MODELLING AND VALUING LAND USE CHANGE

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ABSTRACT

Improving transport access can have a large effect on the shape of population and employment growth. It is easy to observe these effects after the fact – consider the impact of the Auckland Harbour Bridge or Wellington commuter rail on the shape of those cities' growth. However, people rarely attempt to forecast land use change or value the resulting social, economic, and environmental impacts when planning projects.

This paper makes several practical contributions to assist in modelling and valuing land use change in New Zealand.

First, it outlines some of the potential quantifiable economic impacts of land use change and illustrates how they can be incorporated into transport project evaluation. Some patterns of household and business growth may lead to increased economic output and lower infrastructure and environmental costs, relative to others. All else equal, this suggests that transport investments that generate larger benefits from land use change should be prioritised over alternative projects.

Second, this paper sets out several alternative methods for modelling land use change using outputs from conventional strategic transport models. It uses econometric techniques to identify the causal impact of improved transport access on households' and firms' location choices, as opposed to simple correlations between access and land use. These methods are applied to several transport projects in Auckland and Wellington to provide comparative benchmarks. These benchmarks highlight areas where we may be more or less certain about the land use impacts of transport projects.

To conclude, this paper considers the potential impact of transport projects on the availability and price of housing. This is an important area for policy given New Zealand's existing housing affordability challenges and the role of transport investment in unlocking new housing development. However, alternative methods for valuing these benefits produce varying results, highlighting the need for further research.

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The views expressed in this paper are those of the author alone, as are any errors or omissions.

Introduction

In the long run, transport policy *is* land use policy. Transport investments shape how cities and regions grow. Projects like the London Underground, the US interstate highway system, and the Auckland Harbour Bridge have shaped urban growth (Heblich, Redding and Sturm, 2018; Duranton and Turner, 2012; Grimes, 2011). The effects can last decades or even millennia, as shown by the impact of Roman roads on present-day regional development in Europe (Delgaard et al, 2018).

In spite of this, existing transport appraisal methods focus mainly on changes in travel times that are swiftly arbitraged away by changes in people's travel behaviour and location choices (Metz, 2008). Forecasting changes in land use and valuing the resulting social, economic, and environmental impacts are usually put into the 'too hard' basket when evaluating projects.

This paper makes three practical contributions to assist in modelling and valuing land use change arising from transport improvements. First, I provide evidence on the quantifiable economic impacts of land use change in New Zealand and discuss how they can be incorporated into transport project evaluation. Second, I outline two methods for modelling land use change using outputs from conventional strategic transport models, and apply them to major transport projects in Auckland and Wellington.

Third, I consider the impact of transport projects on the pace of housing development. The benefits of unlocking housing development may be large, given current affordability challenges, but there is no consensus about how to model and value these impacts. I see this as a key frontier for further research.

Valuing land use change

Projects that catalyse land use change may generate additional benefits or disbenefits over and above the conventional transport benefits that arise under a 'static' land use scenario. It may be important to value these benefits to understand the full effects of 'city-shaping' projects. Here, I outline how we can value the benefits from land use change and provide an indicative 'order of magnitude' estimate of the scale of some of these benefits.

Conventional transport appraisal methods, as set out in the NZTA's *Economic Evaluation Manual*, focus on valuing the 'first-order' benefits of transport projects that accrue directly to transport users, such as travel time and cost savings due to faster or more reliable journey times, improved quality of travel experience, or increased safety due to prevention of road crashes.

In recent years these procedures have been extended to capture various 'second-order' benefits that arise from the impact of transport activities on society, economic activity, and the environment. These include the health benefits of increased uptake of walking and cycling, environmental and health benefits from reduced emissions, and wider economic benefits (WEBs) resulting from the impact of improved accessibility on productivity, labour force participation, and competition.

Second-order benefits can arise under a 'static' land use scenario in which firms and workers do not relocate to take advantage of transport improvements. However, *additional* second-order benefits may arise from changes to land use resulting from a transport improvement, if improved accessibility and urban amenity encourage some people to relocate. These benefits may include:

- Dynamic agglomeration benefits: If firms and workers relocate to be physically closer to each other, in addition to being more accessible via the transport system, then it will lead to additional increases to economic productivity over and above the benefits of a fixed land use scenario.
- Move to more productive jobs (M2MPJ): If some workers relocate to areas where productivity levels are higher, then additional taxes paid on higher labour income will be an additional benefit not captured by conventional analysis.
- Land use benefits: Increases in land values due to enabling higher-value development; savings on public infrastructure costs; and additional transport, health, and environmental benefits (or disbenefits) resulting from any change in travel behaviours from relocating.

These benefits arise outside of the transport system per se, and thus to value them we must model labour market dynamics, firm productivity, and urban development markets. To assist in understanding and valuing them I briefly outline evidence on dynamic agglomeration benefits, M2MPJ benefits, and some land use benefits. This excludes benefits related to ‘unlocking’ additional housing supply – I return to that issue in the final section.

Dynamic agglomeration benefits

In a 2016 research report for Auckland Council, I analysed the impact of alternative urban form scenarios on economic productivity in Auckland (MRCagney, 2016). I used Auckland’s strategic transport model to model the impact of three alternative land use scenarios on access between firms and workers, holding transport infrastructure constant, and then calculated agglomeration benefits from each scenario using EEM procedures. The results provide an order of magnitude estimate of the potential magnitude of dynamic agglomeration benefits arising from land use change.

As shown in Table 1, a more ‘intensive’ scenario in which the central isthmus area roughly doubled to 310,000 households by 2046, with a corresponding increase in central area employment, would result in an annual net increase in GDP of around $100 million relative to the base case land use scenario. Conversely, a more ‘expansive’ scenario would decrease GDP, because increases in agglomeration potential in outer suburbs would be outweighed by the loss of economic mass in central areas.[1]

The ‘intensive’ scenario would result in a net reallocation of almost 70,000 people from other parts of the Auckland region into the isthmus area, relative to the base case land use scenario. This implies that the average agglomeration benefits from relocating one resident / worker from an outlying area to a more central area are around $1,500 per annum. Conversely, in the ‘extensive’ scenario, there is a net relocation of 50,000 people from central areas to outlying areas, mainly in greenfield development on the fringe. This implies that the average agglomeration *disbenefits* from relocating one resident / worker from the central area to the urban fringe are roughly $7,000 per annum.

