Accessibility: its role and impact on labour and housing markets in New Zealand's main metropolitan areas

October 2021

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Waka Kotahi NZ Transport Agency research report 682

Contracted research organisation – Infometrics Consulting

WAKA KOTAHI NZ TRANSPORT AGENCY

New Zealand Government

ISBN 978-1-99-004435-9 (online)
ISSN 1173-3764 (online)

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Stroombergen, A., Byett, A., Maré, D., & Fabling, R. (2021). *Accessibility: its role and impact on labour and housing markets in New Zealand's main metropolitan areas*. (NZ Transport Agency research report 682). 122 pp.

Infometrics Consulting was contracted by the NZ Transport Agency in 2021 to carry out this research.

Keywords: commuting, house prices, spatial mismatch, worklessness

An important note for the reader

Acknowledgements

The authors thank:

- Members of the Steering Group: Ernest Albuquerque, Ian Binnie, Tony Brennand, Sandy Fong and Wayne Heerdegen.
- Peer reviewers: James Laird (Peak Economics and Leeds University) and Michael Bealing (NZIER)

Disclaimers

Census data: access to the data used in this study was provided by Statistics NZ under conditions designed to give effect to the security and confidentiality provisions of the Statistics Act 1975. The results presented in this study are the work of the author, not Statistics NZ or individual data suppliers.

IDI data: These results are not official statistics. They have been created for research purposes from the Integrated Data Infrastructure (IDI) and/or Longitudinal Business Database (LBD)] which [is/are] carefully managed by Statistics NZ. For more information about the [IDI and/or LBD] please visit https://www.stats.govt.nz/integrated-data/.

The results are based in part on tax data supplied by Inland Revenue to Statistics NZ under the Tax Administration Act 1994 for statistical purposes. Any discussion of data limitations or weaknesses is in the context of using the IDI for statistical purposes and is not related to the data's ability to support Inland Revenue's core operational requirements.

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Executive summary

For the urban economy to function efficiently it is necessary for workers, consumers and suppliers to exchange labour, goods, services and ideas with minimum friction. This requires employment locations to be accessible from housing areas where workers live and for transport costs to be affordable. Overseas research suggests there is a mismatch between where jobs are located and where people live. Under such circumstances access to suitable means of travel can have a substantial impact on the ability of households and individuals to access employment opportunities. For the labour market to function efficiently it is necessary for workers to move freely between jobs and residential areas.

Currently, there is a lack of understanding of the extent of the problems that exist relating to the spatial mismatch in New Zealand, and the mechanisms that can improve accessibility between areas of high housing affordability and areas/centres of employment.

This research study sought to understand whether there was a spatial mismatch between where workers lived and worked in main metropolitan areas and how accessibility could be improved.

The key questions of interest were:

- What is the spatial mismatch between the locations of affordable housing and the location of employment opportunities? What techniques and methods can be used to investigate this issue?
- How does the transport system mediate between areas of high housing affordability and areas/centres of high employment opportunities?
- What transport barriers do workers living in affordable housing areas face in travelling to high employment opportunity centres/areas? This should include an assessment of the cost of travel and the impact this has on job search ability and on lower-income households/individuals.
- How might central and local government respond to such issues and what transport initiatives can be implemented and funded?

The literature review produced a number of interesting findings:

- In studies of residential location, job accessibility is generally found to be statistically significant, but in most cases other factors such as household structure and neighbourhood effects are more significant. In the United States, racial segregation is a major driver of job accessibility.
- Accessibility is also shown to affect property prices, but again individual, household and locational attributes tend to dominate.
- Generally the measured effects of accessibility in longitudinal studies are lower than those found in cross-section studies, a result attributed to better treatment of endogeneity as cross-section data contains the effects of all sorts of past transport investments and locational choices.
- Studies of the effects of accessibility on labour market outcomes, work status and earnings illustrate the importance of heterogeneity in job opportunities and worker skills and show that differences in commuting costs can manifest in wage rates, not just in property prices.
- Spatial mismatch is affected by other factors such as industry, gender, skills and occupation.
- The main moderator of accessibility is the road network for private vehicles. However, public transport can also have a significant role, especially in low-priced housing areas.

- Policy interventions to date that have incorporated measures of accessibility have largely been used to help identify where transport interventions would be of more benefit or to understand equity effects. Standard cost–benefit analysis or multi-criteria analysis is then applied as usual.

Our empirical analysis included:

- calculating a measure of job accessibility for locations within each of four study areas (Auckland, Napier–Hastings, Wellington and Dunedin urban areas), between 2005 and 2018, using data from the census and from the Integrated Data Infrastructure (IDI)
- examining the relationship of job accessibility with:
  - wages and rents to infer how workers and firms value accessibility, and the trade-offs involved in choosing residential and business locations
  - the probability of employment for workers
  - the probability of durations out of work after leaving a job
  - the commute distance experienced by workers
- examining how each of these relationships differs for workers of different skill levels
- analysing selected relationships separately for areas that differ by rent levels and public transport use.

The analysis produced the following key findings:

- Accessibility is associated with higher rents and lower wages, consistent with accessibility being a positive local amenity that residents are willing to pay for.
- Greater accessibility to job opportunities tends to be associated with lower wages (net of commuting costs) and higher house prices. The effect varies in strength across gender and worker skill.
- We failed to find a strong relationship between accessibility and employment rates, which we might expect if spatial mismatch were problematic.
- Commuting distance is negatively related to accessibility to job opportunities, with the strength of the relationship increasing with worker skill. It seems that higher-skilled workers wish to, and can more readily afford to, live further from work.
- However, changes in the level of employment seem to be much more a function of general economic conditions than of job accessibility, although a lack of general variation in transport networks over the sample period could be masking a stronger effect.
- It is likely that reducing transport costs to an affordable area would improve the welfare of local residents. However, there are second-round effects to consider and our research has provided no evidence that persons living in affordable areas have not already adapted to the current transport network.
- One particular second-round effect is through higher house prices – a benefit to existing property owners, but the combined lower transport costs and higher housing costs may end up being a disbenefit to residents who are renting.
- Overall, it seems that in New Zealand the labour market and transport network function fairly well to mitigate the worst effects of spatial mismatch. The housing market functions less well.

We have not been able to answer all the research questions as fully as we would like as it is clear with hindsight that they were based on the exaggerated premise that spatial mismatch is widespread in New

Zealand. This could be because so much of the literature is based on cities in the US, which have had very different patterns of spatial development, residential location and transport infrastructure from those in Europe, and indeed from those in Australia and New Zealand.

Nevertheless, although spatial mismatch may not be pervasive in New Zealand, particular population subgroups or finely defined geographical areas may incur greater work–home separation than is socially desirable.

There are opportunities for further research by:

- repeating the census analysis after the next census (2023), which should lead to more precise estimates of the relationship between accessibility to job opportunities, and rents, wages and commuting
- conducting a longitudinal IDI-based case study of an area that has seen a significant and discrete transport intervention, plus richer data on accessibility and commuting (value of time and direct outlays), employment, housing, education and other demographics. This would enable better attribution of changes in labour market status, commuting and residential location to specific transport interventions – something that has proved difficult in this study.

Abstract

For an economy to function efficiently workers, consumers and suppliers need to be able to exchange labour, goods, services and ideas with minimum friction. Hence employment areas need to be accessible from residential areas, with affordable transport costs. International research, notably that from the United States, finds a 'spatial mismatch' between where jobs are located and where people live. In other countries it is less prevalent. Our investigation suggests that such a mismatch is also not widespread in New Zealand, but it is possible that we simply have not been able to uncover it with the data and tools available, or that there are particular population subgroups (such as lower-skilled workers, secondary earners in a household or minority communities) for whom work-home separation is a significant barrier to employment. This is similar for small geographical areas that are not well served by public transport. Researching these types of cases requires a different approach from that used here.

Lowering the costs of transport to areas with cheaper housing would generally be expected to improve the welfare of local residents. However, there are second-round effects to consider, such as the capitalisation of lower transport costs into rent (housing costs) which may eventually make the area too expensive for those residents the transport intervention was designed to assist. Thus transport interventions have the potential to undermine other policy objectives if they are not carefully appraised across a number of domains.

1 Introduction

Overseas research suggests there is a mismatch between where jobs are located and where people live. Under such circumstances access to suitable means of travel can have a substantial impact on the ability of households and individuals to access employment opportunities. For the labour market to function efficiently workers need to move freely between jobs and employment areas.

Therefore, the ability and capacity of workers to travel across urban areas to access employment opportunities is important. In particular, we wished to understand the role that urban transport systems have in mediating between areas of high housing affordability (or low housing costs) and areas of high employment opportunities. If for example, areas of high housing affordability have low levels of accessibility to centres of employment, the employment opportunities of lower income groups could be adversely affected. There is a need for a better understanding of the mix of transport services to enable lower income households to have improved access to high employment areas.

Currently, there is a lack of understanding of the extent of the problems relating to spatial mismatch in New Zealand, and the mechanisms that can improve accessibility between areas of high housing affordability and areas/centres of employment.

This research sought to understand whether there was a spatial mismatch between where workers lived and worked in main metropolitan areas and how accessibility could be improved to overcome the problems faced.

We examined a range of variables that people would consider when choosing to live in a particular location. This included house prices, amenity values, distance to schools and other relevant variables that would compete against access to jobs. The influence of job location versus these other variables was likely to vary with different household types and in some cases might have limited influence.

Our key questions of interest were:

- What is the spatial mismatch between the locations of affordable housing and the location of employment opportunities? What techniques and methods can be used to investigate this issue?
- How does the transport system mediate between areas of high housing affordability and areas/centres of high employment opportunities?
- What transport barriers do workers living in affordable housing areas face in travelling to high employment opportunity centres/areas? This should include an assessment of the cost of travel and impact this has on job search ability and the impact on lower income households/individuals.
- How might central and local government respond to such issues and what transport initiatives can be implemented and funded?

We began with a review of relevant literature, which is set out in chapter 2 of this study. Empirical analysis follows in chapters 3 and 4, dealing with census data and Integrated Data Infrastructure (IDI) data respectively, with the latter providing the ability to match workers and firms on quality, and allowing for the observed persistence of workers' jobs in industries that demand their skills. Chapter 5 looks at some specific examples and in chapter 6 we offer some thoughts on the role of transport policy in alleviating spatial mismatch and what additional research might be useful.

2 Literature review

2.1 Introduction

> *The only reason to locate anywhere is to be near some people, places, and things, be far from others, and possess still others. Since being far from something is really just being near the absence of that thing, and possession is just the ability to have something (and legally prohibit someone else from having it), we can see that location is about proximity. People make location decisions all the time, from whether to move from North America to Australia, to traveling to the mall by car or bus, to standing near a person at a reception, or even sitting on the chair or the couch.* (Levinson & Wu, 2020)

Our objective was to investigate a particular aspect of proximity – how it interacted with transport within a concept known as 'spatial mismatch'. Broadly speaking this term is used to convey the idea that jobs exist in areas that are not conveniently located relative to where workers live. The growth in employment locations may be some distance from housing areas, especially affordable housing areas, and the costs and inconvenience of travel can have a detrimental effect on the employment opportunities.

Of course unless people work from home or live at work, there will always be a mismatch in that sense. Nevertheless the idea has intuitive appeal. For example there are many jobs in central Auckland, but many people live in Auckland's southern suburbs with a commute that can easily take more than an hour.

If spatial mismatch exists, is there a role for urban transport systems to mediate between areas with low housing costs and areas with high employment opportunities? If for example, areas with low housing costs have low levels of accessibility to areas/centres of employment this could adversely affect employment opportunities for lower income groups.

However, simply observing an inconvenient distance between work locations and residential locations is not evidence that distance is the problem. There may be very good reasons why residential areas and commercial/industrial areas are not conveniently located to each other. For example there may be regulatory reasons (zoning) especially if industries generate health hazards.

Also, households that are prone to low labour market participation (worklessness)[1] tend to cluster in areas where housing is relatively affordable. Apart from income, affordability is affected by a wide range of neighbourhood effects (crime, proximity to amenities etc) that extend beyond transport costs to where jobs are located.

Accessibility to jobs may be largely exogenous for some, being determined by the decisions of many different parties about where to locate (or not locate) housing developments and businesses, and what sort of transport infrastructure to provide. Others may have much more choice about where to live and where to work. Job accessibility, which includes commuting costs, is only one choice, although it is likely to be an important component of accessibility to a wide range of services and amenities including schools, entertainment and recreation facilities.[2]

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[1] We use the term 'worklessness' to capture unemployment, under-employment (those who would work more hours if they had the opportunity) and general disassociation with the labour market.

[2] The term accessibility is used in this report to describe the transport infrastructure and transport options that are available to people to access employment opportunities. We do not specifically address accessibility in a disability context, although clearly it is a dimension of transport disadvantage.

In section 2.2 we present a discussion of research on spatial mismatch. This is followed by a section on measures of accessibility as one cannot make much empirical progress investigating spatial mismatch without an instrumental definition of accessibility.

After that we look at how accessibility is related to the choice of residential location, house prices, worker outcomes and business location. Finally we consider the links with transport policy.

We stress that spatial mismatch is a broad concept so we have tried to focus on our key questions set out in chapter 1.

2.2 Spatial mismatch

As is evident from the introduction to this chapter, spatial mismatch is a broad concept. We interpret it as describing any separation between employment location and home location. The separation may describe a spatial equilibrium or it may describe a disequilibrium that reflects other distortions such as land-use regulations, discrimination against minority groups, or poor transport infrastructure.

The literature on spatial mismatch started in the 1960s with seminal papers such as Kain (1968) who looked at the effect of housing market discrimination on the employment and earnings of black workers in the US. Kain identified central city ghettos with poor access to low-skilled jobs, but saw the problem as primarily a housing issue, rather than a transport issue.

Almost three decades later Kain (1992; and then again in 2004), discusses many papers on the topic published during the intervening years, including studies that largely reject the idea of spatial mismatch as a factor explaining worklessness among black Americans. Instead racial residential segregation is seen as the prime cause of worklessness. The phrase used by various critics 'race, not space, remains the key explanatory variable' (of differences in white versus black employment). However, it would be fair to say that in general the better the measures of worklessness and segregation, the stronger the support for the spatial mismatch hypothesis.

Pugh (1998) lists a number of other factors in addition to racial discrimination that affect worklessness, including significant education and job training needs, difficulty in finding safe and affordable childcare and a lack of good information about job opportunities or hiring networks. Public transport – often the main mode of travel for low-income households – may not be the factor that most constrains access to jobs.

Another factor explored in Durst (2020) is land-use regulation. Durst concludes there is a 'myriad of ways' in which the regulation of land use is correlated with mismatch between housing and employment opportunities and with workers' commuting burdens. However, the direction of causation could go either way, with land-use regulation responding to development patterns.

In a very recent systematic review and meta-analysis, Bastiaanssen et al. (2020) found most of the empirical evidence also suggests a positive association between transport accessibility and employment, even after controlling for endogeneity. The effect is strongest for car ownership, with weaker effects for access to public transport, commuting times and measures of job accessibility (such as the number of jobs within x minutes of travel time). Access to a vehicle may be useful for commuting, but it may also be directly relevant to jobs such as community nursing and construction trades.

Most of the studies reviewed relate to US metropolitan areas, so the results for non-metropolitan areas are described as less robust. The authors also noted that similar findings may not apply to countries where commute distances are shorter and there is more inner city living, or where patterns of urban development differ from those in the US.

Dodson (2005) for the Australian Housing and Urban Research Institute (AHURI) analysed spatial mismatch in Melbourne, Australia. Among the questions examined in the research were:

- Is there evidence for a spatial mismatch in Melbourne between the locations of affordable housing and the location of employment opportunity?
- What transport modes are available in locations of higher unemployment, and conversely, in locations of employment concentration?
- What transport modes are used by households in locations of higher unemployment or higher housing affordability, and conversely, in locations of employment concentration?

Dodson's main finding was that spatial mismatch is not considered to be a strong phenomenon in Melbourne. Unlike US cities, Melbourne has not had the exodus from central city locations that has become part of the pattern of racial residential segregation in US urban areas. Australian cities generally do not exhibit strong ethnic segregation. Melbourne's central city has seen job growth, but so have many suburbs, with some becoming high-cost locations. .

Transit-poor households tend to be socio-economically worse off than those in transit-rich areas and those without cars have limited travel options – in both space and time. Nevertheless, Dodson (2005) found employment tended to be higher in locations with better public transport (PT) than in those with poor PT, surmising that the former group of households include access to PT as a factor in their choice of location. However, it could equally be that the level of PT service provided to households in these areas is sufficient to enable a substantial share of such households to avoid owning a car. Of course it may also be that they cannot afford a car.

Regardless, workers in areas with good PT are more likely to use it for commuting than those with poor PT, and conversely, less likely to use a car.

Dodson (2005) also noted the entanglement and trade-offs between job location, household labour market status, vehicle ownership, access to PT and locational choice. In an earlier AHURI paper (O'Connor & Healy, 2001) suggested job location was probably less influential in determining location choice than price, housing status and dwelling quality, but that sort of analysis was beyond the scope of Dodson's research. In a later AHURI report, Yates et al. (2006) showed commuting patterns differ by occupation with some (such as computing professionals) having a relatively large share of longer commutes, because they choose – and can afford – to live away from the central city.

Similarly, Zhao et al. (2017) in a study of Munich agree that different groups of knowledge workers display distinct joint choices of residential location and commute mode.

Sang (2008) also disaggregated commuting by occupation and by gender, using average distance and job accessibility as measures of commuting. Sang observed differing commuting patterns by occupation and gender, with most of the differences by gender attributed to occupation, due to the dominance of each gender in particular professions. Like other authors Sang noted that differences in accessibility are partly endogenous, being affected by differences in education, family status and whether both partners in a relationship are in paid work.

Fan et al. (2016) in a study of the twin cities of Minneapolis and St Paul found spatial mismatch also differed markedly between industries, noting that access to jobs in some sectors is not much enhanced by access to PT.

Chacon-Hurtado et al. (2019) using a multinomial logit model, agreed that while commuting patterns are a function of the amount of employment at the destination area, mediated by impedance factors (they used

Euclidean distances), industry structure and the household income are also important influences on commuting.

As demonstrated by the AHURI research, different cities have very different mobility requirements. For the UK, Hind (2015) concluded that the degree of dependence on public or private transport is driven by a wide range of factors such as family effects, land prices, planning policies, industrial structure and the configuration of PT – PT is generally not well suited to jobs with rotating shift patterns and non-standard working hours. No clear pattern to the commuting preferences of high or low-skilled workers was observed. In essence though, greater skills are associated with greater mobility and the car is still the 'ultimate enabler of mobility'.

Gobillon et al. (2016) discuss the lack of a theoretical foundation in much of the spatial mismatch literature up to then. They offer a number of options based on variations of labour supply theory (in essence better accessibility to employment opportunities is likely to expand the job search horizon and the range of prospective wage rates, increasing the likelihood of employment) and labour demand theory (for firms better accessibility to workers and other firms means greater connectivity, generating agglomeration benefits).

Although not directly addressing the idea of spatial mismatch, Albouy (2009) tested the theory of spatial equilibrium, finding that wage rates and housing costs are explained more by productivity than by the quality of amenities – and thus by labour supply. The model assumes households are homogeneous, mobile between cities and there is no commuting.

Albouy & Lue (2015) included commuting in their model and the results confirm the expected decline in wages (measured by place of work not residential location) and rent (house prices) with distance from dense work locations. The authors make the additional point that intra-city differences in neighbourhood quality are large, but they relate less to natural amenities than to the amenities produced by the local residents, such as by self-selection on ethnicity. In what may be a perfect example of endogeneity, the residents themselves are one of the amenities. Maré et al. (2012) in a study of residential sorting in Auckland found sorting based on country of birth is the strongest indicator of residential sorting patterns. Sorting by income, education and age also exists. Such clustering is strongest within a range of 1 km and falls markedly over greater distances.

2.3 Accessibility

The literature includes many definitions and measures of accessibility. It is worth looking in more detail at this aspect of the spatial mismatch debate to guide our choice of measures in our later empirical analysis.

For ease of understanding, accessibility is referred to below as people being able to move between a 'population zone' and an 'opportunity zone', eg the population zone could be the place of residence and the opportunity zone could be the place of employment, school, recreation or other attractions. The population zone would be the origin and the opportunity zone would be the destination for the to-work journey, but the roles reverse for the from-work journey. Hansen (1959) introduces the concept of accessibility, referring to it as a measure of the 'potential of opportunities for interaction' and using accessibility to improve forecasts of land development.

Although our interest (within the spatial mismatch concept) is on accessibility and employment, only 16% of trips in New Zealand are for going to work (and presumably about the same for the return journey),[3] so it is possible that accessibility to work zones may not feature highly in people's choices about where to live. On

[3] https://www.transport.govt.nz/mot-resources/household-travel-survey/new-results/why-we-travel/

the other hand, without understanding the utility function we do not know the extent to which people's decisions about where to live – and hence commuting – are affected by constraints such as affordability.

The measures of accessibility currently used by Waka Kotahi NZ Transport Agency trace back to measures created in the UK (see section 2.4.1 for more on UK measures). An early application was by the Auckland Transport Alignment Project (ATAP, 2016), which monitors the number of jobs accessible within a 30-minute drive at the AM peak for each meshblock and a similar measure for a 45-minute PT ride, plus, as a proxy for accessibility between firms, the number of jobs accessible to other jobs by car within a 30-minute trip during the inter-peak. Waka Kotahi has also calculated the first two measures for all meshblocks in New Zealand and updates these measures after receiving the results of the annual Statistics New Zealand *Business Directory Update Survey*, plus it calculates similar measures for a 30-minute walk and a 30-minute cycle ride. Waka Kotahi presents these measures as a percentage of each region's employment total. Also available are accessibility measures to nine social opportunities (different measures for education, health care, supermarkets, work and income centres and town centres).[4]

An earlier measure was provided within a pilot accessibility model for New Zealand, in Christchurch, commissioned by Waka Kotahi in 2013. This study measured potential accessibility to eight opportunities by four transport modes. Two notable differences from the currently reported measures were that employment accessibility was an age-weighted measure of accessible jobs, while the travel component included an exponential decay function for each mode (Abley & Halden, 2013).

Other measures of accessibility and proximity exist currently in New Zealand. Levinson and Wu (2019) present employment accessibility measures for Auckland, Christchurch and Wellington. Waka Kotahi (same web link as in footnote[3] below) provides proximity measures such as zones within 500 m of a bus stop and 1 km of a train station. Statistics NZ provides maps of commuting and school destinations for all New Zealand statistical unit 2 areas based on the 2018 Census.[5] These measures are generally descriptive.[6]

In section 2.3.1 we delve further into how accessibility can be measured, after which we look at how accessibility links to residential location, house prices, worker outcomes and business location. References to previous studies may occur multiple times in connection with these different perspectives.

2.3.1 Measures of accessibility

2.3.1.1 Purpose of measurement

It turns out for such a simple concept, there are many ways of measuring accessibility (Levinson & Wu, 2020). The reason for making the measurement is a key influence on how accessibility is measured. These purposes largely fall into four categories or perspectives (Geurs & Van Wee, 2004).

Location of activities. Some studies focus on the activity itself from the perspective of business owners. For example, owners will seek to site a supermarket or hospital where it can be accessed by a large population, including possibly not travelling from their homes (Wang, 2012).

