted accident procedure is used if there is site-specific data, but fewer than five accidents over the last 5 years have been recorded. This procedure incorporates information for the specific site and similar sites to arrive at an accident rate. Predictions are adjusted for overall reduction in the national accident rate and for different travelling speeds (50 and 70 kph). The predicted change in the accident rate is weighted by the cost of injuries calculated by LTNZ.

Benefits of sealing unsealed roads

The benefits of sealing roads (specific to a road project) include the increase in crop and animal yields (in fields adjacent to the road) due to dust reduction, improvements in driver and passenger comfort, savings in vehicle operation costs, and travel time savings.

6.1.2 Intangible benefits

The following intangible effects (externalities) are considered: air quality, carbon dioxide emissions, road traffic noise, vibration, water quality, special areas, ecological impact, visual impacts, community severance, overshadowing, isolation, psychological distress, site-specific discomfort, and health benefits of walking and cycling.

6.1.3 Uncertainty in the assessment of road project benefits

The section above briefly reviews the methodology involved in calculating the tangible benefits to the community of a proposed road project. Benefits are converted into dollars to allow road projects with a different mix of benefits to be compared. The process of determining the value of a particular benefit (e.g. reduced travel times) involves three factors. The first factor is the measurement of current conditions, which can involve direct measurements of the proposed site or imputed average conditions for the region or New Zealand as a whole. The second factor is the methodology used to estimate the future conditions once the road project has been completed. The third factor is the change in conditions weighted by the (perceived) value (dollars) of that change.

As part of the funding application, LTNZ requires the approved authority to conduct sensitivity analysis on the assumptions and estimates made in evaluating the benefits of a road project. Assumptions and estimates made in the calculations must be documented and the evaluation must be rerun using upper and lower bounds to assess how sensitive the results are to changes in estimated or imputed values. Another factor that might bias the total calculated benefits from a road project is the value placed on a particular benefit. For example, benefits could be biased if travel time is overvalued compared with the value of reducing accidents (cost of a life). In this scenario, road projects that concentrate on reducing travel times might be favoured over road projects that are focused on reducing the accident rate. This could have an effect on road projects of a similar value that focus on different benefits.

7 Appendix B: Issues in the use of aggregate production function models

Early aggregate production function (APF) models used time-series data from a single country to estimate the effect of public infrastructure investment on productivity growth.[37] A key criticism of using a time-series dataset for a single country is the possibility of omitted variable bias (De la Fuente, 2000b). For example, the simultaneous decline in production and public infrastructure investment in the US during the 1970s, observed by Aschauer (1989), could have been a coincidence. Gramlich (1994) suggests that the fall in infrastructure investment was due to the completion of the inter-state highway network and a decrease in the school-age population.[38] A second problem is the issue of the 'spurious regressions' problem. The question is whether regressions that contain non-stationary variables (variables that display a trend) should be estimated using levels or first differences (percentage change).[39] De la Fuente argues that recent advances in econometrics have suggested that levels provide better estimates as long as the variables are co-integrated. However, these new techniques do not completely support the use of levels as there is still considerable variation in the estimated effect of public infrastructure on output across studies that have used co-integration.

Estimating APFs using a panel dataset that combines observations for several years and different countries or regions mitigates some of the econometric issues levelled against using single country time-series data. Panel datasets are less susceptible to the spurious regressions problem arising from common trends in the data and provide the ability to control for unobserved differences between

[37] Aschauer (1989) was one of the first authors to use an APF, to estimate the effect of public infrastructure investment on productivity growth using US time-series data from the 1970s. Aschauer found that a 10% increase in public infrastructure stocks produced a 3.9% increase in national output. It has been suggested that Aschauer's high estimate of the productivity of public infrastructure is implausible. Munnell (1992) finds Archauer's results difficult to believe because the coefficient on public infrastructure stocks is higher than private capital stocks, particularly as public capital stocks include 'non-productive' investments (e.g. a children's playground).

[38] Other omitted variables could include a dramatic rise in energy prices. For example, Tatom (1991) found that including the price of oil reduced Aschauer's reported coefficient.

[39] Using first differences tends to bias downwards the effect of public infrastructure investment on productivity growth.

countries and regions using fixed effects models.[40] Regional analysis does bring additional problems of endogeneity in the decision-making process of infrastructure investment. For example, at the country, level rich countries will demand more infrastructure compared with poorer countries, potentially biasing upward the estimate of public capital investment on production. Within a country there could also be an upward bias if regional governments are responsible for financing infrastructure investments. The bias could be reversed if public investment decisions are made by central government that use infrastructure investment to redistribute income to the regions. From a theoretical perspective regional models implicitly recognise that most (non-military) public capital stock is owned by state and local authorities. These authorities are likely to want to internalise the benefits from infrastructure investment within their own borders.

[40] Researchers (Munnell, 1992; Eberts, 1990) using regional data found the effect of public infrastructure stocks on output to be positive and significant, however the size of the effect relative to Aschauer's coefficient of 0.39 was smaller (around 0.15). Further analysis using fixed effects to control for any unobserved state level differences reduced the elasticity to zero (Holtz-Eakin, 1994; Garcia-Mila et. al., 1996).

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