Table 1: Estimated changes in annual economic output relative to base case land use scenario

Scenario	**Modelled annual change in GDP (2046), by area**				
	North	**West**	**Central**	**South**	**Total**
With congestion pricing					
Intensive	-$8 million	-$8 million	$128 million	-$6 million	$106 million
Expansive	$43 million	$11 million	-$551 million	$127 million	-$369 million
Without congestion pricing					
Intensive	-$13 million	-$15 million	$149 million	-$22 million	$99 million
Expansive	$34 million	$7 million	-$503 million	$112 million	-$350 million

The available evidence from other large cities in New Zealand indicates similar benefits from enabling faster employment growth in central areas (SGS, 2012). I tentatively suggest that dynamic agglomeration benefits are likely to be in the range of $1,000 to $5,000 per added worker in a central location in larger cities, with smaller values in smaller cities.

Move to more productive jobs benefits

I use 2013 Census data to obtain a rough estimate of M2MPJ benefits arising from shifting employment growth to higher-productivity locations. I focus on city centre locations as research by Maré (2008) and others indicates that city centres in large cities tend to be more productive than peripheral locations.

Some observed differences in incomes between locations are due to differences in the composition of jobs or workers. This can bias estimates of opportunities for people to raise their incomes by changing locations. For instance, somebody working in retail in a suburban shopping mall may have a lower

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[1] In addition, there are likely to be additional improvements to consumer amenities resulting from land use change, eg from better access to a variety of goods and services in urban centres. Some evidence suggests that these benefits are likely to be similar in magnitude to agglomeration in production (Tabuchi and Yoshida, 2000; De Groot et al, 2015).

income than somebody working in the city centre head office of a bank, but they may not have the skills required to raise their income by switching to a banking job.

Table 2 summarises my estimates of wage differentials between city centre and non-city centre locations in Auckland, Wellington, and Christchurch. These estimates exclude agriculture (ANZSIC industry A), mining (B), utility services (D), and non-classified industries (T). I report an ‘unadjusted’ city centre wage premium based on the difference between average wages in the city centre and average wages elsewhere in the region, and an ‘adjusted’ wage premium that accounts for differences in industry composition between locations.

As expected, adjusted wage premia are smaller than unadjusted wage premia. This implies that if workers can move locations and move into the higher-paying industries that are more abundant in the city centre, they may earn a larger wage premium from relocating. However, following Melo and Graham (2009) and Maré (2016), I note that controlling for worker characteristics, such as skill levels and motivation, is likely to further reduce estimates of productivity differentials between locations.

Notwithstanding that caveat, wage premia exist even in relatively low-skilled industries like retail and food services. For instance, people working in retail in the city centre earn a $3,300 premium over their peripherally located peers in Auckland, a $6,000 premium in Wellington, and a $9,000 premium in Christchurch. This means that improved city centre access may lead to broad-based economic gains

Most of the economic gains from relocating between locations are internalised by workers in the form of higher after-tax wages, and hence are already indirectly accounted for in analysis of transport user benefits. The added social benefit from M2MPJ is the ‘tax wedge’ on additional labour income, which I estimate as around 32% of added labour income following Kernohan and Rognlien (2011).

Table 2: City centre wage differentials and M2MPJ benefits per worker

Urban area	**Auckland**	**Wellington**	**Christchurch**
City centre employment share	14%	41%	11%
Mean personal income for city centre workers	$72,600	$75,200	$58,200
Unadjusted city centre average wage premium (does not account for industry composition)	$19,300	$26,200	$8,300
Adjusted city centre wage premium (accounts for industry composition differences)	$12,000	$15,200	$6,100
Estimated tax wedge from relocating one job to the city centre (32% of adjusted wage premium)	$3,840	$4,860	$1,950

Notes: Auckland: City centre defined as Auckland Central West, Auckland Central East, Auckland Harbourside, Newton, Grafton West area units; compared against rest of Auckland Region. Wellington: City centre defined as Thorndon-Tinakori Road, Lambton, Willis Street-Cambridge Terrace area units; compared against rest of Wellington City, Lower Hutt City, Upper Hutt City, Porirua City, and Kapiti Coast District. Christchurch: City centre defined as Hagley Park, Avon Loop, Cathedral Square area units; compared against rest of Christchurch City, Selwyn District, and Waimakariri District.

This analysis provides an upper bound estimate of potential M2MPJ benefits in different cities. These benefits are likely to be higher in Wellington and Auckland than in Christchurch. However, citywide average figures camouflage important spatial variations, including the potential for M2MPJ benefits from unlocking added employment growth in some non-city centre locations.

Land use benefits

Transport investments that influence the location of urban growth may in turn affect the magnitude of negative social, environmental, or economic externalities associated with growth. If growth in one location is more environmentally sustainable or cheaper to serve with infrastructure, then encouraging new housing in this location may be socially beneficial.

Development is likely to generate some negative externalities in most locations, but the size of these effects may vary. It is conceptually straightforward to add up and compare the external costs of growth in different locations. In a previous research report I compiled evidence on four broad categories of externalities arising from housing development in Auckland (Nunns and Denne, 2016). These include:

- Costs of infrastructure provision that are not borne directly by users: These reflect the difference between the total cost to provide infrastructure and the revenue recouped from development contributions / targeted rates, petrol taxes, public transport fares, or other user charges. These costs are often site-specific and the degree of subsidy depends upon government decisions about pricing.
- Impacts on transport congestion: These can be valued by applying existing transport appraisal procedures to transport model outputs for alternative land use scenarios.
- Impacts on amenity / quality of life: These include things like loss of light and views from new buildings, loss of access to open space from development, etc. There may be some positive effects as well, eg due to the fact that development may support increased local services.
- Environmental impacts on air, soil, water, biodiversity, etc: These are typically valued using data on health impacts of air quality or surveys on willingness to pay for environmental quality.

Nunns and Denne estimate that the present value of negative externalities ranges from $29,700 to $71,200 per household in urban intensification areas, and $56,900 to $101,400 per household in greenfield areas. The higher figure for greenfield development reflects the fact that it generally involves larger changes to the environment and larger expenditures on new infrastructure.

This analysis implies that the social costs of growth may be around $50-70,000 lower per household in low-externality areas relative to high-externality areas. However, impacts could be higher or lower in some places. For instance, growth in already-urbanised locations with underutilised infrastructure may lead to relatively small externalities, while growth in environmentally sensitive areas may lead to large negative impacts. Accurately valuing land use benefits therefore requires location-specific analysis.