[4] https://www.nzta.govt.nz/planning-and-investment/planning-and-investment-knowledge-base/201821-nltp/monitoring-and-reporting-on-investments/benefits-management-approach/investment-performance-measurement/information-sources-for-investment-performance-measures/

[5] https://www.stats.govt.nz/tools/commuter-waka-2018-census-data-visualisation

[6] A New Zealand analytical study of commuting can be found at https://storymaps.arcgis.com/collections/5e6444b9c673435196a578adcd00386b?item=7

Performance of infrastructure. Transport infrastructure providers tend to focus on the movement of vehicles between locations. Accessibility measures are of interest to transport modellers when it comes to trip generation (Ortúzar & Willumsen, 2011).

Personal access, where the period of time and the purpose of the trip become more relevant. This is often the focus of public transport where time and frequency of travel take on more importance. A clear result of previous research is that accessibility differs between those with and without a private vehicle, as discussed in section 2.2.

Welfare benefits of systems. There is also a large thread of research that seeks to answer to what extent inequitable outcomes such as unemployment are the result of cultural and education factors and to what extent are due to accessibility difficulties, as discussed above in the spatial mismatch hypothesis (section 2.2).

2.3.1.2 Types of models used to measure accessibility

A topology provides a useful framework to consider the variations and issues involved with the measurement of accessibility. Geurs & Van Wee (2004) split measurement into (a) a land component (b) a transport component (c) a temporal component and (d) an individual component.

In general terms the accessibility measure can be shown by equation 2.1, where A_i measures the accessibility for population zone *i* to the weighted sum of opportunities (O_j), with weights being a function of a travel measure (C_{ij}) between zone *i* and zones *j* (Levinson & Wu, 2020).

$$A_i = \sum_j O_j \ f(C_{ij}) \qquad \text{(Equation 2.1)}$$

Various forms have been suggested for the nature of *f(C)*. Those without an explicit variable for cost frequently include a negative exponential term for the relationship between distance and accessibility.

The following notes on measures draw heavily on Geurs (2018) and Levinson & Wu (2020).

2.3.1.3 Land component

The land component is a measure of the size of the opportunity available to the individual of interest. It is 'the what' being accessed.

Employment is one 'opportunity' that has been widely researched, with the link between employment and accessibility typically being job search (Andersson et al., 2018a). Ideally in a job search study the number of job vacancies provides the appropriate measure of potential opportunities available to unemployed people, but this is often difficult to measure and instead total employment in the opportunity zone is commonly used to represent the size of the employment opportunity.

More generally the opportunity could be any measure of activities that people might choose to undertake in the opportunity zone. A further innovation has been to record the utility gained by use of the opportunity rather than the presence or scale of the opportunity itself (Koopmans et al., 2013).

Returning to the use of employment as a proxy for job opportunities, the proxy further weakens should a zone be experiencing a decline in activity or when a zone is not growing and has low staff turnover. In these cases, improving access to a busy work zone may not deliver the desired employment increase if employment, while high, is actually declining. This problem generalises to one of heterogeneity of opportunities between zones, which creates the risk of bias from omitted variables in a regression analysis that tries to relate measures of accessibility and employment. A similar issue exists when the opportunity of interest is productivity should wages within a sector vary by location.

This leads into issues around zone size and segmentation of opportunities. The results of accessibility studies are sensitive to the zone size (Pirie, 1979). The opportunity zone can be segmented to consider the opportunities most relevant to the individual of interest, eg low-income jobs or jobs by occupation classes, but here the trade-off is typically between the cost of measurement versus the risk of bias arising from measurement error (large measurement error tends to bias the estimated effect to zero).

Another issue with matching accessibility measures with a desired response is that an opportunity may be diminished if many other people are competing for access. This is the case for jobs when there are large nearby populations (Shen, 1998). To take into account the reduced opportunity arising from competition, Shen (1998) recommends dividing the gross measure of opportunity per zone by the travel-cost weighted number of workers in the vicinity of the opportunity zone.

More generally, the importance of the opportunity differs in many ways which can be captured by introducing a function *g* into the accessibility measure. Examples include the singly constrained model of Shen above or a more sophisticated doubly constrained model, as used within traffic models, where the size of the population zone is also used to constrain travel (and hence access). Other examples of weighting the opportunity include building in diminishing returns to scale (Levinson & Wu, 2020).

$$A_i = \sum_j g(O_j)\ f(C_{ij}) \quad \text{(Equation 2.2)}$$

2.3.1.4 Transport component

Having derived a measure of the opportunity in nearby zones, the next step is to weight these opportunities according to how easy it is to travel to these zones

The travel function involves three parts: a measure of travel impedance; the functional form of the relationship between this measure and travel demand; and the mode of travel. Whatever the functional form, it needs to capture the idea that accessibility is something people are prepared to pay for, whether in time, money, comfort and so on..

Use of travel cost, as opposed to distance, has been shown to better reflect the travel impedance effect on travel demand (Houston, 2005). Ideally travel costs include any costs encountered from the start to the end of the trip between the population base and the opportunity location, known as the generalised journey cost or, if expressed in terms of time, the (preferably nonlinear) generalised journey time. Bringing external costs into the journey decision, as well as the aforementioned internal costs, could lead to journey choices that differ from those determined by internal costs alone (Cui & Levinson, 2018).

While accessibility based on travel cost is preferred, there are many studies using other measures of spatial separation such as (a) distance to opportunities, (b) the number of access vertices and (c) opportunities available within isochrone or isodistant radii (Pirie, 1979). The latter are relatively easy to compute but they do suffer from the arbitrary choice of zone limit.

Whether distance or travel costs are used, the travel impedance function typically requires a distance-decay element to reflect the diminishing effect of travel cost. This can take the form of a power function (C_{ij}^{-k}) or an exponential function ($\exp(-\alpha C_{ij})$) or a modified Gaussian exponential function $\exp(-C_{ij}^2)/v)$. In each case the parameters *k, α* or *v* are constants empirically derived for the transport network of interest (Vickerman, 1974).

It is worth noting at this stage that the exponential function has the advantage of linking more closely to information theory and is analytically compatible with the multinomial logit models often used in random utility choice models. It is also possible to derive an accessibility measure more directly from choice models using a logsum approach (summed logs of exponential functions with cost and opportunity variables), but this approach is not often used in practical applications (Miller, 2019).

The third element of the travel cost weighting is the mode choice. Travel costs vary considerably between travel modes, as shown by Johnson et al. (2017). Having derived costs for each mode, there is also the issue of combining – or not – the accessibility sums calculated for each travel mode, especially as access varies considerably between those with access to a private vehicle and those without. Variations used include (a) measure accessibility based on minimum travel cost across modes (which tends to bias accessibility measures to car-based access) and (b) a weighted average of accessibility sums, with weights being the mode share of observed travel, which tends to ignore unmet demand for public transport and risks paradoxical results if mode share should change.[7]

It can be important to consider the other components of the accessibility measure when considering the appropriate travel component to use. For example, in employment studies the spatial impedance often occurs both before and during the take-up of opportunities (Delbosc & Currie, 2011), potentially increasing the impedance for those people relying on public transport.

2.3.1.5 Temporal component

The above discussion of travel impedance has generally presumed travel impedance is the same for one day as for one week. This is clearly not the case in cities and is not the case more generally where public transport is infrequent. A number of studies provide accessibility measures for different times of the day, for different travel modes. Where the opportunity of interest – say someone travelling to work – can be isolated to a particular time and mode then the accessibility measure as calculated might be sufficient. When a range of travel times and modes is relevant, the issue of aggregation again arises.

Another variation of the temporal influence is to consider not the average travel costs, but a more extreme percentile of travel costs for the observed distribution of travel times. This would be relevant if the resilience of the travel was of high importance.

2.3.1.6 Individual component

The people accessing the opportunity differ, and so the purpose of any accessibility study will have a large effect on how the travelling population is measured.

For employment studies, the working population is most relevant, but this measure is not always available. For unemployment studies in particular, the people who are available to work but not currently in work can only be measured imprecisely.

For studies of inequality, there is often a difficulty defining the study group and then measuring such a group (Kamruzzaman et al., 2016). Of relevance to this research study is a definition for those people facing zones with 'affordable housing'. Housing affordability can be thought of as the cost of housing relative to income, so changing the numerator is not the only way to change housing affordability.

The usual assumption is that travel for individuals starts at the zone centroid, which is clearly an approximation. This is possibly an issue of the travel component, but also one that arises when considering the population zone. This approximation becomes less representative of all individuals as the population zone size increases (Pirie, 1979).

[7] An example of Simpson's paradox is accessibility declining when more people choose a slower mode such as PT.

2.3.1.7 Concluding comments on measuring accessibility

Levinson & Wu (2020) provide a summary of what the ideal measure of accessibility might look like and what good measure of accessibility is in practice at present. The two are not the same and it is not known whether this matters. For now it is important to:

- take into account the purpose of the study before choosing a measure of accessibility
- consider there are likely to be multiple accessible opportunities that will influence the locational choice of residence
- build in competition for opportunities for employment, but not for retail opportunities
- use generalised internal travel costs where possible, but there may be situations where full social travel costs or perceived travel costs have more influence on travel choices
- use the exponential impedance function as it fits neatly with logit choice models, with the impedance factor for work trips by car empirically shown to be near 0.08
- use time-averaged transit access where possible to explain mode choice behaviour rather than peak access
- be aware that accessibility is at times more sensitive to mode choice than distance to locations.

In addition, an accessibility measure is required to link affordable housing and employment outcomes. Abley & Halden (2013) list some of the general attributes required of such a measure. (See Geurs & Van Wee (2004) for a more extensive set of criteria).

- Consistency: if there is no real change in the system, the indicator should not change. If there is real change in the system, it should change.
- Ordinality: an improvement to the system should result in a change to the indicator in a particular direction. Further improvement should result in a greater change to the indicator in the same direction.
- Linearity: to be properly useful in looking at trade-offs in projects or knowing how much better one project is than another, the indicator must also be a linear measure. Linearity is required whenever indicators are to be combined. (We do not agree with this requirement as nonlinear measures can often be linearised, such as by taking logarithms. An issue may arise, however, if measures are not monotonic).
- Meaningfulness: units should be a meaningful measure of the system being described.

2.3.1.8 Evidence of accessibility effect

Many studies provide a measurement of accessibility using various definitions (see for example Litman, 2020) and the New Zealand measures mentioned above), but fewer studies show the effect of people having more or less accessibility. We consider some of these studies of effect in more detail below, both to show results and draw out methodological issues.

There are probably many reasons for fewer effect studies, but two in particular are relevant to this study. First, transport is a key component of accessibility in many situations and it has proven difficult to show transport effects on the economy. In a review of over 2,300 transport studies, Overman (2015) found only three high-quality OECD studies (these are discussed later) that showed positive effects on employment, productivity or income from road improvements. Overman (2015) found no such studies on the employment effect of rail, buses and active modes, but one study showed the effects of rail on a firm's productivity. Second, isolating the effects of transport – and accessibility more generally – is difficult due to the confounding influence of so many other factors, including the social reasons why people may choose to live where they do.

Hence of particular interest in the studies discussed in this chapter is how accessibility was measured, how account was taken of other factors and how the observed effect was tied back to theory.

A further issue is which benefits measured within accessibility studies can be used as additional benefits in standard welfare-based transport cost–benefit analysis (CBA) (Stead, 2019).

Agglomeration studies are similar to accessibility studies in that they both measure the density of employment around a point. A method has been established to append productivity improvements from agglomeration onto the standard transport CBA, for example Maré & Graham (2009), but it has not yet been determined whether or how employment improvements that result from bringing workers closer to their place of employment, as might be sought by improving accessibility, can be added to transport user benefits.

Likewise whenever a relationship between accessibility and house prices is found, it is possible, at least in theory, to capitalise any reduced transport costs in the house price, thus complicating the separation of user benefits already measured in a standard transport CBA and additional wider economic benefits as might be implied by higher house prices.

In short, whether or not certain types of accessibility benefits are additional to transport user benefits is still unresolved.

2.3.2 Accessibility and worker outcomes

Here we look at how accessibility to jobs affects labour market outcomes.

In models with a monocentric configuration where all employment is located in the city centre, house price differentials compensate workers for commuting costs. However, if jobs are spatially dispersed the compensation is unlikely to be 100%; some may manifest in wage compensation, although Timothy & Wheaton (2001) show that insofar as wages (for statistically equivalent workers) vary across different locations, only variation in average (not individual) commuting costs is capitalised into wages. Irrespective of the distribution of job locations, in a thin labour market where jobs are relatively scarce and search costs are relatively high, wage compensation for commuting costs is likely to be very low, implying more of the cost is transferred into house prices.

Imperfect compensation for commuting is also ascertained by Bartus (2011) in the context of Hungarian villages with persistently high unemployment.

However, Laird (2006) in a study of Scottish households found that compensation for commuting cost was entirely, although not fully, reflected in wage rates. Thus transport policy has little impact on wages, at least from the labour supply side. Demand side effects (such as via agglomeration benefits) are noted as possible, but could not be investigated.

Any such analysis needs to be cognisant of other confounding events. For example, Maré et al. (2009) show that exogenous labour market shocks (such as mass redundancies) simultaneously affect house prices and labour market outcomes.

Bastiaanssen et al. (2020) reviewed a large number of transport studies, including those within the Overman (2015) review, focusing on 33 studies that assessed the relationship between car or public transport job accessibility and employment probability. They also brought eight US studies together within two meta-analyses. They found a negative effect on employment probability of commute times (eg a 10-minute increase in commute time would have 0.14 times lower expected employment probability), with the effect greater for youth (16–25 years).

The Ihlanfeldt & Sjoquist (1990) study is representative of the method used within the eight US studies referred to above. The data was drawn from individual census records. The employment status of low-waged black and white youths was regressed, using a logit model, against individual characteristics (age, sex, education, health, marital status), and family characteristics (family income, household head occupation, sex, education level, employment status) and the average travel time by car. The study was confined to youth as the transport cost as a proportion of the low starting wage was likely to be high and their search costs were likely to be correlated with distance given heavy reliance on family and friends and direct non-referred job applications. The results were found to be insensitive to the use of other modes.

A more recent study, included in the Bastiaanssen et al. (2020) review, but not in their meta-analysis, is Andersson et al. (2018a). Their labour market outcome of interest is the duration of unemployment among lower-income workers in the Great Lakes metropolitan area (Chicago, Minneapolis-St Paul, Detroit etc). The study has four key features that enhance its reliability:

1 The data is longitudinal, following people for a period of nine quarters after job loss (and allows for the associated right censoring in the data).

2 It focuses on individuals who lost jobs due to mass lay-offs, which is a plausibly exogenous shock in the sense that the labour force outcome is not related to a previous choice of residential location. This mitigates the problem of endogeneity (job accessibility affecting choice of residential location) that exists in many cross-section studies.

3 The sample selection was also constrained to nine metropolitan areas believed to be broadly comparable, thus reducing the risk of bias due to heterogeneity.

4 The measure of job accessibility allows for the number of competing job searchers.

The motivation for the relationship between unemployment duration and accessibility was again job search costs, with the regression model specification derived from a model of job search costs. The log form of the accessibility variable so derived was replaced in the regression model by the proxy accessibility equation shown below, with the proxy creating a symmetric and bounded accessibility measure.

Individual employment status and personal characteristics were taken from matched employer–employee administration data. Average neighbourhood characteristics (poverty, home ownership, population density, building vintage and use of PT) were taken from census data and used as control variables. Employment accessibility for each individual was based on peak hour commute times by car and by PT, with an estimated probable mode share (based on individual income and census origin-destination modes) used to weight measures of job opportunities (*JO*) and competing searchers (*CS*). The measure of accessibility (A_{ijtm}) for person *i* living at location *j* at year *t* for an estimated mode mix (*m*) is as below.

$$A_{ijtm} = \frac{(JO_{ijtm} - CS_{ijtm})}{{}^{1}\!/_{2} \cdot (JO_{ijtm} + CS_{ijtm})} \qquad \text{Equation 2.3}$$

– where *i* is an individual

j is the location of residence of the individual

t is time (year)

m is mode mix.

JO were taken as the weighted number of jobs at nearby locations (as a proxy for vacancies). *CS* were calculated using a similar weighted measure of private sector lower-paid workers surrounding each workplace, further discounted by the *JO* that each alternative worker faced.

JO were calculated for car and PT travel by weighting local employment and worker numbers using an exponential impedance function (for commutes beyond 10 minutes) and then a composite *JO* measure was calculated using the average mode share for location *j*. A similar calculation was undertaken for *CS* except the mode share was assumed to be car only (due to lack of mode share data for competing searches). The elasticity parameter in the exponential impedance function (*α* above) was assumed to be 0.1, consistent with Shen (1998) and other previous similar studies.

The land component in these studies (as discussed above) has moved from being a discrete measure of employment to an accessibility measure that includes both the quantum of opportunities and an estimate of competition for jobs.

The results show that although demographic factors and job history are the main determinants of job search outcomes, better job accessibility significantly reduces the duration of joblessness among lower-paid workers. Andersson et al. (2018) found no relation between job accessibility and search duration for non-displaced workers who were searching for jobs.

Additionally, the accessibility effect is stronger among black people, women and secondary income earners in a household (who are frequently women), although some of the observed differences in the strength of the relationships could be attributed to varying suitability of the job accessibility measure.

Access to a car, which affects commute time, was also found to have a powerful effect in reducing the duration of unemployment. Stroombergen & Watt (2003) found a strong link between employment and access to private vehicles, even after allowing for endogeneity. Access to a car is likely to be particularly important for women in family households. Their household roles typically mean they are time-constrained, especially if the household's only vehicle is used by the main (male) earner.

The Anderson composite measure of travel cost provides a method to balance out mode share while also being able to assign a mode probability to individuals, but it is not clear whether this accurately measures accessibility (Levinson & Wu, 2020). As mentioned earlier, Bastiaanssen et al. (2020) also found the odds of employment among those individuals with access to a car was nearly 1.8 times higher than for those without car access, measured across 27 predominantly US studies, confirming the difference between mode costs.

Johnson et al. (2017) also quantified the difference between PT and car effects. A 1% point increase in car availability to individuals (say from 49% to 50%) was estimated to have the same employment effect as a 2.8% decrease in bus travel times to London, but requiring up to 6.3% to 8.8% lower times within the less densely populated rural and urban areas.

The above studies do not address accessibility that may be dependent on travel costs at any particular time of day. The studies also confirm that individual situations and characteristics matter, both in terms of the employment opportunity of interest and the people experiencing the employment disadvantage.

2.3.2.1 Evidence of exclusion effects (heterogeneity)

An issue typically associated with the employment opportunities for residents of affordable housing areas is social exclusion, which more generally is heterogeneity across housing areas.

Currie et al. (2010) found a strong relationship between wellbeing and social exclusion, based on surveys of over 500 stratified respondents in Melbourne, but the relationship between transport disadvantage and social exclusion was much weaker. In part this is likely to reflect the various dynamics at play.

There are some people who have to move away from the city centre due to rising house prices. This potentially means they put more reliance on transportation, including public transport if there is no car or insufficient private transport for all members of the household (Delbosc & Currie, 2011).

Conversely, where central city housing prices are not as prohibitive, some people will choose living towards the centre to avoid car ownership, including living with large numbers per household.

These opposite effects are likely to be captured in a general way in the hedonic house price models discussed below, but the studies viewed appeared not to explicitly consider a socio-economic disadvantage accessibility parameter. Even if such an interaction were considered, the wellbeing effect may not necessarily show in house prices. Put another way, transport improvements to areas with high concentrations of socio-economically disadvantaged households may not necessarily show as higher house prices (Olaru et al., 2017).

There are people who, for historical reasons, currently live in areas that are poorly serviced by public transport. Currie et al. (2010) reported that these areas have higher concentrations of socio-economically disadvantaged people. The latter may or may not be due to the former. As Lucas (2019) cautioned, social exclusion is a multi-faceted phenomenon of which accessibility is only one part.

2.3.3 Accessibility and residential location choice

Marchetti (1994) observed that in many countries, over varying historical periods and regardless of mode, travel time (particularly for commuting) tends to be confined to a maximum of about one hour per day. Hence cities are approximately 'one hour wide'. This phenomenon is sometimes described as the 'Marchetti wall'.

Thus there is a clear a priori indication that changes in accessibility affect the distance people are willing to travel between home and work.

In an early study using logit analysis, Weisbrod et al. (1980) found households do make significant trade-offs between transport services and other locational amenities as reflected in house prices. However, demographic and socio-economic factors were found to be more important in determining where people choose to live.

A small, but statistically significant effect of accessibility on the probability of moving residential locations is reported in Zondag & Pieters (2005). Again though, factors such as household age and income, neighbourhood amenities and dwelling attributes have more powerful effects. The study relates to the Netherlands which has a heavily regulated housing market and generally well-developed transport infrastructure. Both features can be expected to lower the measured sensitivity of residential location choice to changes in accessibility. Additionally, the long lag between a transport investment and changes in location makes it difficult to isolate the effects of other confounding factors.

Angel & Blei (2016) in a study of a number of US cities, found most workers do not move closer to their places of employment provided their workplaces are within an endurable commuting range (time or distance – the Marchetti wall), but they do move residential locations if the required commute is not endurable. Thus analysis that treats commute times/distances or number of jobs within some time or distance radius as exogenous, ignores the possibility that households may have moved, or may move in future, to be within an endurable commuting range. In addition, firms may also shift locations to be closer to where potential workers live.

In a study of Seattle, de Abreu e Silva & Goulias (2008) used a structural equation system to ascertain whether self-selection effects are responsible for the differences in travel behaviour across residents in different urban environments. That is, land-use patterns are related to socio-economic characteristics of household. Both of these variables affect commuting, mediated by long-term and short-term travel decisions (such as car ownership and number of trips respectively). In the reverse direction, travel behaviour affects land use. The results show that people with relatively less access to cars tend to locate their residence and search for employment in areas better served by public transport.

Clark et al. (2003) also looking at Seattle area, agree that reducing commuting distance is a factor in moving residential location, also noting that women commute shorter distances than men. Housing costs do not feature in the analysis. Of a similar nature, Molin & Timmermans (2003) found in a residential choice survey that satisfaction in a couple's housing choice allowed for longer commutes by the (higher earning) male.

This leads us naturally into the relationship between accessibility and house prices.

2.3.4 Accessibility and house prices

Debrezion et al. (2007) traced the emergence of accessibility as a factor in property values, starting from Von Thunen in 1863 explaining that differences in the value of farmland with similar fertility were due to accessibility to markets, through to Rosen in 1974 applying a hedonic model to property prices. Many studies have followed from Rosen, some of which are discussed below.

Diaz & Mclean (1999) summarise the results of a number of previous studies that investigated the effects of rail transit on property values in North America. In most cases proximity to rail is shown to have had positive impacts on property values – around 10%±5% for residential properties within 500 m or so of a station. The main reason for the effect was the increase in accessibility to areas of employment, retail activity and so on. Being in walking distance of a station has a larger effect than having car access to a station. Another effect is transmitted through potential development options that become more attractive at locations near train stations and bus stops.

Insensitivity of property prices to rail transit was also observed, as areas exist where such access is simply not valued by communities. Effects could be negative due to factors such as increased noise, traffic congestion and proximity to industrial establishments.

Similarly, Bowes & Ihlanfeldt (2001) in a study of Atlanta rapid transit also found generally positive effects on house prices, attributable to better access (especially for commuting) and to the attraction of retail development. They used hedonic modelling coupled with some auxiliary equations to include a vast array of potential explanatory variables, reflecting their criticism of many earlier studies as suffering from omitted variable bias.

Distance from the CBD and median neighbourhood income affects the strength of the influence of the explanatory variables – positive and negative. For example households that are very close to stations are more affected by negative externalities (crime and noise) than those somewhat further away who still benefit from enhanced transportation access, but do not incur the higher crime.