Modelling land use change

I now outline two methods for estimating how changes in transport access will cause changes in peoples’ choices of home and work locations. These are relatively simple to implement and can be ‘layered’ over existing transport models, with no need for complex land use-transport interaction models.

The first method estimates the causal relationship between access to jobs via the transport network and local population or employment density (as described by Volterra Partners, 2017). The second method estimates a spatial general equilibrium model in which people simultaneously choose their home and work locations, based on the underlying attractiveness of different locations and the costs of travelling between various locations (Mulalic et al, 2015; Donovan, 2017).

From an econometric perspective, endogeneity is the major challenge to modelling the impacts of transport on land use. Endogeneity means that it is unclear which variable is the ‘chicken’, and which is the ‘egg’. Intuitively, we would expect development to respond to improved transport access. But the opposite can also be true: transport agencies often respond to observed or anticipated demand by building new infrastructure or increasing public transport services.

I therefore employ instrumental variables estimation to control for endogeneity between transport access and location choices in a cross-sectional setting. This requires an additional variable (or several additional variables) that (a) is correlated with the explanatory variable of interest, and (b) is not correlated with other unobserved factors that might affect the outcome variable. To develop appropriate instruments, I exploit the presence of fixed geographical features like hills and harbours that have shaped accessibility both directly (by making some journeys longer or more inconvenient) and indirectly (by raising the cost to build or expand transport infrastructure).

Accessibility-density relationships

First, I develop a simple model of the relationship between transport access to jobs and local population and employment density. This model posits that places that are more accessible are likely to attract more development. It focuses on aggregate outcomes – overall density in specific places – rather than attempting to model people's location choices in any detail. This is both a strength and a weakness: while this model lacks behavioural 'microfoundations', it is less vulnerable to specification error.

The following equation summarises the basic accessibility-density model. D_i is the natural logarithm of population (or job) density in a specific transport model zone, A_i is a measure of transport access (defined below), X_i is a vector of control variables (natural log of straight-line distance to CBD and elevation of model zone centroid), and e_i is the error term.[2] The β terms are coefficients to be estimated.

Equation 1: Accessibility-density models

$$D_i = \beta_1 A_i + \beta_2 X_i + e_i$$

I measure transport accessibility using the effective job density (EJD) measure defined in the NZTA's *Economic Evaluation Manual* and used to calculate agglomeration benefits of transport improvements. EJD calculates the number of jobs accessible via the transport system, assigning a lower weight to jobs that are further away in terms of travel time. The following equation defines the EJD calculation. In this analysis I have calculated EJD using AM peak outputs from strategic transport models. These models do not estimate journey times for walking and cycling and hence I have excluded these modes.

Equation 2: Calculating effective job density

$$\text{Step 1: } avgtime_{i,j} = \frac{pttime_{i,j} * ptdemand_{i,j} + cartime_{i,j} * cardemand_{i,j}}{ptdemand_{i,j} + cardemand_{i,j}}$$

$$\text{Step 2: } EJD_i = \sum_{j \neq i} \frac{jobs_j}{avgtime_{i,j}}$$

I use instrumental variables (IV) estimation to identify the causal effect of transport accessibility on density. To define instruments – ie variables that are correlated with accessibility but not correlated with other unobserved factors that might influence local density – I consider the impact of geographic constraints, which are abundant in both cities. A large share of employment in both cities is concentrated in or around the city centre, and hence places that are more central, as the crow flies, should have a higher EJD. However, hills and harbours can create large, exogenous variations in transport accessibility for places that are a similar distance from the city centre.

For example, the suburbs of Hataitai and Newtown are roughly the same distance from Wellington's town hall, but the presence of Mount Victoria increases travel times for many Hataitai residents, thereby lowering its EJD. Likewise, Eastbourne and Tawa are roughly the same distance from town hall, but the presence of the harbour increases the distance that Eastbourne residents must travel to reach employment and thus lowers its EJD.

While geography affects accessibility, it does not necessarily reduce the intrinsic attractiveness of different locations for residential development. If anything, coastal suburbs like Eastbourne may be more attractive as places to live than inland suburbs like Tawa, as they have better views and beach access.

I define three instruments using GIS analysis of the LINZ Digital Elevation Map: The average slope (absolute value of rise over run) of the straight line from the model zone centroid to town hall, the share of that line that crosses land rather than water, and the square of land share. Statistical tests show that these instruments are both relevant (correlated with EJD) and valid (uncorrelated with other factors that affect density).[3]

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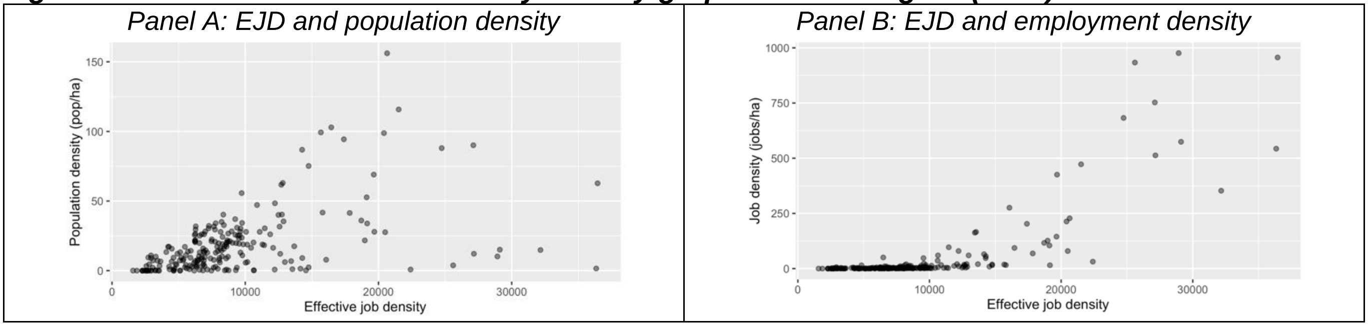
[2] I tested variants of these models, eg with different specifications for the transport accessibility variable, but did not find any major differences. Future work may seek to delve further into these relationships, or include added controls.