However, the house price premium for being close (but not too close) to a station is higher in high-income areas than in low-income areas, consistent with a higher opportunity cost of commuting time for residents of the former. Also, the price premium effect of distance to a station is greater further from the CBD, as time savings from rail transit are proportionately greater for longer distances.

Although the particular results may be specific to the Atlanta metropolitan area, the study demonstrates the importance of allowing for interaction effects in model specification. In another study of Atlanta, Bostic & Carpenter (2018) found spatial mismatch between housing and workforce development centres might be a problem for many Atlanta lower-income families. Good PT networks are mentioned as playing an important mitigation role, but the analysis is not econometric so there is no investigation of interaction effects.

Debrezion et al. (2007) provides a meta-analysis of some of the rail studies between 1974 and 2002. A finding of interest to this study was that the effects on property sectors can differ as commercial prices closer to stations are more affected than residential property prices. Stations closer to the CBD have a higher price impact (consistent with better access to large employment opportunities); the inclusion of accessibility by non-rail modes reduces the estimated rail price effect (showing that accessibility by any one mode is not necessarily a good determinant of prices) and bus rapid transit stations have a smaller property price effect than commuter train stations. The study also found similar effects in the studies that included demographic factors in the initial regression and those that did not, although it would be imprudent to infer this result more generally as the meta-analysis result is simply based on a dummy variable approach (demographic factors included or not). Also of interest, the underlying studies used a mix of distance, time and monetary costs to measure accessibility, but the meta-analysis was conducted in a manner that did not enable us to discern whether the method of measurement mattered.

In a similar vein to above, Armstrong & Rodríguez (2006) more recently employed a cross-section approach to show that residential property prices near four US municipalities (ie towns/suburbs) with commuter rail stations were higher than in three municipalities without. Accessibility was measured as both distance and drive time from the station.

Adair et al. (2010) employed a hedonic specification to explain house prices in Belfast. Accessibility is not a straight-line distance to the CBD as in many prior studies, but rather a gravity type model with generalised travel costs. Results generally echo those summarised by Henneberry (1998) in a review of the literature to date, that the impact of accessibility is low. As discussed above with respect to the Netherlands, it is possible that accessibility is less of an issue in cities with a good transport infrastructure and where most households have access to a vehicle. However, at a suburban level (as opposed to a city-wide level) the effect of accessibility on house prices is greater. The authors surmise that the size of the effect increases as the relevant market becomes more homogeneous. Along with the usual socio-economic factors they also mention religion as very pertinent to Belfast house prices, akin to the role of ethnicity in the early US literature discussed above.

A similar issue arises in Du & Mulley (2006) who applied a hedonic model of house prices to Newcastle and its environs. They found that PT travel time to a secondary school has a negative effect on house prices, as expected, but that car travel time to employment locations (using a gravity model type of specification) has a positive effect. That is, the closer the residence to larger employers by car, the lower the house price.

The authors described this result as being attributable to 'non-stationarity' (a term usually applied to time series data) in the sense that interaction with neighbourhood features can obscure the relationship between house prices and car access to employment. In other words there may well be employment-intensive areas in the wider Newcastle region that are not particularly desirable as residential areas. There is also the problem of endogeneity. The fact that someone has a car, generally made possible by having a job, means they may also be able to afford to live further away from such employment centres.

Overall the model seems to be poorly specified. On the plus side the estimation uses a form of weighted least squares to deal with spatial autocorrelation, but it is not clear what effect this has on the car-employment accessibility coefficient.

Du & Mulley (2006) were interested in the relationship between accessibility and house prices in the context of potential land value capture (LVC). Medda (2012) has a similar interest with the aim of using LVC to help recover the cost of transport investments, but such financing may run counter to achieving an equity benefit.

Iacono and Levinson (2016) in a study of the effect of accessibility on house sale prices in the Minneapolis-St Paul metropolitan area, compared the results from cross-section models with those from first difference (dynamic) models. Their key finding is that the latter models provide a much lower fit to the data and that most of the coefficients, including that for access to employment, are not statistically significant, although usually of the same sign as in the cross-section models.

A number of reasons for this are suggested, most notably that marginal effects differ from average effects in areas where transportation networks are well established, so incremental changes are unlikely to markedly alter broad measures of accessibility (as also mentioned above with respect to Amsterdam). That is, cross-section-based coefficients capture the effects of many historical investments which have significantly influenced city development patterns.

Another possible reason for the contrasting results is that the longitudinal data spans only five years which may be insufficient for a noticeable house price effect to materialise. Additionally, the models contain few variables that capture the effects of amenities and other neighbourhood characteristics, possibly leading to omitted variable bias that could be overstating the cross-section results.

Returning to the point about demographic influences and extending this to any non-accessibility factors, Olaru et al. (2017) looked at the effect of spatial autocorrelation within hedonic property price models, both on the estimated residential property price parameter and on the usefulness of models for policy use. They analysed residential property sale prices in two case studies – Perth and south-east Sydney – using a mix of local models, where parameters are estimated for each zone or submarket, and global models, where spatial autocorrelation is taken into account separately from the other parameters.

The 'local' models using multiple ordinary least squares (OLS) or the Casetti (1972) expansion method with different parameters for location coordinates within a single model, are relatively easy to compute but produce many parameters which at times are difficult to interpret or generalise. A generalised weighted regression method, which replaces the location coordinates with a weighted distance from a selected neighbourhood centroid, is more computationally demanding and also produces many local parameters which are difficult to interpret. In each local model it is important to identify the various homogeneous submarkets outside the model. The 'global' models, which incorporate any spatial autocorrelation more directly into the model, produce city-wide (or study zone-wide) parameter estimates for accessibility, house characteristics and neighbourhood socio-economic factors that are easier to interpret and also provide better fitting models, but the spatial correlation is often difficult to understand. In sum, the authors found different models suited different policy decisions. For example, the localised accessibility parameters when mapped, readily showed areas where improved transport would be more effective, whereas in studies of agglomeration the effects of co-location were more readily apparent with the global spatial models.

Different accessibility measures were used in each case study. In both cases the shortest distance to the CBD and to the nearest freeway were included. Other measures of accessibility differed between cities. Some of these were the shortest distance to the CBD, shops, hospitals, schools, universities, parks, rivers/ocean and train stations, but also activities that were likely to have a negative effect on accessibility such as airports or water treatment plants. Further measures included the quickest bus times to the closest shopping, employment and commercial centres. All accessibility measures were unweighted in the sense that the size of the accessible opportunity was not taken into account.

Socio-demographic factors, such as the local district average for household income, employment, cars, size, social-economic disadvantage, economic resources and population density were also included in the house price model. Generally the socio-economic measures were found to affect house prices.

The third set of factors in the models were property characteristics such as the number of bedrooms, bathrooms, property area and access to parking. The importance of these characteristics differed between the two case studies, eg parking access being important in Sydney but not in Perth. This is most likely due to the ready availability of street parking in Perth suburbs.

In a comprehensive report, Nellthorp et al. (2019) investigated the relationship between transport and property values in the north of England using a cross-section hedonic model. As above, house prices were regressed against property characteristics, zone characteristics (only household income was used as a socio-economic variable due to high correlation with other factors, but local tourist numbers and crime rates were also used as potential measures of vibrancy and safety), accessibility measures (to employment, schools, greenspace and town centres) and several neighbourhood housing supply-demand factors (eg the number of house sales per houses listed for sale). Travel impedance was measured with adjusted exponential functions fitted to different travel patterns, using generalised journey costs. Accessibility was calculated for car (at peak), rail (unchanged during day and including ingress and egress and delay/crowding costs) and walking (assume 4.8 km/h) modes. The authors found that global spatial models and a geographically weighted regression model improved the OLS estimates but did not improve their policy relevance. Interestingly the authors did not use competing searchers in their measures of accessibility.

The main finding from the cross-section model was that for every additional 10,000 jobs accessible from a home location, there was a property price premium of 0.16% for rail and 0.19% for car, but the effects varied between low and high-income areas. The effect of walk accessibility to employment was even more powerful at 3.6% (bus access is the zero base). However, after allowing for spatial autocorrelation the car effect rose while the effect for rail and walking declined.

The core cross-section analysis was complemented with a study of a new metro link in the greater Manchester area using panel data, which permitted controlling for the effects of unobserved time-invariant heterogeneity of areas (eg historical employer links, topography) on property prices. In general the panel model showed slightly larger effects for accessibility to rail than the cross-section models, but the effect varied by rail corridor.

In another UK study, Gibbons & Machin (2008) discuss the difficulties in regressing house prices against housing and locational attributes. They also refer to their earlier London study that showed a 1% to 4% decrease in house prices for each 1 km increase in distance between home and rail station.

In two papers related to New Zealand, Grimes & Liang (2008) and Grimes & Young (2010) found relative land values rose for land close to the exits for a motorway extension, and house values increased in areas located near stations on an upgraded passenger rail line – before the project was completed, but after its announcement. For the hedonic approach, the only example we have found applied to New Zealand data is by Donovan & Munro (2013) who used it to estimate land values in the context of potential agglomeration economies.

The above-mentioned house price studies largely consist of regressing house prices against a set of explanatory variables, including some measure of accessibility. An alternative approach is to question people about the contribution made by various housing and location attributes when choosing to buy or rent a house. Quigley (1985) in a Pittsburgh survey of 584 recent movers into rental accommodation, inferred a willingness to pay extra rent equivalent to 62% of the average wage to save one hour of commuting time per month. A challenging housing issue noted in a review of choice model analysis of housing by Van De Vyvere (1994) is pertinent to all housing studies: housing markets can be very segmented, housing markets (where prices are observed) can be relatively thin and people make complex choices typically in a constrained environment.

2.3.5 Accessibility and business location

As with residential location, firms consider factors such as land prices (rents), accessibility to labour and agglomeration economies in location decisions. Timothy and Wheaton (2001) noted that firm mobility should eventually equalise wages across locations unless agglomeration economies existed to sustain the differences.

Diaz & Mclean (1999) found that prices for commercial and industrial land rose with access to rail transit, especially for the former as offices tend to cluster in dense concentrations with a correspondingly wider labour supply pool.

Focusing on agglomeration, Duranton & Overman (2005; 2008) found that in the UK, industries clustered together, relative to the general clustering that occurs in population centres (sometimes known as urbanisation effects). Their methodology was entirely statistical in that it determined the probability of clustering relative to randomly generated locations (computing the density of bilateral distances between all pairs of establishments in an industry). Such clustering or 'localisation' was observed among many industry groups at the 4-digit and 3-digit level of industry classification. The reasons for localisation were not explored. There could be external effects such as access to a labour pool or there could be natural endowments.

Two other possible reasons for localisation are transport accessibility and agglomeration benefits. These, along with other possible determinants of firms' location decisions are examined in Alañón-Pardo & Arauzo-Carod (2013) using a sample of firms at the Spanish municipality level, in 10 industries. Their results show agglomeration economies and road accessibility are important in industrial location decision making.

Accessibility effects are positive, which may be as expected given that greater accessibility enlarges the home market and the geographic scope of agglomeration economies. However, that process dilutes the benefits of agglomeration, so the sign on the coefficients is not necessarily obvious a priori. Greater accessibility to labour can also bid up wages, land prices or lead to increased congestion. These possibly confounding effects are addressed through using instrumental variables.

Nellthorp et al. (2019) used a hedonic model to assess how commercial property prices (asking rents) were affected by building characteristics, place quality and accessibility. The study area encompassed the UK areas of Leeds and Bradford. Accessibility has two measures, one for agglomeration and one for proximity to a workforce. The results suggested there was a premium for good accessibility in the commercial sector with regard to both measures, but that it was difficult to isolate their separate effects as firms desire locations close to other firms (walking access) and locations close to a railway station as a 'source' of workers – these measures are correlated.

Overall it seems that accessibility to labour (and suppliers and customers) are more important to business than households in decisions about location. Households face many competing objectives when choosing where to locate. Access to employment is only one factor in utility maximisation for households and individuals.

2.4 Links to policy

As with the many ways of measuring accessibility, there are many ways that accessibility can enter into policy. The key policy channels reflect the research into measuring the effects of accessibility, namely around issues of equity and general improvements in productivity.

From a narrow perspective, transport policies can be thought of as concerning issues of vehicles and journeys and the infrastructure that enables this movement. Bringing in an accessibility perspective widens the focus to the people undertaking activities across space and time. This wider perspective makes more evident, and more important, the interplay between the transport issues above and non-transport matters such as evolving land-use changes, developing people capabilities and changing connections between people and places (Litman, 2020).

Angel & Blei (2016) show that because larger cities tend to be denser than smaller ones, they are also more productive, leading to two broad policy implications:

1 With regard to transport, policies should increase overall regional connectivity by promoting metropolitan-wide commuting that is efficient – that is, faster and more convenient.

2 For land use, policies should reduce barriers to the locational mobility of workers residences and workplaces, to further enhance accessibility.

A discussion follows based around examples of policy applications in the UK, one of the countries that Chapman & Weir (2008) identified as having explicitly integrated accessibility into their transport policies, with particular attention to the areas of legislation, strategy, measurement, evaluation and intervention. This is followed by some selected examples for other countries. That is not to say that countries not mentioned are not paying attention to accessibility but it is more likely, to paraphrase a comment made to a UK researcher, 'something that we have always done but had not formalised'.

Nor does it mean that non-transport policies should be ignored. For instance, Zhou et al (2016) recommend corridors of jobs and housing to minimise suburb to centre commuting. Housing policies are another example, but illustrating the difficulty of evaluating such measures, Stacy et al. (2020) observed that spatial mismatch was worse for households that received vouchers than for similar households that did not. The complication is that the former group have a particularly limited choice of locations, so the vouchers could still be having a beneficial effect, just not sufficient to offset the initial relative disadvantage. This sort of problem is common in cross-section studies.

2.4.1 Accessibility in UK transport policy

Regulation. Consideration of accessibility is one requirement of road authority land transport plans, initially required every five years but now as desired. The Greater London Authority took this one step further and embedded an accessibility measure, see public transport access level (PTAL) below, into their statutory 25-year London Plan (Inayathusein & Cooper, 2018). The Equality Act 2010 also shapes transport plans via its provisions relating to disabled people and the public sector equality duty, which includes 'to promote equality of opportunity'[8].

Strategy. Accessibility was entered explicitly into the planning process of UK local transport authorities, whereby accessibility baselines, objectives and programmes were to be included in land transport plans (Chapman and Weir, 2008). It is not clear whether requirements are still as explicit. For example, the current West Yorkshire Combined Authority Transport Strategy (2040), provided to meet their statutory requirements, makes much mention of 'access' but does not explicitly provide an accessibility measure or objective; likewise the Transport for the North (TfN) 2019 Strategic Transport Plan.

Nonetheless, measures of accessibility are being used to shape transport programmes and also influence land use. The aforementioned Nellthorp et al. (2019) study was part of investigations by West Yorkshire and TfN into rail needs in the region. In London, measures of accessibility are used to investigate ways the London Mayor's Transport Strategy (2017) objectives of higher PT, active and sustainable mode shares can be achieved. London also uses the PTAL measure to prioritise locations for higher-density employment and housing (Inayathusein and Cooper, 2018).

From a national perspective, there have also been recent Department for Transport (DfT) reports on transport and impairment and transport and inequality that include accessibility measures and which will be shaping local policy makers' thinking.

Measurement. For a time the DfT was producing accessibility measures based on fastest travel time for lower layer super output areas, zones of around 1,500 people, for seven services (primary school, secondary school, further education, employment, hospital, doctor, food stores), three modes (PT, car, cycle) and

[8] https://jimbyrne.co.uk/public-sector-equality-duty-summary/

various population segments (including age and an Index of Multiple Deprivation) (DfT, 2014) but this data[9] is no longer current.

Transport for London (TfL), the transport arm of Greater London, provides several accessibility measures. The statutory required PTAL, strictly speaking a connectivity measure, creates an index based on the notional frequency of PT services at any one location during the 8.15 to 9.15 AM peak, taking into account modes, frequency of stops and walking distance to nearest stops. The measure largely relates to transportation as it takes no account of user requirements or the scale of the opportunity that can be accessed by the most frequent PT service, but it is claimed to be good proxy for access to services and jobs, based on comparison of PTAL results with more sophisticated (and discontinued) accessibility measures. TfL also calculates and makes available other accessibility measures through its web-based WebCat[10]. These provide isochrone measures of employment and populations, with some segmentation, for user-selected locations at three times per day and three travel modes (but not car) for now and future years, with the underlying data provided by a London transport model that is updated every few years. It is freely available to local planners, developers and whoever wishes to investigate accessibility for locations within London, including staff within TfL when planning and assessing London transport projects (Inayathusein & Cooper, 2018).

Evaluation. Accessibility measures are not formally required in transport evaluations, but could be used in evidence to support benefit estimates for agglomeration, employment and social distribution effects. This is likely to be the case with the Nellthorp et al. (2019) report, which forms part of a business case for a northern rail project. The approach to evaluation taken by the DfT is that if measured ideally the transport users' welfare benefits, as measured using standard transport appraisal methods and utilities derived from accessibility models, will provide alternative ways of measuring the same quantum of benefit. That is, adding user benefits and accessibility benefits together would represent double counting (Stead, 2019). However, neither method is applied ideally so DfT allows opportunity for business case writers to provide an evidence-based case that benefits derived from accessibility measures are additional to benefits derived from travel cost savings.

The other major use – the primary use – of accessibility measures in evaluation is to assess the distributional impact of transport interventions through the application of DfT TAG 4.2 methods[11], giving effect to linking transport interventions back to social inclusion requirements. The DfT has a mandatory requirement that the distribution effects of any transport intervention (that it has approved) are included in an appraisal. From the accessibility perspective the focus is on PT interventions. The first step is to screen who might be affected differently, including possibly children, older people, people with a disability, black and minority ethnic communities, people without access to a car and people on low incomes (although the people affected initially might not be those affected later). If the screening step points to the likelihood of significant effects on vulnerable people, a fuller impact analysis is required to identify the changes in access to opportunities. The guide specifically mentions use of catchment time bands so it is not clear whether gravity-type measures are also acceptable. Changes in accessibility measures for each opportunity are converted to an accessibility score, using a mapping provided by the DfT (eg >+16% change = 'large beneficial'). Note, a separate method (Tag 4.2) pertaining to accessibility for people with a disability is also required for access on/off parts of the PT network.

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[9] https://www.gov.uk/government/statistical-data-sets/acs04-travel-time-destination-and-origin-indicators-to-key-sites-and-services-by-local-authority

[10] https://tfl.gov.uk/info-for/urban-planning-and-construction/planning-with-webcat/webcat

[11] https://www.gov.uk/guidance/transport-analysis-guidance-webtag

Intervention. Kilby & Smith (2012) have grouped UK initiatives to address accessibility into four types. There have been generic localised improvements, such as providing more PT services and active mode infrastructure. There have been trigger interventions, typically of a one-off and personalised nature, which have involved working with groups (eg job seekers, disabled) to improve their access using the existing transport system. Then there have been targeted transport interventions of a more general and longer-term nature focused on groups (eg PT subsidies for older people or students). Last, there are also interventions where the service has been brought to the population, such as mobile medical clinics, rather than the transport link changed.

One recent DfT observation of interest is that targeted PT subsidies are recommended, but unlike students and older people, it is not always easy to identify the target groups (Gates et al., 2019).

Lucas (2019) points to some shortcomings of the UK approach: there are no standards set for accessibility; analysis is usually only undertaken for major new projects; local accessibility deficits are not assessed; land use is largely not controlled on the basis of accessibility; and service closures, either transport or land use, are not being assessed for accessibility impact. Lucas has also provided examples of where accessibility measures have been used to assess distributional impacts but does caution that outputs provided from GIS models can be difficult for policy-makers to interpret.

2.4.2 Accessibility in transport policy elsewhere

Litman (2020) provides a cross section of the type of interventions that can be used to improve accessibility. Some examples of how accessibility measures are used outside the UK follow.

The Netherlands' ABC Planning Policy has been quoted as an example of accessibility policies in action (Chapman & Weir, 2008). Areas are rated (A, B, C or R) as suitable for development on the basis of the area's balance of public transport and private vehicle access (Baht & Handy, 2000). However, the type of accessibility measures discussed in this report are not part of that process and the rating does not apply to residential areas[12].

Otherwise, transport is managed in the Netherlands on a similar basis to elsewhere, based around multi-year transport plans. These lead to national and regional collaboration on the competitive strength, accessibility and liveability of the Netherlands (Ministerie van Infrastructuur en Waterstaat, 2018), including adaptive solutions. However, the models and indicators used do not include the accessibility measures described in section 2.4.1, although research into their application continues. There are no accessibility measures being explicitly used for performance assessment at present. National and regional transport policy and planning processes rely on infrastructure-based measures such as congestion, travel speeds, travel time reliability and service levels. The use of an accessibility measure within a national land use/transport interaction (LUTI) model has been explored and has shown how modest land-use changes can have significant effects, but Geurs (2018) states it is not (at least at the time) being applied in a policy setting. Social CBA is used, as it is widely elsewhere.

The US has an evolving use of accessibility within policy. Proffitt et al. (2019) point to accessibility being a common goal stated in regional transport plans, but go on to find that only a few plans define accessibility and the vast majority of plans employ accessibility in the limited sense of 'access to mobility', often justified as a means to reduce congestion.

As an example of one agency that has operationalised accessibility, the Virginia Department of Transportation (not included in the Proffitt et al. 2019 survey), has acted in several ways (Sundquist et al.,

[12] https://p2infohouse.org/ref/24/23345.htm

2017). At a statutory level, a smart scale system requires prioritising transport projects on several objective criteria, including accessibility as one of six criteria at present[13]. The calculation of accessibility scores for jobs, jobs for disadvantaged persons and multi-modal choices is contracted out to Citilabs, who also provide similar information to other US states and commonwealths. The web-based software enables some user customisation of the opportunities and modes and the weighting to apply to each in any composite measure. The accessibility measures in Virginia (but not in all other states) are available for current and future periods, where projections are derived from transport demand models.

One aspect of interest in the application of accessibility measures is Virginia's experience with walking times within the travel component. They have found it is not the actual walk time that is acting as an impedance but also the environment that people are walking in. Thus some adjustment is required to walking time to more accurately measure the potential for actual access. Another practical aspect is the need when considering actual project interventions to examine accessibility in a finer level of detail than might be possible with the global accessibility tool being initially used.

2.4.3 Accessibility in New Zealand transport policy

The (limited) use of accessibility measures is similar in New Zealand to overseas. In Auckland, the ATAP has set an objective to 'improve access to employment and labour' (ATAP, 2016) and has established the 30-minute drive and 45-minute PT accessible job totals as key performance indicators (KPIs). Another KPI is 'accessibility from high deprivation areas', used to monitor a social exclusion and equity outcome, although both the KPI and the outcome are not explicitly defined (although this could potentially be done using the NZ Index of Deprivation[14]). The employment accessibility measures have been used to inform the strategic planning of Auckland transport projects but the main evaluation remains the standard analysis of mobility.

More recently the Government Policy Statement on land transport (GPS) has set three measures of accessibility as indicators for the strategy of 'Providing people with better travel options to access places for earning, learning and participating in society', namely (a) access to jobs, (b) access to essential services (ie shopping, education and health facilities) and (c) percentage of the population with access to frequent public transport services.

2.5 Summary

Figure 2.1 presents a schematic summary of main streams of work on spatial mismatch discussed above.

Studies relating to the selection of residential location are usually based on some form of choice modelling, such as multinomial logit models. Accessibility (notably job accessibility) is generally found to be statistically significant, but in most studies other factors such as household structure and neighbourhood effects are more significant.

The effects of accessibility on property prices are usually analysed with cross-sectional hedonic models of the service provided by housing. Apart from accessibility, other explanatory variables typically include a collection of individual, household and locational attributes. Again the accessibility measures are usually statistically significant, but often not especially powerful. In these models spatial correlation and endogeneity can distort results.

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[13] https://www.citilabs.com/citilabs_blog/citilabs-sugar-access-enables-transportation-project-scoring-virginia/

[14] A New Zealand Index of Deprivation derived from nine measures is available for New Zealand meshblocks by census at https://ehinz.ac.nz/indicators/population-vulnerability/socioeconomic-deprivation-profile/

The other way to look at the relationship between property prices and accessibility is to use time series data in which the timing of investment in transport infrastructure can be simulated, such as by using dummy variables. Generally the measured effects of accessibility are lower than found in cross-section studies, a result attributed to better treatment of endogeneity as cross-section data contains the effects of all sorts of past transport investments and locational choices. Amelioration of measured effects may also be due to insufficient time for land-use and housing markets to respond to changes in accessibility.

Another tranche of studies relates to the effects of accessibility on labour market outcomes, work status and earnings. These studies illustrate the importance of heterogeneity in job opportunities and worker skills and show that differences in commuting costs can manifest in wage rates, not just in property prices.

The main findings from the literature are:

- In studies of residential location, job accessibility is generally found to be statistically significant, but in most cases other factors such as household structure and neighbourhood effects are more significant. In the US, racial segregation is a major driver of job accessibility.
- Accessibility is also shown to affect property prices, but again individual, household and locational attributes tend to dominate.
- Generally the measured effects of accessibility in longitudinal studies are lower than those found in cross-section studies, a result attributed to better treatment of endogeneity as cross-section data contains the effects of all sorts of past transport investments and locational choices.
- Studies of the effects of accessibility on labour market outcomes, work status and earnings illustrate the importance of heterogeneity in job opportunities and worker skills and show that differences in commuting costs can manifest in wage rates, not just in property prices.
- Spatial mismatch is affected by other factors such as industry, gender, skills and occupation.
- The main moderator of accessibility is the road network for private vehicles. However, public transport can also have a significant role, especially in low-priced housing areas.

2.6 Lessons

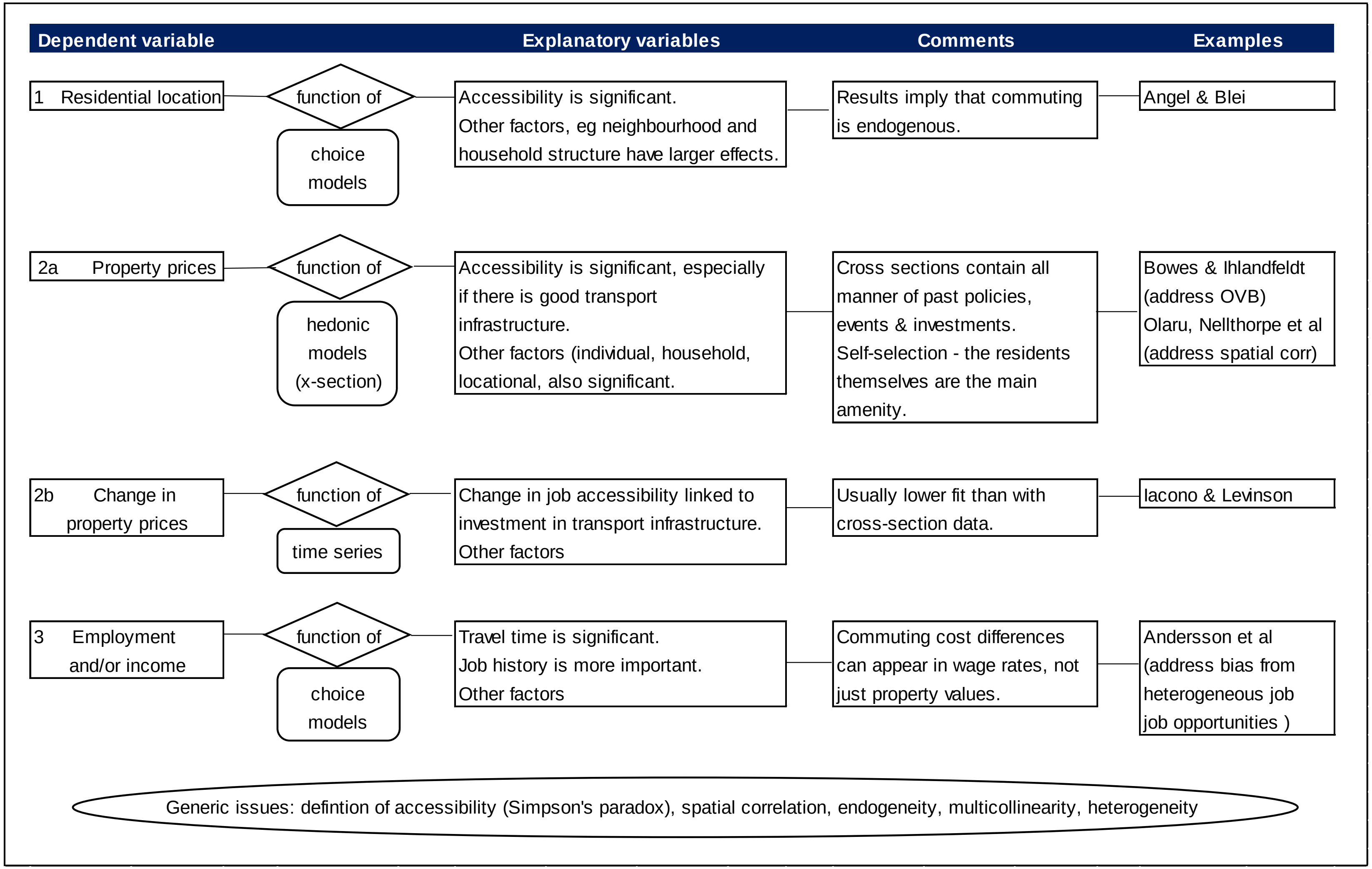
In drawing out main lessons from the above we should be mindful of an interesting result from a very different perspective on spatial mismatch taken by Morris & Zhou (2018). Using data from the American Time Use Survey they analysed the relationship between commuting and subjective wellbeing. Their key finding was that no association existed between wellbeing and commute duration. In other words, there may be spatial mismatch in a purely geographic sense, but under the hypothesis of utility maximisation people are balancing the costs of longer commuting with the benefits it delivers, which they demonstrate include higher wages and higher rates of home ownership – even after controlling for income. An alternative explanation is that the costs and benefits of commuting are relatively minor factors within the overall wellbeing regimen – job satisfaction, family life, health, the local environment and so on. It is also possible the measure of subjective wellbeing is not sufficiently nuanced to pick up negative effects of commuting such as exposure to air pollution and higher blood pressure.

What have we learnt from the above review of literature that helps us answer the original questions?

- Accessibility measures for New Zealand exist already, but most are derived in a simplistic fashion and may not inform the potential for improved income outcomes from any transport intervention – this is to be investigated.

- Accessibility includes the search costs associated with obtaining information about jobs and the costs of commuting.
- A hedonic approach can be used to estimate the effect of accessibility on housing costs, commuting costs and labour market outcomes, but endogeneity and spatial correlation are potential econometric issues.
- House prices (and wage rates) respond to changes in accessibility, so the beneficiaries of an intervention may not be those to whom the intervention was targeted.
- Policy interventions to date that have applied measures of accessibility have largely been used to help identify where transport interventions would be of more benefit or to understand equity effects. Standard CBA or MCA analysis is then applied as usual.

Figure 2.1 Schematic of literature on spatial mismatch



2.7 Next steps

Two of the key findings in the literature were that house prices, travel costs and job accessibility are linked and any relationship may differ for different industries and skill sets.

This research study sought to explore these relationships for New Zealand over recent years by analysing levels and changes in proxies for these variables. Two data sets were available that provide appropriate information, namely the census data for 2006, 2013 and 2018 and the IDI spanning the period 2005 to 2017. These data sets enable analysis below a suburb level for different periods and over a 12 to 13-year period, with segmentation by people skills and industry sector.

However, there is one major shortcoming of this approach (or any approach relying on a time series of more than several years). There are no readily available accessibility series that can be modelled with the other data; hence this research project had to calculate accessibility measures. To enable an analysis in the time frame and budget available the analysis proceeded using a distance-weighted employment accessibility measure, judged to be an index that would capture the key trends, but unfortunately one that would also miss many intricacies. This remains a matter for further research.

However, it was possible to also calculate and test a job surplus accessibility measure that takes into account the competition for jobs from the job opportunities calculated within this project.

We have reported both the gross and surplus measures of job opportunities in natural log terms, primarily because the relationship between accessibility and the other variables is linear after this transformation.

The literature generally refers to a relationship existing between house prices and accessibility plus other factors. Again a data series for house prices was not readily available that matched the time and area covered by other data series, but the census data does enable the calculation of a comparable series of rents. We have used this rent series as a proxy for house prices in this project.

A further practical choice was to primarily study the relationships within four major New Zealand urban areas. Analysis at an urban area level enabled locational differences to be more readily identified and modelled while the four centres were judged to provide a cross section of experiences. Auckland is New Zealand's largest city and has grown very quickly, including within existing and newly developed areas. Both the population and the number of employees within the region increased by 20% between 2006 and 2018. Wellington is the third largest city and the nation's capital. Note Christchurch, the second largest city, was not chosen for analysis due to the disruptions of major earthquakes. The Dunedin urban area in the South Island, and the combined Napier and Hastings urban area complete the selection. All three areas experienced more moderate population and employment growth than Auckland.

The following two chapters are devoted to the two major analyses. Chapter 3 combines a hedonic pricing model that was developed by the project team to test the interplay between house prices, wages and job accessibility with data from the last three censuses in New Zealand. Chapter 4 analyses how the relationship between job accessibility and commuting has evolved over the period 2005 to 2017, with specific account of differences for people of different skills.

The analysis section of the report concludes by discussing the transport implications of these two studies.

3 The impacts of accessibility – census analysis

3.1 Introduction

In this chapter, we examine the impacts of accessibility on labour and housing markets in four New Zealand urban areas, using data from New Zealand censuses of population and dwellings. As a first step, we defined a measure of accessibility that incorporated the density of local employment as well as the extent of competition for local jobs. We then examined whether accessibility had an effect on the housing costs of employed residents and on the wages they received. If there was a problem of spatial mismatch due to poor transport infrastructure or discrimination, low accessibility would be associated with long commutes, low wages, high rents and poor employment prospects. However, if accessibility was merely a desirable feature ('local amenity') of a local area, we would expect residents to pay higher rents and accept higher wages in areas of *high* accessibility. Furthermore, if accessibility was a positive amenity, policies to increase accessibility might have an unintended effect of reducing housing affordability, by raising rents and lowering wages. To investigate these issues, we estimated a model of how wages and housing costs were related. Of course, spatial mismatch might also reduce the probability of being employed at all or increase the length of time residents took to find employment after job loss. We therefore also estimated the relationship of accessibility with employment rates and non-employment durations.

In addition to our examination of overall patterns, we looked at whether accessibility effects varied for subgroups of residents (by gender and qualification level). We also investigated heterogeneous patterns further – see chapter 4.

A persistent theme in the literature is an interaction between accessibility, house prices and wages. This chapter sets out a model for New Zealand that considers this relationship over recent years. The information derived from this model can inform the potential role for transport intervention. The chapter proceeds by describing the data and detailing the hedonic pricing model to be used to explore relationships and then applying the model to data from four New Zealand urban centres, chosen as a cross section of large New Zealand urban areas.

3.2 Data description

For the analysis presented here we used unit-record census data from the 2006, 2013 and 2018 New Zealand censuses of population and dwellings, with geographic coding based on 2013 meshblock boundaries.[15] We used data on the usually resident adult population (15 years and over). The measurement of local job accessibility and local exposure to excess labour demand was based on people who were classified as full-time or part-time employed at the time of the census. Records with imputed information for labour force status, workplace address or residential address have not been used. For some employed usual residents, workplace location was not available at meshblock level. We reweighted the observations for which we knew the residence and workplace meshblocks, so the sum of weights in each meshblock matched the number of employed residents in the meshblock (including imputed records).

Data on unemployment duration was obtained from the Statistics NZ Integrated Data Infrastructure (IDI). The labour tables documented in Fabling and Maré (2015) were used to identify all jobs ending in March 2013

[15] Meshblocks are the finest level of geographic coding available in the census data. At the time of starting this project, consistent coding of all censuses to 2018 meshblock boundaries was not available. More recently, Statistics NZ has provided updated (2018) meshblock coding for 2006 to 2018 censuses.

and 2018 (the same months as the censuses). We linked these to census data within the IDI to provide relevant demographic information. Census data for 2006 was not available in the IDI, and so was excluded from the unemployment duration analysis. For each job end, we identified the number of subsequent months each individual was without any employment.

3.3 Empirical approach

This section provides technical details of how we measured accessibility (section 3.3.1) and derived an economic model of accessibility as a local amenity (section 3.3.2). It also documents our approach to estimating the relationships between accessibility and the housing (housing costs) and labour markets (wages, employment and non-employment duration). Readers who are interested primarily in the empirical findings may wish to skip this section and continue reading from section 3.4, where we describe the study areas.

3.3.1 Measurement: net job accessibility

We used two main measures to capture job accessibility for each meshblock 'job opportunities' (JO_m) and 'exposure to job surplus' ($\bar{X}_m$). The job opportunities measure captured the number of jobs that could be accessed from a residential location, with more distant jobs being given a reduced weight. Exposure to job surplus captured the extent to which there was competition from workers in other areas for the same jobs. Multiplying these two variables provided a measure of new job accessibility.

Equation 3.1 provides an expression for job opportunities *(JO).* The subscript *j* is used to refer to workplace (job) locations and the subscript *h* refers to residential (home) locations. E_j is the number of jobs in workplace *j*, and $g(dist_{hj})$ is a function of the distance between residential and workplace meshblocks. The form of this weighting function is discussed further below.

$$\text{Job Opportunities by residential area } h$$

$$JO_h = \sum_j g(dist_{hj})E_j = W_h[E] \qquad \text{(Equation 3.1)}$$

To measure competition for job opportunities, we first calculated the effective supply of workers to each workplace, adjusting for distance using the same distance weighting function as used to calculated job opportunities. N_h is the number of employed residents in residential area *h*, and each resident was assumed to supply a distance-weighted fraction of labour to each of the job opportunities they could access.

$$\text{Total supply to workplace area } j$$

$$S_j = \sum_h N_h \frac{g(dist_{hj})E_j}{JO_h} = W_j\left[N_h \frac{E_j}{W_h[E]}\right] \qquad \text{(Equation 3.2)}$$

Each workplace area offered a fixed number of jobs, which might differ from the amount of effective labour supplied. We measured the surplus of jobs relative to supply as an index that ranged from -2 (positive supply to an area with no jobs) to 2 (jobs with no effective supply)[16].

[16] This index was popularised by Davis et al. (1998). It is monotonically related to the ratio (*r*=E_j/S_j): $JS_j = 2\left(\frac{r-1}{r+1}\right)$ and has the advantage that it is not unduly affected by small (or zero) values for S_j.

$$Job\ surplus\ at\ workplace\ area\ j \qquad \text{(Equation 3.3)}$$

$$JS_j = \frac{(E_j - S_j)}{\frac{(E_j + S_j)}{2}}$$

The mean exposure of workers in each residential area to job surplus is the weighted average job surplus across all their job opportunities.

$$Mean\ exposure\ to\ Job\ surplus\ for\ residents\ of\ area\ h \qquad \text{(Equation 3.4)}$$

$$EJS_h = \sum_j g(dist_{hj}) \frac{E_j}{JO_h} JS_j^i = W_h \left[JS_j^i \frac{E_j}{W_h[E]} \right]$$

Our focal measure of job accessibility summarises the number of job opportunities each worker faced and the degree of competition they faced from other jobseekers. We normalised the contribution of EJS_h to accessibility to be zero when the job surplus was zero, ie when the number of jobs matched the number of competing jobseekers. With this normalisation, accessibility has been captured by the following expression:

$$Accessibility\ for\ residents\ in\ h \qquad \text{(Equation 3.5)}$$

$$A_h = JO_h * (1 + EJS_h)$$

$$\ln A_h = \ln JO_h + EJS_h$$

3.3.1.1 Choice of weighting matrix

A key choice when estimating job opportunities and job accessibility is the choice of a distance weighting function ($g(dist_{rw})$), as per section 2.3.1 of literature review. The weighting function captures the fact that more distant jobs are less accessible, but the strength of distance decay is unknown. The weighting function we used for our main analysis is a modified exponential decay function, as described below. Exponential decay assigns a weight of 1 to a distance of zero, and then imposes a proportional drop in the weight with every km of distance. A single parameter (γ) captures how rapidly the weight drops. Equation 3.6 gives the formula for an exponential decay, and Figure 3.1 illustrates the exponential weight function, with parameters of 0.1 and 0.2. With $\gamma = 0.1$, the weight fell to half after about 7 km; with $\gamma = 0.2$, the weight halved after about 3.5 km.

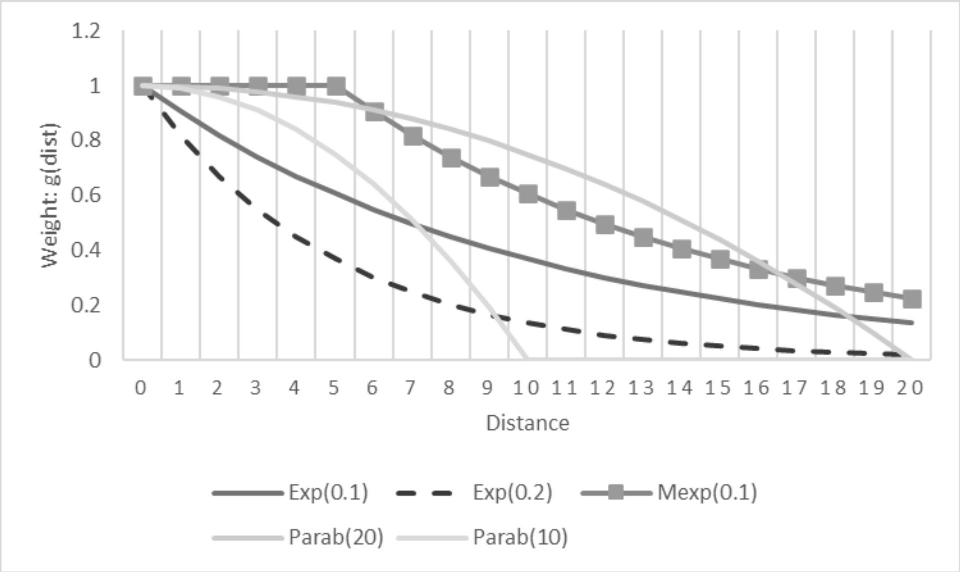
$$g^{Exp}(dist_{hj}; \gamma) = \exp(-\gamma\ dist_{hj}) \qquad \text{(Equation 3.6)}$$

The modified exponential weighting function imposes a flat range at low distances, over which all potential commutes are equally weighted with a weight of one. This captures the idea that within a relatively short distance, all jobs are regarded as equally accessible. Andersson et al (2018b) adopted this form of weighting, applied to travel time, with a weight of one for all commutes of less than 10 minutes, beyond which there is exponential decay with a parameter of 0.1. In our application, we imposed a weight of one for distances of less than 5 km ($\delta = 5$), with a decay parameter of 0.1 ($\gamma = 0.1$)[17]. The weighting formula is shown below as equation 3.7 and is illustrated in Figure 3.1.

$$g^{Mexp}(dist_{hj}; \gamma, \delta) = \exp(-\gamma \max(0, dist_{hj} - \delta)) \qquad \text{(Equation 3.7)}$$

[17] The parameter values were chosen to approximate Andersson et al.'s specification. As outlined in Appendix A, the resulting weighting function roughly matches the observed distribution of commuting distances for Auckland. Where workers work and live within the same meshblock, we approximated travel distance based on the land area of the meshblock (A_m), using the approximation $dist_{mm} = \sqrt{A_m/\pi}$.

Figure 3.1 Alternative distance decay kernels



The final form of the weighting function that we considered is a parabolic function that imposes an outer limit for accessibility, beyond which jobs are assigned a weight of zero. Using a (downward-concave[18]) parabolic function creates a relatively flat portion at lower distances and declines increasingly rapidly as the imposed outer limit is approached. The weight remains above 0.5 for distances up to 70% of the imposed outer limit. The equation is shown as equation 3.8 and illustrated in Figure 3.1 using parameter values of $\gamma = 2$ and outer limits (*k*) of 10 km and 20 km. One of the attractions of using a fixed outer limit was computational – potential commutes beyond the limit could be ignored, but the function did not approximate the commuting density very well. We considered it mainly to provide an indication of the sensitivity of accessibility measures to a markedly different weighting scheme.

$$g^{Parab}(dist_{hj};\gamma,k) = 1 - \left(\frac{\min\left(dist_{hj},k\right)}{k}\right)^{\gamma} \quad \text{(Equation 3.8)}$$

3.3.2 Net job accessibility as a local amenity

We wished to identify the extent to which net job accessibility (NJA) made an area attractive to residents. We hypothesised that living in areas with more exposure to areas with a job surplus reduced the costs of job search and commuting, and that residents were therefore willing to pay higher rents or accept lower wages to locate in such areas. In contrast, employers would prefer to live in areas where the job surplus was negative, meaning they would locate in high NJA areas only if the costs of doing so were lower, in the form of lower rents or lower wage costs. To formalise this logic, we present a stylised model that reflects the location choices made by workers and firms.[19]

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[18] A downward convex parabolic function such as $g^{Parab}(dist_{hj};\gamma,k) = \left(\frac{\min\,(dist_{hj},k)}{k} - 1\right)^{\gamma}$ provides a weighting scheme that is similar in shape to an exponential weight, albeit with less curvature.

[19] The presentation here drew on the exposition in (Maré & Poot, 2019).