[3] Wellington: Weak instruments test rejected the null hypothesis of weak instruments (F-stat of 33.519, p-value less than 0.1% for regression of EJD on instruments); Sargan chi overidentifying restriction test failed to reject null hypothesis of instrument exogeneity (J-stat of 0.846, p-value=65.5% for population density; J-stat of 3.169; p-value=20.5% for employment density).
Auckland: Weak instruments test rejected the null hypothesis of weak instruments (F-stat of 59.710, p-value less than 0.1% for regression of EJD on instruments); Sargan chi overidentifying restriction test failed to reject null hypothesis of instrument exogeneity (J-stat of 3.506, p-value=17.3% for population density; J-stat of 1.843; p-value=39.8% for employment density).

Accessibility-density curves in Wellington

I estimate accessibility-density relationships for Wellington using 2013 base year outputs from the Wellington Strategic Transport Model (WSTM). The following scatterplots illustrate the basic result, which is that areas that are more accessible to jobs via the transport system *also* tend to be denser.

Figure 1: Cross-sectional accessibility-density graphs for Wellington (2013)



Panel A: EJD and population density

Panel B: EJD and employment density

Table 3 summarises my estimates of the causal effect of EJD on population and employment density based on IV estimation. The coefficients on the EJD variable (highlighted in bold) indicate that a 10% increase in EJD causes a 39% increase in local job density and a 22% increase in local population density, ie jobs or residents per hectare in the model zone.

Both effects are statistically significant. Unlike the simple correlations shown in the charts above, these reflect causal effects, and hence I can use them to predict how changes in EJD will cause long-run changes in density.[4]

Table 3: Accessibility-density relationships in Wellington (2013)

Model	**Population density model**			**Employment density model**		
Outcome variable	**ln(2013 population density)**			**ln(2013 job density)**		
Explanatory variables	**Coefficient**	**Robust SE**	**p-value**	**Coefficient**	**Robust SE**	**p-value**
ln(effective job density)	**2.167**	0.710	0.003**	**3.881**	0.564	0.000***
ln(distance to CBD)	0.074	0.233	0.753	0.287	0.175	0.101
Elevation of model zone centroid	-0.008	0.001	0.000***	-0.010	0.001	0.000***
Constant	-17.6	8.5	0.040*	-35.5	6.7	0.000***
Model statistics						
R^2	0.43				0.78	
Wald test	55.13*** (df = 3; 221)				167.4*** (df = 3; 221)	

*Notes: (1) ln(EJD) is instrumented with three variables: average slope of straight line from model zone centroid to town hall; share of that line that crosses l.7.5and, and the square of land share. (2) Statistical significance levels: . p<0.1; * p<0.05; ** p<0.01; *** p<0.001*

Accessibility-density curves in Auckland

I estimate accessibility-density relationships for Wellington using 2016 base year outputs from the Macro Strategic Model (MSM). As in Wellington, areas that are more accessible to jobs via the transport system also tend to be denser.

Table 4 summarises my estimates of the causal effect of EJD on population and employment density based on instrumental variables estimation. The coefficients on the EJD variable (highlighted in bold)

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[4] Interestingly, the scatterplots above show a weaker correlation between EJD and population density than the causal effect I have measured. This suggests that some relatively inaccessible places, like Eastbourne, may have attracted more development due to the presence of local amenities like beaches or attractive views.

indicate that a 10% increase in EJD causes a 15% increase in local job density and a 20% increase in local population density, ie jobs or residents per hectare in the model zone.

Both effects are statistically significant and estimate the causality from accessibility to density. As in Wellington, IV estimation results in a higher estimate of the impact of EJD on population density than a naïve ordinary least squares (OLS) regression, which reflects the fact that local amenities such as beaches or views have caused some locations to develop *in spite of* their poor accessibility.

Table 4: Accessibility-density relationships in Auckland (2016)

Model	**Population density model**			**Employment density model**		
Outcome variable	**ln(2016 population density)**			**ln(2016 job density)**		
Explanatory variables	**Coefficient**	**Robust SE**	**p-value**	**Coefficient**	**Robust SE**	**p-value**
ln(effective job density)	**2.012**	0.495	0.000***	**1.552**	0.319	0.000***
ln(distance to CBD)	-0.129	0.160	0.422	-0.396	0.103	0.000***
Elevation of model zone centroid	-0.002	0.001	0.305	-0.003	0.001	0.005**
Constant	-15.5	6.2	0.013*	-9.3	4.0	0.020*
Model statistics						
R^2	0.17			0.62		
Wald test	97.3*** (df=3; 592)			150.6*** (df=3; 592)		

*Notes: (1) ln(EJD) is instrumented with three variables: average slope of straight line from model zone centroid to town hall; share of that line that crosses land, and the square of land share. (2) Statistical significance levels: . p<0.1; * p<0.05; ** p<0.01; *** p<0.001*

Travel times and location choices

Second, I estimate a location choice model that analyses the impact of faster car or public transport journey times on the total volume of commuting flows between origin and destination points. This model posits that faster journey times will encourage more people to live in one and work in the other. It attempts to estimate impacts on commuting decisions, rather than aggregate land use outcomes.

This model builds upon methods used to analyse the impact of transport costs on mode choice, and hence to calibrate transport forecasting models (Small and Verhoef, 2007). Transport choice models often assume that agents have fixed origin and destination locations that deliver them a set level of utility, and that they are seeking to minimise the disutility associated with travelling between locations.

However, in practice, transport improvements also appear to affect location choices (Duranton and Turner, 2012). Some recent papers extend the transport mode choice framework to also consider choice of home and work locations (Mulalic et al, 2015; Donovan, 2017).

In this expanded setting, each individual i is assumed to choose home location j, work location k, and commuting mode m to maximise utility, as in the following equation. U_j and W_k denote the utility derived from living in location j and working in location k, respectively; X_{jkm} is a vector of variables that reflect the cost of commuting from j to k by mode m; and ϵ_{ijkm} is an error term. β_m are coefficients to be estimated.

Equation 3: Utility maximisation via location and transport mode choice

$$\max_{j,k,m} U_{ijkm} = U_j + W_k + \beta_m X_{jkm} + \epsilon_{ijkm}$$

Assuming that ϵ_{ijkm} is independent and identically distributed and that it follows a Type I extreme value distribution, which is commonly assumed for count data, I can write the probability that individual i chooses locations j and k and mode m as shown in the following equation.

Equation 4: Probability of travelling between origin and destination by a given mode

$$p_{ijkm} = \frac{\exp(U_j + W_k + \beta_m X_{jkm} + \varepsilon_{jkm})}{\sum_j \sum_k \sum_m \exp(U_j + W_k + \beta_m X_{jkm} + \varepsilon_{jkm})}$$

By extension, the following formula estimates the number of people who are travelling between home location j and work location k (N_{jk}), where X_{jk} is a vector of transport costs (for all modes) for travel between j and k, and other variables are as defined above. β is a vector of coefficients to be estimated.