3.3.2.1 Valuation by workers

Workers gain utility from their consumption of land (for housing) (H_{ic}) and consumption of goods (Y_{ic}), and from local amenities (A_c) such as NJA. The utility of worker *i* in area *c* was assumed to take the following general form:

$$U_{ic} = \left[\mathrm{e}^{\theta_{\mathrm{u}} A_c}\right] H_{ic}^{\alpha} Y_{ic}^{1-\alpha} \qquad \text{(Equation 3.9)}$$

where $\mathrm{e}^{\theta_{\mathrm{u}} A_c}$ represents the worker's valuation of NJA.[20]

Mobile workers choose to locate in an area that maximises their utility. Their expenditure (E_{ic}) is determined by the (after commuting cost) wage they can earn while living in an area. Without loss of generality, we assumed workers supplied one unit of labour, so expenditure equals the wage rate, less commuting costs $(E_{ic} = w_{ic}(1 - \chi_c))$, where χ_c could depend on mode as well as distance. They allocate expenditure to land and goods consumption according to first order conditions:

$$H_{ic} = \frac{\alpha}{r_c} E_{ic}\,; \quad Y_{ic} = \frac{(1-\alpha)}{p_c} E_{ic} \qquad \text{(Equation 3.10)}$$

giving them indirect utility of:

$$\nu_{ic} = \kappa_{\nu}\left[\mathrm{e}^{\theta_{\mathrm{u}} A_c}\right] \frac{E_{ic}}{r_c^{\alpha} p_c^{1-\alpha}} = \frac{\kappa_{\nu}\left[\mathrm{e}^{\theta_{\mathrm{u}} A_c}\right] w_c (1-\chi_c)}{r_c^{\alpha} p_c^{1-\alpha}} \qquad \text{(Equation 3.11)}$$

where $\kappa_{\nu} = \alpha^{\alpha}(1-\alpha)^{1-\alpha}$

3.3.2.2 Valuation by firms

Firm *j* produces Y_{jc} using land H_{jc} and labour L_{jc}, at prices of r_c and w_c respectively. The production function was assumed to be:

$$Y_{jc} = \left[\mathrm{e}^{\theta_y A_c}\right] H_{jc}^{\gamma} L_{jc}^{1-\gamma} \qquad \text{(Equation 3.12)}$$

Profit maximisation under perfect competition (implying zero profits) yields first order conditions for the use of land and labour, and a marginal cost function:

$$H_{jc} = \gamma \frac{p_c Y_{jc}}{r_c}; \quad L_{jc} = (1-\gamma)\frac{p_c Y_{jc}}{w_c} \qquad \text{(Equation 3.13)}$$

$$p_c = \frac{r_c^{\gamma} w_c^{1-\gamma}}{\kappa_p\left[\mathrm{e}^{\theta_y A_c}\right]} \qquad \text{(Equation 3.14)}$$

where $\kappa_p = \gamma^{\gamma}(1-\gamma)^{1-\gamma}$.

3.3.2.3 Equilibrium wages and rents

The traded good was assumed to sell at the same price everywhere, so its price was set as the numeraire $(p_c = 1)$. Spatial equilibrium requires that indirect utility and marginal costs are equalised across areas. For firms, equation 3.14 implies t $r_c^{\gamma} w_c^{1-\gamma} = \kappa_p\left[\mathrm{e}^{\theta_y A_c}\right]$. For workers, equation 3.11 implies $r_c^{-\alpha} w_c (1-\tau_c) =$

20 One of the problems with this simple Cobb-Douglas exposition is that households are assumed to spend a constant proportion of their income on land. The framework is unhelpful for looking at housing affordability if housing affordability is measured as an expenditure share.

$\bar{\bar{v}}\,/\left(\kappa_v\left[e^{\theta_u A_c}\right]\right)$, where $\bar{\bar{v}}$ is the equilibrium level of utility. Solving for rents and wages yields the following equilibrium conditions:

$$lnr_c = \left(\frac{1}{1-(1-\gamma)(1-\alpha)}\right)\left[ln\kappa_p + (1-\gamma)ln\left(\frac{\kappa_v}{\bar{\bar{v}}}\right) + \left[\theta_y A_c\right] + (1-\gamma)[\theta_u A_c]\right] \quad \text{(Equation 3.15)}$$

$$lnw_c = \chi_c + \left(\frac{1}{1-(1-\gamma)(1-\alpha)}\right)\left[\alpha ln\kappa_p - \gamma ln\left(\frac{\kappa_v}{\bar{\bar{v}}}\right) + \alpha\left[\theta_y A_c\right] - \gamma[\theta_u A_c]\right] \quad \text{(Equation 3.16)}$$

Although we could not separately identify the effects of $\left[\theta_y A_c\right]$ and $[\theta_u A_c]$, we followed Roback (1982) and Chen & Rosenthal (2008) in interpreting the joint behaviour of $(\partial lnr\_c)/(\partial A\_c)$ and $(\partial lnw\_c)/(\partial A\_c)$ to identify the dominant impact of A_c as a positive or negative consumption or production amenity. All four cases are shown in Table 3.1.

Table 3.1 Dominant amenity impact

	$\frac{\partial lnw_c}{\partial A_c} < 0$	$\frac{\partial lnw_c}{\partial A_c} > 0$
$\frac{\partial lnr_c}{\partial A_c} < 0$	Negative production amenity	Negative consumption amenity
$\frac{\partial lnr_c}{\partial A_c} > 0$	Positive consumption amenity	Positive production amenity

3.3.2.4 Hedonic valuation of NJA

To capture the valuation of A_c by workers and for firms, we derived indexes of 'consumption value' to workers (V_c^w) and 'production value' to firms (V_c^f). The V_c^w index is derived from the position of iso-utility curves, capturing the tradeoff that workers are willing to make between wages and rents, which depends on the expenditure share of rents $\left(\frac{\partial lnw_c}{\partial lnr_c}\Big|_{utility} = \alpha\right)$. The resulting index is thus $V_c^w = \alpha lnr_c - lnw_c$.

The V_c^f index reflects the relative importance of labour and land expenditures in costs. The firm's iso-cost curve is given by $\left(\frac{\partial lnw_c}{\partial lnr_c}\Big|_{cost} = -\frac{\gamma}{1-\gamma}\right)$, implying an index of $V_c^f = \frac{\gamma}{1-\gamma} lnr_c + lnw_c$.

The impact of NJA on the valuation of an area by workers and on the valuation of an area by businesses was calculated as:

$$\begin{aligned}\frac{\partial V_c^w}{\partial A_c} &= \frac{\partial V_c^w}{\partial lnr_c}\frac{\partial lnr_c}{\partial A_c} + \frac{\partial V_c^w}{\partial lnw_c}\frac{\partial lnw_c}{\partial A_c} \\ &= \alpha\frac{\partial lnr_c}{\partial A_c} - \frac{\partial lnw_c}{\partial A_c}\end{aligned} \quad \text{(Equation 3.17)}$$

and

$$\begin{aligned}\frac{\partial V_c^f}{\partial A_c} &= \frac{\partial V_c^f}{\partial lnr_c}\frac{\partial lnr_c}{\partial A_c} + \frac{\partial V_c^f}{\partial lnw_c}\frac{\partial lnw_c}{\partial A_c} \\ &= \left(\frac{\gamma}{1-\gamma}\right)\frac{\partial lnr_c}{\partial A_c} + \frac{\partial lnw_c}{\partial A_c}\end{aligned} \quad \text{(Equation 3.18)}$$

Estimates of $\frac{\partial V_c^w}{\partial A_c}$ and $\frac{\partial V_c^f}{\partial A_c}$ summarise the contingent valuation of amenities (A_c) occurring in area *c*. The key amenity of interest in our study was NJA, which we split into two components: job opportunities ($\ln JO_c$) and mean exposure to job surplus (EJS_c).

Although this model is presented for the case where all workers are the same and there is a single relevant measure of job opportunities associated with each area, the framework can be applied more generally to the case where there are multiple groups of workers that differ in their valuations of (possibly group-specific) accessibility. In our empirical analysis, we examined valuations for skill and gender subgroups, and estimated each group's response to overall job opportunities, and to their access to jobs filled by workers from their group. Although the labour market is not so strictly stratified that workers are concerned only with group-specific employment, the comparison of estimates provides a guide to the relative importance of labour market segmentation.

3.3.3 NJA and labour market outcomes

To complement the analysis of NJA as a local amenity, we also estimated more directly the relationship between NJA and labour market outcomes. Specifically, we considered whether NJA raised the proportion of the local population that was employed, as would be the case if accessibility lowered the cost of job search or led to lower commuting costs. We also examined whether living in an area with higher NJA made it easier to find employment following the end of a job, as captured by the duration of non-employment spells following the end of a job. For the analysis of employment rates and of search durations, we provide estimates based on overall job opportunities as well as estimates based on group-specific job opportunities for skill and gender groups, as outlined in the previous section.

3.3.3.1 NJA and employment rates

The relationship we examined between local NJA and local employment rates is summarised by the following equation:

$$\left(\frac{Employment}{Working\ age\ population}\right)_{mt} = \gamma^E A_{mt} + X'_{mt}\beta^E \qquad \text{(Equation 3.19)}$$

The proportion of the working age population (aged 15 and over) in a meshblock (*m*) in year *t* depends on local contemporaneous NJA (A_{mt}), with the strength of the relationship summarised by a single parameter γ^E. It may also depend on other characteristics of the local population and labour market (X_{mt}), which will potentially vary over time.

3.3.3.2 NJA and the duration of non-employment

Our analysis of non-employment duration was based on the following assumed relationship between NJA and the hazard rate for exit from non-employment to employment:

$$h_d = h^0_{md} exp(\gamma^D A_m + X'_{it}\beta^D) \qquad \text{(Equation 3.20)}$$

The hazard rate (h_d) captures the probability that the exit occurs after *d* months, for people who have not exited prior to that. The 'baseline hazard function' (h^0_{md}), which potentially varies across meshblocks, captures the relationship between duration and the exit hazard rate, across all possible durations. The effect of local NJA and of other personal characteristics (*i* indexes individuals) on the hazard was assumed to have a proportional effect on the baseline hazard. A positive value of γ^D, the effect of NJA, implies a scaled-up probability of exit, and hence a shorter duration without employment. Other personal characteristics (X'_{it}) can also scale up or scale down the baseline hazard.

3.3.4 Estimation and identification

When we estimated the relationships summarised in sections 3.3.2 and 3.3.3, we needed to take into account variation in the data arising from factors other than NJA, which was our main focus. In this section, we outline the methods we adopted to detect the importance of such factor *s*. The main objective was to estimate the value of accessibility as a local amenity, with additional objectives of gauging the links with employment rates and job search durations. For each of these three objectives, our estimation approach identified the influence of other local characteristics, and also attempted to control for 'endogeneity', using an instrumental variables approach as described below.

3.3.4.1 Estimating the amenity value of NJA

For hedonic valuation, estimation is based on empirical versions of equations 3.15 and 3.16.

$$lnr_{mt} = \boldsymbol{\beta^r A_{mt}} + \beta_X^r X_{mt}^r + \alpha_m^r + \tau_t^r + \epsilon_{mt}^r \qquad \text{(Equation 3.21)}$$

$$lnw_t^h = \boldsymbol{\beta^h A_{ht}} + \chi^w \text{dist}_{hj} + \beta_X^h X_{mt}^h + \alpha_m^h + \tau_t^h + \epsilon_{ht}^h \qquad \text{(Equation 3.22)}$$

$$lnw_t^j = \boldsymbol{\beta^j A_{jt}} + \beta_X^j X_{mt}^j + \alpha_m^j + \tau_t^j + \epsilon_{ct}^{wj} \qquad \text{(Equation 3.23)}$$

The rent equation 3.21 was estimated using panel variation across meshblocks (*m*). The unit of observation is a non-owner-occupied private rental dwelling rented by someone who is usually resident in New Zealand. Our estimate of the consumption value of location and housing was the weekly rental reported for these observations. In some specifications, we controlled for observed dwelling characteristics, to obtain a proxy for the consumption value of location. Whether controlling for dwelling characteristics or not, we averaged the rental measure to obtain a value for each meshblock-year. The reliance on a rental measure abstracts from expected capital gains (which would be a confounded factor if house sales prices were used). We relied on residential-rent-based measures to proxy for the rental cost of location for businesses, due to the absence of business rental data by meshblock.

For wage equations, we estimated separately the relationship between wages received by residents of home meshblock *h*, net of commuting costs (equation 3.22) and the wages paid to workers employed in job meshblock *j* (equation 3.23). Estimation was based on annual income reported by people who were full-time employees at the time of the census. Annual income of full-time employees was the best (though clearly imperfect) proxy of wages available in the census data. In the same way that rental data can be adjusted for housing composition, wage data was adjusted in some specifications for observable differences in the composition of employees in each meshblock.

The analogues of equations 3.17 and 3.18, which provide estimates of the valuation of NJA by workers and businesses respectively, were obtained as linear combinations of the parameters of the system of equations shown as equations 3.21 to 3.23: $\frac{\partial V_{wc}}{\partial lnA_c} = \alpha\widehat{\beta^r} - \widehat{\beta^h}$ and: $\frac{\partial V_{wc}}{\partial lnA_c} = \alpha\widehat{\beta^r} - \widehat{\beta^h}$. We used a value of $\alpha = 0.2$ to approximate the land (housing) share of expenditure in our main results,[21] and $\gamma = 0.1$ as an approximation of the cost share of land and buildings in our main results.[22] Equations 3.21 to 3.23 are estimating jointly as

[21] The Ministry of Business, Innovation and Employment (2015) reports average household income and average weekly rental for each of 16 regions. The ratio of average annual rent to average income is 0.2 nationally and varies across regions from 0.12 in Southland to 0.24 in Auckland. The utility function specified in equation 3.1 implies an elasticity of substitution of 1 and cannot account for housing taking a larger share of expenditure in areas where prices and rents are high, which would imply a utility function with an elasticity of substitution less than 1. Rather than increasing the mathematical complexity by introducing more flexible utility functions, it would be possible to investigate the sensitivity of our findings to alternative values of α.

[22] Reliable estimates of the value of γ are not available. Fabling and Maré (2019) report aggregate Cobb Douglas production function estimates. Their estimates suggest that capital accounts for 14% of expenditure, labour 24% and intermediate purchases and taxes 62%. Hence the capital share of factor payments is 0.14/(0.14+0.24), ie 37%. However, in our model land is the only variable capital input. Rental leasing and rates (RLR) account for around 30% of

seemingly unrelated regressions, which facilitates the estimation of standard errors on the linear combinations of coefficients.

We present five separate sets of estimates for each chosen area, which differ in the nature of controls for omitted variables and endogeneity. First, we estimated a baseline specification which regressds averages of *ln(wage)* and *ln(rent)* on the two NJA measures (ln*(JO)* and exposure to jobs surplus) and time intercepts, with no other controls. Our second specification controlled for the composition of workers and of the dwelling stock within each meshblock. Analysis was carried out in two stages – the first stage used observations on either dwellings or employees, and the second stage analysed mean adjusted wages and rents summarised by meshblock and year. For rents, we used dwelling information and control for the dwelling type, the number of bedrooms and other rooms, and the number and type of heating fuels used in the dwelling, allowing for year-specific coefficients on each of these characteristics. Our adjusted rent measure was the average of the residual rent by meshblock and year as our measure of adjusted rents. Similarly, for wages, we used employee information and control for level of highest qualification, distinguishing four levels, industry of employment and an age-specific quartic in age, and calculated residual wage as the average of the residual wage by meshblock and year.

Our third specification estimated the same specification as the second but using instrumental variables methods. This controls for the potential endogeneity of accessibility, which may arise if changes in wages or rents induce an accessibility response. We constructed instruments by estimating where jobs and residents would have been located if each local industry had grown at the same rate that the industry had grown nationally since the previous census, and the number of locally employed residents of a given age had increased in proportion to the growth in that age group nationally. Equation 3.22 shows the 'shift-share' formulae used to calculate the estimates of the number of jobs in each workplace, $j\ (E_{jt}^{IV})$ and the number of employed residents in each residential meshblock (N_{ht}^{IV}).

$$E_{jt}^{IV} = \sum_{i=industry} E_{ij,t-1}\left(\frac{E_{i,t}}{E_{i,t-1}}\right); N_{ht}^{IV} = \sum_{a=agegroup} N_{ah,t-1}\left(\frac{N_{a,t}}{E_{a,t-1}}\right) \qquad \text{(Equation 3.24)}$$

Using these measures, accessibility instruments were constructed in the same way as described in section 3.3, giving measures of $lnJO_{mt}^{IV}$ and EJS_{mt}^{IV}. The instruments were correlated with actual accessibility but uncorrelated with exogenous changes in wages or rents that could differentially affect local accessibility.

In our fourth and fifth specifications, we allowed for meshblock-specific intercepts (α_m^*) in each equation. We implemented this by estimating the equations in first-differenced form. The impact of NJA was thus estimated from the relationship between changes in NJA and changes in wages and rents. This specification removed the potential bias from other meshblock characteristics that might be correlated with both NJA and wages or rents – at least to the extent that they are time invariant. One possible drawback of this specification is that short-run (over five years) housing and labour market dynamics may have confounded our ability to identify equilibrium relationships, which underlie the assumed relationships derived in section 3.3.2. By eliminating between-meshblock differences, it also greatly reduced the variation used to identify effects. The fifth specification differed from the fourth only in that it uses instrumental variables estimation, with instruments

capital inputs, implying that γ is around 0.11 (=0.37*0.30). However, the RLR measure includes some but not all land-related costs and excludes relevant costs for businesses that own their own land and buildings. A mean expenditure share derived from industry-specific weights used in the calculation of Statistics NZ's Producer Price Index (inputs) yields an estimate for γ of 0.16. We use a benchmark value of $\gamma = 0.1$, but as with α the sensitivity of findings to this choice could be further explored. The discussion of sensitivity will also shed light on the impact of spatially varying elasticities of substitution. The choice of a production function with an elasticity of substitution between labour and land inputs of one (equation 3.4) implies that the cost share of land and buildings is assumed constant across cities.

for accessibility change constructed from the instruments described in the previous paragraph ($dlnJO_{mt}^{IV} = lnJO_{mt}^{IV} - lnJO_{m,t-1}$ and $dEJS_{mt}^{IV} = EJS_{mt}^{IV} - EJS_{m,t-1}$).

Selected estimates are presented of within-group relationships, for groups defined by gender and highest qualification. For these estimates, we calculated group-level accessibility measures based on the residential and job locations of group members and estimate equations separately by group.

3.3.4.2 NJA and employment rates

The relationship between NJA and employment rates was estimated based on empirical versions of equation 3.19 estimated by linear regression.

$$\left(\frac{Employment}{Working\ age\ population}\right)_{mt}^{G} = \gamma_G^E A_{mG} + \alpha_m + \tau_t + e_{mt} \qquad \text{(Equation 3.25)}$$

Heterogeneity (X'_{mt} in equation 3.19) was controlled for parsimoniously by including time intercepts (τ_t) and, in some specifications, separate meshblock intercepts (α_m) (estimating the equation in first differences). Instrumental variable estimation is also reported, using the same accessibility instruments described in the previous section. Selected group-level estimates are also reported, to determine whether the employment rate of different gender or skill groups depends on overall accessibility or group-specific accessibility.

3.3.4.3 NJA and the duration of non-employment

The relationship between NJA and the time taken to find employment after a job end was estimated using a Cox proportional hazard model, based on equation 3.20. For each census year, we identified individuals who ended a job in the month of the census (March) and used administrative data to identify when they were next observed employed.

$$h_d = h_{md}^0 exp(\gamma_G^D A_{mG} + X_{it}\beta) \qquad \text{(Equation 3.26)}$$

The estimation was carried out on individual-level data, including controls for census year, highest qualification and a gender-specific quadratic in age. In our base specification, we imposed a common baseline hazard ($h_{md}^0 = h_d^0$), which we subsequently relaxed by stratifying the estimation by meshblock, but maintaining a common set of parameter estimates ($,\beta$). In our main estimates, we also imposed a common effect of accessibility across groups ($\gamma_G^D = \gamma^D$), which we subsequently relaxed to estimate group-specific regressions using either overall or group-specific accessibility measures. Endogeneity was controlled for using the instruments described above, and a control-function approach to estimation. Accessibility measures are first regressed on instruments and other independent variables by linear regression. The residuals from these regressions are then included in the hazard regression together with the accessibility measures (Martínez-Camblor et al., 2019).

3.4 Study areas

We focused our analysis on four urban areas in New Zealand: Auckland, Napier–Hastings, Wellington and Dunedin. Figure 3.2 shows the location of these areas within New Zealand. The four areas provide a range of densities and sizes. Auckland is by far the largest area, with over 750,000 employed workers and residents in 2018, across four urban zones with a combined land area of over 1,000 km^2. Napier–Hastings and Wellington urban areas have a similar land area of around 380 km^2, but Wellington has over three times as many jobs and residents as Napier–Hastings (around 230,000 and 67,000 respectively). The number of jobs or residents in Dunedin is about 90% of the number in Napier–Hastings, but it has a land area that is about two-thirds that of Napier–Hastings, giving it a higher average density. The size and density of the study areas are summarised in Table 3.2.

Table 3.2 also provides weighted density measures. For jobs, this captures the average job density in meshblocks where jobs are located. Given the uneven distribution of jobs, this is much higher than the average density over the entire urban area. In Auckland, the weighted job density is over 19,000 jobs per km^2, compared with 726 jobs per km^2 for the urban area as a whole. Similarly, the weighted density of residents, weighted by where residents live, is 2,876 residents per km^2, compared with an Auckland-wide average of 705. The table also shows the 'peak density', which is the density in the most dense meshblock. In Auckland, the peak job density is almost 500,000 per km^2, which relates to a single central-city block with about 2,000 jobs on a land area of about 4,000 m^2.. The peak residential density (2,900 per km^2) is for a part of a central city block, with 200 residents and a land area of about 1,400 m^2.

Wellington has a weighted residential density very similar to that of Auckland (2,900 per km^2), but has a considerably higher weighted job density, of almost 60,000 per km^2. Despite this, the peak job density in Wellington is only about three quarters of the Auckland peak, with 2,000 jobs in about 5,500 m^2. Napier–Hastings and Dunedin have similar weighted residential densities, of 1,200 and 1,400 per km^2 respectively. Dunedin has a somewhat higher peak residential density, and a markedly different weighted job density. In Dunedin, the average job is in a meshblock with a density of 13,000 jobs per km^2, compared with only 4,000 per km^2 in Napier–Hastings. Dunedin also has a considerably higher peak density of 110 per km^2, about four times that of Napier–Hastings.