Equation 5: Number of people travelling between origin and destination

$$N_{jk} = \exp(U_j + W_k + \beta X_{jk} + \varepsilon_{jk})$$

I estimate Equation 5 using a Poisson regression model. The dependent variable is the number of people who reported commuting between area units at the 2013 census. The following explanatory variables are drawn from 2013 transport model outputs (for Wellington) and May 2018 Google API travel data (for Auckland):

- Car travel time between area units j and k, during the AM peak period, in minutes;
- Public transport travel times between area units j and k, during the AM peak period, in minutes – including walk time, wait time, and in-vehicle time, but excluding boarding/transfer penalties; and
- Public transport fares for travel between area units j and k, during the AM peak period, in cents.

I also control for the straight-line distance between area unit centroids, meaning that results should be interpreted as the impact of faster or slower travel times for a journey of a similar length.

Commuting flows and travel times may be endogenous as transport agencies may respond to expected levels of demand by increasing road capacity or providing faster or more direct public transport services.

I therefore use the control function method to deal with this issue (Imbens and Wooldridge, 2007). First, I estimate an OLS regression of the endogenous variables (car and PT travel times) on the other explanatory variables plus three instrumental variables. For instruments, I use the average slope of the straight line between area unit centroids, the share of that line that crosses a water body, and the straight-line distance between the centroid of the nearest neighbouring area units. Model testing using the Hansen’s J test failed to reject the null hypothesis that these instruments are exogenous.

Second, I save the fitted residuals from the first stage models and include them as additional control variables in the Poisson regression model. In effect, this controls for the endogenous component of car and PT travel times. This required me to estimate standard errors using the bootstrap method.

Location choice model for Wellington

The first column in Table 5 summarises key results from a Poisson model of total commuting flows between Wellington area units as a function of car and PT travel times. The coefficients of interest, highlighted in bold, reflect the degree to which faster car or public transport travel times increase commuting volumes between home and work area units. Both coefficients are negative, indicating that reductions in car or public transport travel times cause an increase in commuting flows, and vice versa.

The coefficient on the PT travel time variable is around 50% larger than the coefficient on car travel times, which indicates that PT travel times have a larger impact on location choice. These coefficients are statistically significant at the 1% and 5% level, respectively.

Location choice model for Auckland

The second column in Table 5 summarises results from key results from a Poisson model of total commuting flows between Auckland area units as a function of car and PT travel times.

Results from the Auckland model are somewhat perplexing. The coefficients on car and PT travel times are an order of magnitude larger than the Wellington coefficients. Moreover, the coefficient on car travel times is positive, indicating that longer car travel times cause an increase in commuting flows. These findings are counterintuitive and do not line up well with other evidence, which leads me to believe that there may be an issue with this model specification or instrumental variables strategy. When applying the Auckland results I divide coefficients by ten (resulting in a coefficient of -0.015 for PT travel times), preserving their relative magnitude while better aligning with earlier, unreported analysis and estimates of location responses in other cities (eg Donovan, 2017).

Table 5: Location choice models for Wellington and Auckland, 2013

Model	**Wellington model**			**Auckland model**		
Outcome variable	**Number of commuters**			**Number of commuters**		
Explanatory variables	**Coeff**	**Std err**	**p-value**	**Coeff**	**Std err**	**p-value**
Car travel time (1)	**-0.0253**	0.0106	0.0169 *	**0.188**	0.0146	0.0000 ***
PT travel time (1)	**-0.0360**	0.0036	0.0000 ***	**-0.153**	0.0066	0.0000 ***
PT fare	-0.0012	0.0003	0.0004 ***	-0.0247	0.0099	0.0127 *
Straight line distance	0.0156	0.007	0.0263 *	0.0389	0.0094	0.0000 ***
Constant	6.8557	0.1524	0.0000 ***	4.5279	0.1234	0.0000 ***
Home location fixed effects	TAs + CBD indicator			Local boards		
Work location fixed effects	TAs + CBD indicator			Local boards		
Control function	First stage residuals			First stage residuals		

*Notes: (1) The control function approach entailed OLS estimation of car and PT travel times as a function of the exogenous variables plus three geographic instruments, and then including OLS residuals as additional control variables in the Poisson regression model. (2) These models were estimated on a dataset of total commute flows between area units (home and work locations) in each city. There are 158 area units in Wellington and 403 in Auckland. (3) Standard errors are estimated using the bootstrap method. (4) Statistical significance levels: * p<0.05; ** p<0.01; *** p<0.001.*

Predicted effects of transport upgrades

I apply the above models to predict the effects of two major transport investment proposals on the distribution of population and employment growth in Auckland and Wellington. To do so, I apply the coefficients I estimated above to modelled changes in travel times arising from these projects.[5]

In this analysis, I assume that transport projects will not affect the overall *level* of population growth in the region. I therefore scale results to ensure that regional population and employment stays fixed. This is an important assumption that I revisit in the following section.

Wellington: Let's Get Welly Moving (LGWM) programme

The Let's Get Welly Moving programme comprises proposed improvements to public transport, state highways, walking, cycling, and urban amenity focused on central Wellington. I use strategic transport model outputs to estimate changes in journey times in 2036 and hence potential impacts on land use.

Figure 2 shows the spatial distribution of changes in employment and population estimated by each of the two models described above. Red and yellow shading indicates a reduction in growth relative to the base case land use scenario for 2036, while greens and blues indicates an increase. This illustrates that although the programme focuses investment in central Wellington, it is likely to shape growth at a regional level.

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[5] I apply the accessibility-density model using the following formulas: $PctChangeJobs_i = \left(EJD_i^{Opt}/EJD_i^{DM}\right)^{\delta} - 1$; $PctChangePop_i = \left(EJD_i^{Opt}/EJD_i^{DM}\right)^{\varepsilon} - 1$, where EJD_i^{Opt} and EJD_i^{DM} are effective job density in model zone i under the Option and Do-Minimum, respectively; δ is the elasticity of model zone employment density with respect to EJD; and ε is the elasticity of model zone population density with respect to EJD. I then apply the modelled percentage changes in jobs and population to base case land use assumptions.
I apply the location choice model using the following formula: $\Delta N_{jk} = \exp\left(\beta \Delta PTtime_{jk} + \gamma \Delta Cartime_{jk}\right) - 1$, where β and γ are coefficients based on Poisson regression models of location choice, and where the outcome is the percentage change in commuting flows between zones. I then sum up changes by origin and destination zones to calculate the modelled change in the number of people living in each origin zone and working in each destination zone.

Figure 2: Changes in employment and population relative to base case land use scenario (2036)

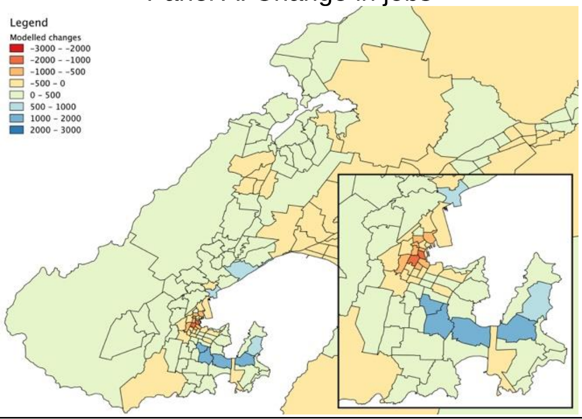
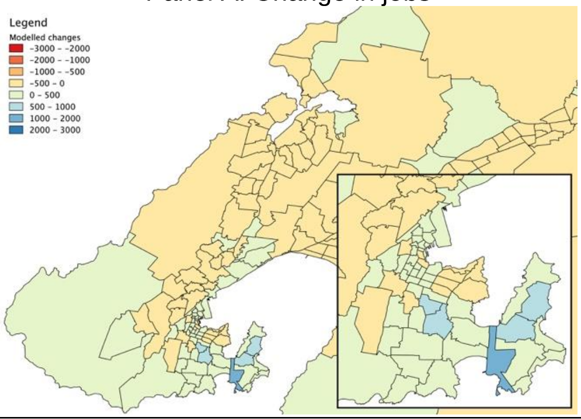
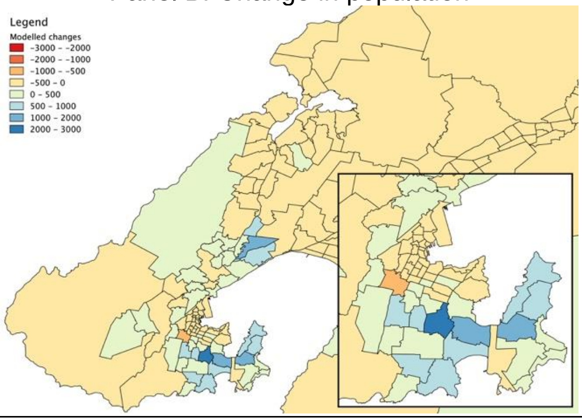
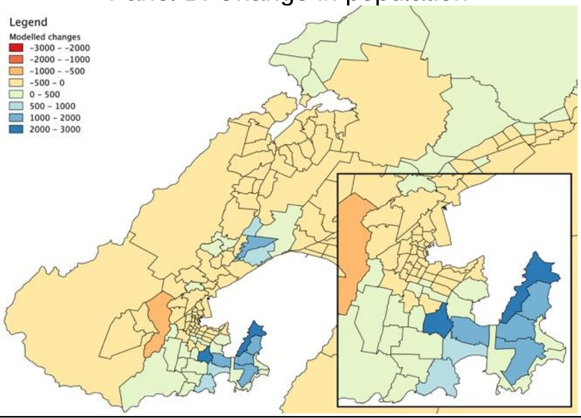
Accessibility-density model	Location choice model
Panel A: Change in jobs  	Panel A: Change in jobs 
Panel B: Change in population  	Panel B: Change in population 

Table 6 compares key results from the two models. The accessibility-density model implies that around 5.4% of regional jobs and 3.0% of population will relocate, relative to base case land use assumptions, while the location choice model estimates that around 3.5% to 3.7% will shift location.

The models 'agree' on the locations where population growth will increase or decrease (R^2 of 70%). Both models imply that population growth will spread out from the city centre to areas in Newtown and Miramar that become more accessible, and to a lesser extent to Wellington City's northern suburbs. However, they 'disagree' about where job growth will increase or decrease (R^2 of only 9.5%). The location choice model implies that LGWM will increase job growth in the city centre, while the A-D model suggests that job growth will disperse to the south of the city centre.[6]

Table 6: Estimated share of employment and population shifted between model zones (2036)

Model	Accessibility-density model	Location choice model	Correlation between changes at the model zone level (R^2)
Share of jobs redistributed between model zones (2036)	5.4%	3.7%	0.095
Share of population redistributed between model zones (2036)	3.0%	3.5%	0.697

This suggests that there is more certainty about the broad magnitude of changes (3-5% of regional population and employment) and the types of locations that will see faster or slower population growth, and less certainty about impacts on the distribution of job growth.

Auckland: Northwestern Rapid Transit Corridor (NWRTC)

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[6] This reflects the different emphasis that these models place on changes to car travel times as a driver of changes to location choice. The EJD calculation used in the A-D analysis places more weight on reductions to car journey times, since transport modelling predicts that cars will continue to serve most trips. By contrast, coefficients from the location choice model suggest that commuting flows are less sensitive to car travel times than to public transport travel times.

The Northwestern Rapid Transit Corridor runs from central Auckland to Westgate via State Highway 16. It is expected to significantly improve public transport journey times to an area that is seeing rapid suburban expansion. I use strategic transport model outputs to estimate changes in journey times resulting from full implementation in 2046 and hence potential impacts on land use.

Figure 3 shows the spatial distribution of estimated changes in employment and population, relative to the base case land use scenario for 2046. The green and blue shading indicates that both models expect the project to boost both employment and population growth in the northwest, especially around Westgate, and increase employment growth in the city centre. This will be balanced out by a modest reduction of growth rates elsewhere in Auckland.