Figure 3.2 Location of study areas

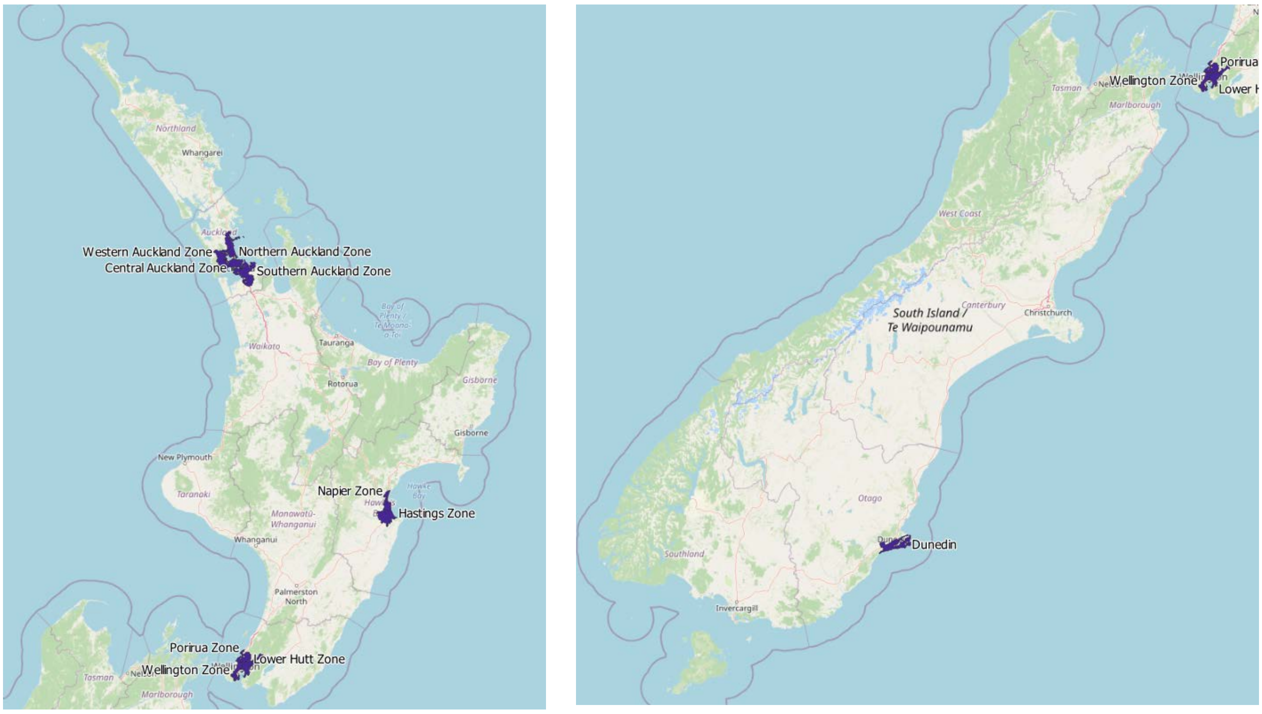


Table 3.2 Size and density of urban areas (2018)

		Land area (km^2)	Jobs	Residents
Auckland	Total	1,076	781,500	758,100
	Density (per km^2)		726	705
	Weighted density (per km^2)		19,270	2,876
	Peak density (per km^2)		488,897	152,117
Napier–Hastings	Total	384	68,300	66,600
	Density (per km^2)		178	173
	Weighted density (per km^2)		3,622	1,213
	Peak density (per km^2)		26,418	4,094
Wellington	Total	392	233,700	224,200
	Density (per km^2)		596	572
	Weighted density (per km^2)		59,506	2,865
	Peak density (per km^2)		371,233	77,820
Dunedin	Total	251	59,400	58,700
	Density (per km^2)		236	234
	Weighted density (per km^2)		12,690	1,361
	Peak density (per km^2)		109,269	6,524

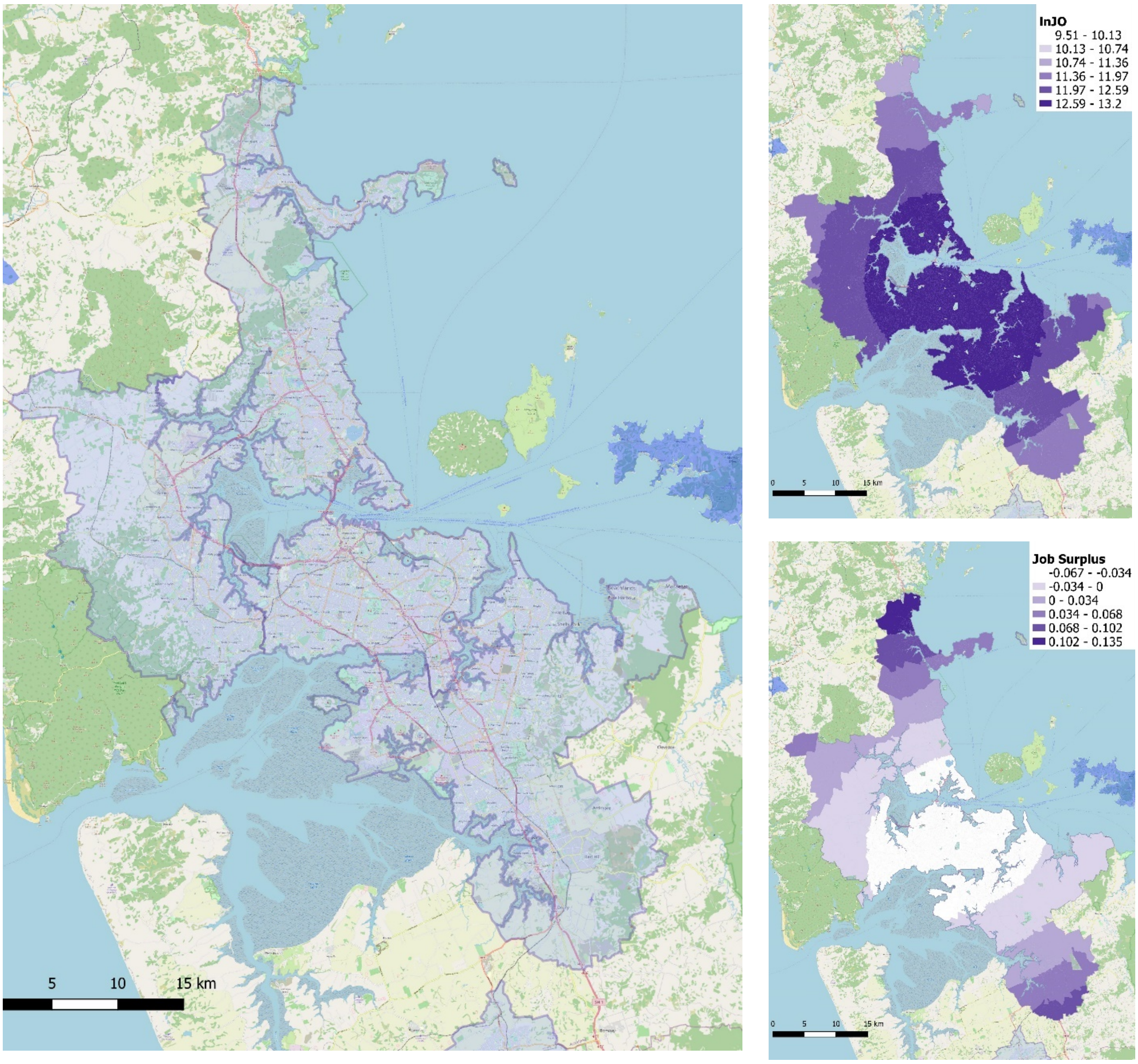
Notes: Land area is restricted to meshblocks that contain at least one resident or workplace. Peak density is the density of the most dense meshblock in each urban area in 2018.

Figure 3.3, Figure 3.4, Figure 3.5 and Figure 3.6 illustrate how the densities of residents and jobs interact in each urban area to affect job accessibility, as captured by job opportunities and exposure to job surpluses. For each urban area, we have provided a map showing the geographic extent of the study area, as well as maps highlighting the pattern of geographic variation in job opportunities and exposure to job surpluses. The maps were drawn for 2018 data, with a table of summary measures for other years included in Table 3.3, which follows these figures.

3.4.1 Auckland urban area

The Auckland statistical urban area extends from just south of Waiwera in the north, down to Drury in the south. Job density, and therefore job opportunities, are highest around the central city, with a peak slightly south of Auckland Central – around Market Road. Many residents have access to the job opportunities that are accessible from the central city. The map of job surplus in Figure 3.3 shows it is only towards the outer edges of the urban area that residents have a net positive exposure to job surpluses. As shown in Table 3.3, job opportunities rose slightly between 2006 and 2013 – primarily due to increases in the north of the urban area. There were more substantial increases between 2013 and 2018, concentrated largely in south Auckland.

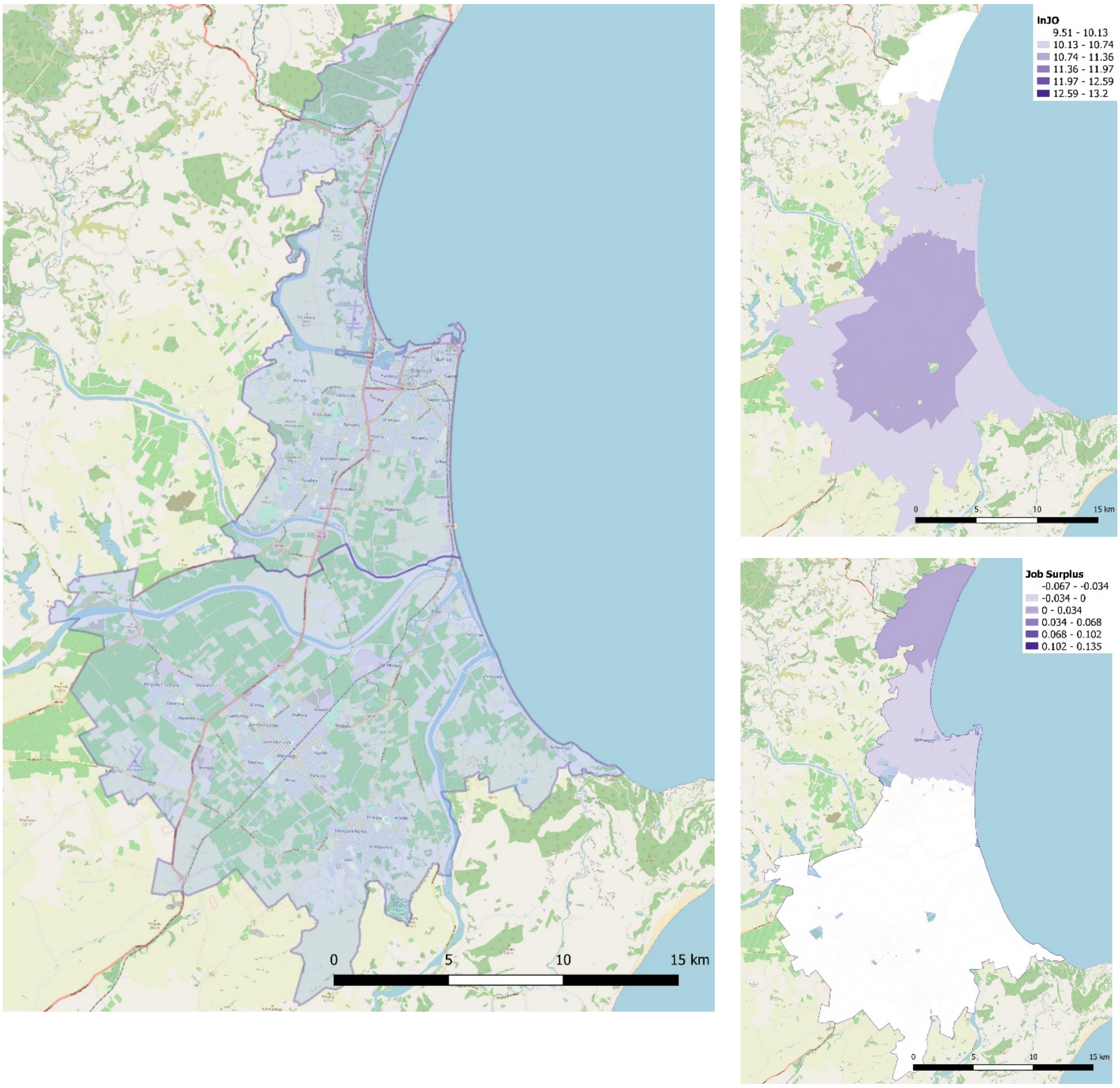
Figure 3.3 Auckland urban area (2018): boundaries, log of job opportunities and job surplus



3.4.2 Napier Hastings urban area

The Napier–Hastings statistical urban area encompasses Napier, Hastings and Havelock North, extending North to Whirinaki. The job opportunities measure is highest in the area between Napier and Hastings, although job and residential density are relatively low between the two cities. As in Auckland, exposure to job surplus is highest towards the edge of the urban area – in the north for Napier–Hastings. As shown in Table 3.3, Napier–Hastings not only has the lowest levels of job opportunities, it also has relatively little variation across meshblocks. The within urban area resident-weighted standard deviation of ln*JO* is only 0.14, compared with 0.4 in Auckland and Wellington, and 0.2 in Dunedin. The increases in job opportunities between 2013 and 2018 occurred mainly around and to the west of Hastings.

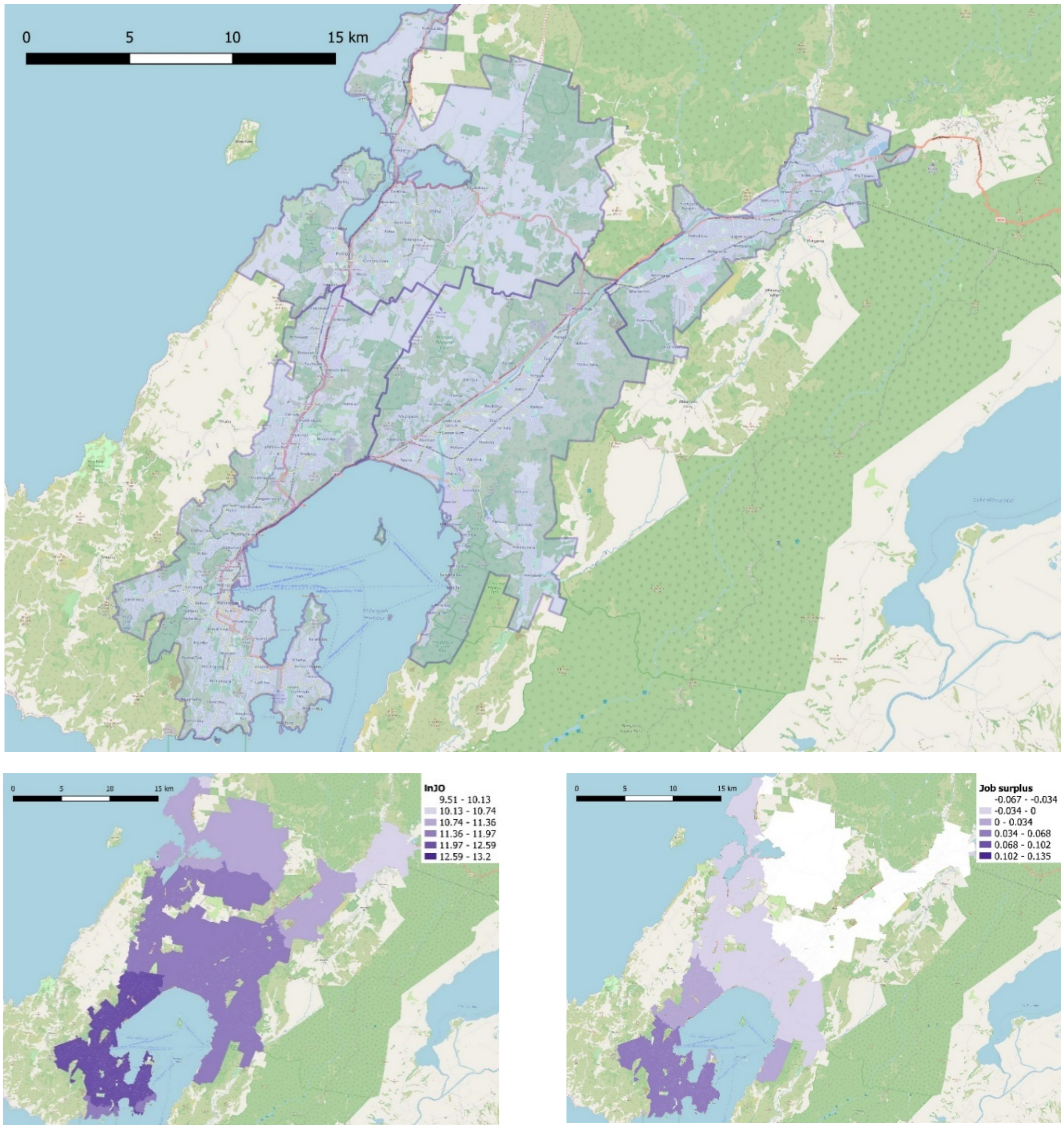
Figure 3.4 Napier–Hastings urban area (2018): boundaries, log of job opportunities and job surplus



3.4.3 Wellington urban area

The Wellington statistical urban area comprises Porirua, the Hutt Valley as well as central Wellington. It extends north-west to Pukerua Bay and past Birchville in the north of Upper Hutt. The job opportunities measure is highest around central Wellington, across an area from Newlands in the north to Island Bay in the south and including most of the Miramar Peninsula. In contrast to the other urban areas, central Wellington also has relatively high exposure to job surplus. It is highest in the south, around Island Bay. The increases in job opportunities in Wellington, as shown in Table 3.3, occurred in the south of the urban area throughout the 2006–2018 period, and increasingly in the north of Porirua and Upper Hutt between 2006 and 2018.

Figure 3.5 Wellington urban area (2018): boundaries, log of job opportunities and job surplus



3.4.4 Dunedin urban area

The Dunedin statistical urban area reaches to Mosgiel and Brighton in the south and along the edge of the harbour to Aramoana in the north. The average job opportunities measure is higher in Dunedin than in Napier–Hastings or Wellington, and is relatively high throughout most of Dunedin, from Green Island in the south to Normanby in the north. Exposure to job surplus is negative throughout Dunedin, though less so on the northern and southern edges of the urban area. The strongest increases in job opportunities between 2013 and 2018 occurred disproportionately in the south of the urban area – in St Kilda and south Dunedin.

Figure 3.6 Dunedin urban area (2018): boundaries, log of job opportunities and job surplus

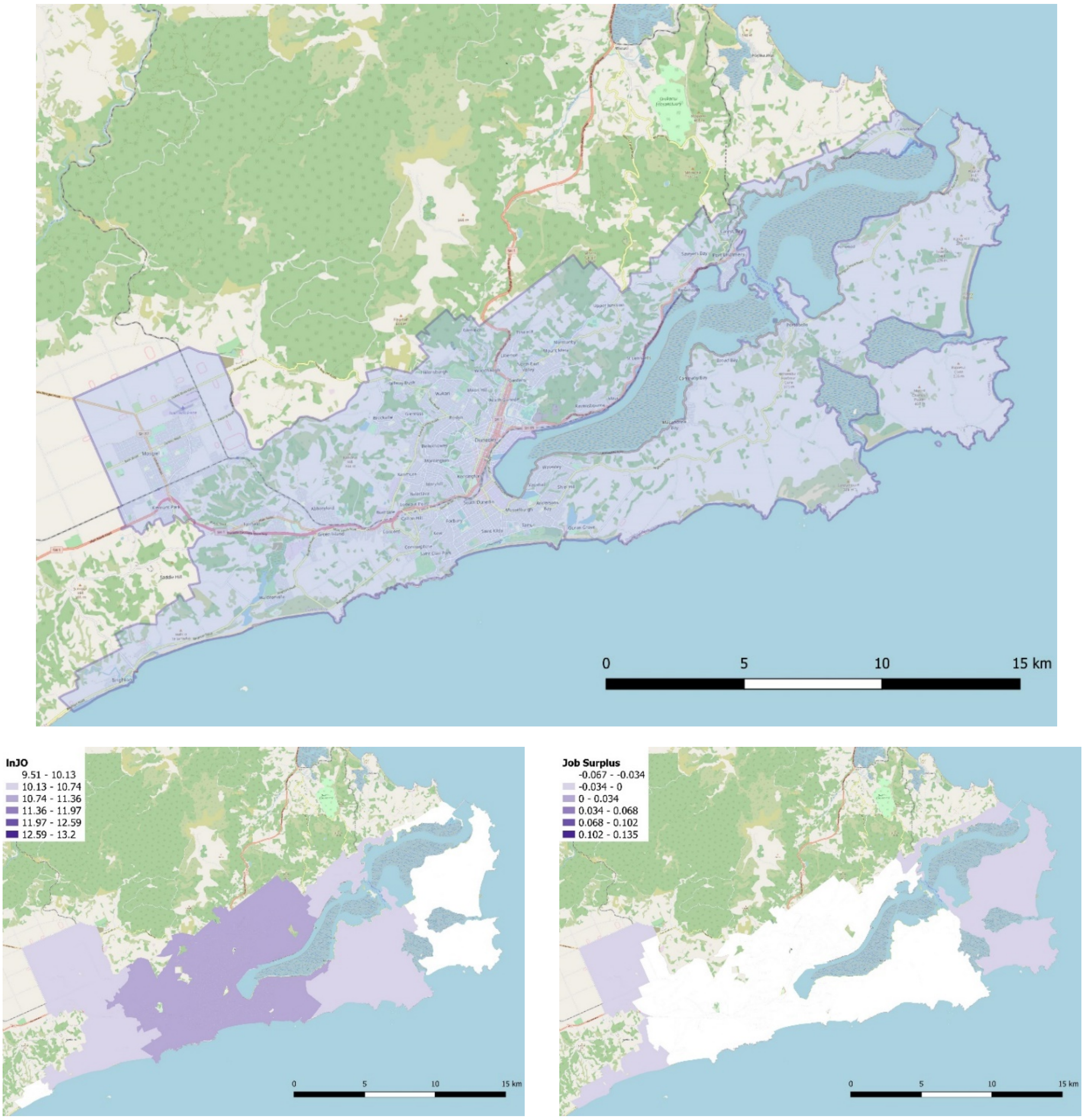


Table 3.3 Mean in (job opportunities) and exposure to job surplus, by urban area and year

	2006	2013	2018	Total
	(a) Ln(job opportunities)			
Auckland	12.500	12.526	12.753	12.607
	(0.388)	(0.392)	(0.400)	(0.411)
Napier–Hastings	10.551	10.505	10.703	10.594
	(0.135)	(0.136)	(0.138)	(0.161)
Wellington	11.591	11.613	11.752	11.658
	(0.384)	(0.403)	(0.408)	(0.406)
Dunedin	10.756	10.675	10.842	10.761
	(0.218)	(0.221)	(0.222)	(0.231)
Total	12.069	12.102	12.326	12.178
	(0.750)	(0.764)	(0.783)	(0.776)
	(b) Mean exposure to job surplus			
Auckland	-0.038	-0.040	-0.033	-0.037
	(0.036)	(0.037)	(0.034)	(0.036)
Napier–Hastings	-0.048	-0.034	-0.041	-0.041
	(0.009)	(0.011)	(0.012)	(0.012)
Wellington	-0.004	0.011	0.004	0.003
	(0.030)	(0.033)	(0.035)	(0.033)
Dunedin	-0.042	-0.080	-0.050	-0.057
	(0.012)	(0.011)	(0.010)	(0.020)
Total	-0.032	-0.031	-0.027	-0.030
	(0.036)	(0.041)	(0.036)	(0.038)

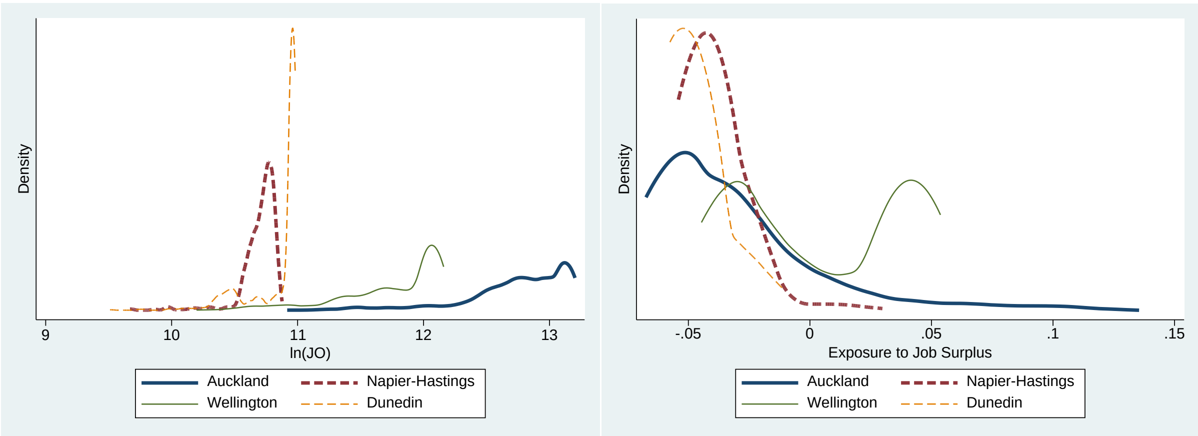
Note: Weighting is Mexp(0.1, 5). Resident-weighted standard deviations are shown in brackets.