Figure 3: Changes in employment and population relative to base case land use scenario (2046)

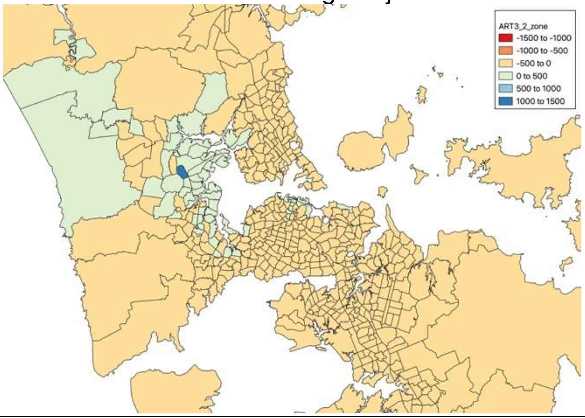
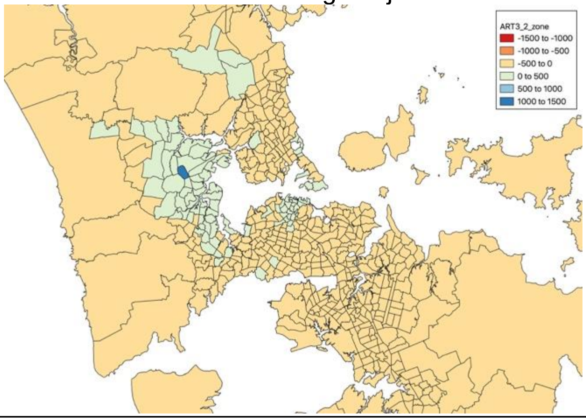
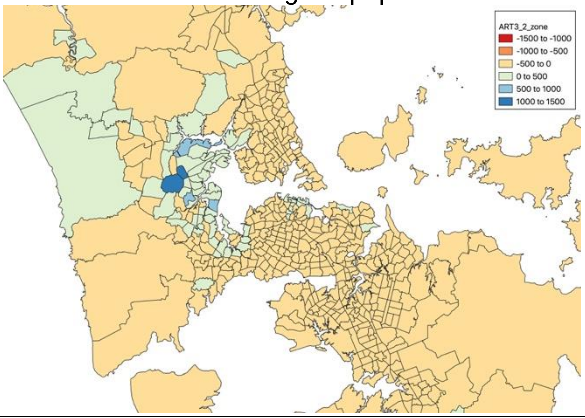
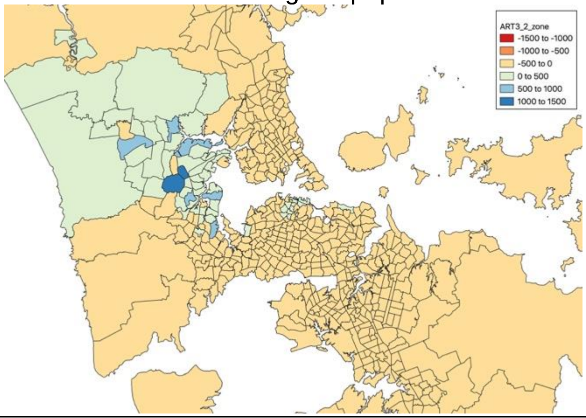
Accessibility-density model	**Location choice model**
Panel A: Change in jobs  	Panel A: Change in jobs 
Panel B: Change in population  	Panel B: Change in population 

Table 7 compares key results from the models. The models 'agree' on the locations where population and employment growth will increase or decrease (R^2 of 83% for population changes, and 80% for employment changes). Moreover, they predict that a similar share of jobs and population will redistribute as a result of the project – between 0.3% and 0.6%. However, this result should be interpreted with caution given uncertainty about the coefficients estimated for the Auckland location choice model.

Table 7: Estimated share of employment and population shifted between model zones (2046)

Model	**Accessibility-density model**	**Location choice model**	**Correlation between changes at the model zone level (R^2)**
Share of jobs redistributed between model zones (2046)	0.3%	0.4%	0.801
Share of population redistributed between model zones (2046)	0.4%	0.6%	0.827

NWRTC is predicted to have a smaller proportional impact on land use than LGWM. This is because the modelled LGWM option is a larger project than the modelled NWRTC option, and hence has larger impacts on travel times. And, as Auckland is a larger city than Wellington, any given project will affect a smaller share of the region.

Discussion

This analysis suggests that there is no reason to continue to consign analysis of the land use impacts of transport investments to the 'too hard' basket. These methods can be implemented using outputs from conventional strategic transport models. They are simple and transparent compared with land use-transport interaction models and hence can and should be improved through further analysis.

Furthermore, some economic impacts of land use change can be valued using extensions or variants of existing appraisal methods. This includes dynamic agglomeration benefits, move to more productive job benefits, and many land use change benefits. Provided that an analysis of land use impacts of a transport project is available, it is conceptually straightforward to value these impacts.

Valuing housing development opportunities

The above results suggest that major transport investments can help to shape the location of both job growth *and* population growth. However, existing or emerging evaluation techniques mainly focus on benefits that arise from changes to employment location, and provide little useful guidance for valuing the benefits of enabling additional *housing* development.

Impacts on housing development are *not* straightforward to value, as they may arise in housing, land, and labour markets, or in inter-regional or international migration, none of which is addressed in existing transport models. Different methods are needed to value impacts on declining versus growing areas, or to value projects that have an incremental or systemic impact on housing development.

This is an important frontier for research given New Zealand's housing affordability challenges and the potential role of transport investment in unlocking new housing development. I therefore conclude by discussing some conceptual challenges for valuing the impact of transport investment on housing development opportunities and highlight areas where further work is needed.

Incremental versus systemic change

UK transport appraisal guidance suggests that incremental changes in land values arising from new residential or commercial development can be used to value the benefits of unlocking development via transport investment.[7] Dutch guidance on cost benefit analysis of urban development projects, discussed in de Groot et al (2015), takes a similar view. A 2010 Centre for International Economics study used this method to compare the housing benefits of more intensification or greenfield development in Sydney.

This is appropriate for valuing small changes in development opportunities in situations where land is undervalued due to a lack of transport access. Increases in land values should reflect the increased value of the development opportunity to new residents or businesses under the following assumptions. First, the construction market and housing purchase markets must be competitive. Second, evaluators must avoid double-counting travel time savings that are 'capitalised' into land values and must adjust for displacement of activity that would have occurred elsewhere in the absence of the project.

However, this approach will break if it is applied to transport investments that have a large impact on housing development opportunities. Cities with pervasive housing development constraints may have land price gradients that are *extensively* distorted by restrictions on building height and density, zoning restrictions on which activities can occur in which locations, and barriers to new subdivision.

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[7] See Department for Transport (2018), Appendix D to TAG Unit A2.2, which suggests valuing these benefits using a 'residual value' approach, preferably implemented by a property valuation professional. This approach entails estimating the final value of the development and subtracting estimated development costs (including a profit margin to reflect the risk and effort incurred by the developer).

The estimates of urban land price distortions summarised in Table 8 suggest that the effect is to *increase* the overall price of urban land. A large increase in housing development opportunities is therefore likely to have a net downward impact on land values. Prices would rise in some locations, such as inner-city locations where intensification is attractive or greenfield locations newly serviced for developments, but fall in many other places.

The UK approach implies that this would be a net *disbenefit* for society. That is difficult to reconcile with the perception that excessively high house prices have large adverse effects, such as the health costs of overcrowding and homelessness and the social impacts of declining housing affordability for young and low-income people. A different approach is therefore needed to value 'systemic' changes.

Table 8: Land value discontinuities at selected rural-urban zoning boundaries

Urban area	Ratio	Difference ($/m2)	Difference ($/600m2 section)
Auckland	3.15	$345	$206,700
Christchurch	2.23	$150	$90,100
Dunedin	1.29	$38	$22,500
Hamilton	2.42	$227	$136,200
New Plymouth	1.61	$92	$55,100
Palmerston North	1.57	$73	$43,900
Queenstown	3.12	$337	$202,500
Tauranga	2.02	$232	$139,100
Wellington	2.30	$201	$120,400
Whangarei	2.00	$80	$48,100

Source: https://mbienz.shinyapps.io/urban-development-capacity/

Housing supply dynamics in growing cities

In growing cities, the elasticity of housing supply will determine how demand translates into prices and new construction (Glaeser and Gyourko, 2018).[8] Cities with unresponsive supply will get fewer homes and higher prices over time, while cities with responsive supply will get more homes and lower prices.

The elasticity of housing supply varies significantly between regions, reflecting both geographical and policy constraints (Saiz, 2010; Nunns, 2018a). Transport investment can improve the responsiveness of housing supply by bridging geographic barriers that limit the extent of urban development, a la the Auckland Harbour Bridge, or alleviating capacity constraints that make it impractical or unattractive to rezone areas for higher density development. This can allow cities to grow and remain affordable.

Macroeconomic impacts of housing supply

Unlocking additional housing development in a growing city may also generate broader economic impacts. If a city can build more in response to demand shocks, its population may grow more rapidly as fewer people will be 'priced out' of the city by higher house prices. Residents' quality of life is also likely to improve as they can afford to live in nicer or less crowded homes.

This can in turn affect the size and productivity of the national economy. First, an increase in city size or density will increase economic productivity via agglomeration effects (Duranton and Puga, 2004; Melo, Graham and Noland, 2009; Maré and Graham, 2009). Second, building more housing in a productive city may allow people to relocate from lower-productivity places, lifting national productivity levels.

Several recent studies attempt to estimate the resulting impacts on economic output by calibrating spatial equilibrium models of location choice and using them to test counterfactual scenarios for urban growth. Hsieh and Moretti (2015) estimate that if San Francisco, San Jose, and New York had more permissive land use regulations, US GDP would have been between 3.7% and 8.9% higher in 2009, depending upon the degree to which people face frictions to moving and the strength of their preferences

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[8] Because housing is durable, cities that have declined relative to past population levels experience different dynamics. Prices for existing houses will increase in response to growth or fall in response to further decline, but less new construction will be required to handle any growth.

to live in specific places. Glaeser and Gyourko (2018) use a variant of this approach and estimate that housing supply constraints in productive US cities impose a cost of around 2% of GDP.

These studies do not address a third effect, which is that increasing housing supply and reducing prices may reduce emigration of New Zealanders or even attract additional international migrants. The economic benefit from this will be equal to the increase in GDP from a larger labour force, minus any costs from diluting or damaging scarce natural resources.

Nunns (2018b) applies Hsieh and Moretti's spatial equilibrium model to New Zealand regions and extends it to account for trans-Tasman migration of New Zealanders, which is the component of international migration most likely to be affected by local house prices. This model implies that comprehensively improving the responsiveness of housing supply and hence reducing house price distortions could have the following effects:

- Output per worker rises by 0.5% to 1.5%, reflecting faster growth in higher-productivity regions, ie Auckland and Wellington
- The size of the New Zealand labour force increases by 2% to 7%, reflecting a reduction in net migration of New Zealanders to Australia
- Total economic output rises by 3% to 8% as a result.[9]

As New Zealand's GDP in 2017 was $270bn, this translates to annual benefits on the order of $8 billion to $21 billion. The specific figure is less important than the general observation that transport interventions that systemically increase opportunities for housing development may generate economic benefits by affecting the inter-regional and international distribution of population. These benefits are not captured by existing transport appraisals practices that assume a fixed regional and national population.

Comparison of 'incremental' and 'systemic' approaches

An 'incremental' approach to valuing housing development opportunities may lead to a fundamentally different result than a 'systemic' approach employing a spatial equilibrium model.

To illustrate, I use the model from Nunns (2018b) to estimate the macroeconomic effects of relaxing housing supply constraints in a single city, Auckland. My upper bound estimate is that this would increase employment in Auckland by 18% and hence increase New Zealand's GDP by 1.8%, or around $5 billion per annum.[10] If we project this impact forward and convert it to present value terms using a 6% discount rate, this equates to total economic benefits of $80 billion.

To accommodate an 18% increase in employment, Auckland would have to increase its housing stock by almost 100,000 homes.[11] Table 8 suggests that the incremental uplift in land values between rural and urban-zoned residential land in Auckland is equal to around $206,700 per dwelling. If we valued an 18% increase in dwellings using the approach in UK transport appraisal guidance, assuming zero displacement, it would equate to total benefits of almost $20 billion.

Both methods result in large numbers but the 'systemic' estimate is much larger. This highlights that different approaches may be needed to value investments that have 'incremental' impacts on housing supply versus investments that may have 'systemic' impacts.

To conclude, I observe that at this stage there is no obvious way to model how specific transport investments will affect housing development opportunities and hence house prices. While the effects of unlocking housing development may be large, further work is needed to identify causal linkages.

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[9] This estimate accounts for dilution of natural resources and land capital with a larger population, but does not account for agglomeration economies from larger or denser cities.

[10] Accounting for frictions to moving or preferences to live in specific places would halve this estimate.

[11] Around 125,000 new dwellings were consented in Auckland over the 2000-2016 period – an average of just under 7,400 per annum. If the city had instead consented 13,000 per annum, which is close to current levels, it would have met this target.

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