Our empirical estimation relied primarily on variation between meshblocks in each urban area, which we controlled for year effects. This variation was much less pronounced than the variation between urban areas or for a given urban area over time. As we will see, this limited our ability to identify statistically significant effects of accessibility. Figure 3.7 provides a graphical summary of the extent of the within-urban area variation in accessibility, using 2018 data. The left panel shows the density of resident populations by meshblock levels of job accessibility. For Wellington, there is a peak density at values of ln*(JO)* slightly above 12, though with considerable variation at lower levels. Similarly, in Auckland there is reasonable variation in ln*(JO)* below the peak value of around 13.1. In contrast, there is very limited variation in ln*(JO)* within Dunedin or Napier–Hastings. The difference between the 10th percentile and 90th percentile in 2018 is only 0.2 in Napier–Hastings, compared with 0.5 in Dunedin, and around 0.9 in Auckland and Wellington.

The right panel of Figure 3.7 shows the 2018 within-urban area variation in exposure to job surplus. The horizontal scale is much narrower than for ln*(JO)*, and is relatively small even given the maximum possible range of the measure – from -2 to 2. As seen in Figure 3.5, within-Wellington variation in exposure to job surplus is atypical, with the greatest exposure occurring in the areas with the highest job opportunities. The pattern for Wellington in the right panel of Figure 3.7 is also unusual, with a pronounced bimodality – a density of meshblocks with positive exposure roughly balanced by a density with negative exposure.

Regression estimates that rely on changes in ln*(JO)* or *EJS* are even more demanding of the data, as they depend on variation across meshblocks in the size of intercensal changes. This variation is most substantial in Auckland, although even there it is limited. Average ln*(JO)* grew by 0.233 in Auckland between 2013 and 2018, with a standard deviation of 0.025. In Dunedin, the comparable change was 0.167, but the changes were fairly uniform across the urban area, with a standard deviation of only 0.003. For changes in *EJS*, the within-urban area variation is even smaller – around 0.001 in Dunedin and Napier–Hastings, and only 0.004 in Auckland. The limited variation in some of the measures will restrict how much we can say about the impacts of accessibility from our econometric analysis, which we turn to in the next section.

Figure 3.7 Density of accessibility measures (2018)



Overall job accessibility $(\ln A_h)$ is the sum of $\ln JO_h$ and EJS_h (equation 3.5). Job opportunities account for by far the greatest share of variation in overall job accessibility. Table 3.4 summarises the variance of each component of NJA – within each study area and pooled across the four areas. It also reports the covariance of $\ln JO_h$ and EJS_h, which is negative with the exception of Wellington.

Table 3.4 Variance of net job accessibility components

	$Var[\ln A_h]$	$Var[\ln JO_h]$	$Var[EJS_h]$	$Cov[\ln JO_h, EJS_h]$
Auckland	0.144	0.169	0.0013	-0.013
Napier–Hastings	0.024	0.026	0.0001	-0.001
Wellington	0.186	0.165	0.0011	0.010
Dunedin	0.051	0.053	0.0004	-0.002
Pooled	0.585	0.602	0.0014	-0.009

In the analysis that follows, we include both $\ln JO_h$ and EJS_h as measures of job accessibility. The estimated effects of overall accessibility are almost identical to the estimated effects of $\ln JO_h$, with EJS_h playing a minor secondary role. Our discussion of findings is therefore focused primarily on the estimated effects of $\ln JO_h$.

3.5 Results: How does NJA affect labour and housing markets?

In this section, we report on three sets of analysis to examine the relationship between job accessibility, as captured by ln*(JO)* and *EJS*, and local labour and housing markets.

First, we examined the joint behaviour of wages and rents in relation to meshblock-level accessibility measures. We combined the estimated wage and rent effects to estimate whether accessibility was valued by firms or by workers. We did this by applying the hedonic framework outlined in section 3.3.2.4.

Second, we estimated the relationship between accessibility and the probability of employment within each meshblock. The employment rate was calculated as the proportion of the working-age population (aged 15 and over) that was employed.

Third, we estimated whether accessibility affected how long it took for people to find employment after their job ended.

Our main findings were that accessibility was associated with higher rents and lower wages, consistent with accessibility being a positive local amenity that residents are willing to pay for. We also failed to find a strong relationship between accessibility and employment rates, which we might have expected if spatial mismatch were problematic.

3.5.1 Results: Does NJA affect wages and rents?

3.5.1.1 Auckland urban area

Table 3.5 reports the estimation of equations 3.21. to 3.23 for the Auckland urban area. The first column contains a base specification that has no adjustment for composition of housing or employees. It shows that meshblocks with higher ln*JO* are areas where residents earn lower wages, adjusted for commuting costs (-0.258) and do not pay a systematically different level of rents (0.009). Controlling for the composition of employees and housing, the estimates in column (2) show a reduced negative relationship with wages (-0.146), and a now significant positive relationship with rents (0.112). Column 3 uses instrumental variables to control for potential endogeneity of accessibility measures. The main difference from column 2 is that the effects on rents become stronger, suggesting higher rents may discourage local job opportunities and competing jobseekers, leading to a downward bias in the estimates in column 2.[23]

To interpret the magnitude of the effects in column 3, we can consider the impact of a one standard deviation increase in ln*JO* within Auckland. A one standard deviation change in ln*JO* is approximately 0.4, so the effect on log wages (ln*W*) is around -0.06 or about -6%. This compares with a standard deviation of ln*W* within Auckland of about 0.2, so a one standard deviation change in ln*JO* is associated with a -0.3 standard deviation change in ln*W*. Analogously, the 0.226 coefficient for rents implies that a one standard deviation change in ln*JO* is associated with a 9% change in *lnRent*, which is about a 0.27 standard deviation in *lnRent* (sd(*lnRent*)≅0.33). Although the size of coefficients is larger for *EJS*, the size of impacts is similar to that of ln*JO*. A one standard deviation change in *EJS* in Auckland in 2018 was 0.034 (Table 3.3), so the coefficient on -1.737 for the wage equation in column 3 implies a wage change of -6%, similar to the effect of a one standard deviation change in ln*JO*.

Within the equilibrium framework outlined in section 3.3.2 above, the fact that high accessibility meshblocks are associated with lower wages and higher rents implies they are valued by workers – something worth paying for. The estimated impact on the value of accessibility for workers $(\partial V_c^w / \partial A_c)$ is equivalent to 7.4% increase in wages for ln*JO* and a 7.1% increase for *EJS*. The implied impact on businesses is for a negligible (quantitatively and statistically insignificant) effect of ln*JO* and a small (0.5% of wages) statistically insignificant effect of *EJS*.

[23] Note the difference may also be due to the regressions being estimated on a different sample – the IV instrument is not available for 2006 as it was constructed using lagged values.

Table 3.5 Auckland – wages, rents and accessibility

		Baseline	Composition -adjusted wages and rents	IV-estimation of (2)	Change regression	IV-estimation of (4)
		(1)	(2)	(3)	(4)	(5)
Wage rcvd	$\ln JO$	-0.258***	-0.146***	-0.139***	-0.112	-0.316***
		(0.018)	(0.013)	(0.017)	(0.064)	(0.094)
	EJS	-3.358***	-1.746***	-1.737***	2.766***	5.495***
		(0.195)	(0.139)	(0.187)	(0.416)	(0.611)
Rent	$\ln JO$	0.009	0.112***	0.226***	0.243**	0.334**
		(0.023)	(0.022)	(0.028)	(0.082)	(0.121)
	EJS	-0.033	0.119	1.508***	-0.867	-0.932
		(0.256)	(0.240)	(0.314)	(0.537)	(0.787)
Wage paid	$\ln JO$	-0.038	-0.025	-0.025	-0.179	-0.337
		(0.033)	(0.028)	(0.036)	(0.226)	(0.332)
	EJS	-0.648	-0.274	-0.313	3.738*	7.300***
		(0.361)	(0.310)	(0.398)	(1.470)	(2.157)
	$\partial V_c^w / \partial \ln JO$	0.259***	0.169***	0.184***	0.161**	0.383***
		(0.016)	(0.011)	(0.015)	(0.066)	(0.097)
	$\partial V_c^f / \partial \ln JO$	-0.037	-0.013	0.001	-0.152	-0.299
		(0.033)	(0.028)	(0.036)	(0.226)	(0.333)
	$\partial V_c^w / \partial EJS$	3.352***	1.770***	2.039***	-2.940***	-5.681***
		(0.173)	(0.122)	(0.164)	(0.429)	(0.630)
	$\partial V_c^f / \partial EJS$	-0.651*	-0.261	-0.145	3.641**	7.197***
		(0.367)	(0.315)	(0.405)	(1.471)	(2.159)
N obs		23,401	23,328	16,206	13,121	13,121

Note: Each column of the table reports estimates for three separate regressions, estimated jointly. The reported estimates are from the second stage of a two-stage estimation procedure, as described in section 3.3.4. First-stage wage and rent regressions control for a range of personal and dwelling characteristics, as documented in that section. Estimates below the horizontal line are for linear combinations of coefficients, as described in the text. V_c^w denotes the contingent valuation by workers. V_c^f denotes the contingent valuation by firms. Standard errors are clustered by meshblock. Significance indicators: 0.1%(***), 1%(**), 5%(*).

The change regression estimates shown in column 4 have the advantage that they control for time-invariant meshblock characteristics that may be related to wages and rents. If such characteristics are also correlated with accessibility, and are not controlled for, they would cause the estimates in column 3 to be biased. The disadvantage of relying on the change estimates from column 4 is that the variation in accessibility between census years is relatively small, making it harder to identify the underlying relationships. In addition, interpreting the estimated coefficients in terms of our theoretical model may be less appropriate. That the model captures equilibrium relationships, and estimates based on changes over five or seven years may be more influenced by short-run dynamics and therefore less informative about equilibrium relationships.

The main impact on the estimates of controlling for meshblock-specific intercepts was on the coefficients on *EJS*. *EJS* was found to be positively associated with wages and insignificantly negatively associated with rents. The change from the previous column implies that, controlling for the effects of ln*JO*, residents in meshblocks with relatively high *EJS* tended to have low wages and relatively high rents, for reasons other than the exposure to job surplus. In contrast, if exposure to high *EJS* is a consumption disamenity, high wages and lower rents are required to offset the disamenity. Firms operating in an area where local workers have access to job surplus pay higher wages, consistent with these firms being more productive. The main pattern that is fairly stable across columns 3 and 4 and is thus robust to controlling for meshblock fixed effects, is that job opportunities are associated with lower wages and higher rents, consistent with accessibility being a positive local consumption amenity.

3.5.1.2 Napier–Hastings urban area

Analogous estimates for the Napier–Hastings urban area are shown in Table 3.6. The impact of controlling for personal and housing characteristics (comparing columns 1 and 2) is similar to what is seen for Auckland in Table 3.5. Areas with high accessibility (ln*JO* or *EJS*) tend to have housing with characteristics generally associated with lower rents, and workers with characteristics associated with low wages. Adjusting for these compositional differences in column 2 reveals a more positive (or less negative) association between accessibility and wages or rents. The effect of controlling for meshblock heterogeneity (comparing columns 3 and 4) is to remove a cross-sectional correlation between accessibility and low rents and to a lesser degree between accessibility and high wages. This may in part reflect the geography of the Napier–Hastings area which, as described above, has the highest levels of measured ln*JO* in the area between Napier and Hastings, which are not particularly high-rent areas.

As shown in Figure 3.7, there is relatively little variation in ln*JO* within Napier–Hastings. The impact of this low variation is magnified when the equations are estimated in first differences (column 4). Standard errors increase substantially, particularly for coefficients on ln*JO*. None of the coefficients in column 4 is statistically significant, though the pattern of point estimates is similar to that seen in Auckland. Job opportunities are associated with rent premiums and lower wages, consistent with their being a positive consumption amenity valued by workers. Using the point estimates, the value of a one standard deviation change in ln*JO* in Napier–Hastings (a change of 0.138) would be equivalent to about a 13% change in wages, The lack of precision in the estimates does, however, make any inferences tentative at best.

Table 3.6 Napier–Hastings – wages, rents and accessibility

		Baseline	Composition-adjusted wages and rents	IV-estimation of (2)	Change regression	IV-estimation of (4)
		(1)	(2)	(3)	(4)	(5)
Wage rcvd	$\ln JO$	-0.259***	-0.092*	-0.087	-0.532	7.211
		(0.055)	(0.036)	(0.046)	(0.996)	(4.019)
	EJS	2.219**	1.098*	1.047	1.955	21.333*
		(0.686)	(0.450)	(0.548)	(2.736)	(9.900)
Rent	$\ln JO$	-0.603***	-0.412***	-0.446***	2.052	7.227
		(0.066)	(0.058)	(0.072)	(1.163)	(4.584)
	EJS	-4.247***	-1.822*	-2.149*	4.949	12.079
		(0.821)	(0.719)	(0.855)	(3.195)	(11.292)
Wage paid	$\ln JO$	-0.127	-0.095	0.034	-2.560	-3.994
		(0.099)	(0.083)	(0.098)	(2.786)	(10.903)
	EJS	3.232**	1.886	2.358*	-7.607	-6.589
		(1.229)	(1.035)	(1.154)	(7.653)	(26.856)
	$\partial V_c^w / \partial \ln JO$	0.138***	0.010	-0.002	0.942	-5.765
		(0.051)	(0.034)	(0.044)	(1.014)	(4.063)
	$\partial V_c^f / \partial \ln JO$	-0.194*	-0.141*	-0.015	-2.332	-3.191
		(0.100)	(0.084)	(0.099)	(2.788)	(10.910)
	$\partial V_c^w / \partial EJS$	-3.068***	-1.462***	-1.477***	-0.965	-18.917*
		(0.638)	(0.427)	(0.524)	(2.785)	(10.008)
	$\partial V_c^f / \partial EJS$	2.761**	1.684	2.119*	-7.057	-5.247
		(1.242)	(1.047)	(1.170)	(7.658)	(26.873)
N obs		2815	2793	1939	1543	1543

Note: Each column of the table reports estimates for three separate regressions, estimated jointly. The reported estimates are from the second stage of a two-stage estimation procedure, as described in section 3.3.4. First-stage wage and rent regressions control for a range of personal and dwelling characteristics, as documented in that section. Estimates below the horizontal line are for linear combinations of coefficients, as described in the text. V_c^w denotes the contingent valuation by workers. V_c^f denotes the contingent valuation by firms. Standard errors are clustered by meshblock. Significance indicators: 0.1%(***), 1%(**), 5%(*).

3.5.1.3 Wellington urban area

In Wellington, the characteristics of residents and housing in high-accessibility areas are associated with slightly lower rents (as in Auckland), but somewhat higher wages. Comparing column 2 to column 1, wage coefficients become less positive (more negative) and rent coefficients more positive when these characteristics are controlled for. Consistent with the high levels of job accessibility around central Wellington, controlling for average meshblock characteristics (comparing columns 3 and 4) removes an upward bias in the estimated effect of ln*JO* on both wages received and on rents paid. The resulting estimates show a significant negative effect on both wages and rents, although the net effect is that ln*JO* is still estimated to be a positive consumption amenity. The implied effect of a one standard deviation (0.408) increase in ln*JO* is equivalent to 16% higher wages. For a one standard deviation increase in *EJS*, the implied consumption amenity effect is negative, with an effect equivalent to 10% of wages.

As in the results for Auckland and Napier–Hastings, the standard errors are also greatly inflated when change regressions are estimated.

Table 3.7 Wellington – wages, rents and accessibility

		Baseline	Composition-adjusted wages and rents	IV-estimation of (2)	Change regression	IV-estimation of (4)
		(1)	(2)	(3)	(4)	(5)
Wage rcvd	$\ln JO$	0.058***	0.028***	0.023*	-0.541**	-3.539**
		(0.012)	(0.008)	(0.009)	(0.199)	(1.322)
	EJS	1.110***	0.971***	0.962***	2.889**	16.917**
		(0.151)	(0.093)	(0.115)	(0.966)	(6.281)
Rent	$\ln JO$	0.008	0.027*	-0.008	-0.759**	-5.247**
		(0.015)	(0.013)	(0.016)	(0.260)	(1.748)
	EJS	4.672***	5.648***	5.750***	0.669	22.311**
		(0.181)	(0.157)	(0.193)	(1.265)	(8.304)
Wage paid	$\ln JO$	-0.003	-0.013	-0.018	0.166	0.223
		(0.023)	(0.019)	(0.023)	(0.765)	(4.941)
	EJS	0.852**	0.720**	0.744**	-3.223	-3.495
		(0.283)	(0.231)	(0.280)	(3.718)	(23.479)
	$\partial V_c^w / \partial \ln JO$	-0.056***	-0.022***	-0.025***	0.390*	2.490*
		(0.011)	(0.007)	(0.009)	(0.205)	(1.341)
	$\partial V_c^f / \partial \ln JO$	-0.002	-0.010	-0.019	0.082	-0.360
		(0.023)	(0.019)	(0.024)	(0.767)	(4.954)
	$\partial V_c^w / \partial EJS$	-0.175	0.159*	0.188*	-2.755***	-12.455*
		(0.140)	(0.085)	(0.106)	(0.995)	(6.370)
	$\partial V_c^f / \partial EJS$	1.371***	1.347***	1.382***	-3.149	-1.016
		(0.287)	(0.234)	(0.285)	(3.727)	(23.540)
N obs		8,221	8,187	5,680	4,384	4,384

Note: Each column of the table reports estimates for three separate regressions, estimated jointly. The reported estimates are from the second stage of a two-stage estimation procedure, as described in section 3.3.4. First-stage wage and rent regressions control for a range of personal and dwelling characteristics, as documented in that section. Estimates below the horizontal line are for linear combinations of coefficients, as described in the text. V_c^w denotes the contingent valuation by workers. V_c^f denotes the contingent valuation by firms. Standard errors are clustered by meshblock. Significance indicators: 0.1%(***), 1%(**) 5%(*)

3.5.1.4 Dunedin urban area

As for Napier–Hastings, Dunedin has limited variation in accessibility across the urban area. It also has the smallest within-urban area variation in accessibility changes – the changes that did happen were relatively uniform across Dunedin. As a result, wage and rent regressions for Dunedin are particularly imprecise, especially for our preferred (first difference) specification. The estimates for Dunedin are shown in Table 3.8.

Controlling for worker and housing composition in column 2 removes the bias from high accessibility areas having workers with low wage-related characteristics (young, low qualifications) and high rent-related characteristics (larger houses). Removing the remaining bias from unobserved meshblock characteristics in column 4 has the primary effect of greatly inflating standard errors – by a factor of 6 to 9 for coefficients on *EJS* and by a factor of 60 to 90 for coefficients on ln*JO*, which are most affected by a lack of variation.

Table 3.8 Dunedin – wages, rents and accessibility

		Baseline	Composition-adjusted wages and rents	IV-estimation of (2)	Change regression	IV-estimation of (4)
		(1)	(2)	(3)	(4)	(5)
Wage rcvd	$\ln JO$	-0.455***	-0.032	-0.071	-0.871	7.742
		(0.111)	(0.065)	(0.090)	(5.923)	(13.398)
	EJS	-2.649	1.724	1.314	1.211	-16.054
		(2.154)	(1.265)	(1.831)	(12.152)	(23.532)
Rent	$\ln JO$	0.285**	0.178*	0.187	0.368	-14.877
		(0.097)	(0.078)	(0.108)	(6.532)	(14.793)
	EJS	0.899	-0.754	-0.349	-5.930	24.163
		(1.873)	(1.518)	(2.198)	(13.402)	(25.984)
Wage paid	$\ln JO$	-0.242	0.000	-0.065	-4.250	30.538
		(0.134)	(0.110)	(0.150)	(13.174)	(29.868)
	EJS	-3.596	0.396	-0.907	9.418	-44.987
		(2.601)	(2.128)	(3.055)	(27.028)	(52.462)
	$\partial V_c^w / \partial \ln JO$	0.512***	0.068	0.108	0.944	-10.718
		(0.115)	(0.067)	(0.093)	(6.075)	(13.750)
	$\partial V_c^f / \partial \ln JO$	-0.211	0.020	-0.045	-4.209	28.885
		(0.135)	(0.110)	(0.151)	(13.174)	(29.862)
	$\partial V_c^w / \partial EJS$	2.829	-1.875	-1.384	-2.397	20.886
		(2.227)	(1.301)	(1.883)	(12.464)	(24.151)
	$\partial V_c^f / \partial EJS$	-3.497	0.312	-0.946	8.759	-42.303
		(2.613)	(2.138)	(3.073)	(27.029)	(52.451)
N obs		2,653	2,630	1,829	1,375	1,375

Note: Each column of the table reports estimates for three separate regressions, estimated jointly. The reported estimates are from the second stage of a two-stage estimation procedure, as described in section 3.3.4. First-stage wage and rent regressions control for a range of personal and dwelling characteristics, as documented in that section. Estimates below the horizontal line are for linear combinations of coefficients, as described in the text. V_c^w denotes the contingent valuation by workers. V_c^f denotes the contingent valuation by firms. Standard errors are clustered by meshblock. Significance indicators: 0.1%(***), 1%(**) 5%(*)

3.5.1.5 Labour market stratification

Overall job opportunities and exposure to general job surplus may not be the most salient measure for workers. For instance, wages and rents for low-skilled workers may be more closely related to the job opportunities for low-skilled workers and their exposure to surplus jobs for low-skilled workers. To investigate this possibility, we estimated the wage and rent effects of overall accessibility separately for workers with low (less than tertiary) and high (tertiary) qualifications, and for men and women. We also calculated group-specific measures of job opportunities and exposure to job surplus.

Table 3.9 and Table 3.10 present the estimates for each study area, using estimates from our preferred first-difference specification, as shown in column 4 of the preceding tables. Table 3.9 presents estimates for Auckland and Napier–Hastings, and Table 3.10 provides analogous estimates for Wellington and Dunedin. The first row of each panel reproduces selected coefficients from the fourth column of the relevant table in the previous section, showing the overall effects of accessibility on wages received (net of commuting costs), rents and the implied consumption value of accessibility. The left half of the table provides estimates for the impact of ln*JO* and the right half shows estimates for *EJS*.

The panel for Auckland shows a consistently positive and statistically significant effect of ln*JO* on rents. The effect on wages is significantly positive for men, and significantly negative for women and for the effect of opportunities for low-qualified workers on the wages of low-qualified workers. The implied estimate of the value of job opportunities as a consumption amenity differs depending on whether opportunities are captured by overall opportunities or group-specific amenities. For low-qualified workers and for women, own-group job opportunities appear to be more valuable than overall job opportunities.

Table 3.9 Stratified labour markets: wages, rents and accessibility (Auckland and Napier–Hastings)

Group	Accessibility measure	Coefficient on *lnJO*: lnWage	Coefficient on *lnJO*: lnRent	Coefficient on *lnJO*: V_c^w	Coefficient on *EJS*: lnWage	Coefficient on *EJS*: lnRent	Coefficient on *EJS*: V_c^w
				(a) Auckland			
All	All	-0.112	0.243**	0.161**	2.766***	-0.867	-2.940***
LQ	All	0.025	0.230**	0.021	3.425***	-1.143*	-3.654***
	Own	-0.166*	0.297***	0.226*	2.379***	-1.134*	-2.606***
HQ	All	-0.046	0.293***	0.105	2.900***	0.661	-2.768***
	Own	0.113	0.371***	-0.039*	2.107***	0.939*	-1.919***
Men	All	0.241**	0.326***	-0.176**	2.930***	-0.349	-2.999***
	Own	0.400***	0.256***	-0.348*	2.728***	-0.647	-2.857***
Women	All	-0.254***	0.186*	0.291***	3.349***	-0.297	-3.408***
	Own	-0.438***	0.230**	0.484*	2.881***	-0.117	-2.905***
				(b) Napier–Hastings			
All	All	-0.532	2.052	0.942	1.955	4.949	-0.965
LQ	All	0.317	2.409	0.165	5.757	4.278	-4.902
	Own	-1.139	0.017	1.142	2.800	2.601	-2.280
HQ	All	0.282	2.368	0.192	3.048	2.023	-2.644
	Own	1.570**	0.380	-1.494	1.661	-1.238	-1.909
Men	All	-0.385	2.679*	0.920	3.562	6.186	-2.325
	Own	-0.046	2.092**	0.464	1.875	3.668	-1.141
Women	All	-1.172	2.254*	1.623	1.562	1.836	-1.195
	Own	-1.417	2.157	1.848	14.074	0.665	-13.941*

Note: Each row reports estimates for a separate set of two (jointly estimated) regressions. For each subgroup identified in the leftmost column, wage and rent regressions are run on either overall job accessibility (labelled 'all' in the second column) of group-specific job accessibility (labelled 'own'). Standard errors are clustered by meshblock. Significance indicators: 0.1%(***), 1%(**) 5%(*)

There are no clear patterns for the other panels of Table 3.9 or Table 3.10. For Napier–Hastings and Dunedin, the lack of precision in most of the estimates precludes any clear inferences. For Wellington, the estimates of the effect of group-specific accessibility measures on wages and rent generally reflect the overall pattern reported in the first row of Table 3.10 and in Table 3.7. Job opportunities are associated with lower wages and rents, with the implied impact on the value to workers being positive. The impacts of overall ln*JO* on valuation are statistically significant in some cases, though never significantly different from the effect of own-group ln*JO*

Table 3.10 Stratified labour markets: wages, rents and accessibility (Wellington and Dunedin)

		Coefficient on ln*JO*			Coefficient on *EJS*		
Group	Accessibility measure	lnWage	lnRent	V_c^w	lnWage	lnRent	V_c^w
(c) Wellington							
All	All	-0.541**	-0.759**	0.390*	2.889**	0.669	-2.755***
LQ	All	-0.656*	-0.698**	0.517*	1.655	0.165	-1.622
	Own	-0.529*	-0.390	0.451	0.257	-3.075*	-0.872
HQ	All	-0.371	-0.644*	0.242	2.775*	0.512	-2.673**
	Own	-0.537*	-1.185***	0.300	0.836**	0.137	-0.809***
Men	All	-0.488*	-0.582*	0.372*	3.316**	0.412	-3.233***
	Own	-0.292*	-0.535***	0.185	2.930***	1.051	-2.720***
Women	All	-0.581*	-0.631**	0.454*	2.266*	0.746	-2.116*
	Own	-0.396	-0.453	0.305	0.437	-0.866	-0.610
(d) Dunedin							
All	All	-0.871	0.368	0.944	1.211	-5.930	-2.397
LQ	All	-2.997	1.172	3.231	6.330	-1.756	-6.681
	Own	0.035	1.666	0.298	0.318	-0.520	-0.422
HQ	All	-3.203	-2.075	2.788	8.736	-9.215	-10.579
	Own	4.091	-8.593*	-5.809	1.079	-14.636*	-4.006
Men	All	-2.252	-5.913	1.070	1.834	9.218	0.009
	Own	-4.773	2.890	5.351	9.651	-7.404	-11.132
Women	All	0.239	-1.863	-0.611	1.160	-1.138	-1.387
	Own	0.806	-3.639	-1.534	0.547	-2.927	-1.133

Note: Each row reports estimates for a separate set of two (jointly estimated) regressions. For each subgroup identified in the leftmost column, wage and rent regressions are run on either overall job accessibility (labelled 'all' in the second column) of group-specific job accessibility (labelled 'own'). Standard errors are clustered by meshblock. Significance indicators: 0.1%(***), 1%(**) 5%(*)

3.5.2 Results: Does NJA affect employment rates?

In this section, we report estimates of whether greater job accessibility, due either to higher job opportunities or to higher exposure to job surplus, increases the likelihood of local residents being employed. Table 3.11 presents estimates of the equations described in section 3.3.4.2, with separate panels for each of the four study areas. The ordinary least squares (OLS) estimates in the first column are very similar to those in the second, suggesting there is minimal bias from the endogeneity of job accessibility.[24] The third column shows estimates based on first-differenced regressions – estimating the relationship between changes in accessibility and changes in employment rates. This specification has the advantage of controlling for meshblock-specific differences in employment rates that are correlated with accessibility but which arise for reasons other than accessibility (eg: differences in demographic composition). Comparing the estimates in the first two columns with those in the third column suggests that, apart from in Dunedin, high ln*JO* meshblocks tend to have relatively low employment rates and high exposure to job surplus. Controlling for these cross-sectional relationships, we find that increases in ln*JO* are associated with increases in employment rates. In contrast, increases in exposure to job surplus are associated with declines in employment rates. The estimates for Auckland show a coefficient on *lnJO* of 0.557, implying that a one standard deviation increase in ln*JO* (0.40 in Auckland) implies a 22 percentage point increase in employment rates, which is substantial. The analogous estimates for Wellington and Napier Hastings are 13 percentage points and 11 percentage points respectively. A one standard deviation increase in *EJS* is associated with employment rates that are lower by seven percentage points in Auckland, 14 percentage points in Wellington, and one percentage point in Napier Hastings.

The first-difference results for Dunedin in column 3 are implausibly large, which we attribute to the lack of variation in ln*JO* within Dunedin. The standard errors on the estimated effect of ln*JO* in Dunedin are inflated by a factor of around 90 (from 0.027 to 2.360) when estimated on first differences. The coefficient of -11.028 implies that a one standard deviation (0.22) higher value of ln*JO* is associated with an employment rate that is 243 percentage points higher, which is non-sensical.

Instrumental variables estimates of the change regression are reported in column 4 of Table 3.11. Although the instruments pass standard statistical tests, the resulting coefficients are, with the exception of Auckland, inflated implausibly. We therefore rely on the un-instrumented estimates in column 3 as our preferred estimates.

Table 3.11 Employment rates and accessibility

	OLS	IV	Meshblock fixed effects (change)	Meshblock fixed effects (IV (change))
	(1)	(2)	(3)	(4)
		(a) Auckland		
ln*JO*	-0.050***	-0.048***	0.557***	0.334***
	(0.007)	(0.006)	(0.042)	(0.074)
EJS	-0.615***	-0.631***	-1.964***	-2.502***
	(0.094)	(0.073)	(0.313)	(0.348)
Nobs (rr3)	30,226	20,182	20,036	20,036
UnderID KP		1,659.060		1,772.310
p		0.000		0.000
WeakID KP		15,945.190		951.042
		(b) Napier–Hastings		
ln*JO*	-0.112***	-0.069**	0.761	-3.797**
	(0.028)	(0.023)	(0.500)	(1.429)
EJS	-0.498	-0.384	-1.095	-8.267
	(0.383)	(0.266)	(1.515)	(4.415)
Nobs (rr3)	3707	2464	2445	2445

[24] For each study area, the instruments easily pass statistical tests for under-identification and weak identification. The IV estimates are based on 2013 and 2018 data only, given the lack of an instrument for 2006.

	OLS	IV	Meshblock fixed effects (change)	Meshblock fixed effects (IV (change))
UnderID KP		607.765		113.888
p		0.000		0.000
WeakID KP		6,832.045		30.662
			(c) Wellington	
ln*JO*	0.008	-0.002	0.317**	16.117***
	(0.006)	(0.004)	(0.103)	(3.402)
EJS	0.418***	0.420***	-3.939***	-80.929***
	(0.061)	(0.051)	(0.573)	(16.591)
Nobs (rr3)	11,454	7,653	7,559	7,559
UnderID KP		1,976.428		29.587
p		0.000		0.000
WeakID KP		207,592.610		14.413
			(d) Dunedin	
ln*JO*	-0.125***	-0.130***	-11.028***	-21.160***
	(0.031)	(0.027)	(2.360)	(6.107)
EJS	-1.944**	-2.242***	22.012***	35.787***
	(0.698)	(0.610)	(4.558)	(10.586)
Nobs (rr3)	3,710	2,472	2,459	2,459
UnderID KP		248.712		114.005
p		0.000		0.000
		2,818.742		WeakID KP

Note: Standard errors are clustered by meshblock. Significance indicators: 0.1%(***), 1%(**), 5%(*)

3.5.2.1 Labour market stratification and the probability of employment

It is possible that employment rates for particular subgroups of workers depend more on the local accessibility of the sort of jobs that they are likely to work in rather than on the accessibility of all jobs. To test this possibility, we present in Table 3.12 a set of results analogous to those in Table 3.9 and Table 3.10. For four subgroups of workers (low qualifications, high qualifications, men, and women), we estimate the relationship between the group's local employment rate and either overall job accessibility, or group-specific job accessibility.

In Auckland, the employment of workers with relatively low qualifications appears to be more strongly affected by overall ln*JO* (coefficient of 0.351) than by the job opportunities for just low qualified workers (coefficient of 0.179). Similarly for high-qualified workers, the coefficient on overall accessibility (0.146) is higher than the coefficient on job opportunities for high-qualified workers (0.054). For women, job opportunities as captured by where women are employed appears to be more important than overall job opportunities. It should be noted, however, that the differences in the strength of overall and own-group job opportunities is not statistically strong for any group.

In contrast to the overall negative relationship between *EJS* and employment rates, exposure to job surplus is positively related to employment rates for low-qualified workers, implying that low qualified workers benefit from living in areas where there are relatively few competing jobseekers.

In urban areas other than Auckland, the estimates in Table 3.12 are less systematic, and in many cases implausible for Napier–Hastings and Dunedin. Even in Wellington, the lack of precision in the estimates makes it difficult to draw any strong conclusions about the importance to the different subgroups of overall as opposed to group-specific accessibility.

Table 3.12 Stratified labour markets: employment rates and accessibility (first difference specification)

		Auckland		Napier–Hastings		Wellington		Dunedin	
		ln*JO*	EJS	ln*JO*	EJS	ln*JO*	EJS	ln*JO*	EJS
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All	All	0.557***	-1.964***	0.761	-1.095	0.317**	-3.939***	-11.028***	22.012***
		(0.046)	(0.322)	(0.457)	(1.526)	(0.106)	(0.565)	(2.199)	(4.154)
LQ	All	0.351***	0.942**	0.965	0.990	0.260	-1.141	-11.503***	24.894***
		(0.050)	(0.327)	(0.511)	(1.749)	(0.141)	(0.624)	(2.409)	(4.612)
	Own	0.179***	1.278***	1.267	-4.989*	0.344*	-0.667	-3.713**	5.136**
		(0.039)	(0.279)	(0.862)	(2.202)	(0.137)	(0.608)	(1.275)	(1.681)
HQ	All	0.146**	-1.641***	-0.395	-2.078	-0.026	-1.938***	-9.176***	17.736***
		(0.050)	(0.322)	(0.482)	(1.704)	(0.110)	(0.573)	(1.975)	(3.735)
	Own	0.054	-0.729**	-0.002	-0.409	0.197	-1.131***	-5.159***	-2.651
		(0.067)	(0.242)	(0.294)	(0.794)	(0.151)	(0.167)	(1.439)	(2.525)
Men	All	0.495***	-1.139**	0.472	-0.331	0.447***	-3.518***	-14.515***	31.281***
		(0.054)	(0.355)	(0.491)	(1.714)	(0.122)	(0.612)	(2.403)	(4.676)
	Own	0.443***	-1.415***	0.342	-0.134	0.408***	-4.216***	-3.508*	9.612**
		(0.053)	(0.290)	(0.351)	(0.969)	(0.089)	(0.555)	(1.631)	(3.625)
Women	All	0.612***	-2.656***	0.793	-1.069	0.115	-4.103***	-8.019***	13.847**
		(0.049)	(0.324)	(0.498)	(1.630)	(0.115)	(0.596)	(2.337)	(4.436)
	Own	0.723***	-2.058***	1.058	-0.142	-1.092***	1.101*	-2.266	1.199
		(0.050)	(0.339)	(0.712)	(3.987)	(0.137)	(0.483)	(1.634)	(3.332)

Note: Each row reports estimates for four separate (study-area-specific) regressions. For each subgroup identified in the leftmost column, group-specific employment rates are regressed on either overall job accessibility (labelled 'all' in the second column) of group-specific job accessibility (labelled "own"). Standard errors are clustered by meshblock. Significance indicators: 0.1%(***), 1%(**) 5%(*)

3.5.3 Results: Does NJA affect the ease of finding a new job?

In this section, we report the results of our final set of estimates – to examine whether living in an area with strong job accessibility reduces the length of time it takes for workers who finish a job to find a new one.

Table 3.13 reports the estimate of proportional hazard models, as described in section 3.3.4.3. A positive coefficient on job accessibility means job accessibility makes it easier to find a new job, as evidenced by a lower duration out of work (the 'hazard' of finding a job increases).

Table 3.13 Accessibility and the ease of finding a new job

	Cox proportional hazard	Cox proportional hazard (control function)	Stratified Cox proportional hazard	Stratified Cox proportional hazard (control function)
	(1)	(2)	(3)	(4)
		(a) Auckland		
ln*JO*	-0.089**	-0.098**	0.434	-3.420
	(0.034)	(0.037)	(0.363)	(2.220)
EJS	-0.572	-0.670	-1.836	4.859
	(0.381)	(0.416)	(2.517)	(14.902)
Nobs (rr3)	62,148	62,148	62,148	62,148
Pseudo_R-sq	0.001	0.001	0.003	0.003
		(b) Napier–Hastings		
ln*JO*	0.061	0.016	11.405	16.847
	(0.133)	(0.132)	(7.712)	(13.486)
EJS	-1.559	-2.079	56.029*	-0.562
	(1.513)	(1.533)	(23.197)	(55.859)
Nobs (rr3)	6,546	6,546	6,546	6,546
Pseudo_R-sq	0.001	0.001	0.006	0.006
		(c) Wellington		
ln*JO*	-0.018	-0.016	-1.597	-5.297
	(0.027)	(0.027)	(2.733)	(4.990)
EJS	-0.098	-0.126	10.482	-118.796
	(0.312)	(0.313)	(7.496)	(75.720)
Nobs (rr3)	19,443	19,443	19,443	19,443
Pseudo_R-sq	0.001	0.001	0.002	0.002
		(d) Dunedin		
ln*JO*	0.251	0.231	12.557	29.348
	(0.228)	(0.226)	(24.150)	(32.648)
EJS	7.076	6.680	9.546	-217.250
	(4.727)	(4.749)	(62.843)	(244.704)
Nobs (rr3)	5,871	5,871	5,871	5,871
Pseudo_R-sq	0.001	0.001	0.004	0.004

Notes: Unit of observation is an individual who ended a job in the month of March 2013 or March 2018. All regressions include controls for age, gender, qualifications, and census year. Standard errors are clustered by meshblock. Significance indicators: 1%(**).

The base specification in column 1 shows similar patterns to those in the instrumental variables (control function) specification in column 2. The Auckland estimates for the effect of ln*JO* are the only statistically significant estimates. They show that the ease of finding a new job is lower in areas with higher accessibility. However, once we control for between-meshblock differences in column 3, stratifying by meshblock, the coefficient on ln*JO* becomes positive, suggesting that higher ln*JO* is associated with greater ease of finding a job, and less time out of work. The coefficient estimate is not, however, statistically significant.

In fact, across all urban areas and specifications, there is very weak evidence of any systematic relationship between accessibility and the ease of finding a new job. The inflated standard errors and, in many cases, the coefficients in Table 3.13 suggest we do not have sufficient variation in the data we use to really pin down effects even if they were to exist.

In analysis not reported here, we investigated whether job-finding success for subgroups of workers was more strongly linked to overall or own-group accessibility. Estimates were universally imprecise or implausible (highly inflated coefficients), which we interpreted as implying there was insufficient variation on which to base any inferences.

3.6 Summary/ discussion/conclusions

3.6.1 Summary of results

Table 3.14 brings together the main estimates from our various statistical analyses. The first four columns of the table summarise the effects of job accessibility on wages and rents, and on the implied valuation of accessibility by workers (V_c^w) and by firms $\left(V_c^f\right)$. The top panel shows the size of estimated effects of $\ln JO$.

Table 3.14 Summary of findings

	Std dev (2018)	Wage effect as % of wage	Rent effect as % of rent	V_c^w as % of wage	V_c^f as % of wage	Employ-ment rate	Job-finding hazard
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Effect of ln*JO*			
Auckland	0.400	-4.5%	**9.7%**	**6.4%**	-6.1%	**22 ppt**	0.17
Napier–Hastings	0.138	-7.3%	28.3%	13.0%	-32.2%	11 ppt	1.57
Wellington	0.408	**-22.1%**	**-31.0%**	**15.9%**	3.3%	**13 ppt**	-0.65
Dunedin	0.222	-19.3%	8.2%	21.0%	-93.4%	**-245 ppt**	2.79
				Effect of *EJS*			
Auckland	0.034	**9.7%**	-3.0%	**-10.3%**	**12.7%**	**-7 ppt**	-0.06
Napier–Hastings	0.012	2.3%	5.9%	-1.2%	-8.5%	-1 ppt	**0.67**
Wellington	0.035	**10.1%**	2.3%	**-9.6%**	-11.0%	**-14 ppt**	0.37
Dunedin	0.010	1.2%	-5.9%	-2.4%	8.8%	**22 ppt**	0.10

The lower panel provides analogous estimates for the effect of EJS.

Coefficients from the tables in section 3.5 are multiplied by an area-specific one standard deviation change in accessibility (from the 2018 column of Table 3.3, reproduced in column 1 of Table 3.14). In columns 2 to 5, log changes are expressed as percentage changes. In column 6, the effect is shown as a percentage point change in the employment rate, and in column 7, as a proportional change in the job-finding hazard. All figures in Table 3.14 are based on regression specifications that control for meshblock-specific effects (first difference estimation for columns 2 to 6, and stratified proportional hazards in column 7), but do not use instrumental variables.

We consider the estimates for Auckland are the most credible as the sample size is larger than that of the other areas, but it is also possible that workers in Auckland, being accustomed to long commuting times, are relatively more mobile than those elsewhere. There is also a greater degree of variation in accessibility across Auckland, which helps in identifying the key relationships. As noted in section 3.4, cross-sectional variation in accessibility is limited in the two smaller study areas, Napier–Hastings and Dunedin. In Wellington, the extent of variation is similar to that in Auckland, but the lower number of meshblocks (around 10,300 in Auckland and around 4,000 in Wellington) results in less statistical precision. Meshblock-level variation over time is even more limited in all urban areas. This further restricted our ability to pin down the impacts of accessibility empirically.

In Auckland, our estimates imply that resident workers value living in areas with higher access to job opportunities. In response to a one standard deviation higher level of job opportunities $(ln\,JO)$, residents pay higher rents (9.7%) and receive lower wages (4.5%). This implies that job opportunities are a positive consumption amenity with an implied value of around 6.4% of wages. One implication of the combined rent and wage effects is that accessibility, as captured by $ln\,JO$, serves to reduce housing affordability – at least if it is measured as a ratio of rental costs to incomes. Higher local job opportunities in Auckland are also associated with a 22 percentage point higher employment rate, and a slight (statistically insignificant) 0.17 increase in the ease of finding a new job.

The estimated effects of exposure to job surplus in Auckland imply it is a consumption disamenity – for which residents are compensated in the form of lower rents and higher wages. Operating in an area where local workers face short job queues (high exposure to job surplus) is estimated to be a positive productive amenity for firms. The implied effects of *EJS* on employment rates and ease of job finding are estimated to be negative but are small relative to the effects of ln*JO*.

Wellington has a geographical structure different from that of the other urban areas. Central and southern areas of Wellington, in particular, have relatively high job opportunities *and* exposure to job surplus. In other areas, job opportunities are also highest in central areas, but exposure to job surplus tends to be higher at the edges of the urban area. Relatedly, in Wellington, access to job opportunities is associated with lower wages (as in other areas) but also with lower rents. The net effect is still that ln*JO* is a positive consumption amenity, comparable in size to a 16% higher wage, and is associated with higher employment rates (13 percentage points).

At the risk of overinterpreting the weak patterns for Napier–Hastings and Dunedin, both are suggestive of ln*JO* being a positive consumption amenity, associated with higher rents and lower wages. In Napier–Hastings, ln*JO* has an insignificant positive effect on the local employment rate. In Dunedin, the effect on the employment rate is statistically significant and negative but implausibly large, which we attribute to weak identification.

In estimating the labour market and housing market impacts of job accessibility, we have been challenged by the lack of variation in the data, especially for urban areas other than Auckland. This has made it difficult to obtain estimates with statistical precision, especially when we have tried to control for meshblock level differences that may exist for reasons other than job accessibility.

3.6.2 Discussion

An objective of this research project was to show how the transport system mediates between areas of high housing affordability and areas of high job opportunities.

A key finding of this chapter is that there is much sorting in the residential-work choice, generally confirming the findings of the literature review.

First, higher accessibility to jobs has shown in New Zealand since 2006 as higher rents, and implicitly higher house prices, or, put another way, an increase in job accessibility alone would be expected to lead to higher house prices (given similar conditions to the last 15 years). This serves as a warning that a policy aimed at decreasing travel costs for residents in an 'affordable suburb', thus inducing the equivalent of the higher spatial accessibility modelled here, may reduce the affordability of the suburb, including through a process that prices out the persons initially targeted to benefit. This process is sometimes known as gentrification, especially when the housing stock transitions from mostly tenanted to mostly owned.

However, this result need not be universal. The rent-accessibility effect differed in Wellington for reasons that require further research although the wage-accessibility effect, to be discussed next, was the same as in other centres.

Second, the mixed relationship between accessibility and wages suggests there are many reasons for choosing the resident-job location mix, again consistent with the literature review. There are various interpretations possible for the results found. One plausible explanation is that people will commute further to achieve a higher wage at a large centre rather than take nearby (lower paid) employment. Also there are likely to be non-employment attractions near employment centres, including possibly in Auckland schooling near major centres that may entice partners to accept lower paid jobs as part of a family residence-school-job choice.

Third, the model did not detect a consistent discernible effect for lower-skilled workers and hence failed to provide evidence that a spatial mismatch existed that might be preventing lower-income workers from obtaining higher-paid jobs. The literature review pointed to any spatial mismatch effect likely being greater for lower-skilled people, for women and for minority races. The model found that in Auckland, lower-skilled workers had higher wages if they lived near their work location, implying an advantage to be gained by using transport links to improve their work access. This result was repeated in Napier–Hastings, although it was not statistically significant. However, the opposite low-qualification effect occurred in Wellington and Dunedin, with again one effect not being statistically significant. This further cautions against using a blanket transport policy to improve accessibility targeted at low-skill jobs. Indeed it may be better to disaggregate skill into education and work experience rather than relying on relative wage rates – if that is possible.

3.6.3 Next steps

This completes the results of the census modelling. The next chapter turns to confirming, or not, these findings when a time series is examined and brings commuting into the relationship. Further discussion of the transport implications of both sets of results will then follow.

4 Long-term trends in job opportunities by worker skill – IDI analysis

4.1 Introduction

Much of the policy concern around spatial mismatch is related to distributional concerns – whether disadvantaged workers are further disadvantaged by being constrained to live in areas with low housing costs and low job accessibility, resulting in high commuting costs. In this section, we examine in more detail the variation in accessibility and commuting across our study areas. We also document separately the patterns for groups of workers. We classify workers according to their earning ability, which we estimate based on their age and whether they generally earn high wages. We refer to this earning ability as 'skill'.

To investigate these issues, we switched data sources from the census to the administrative data available in the Integrated Data Infrastructure (IDI). IDI administrative data allowed us to extend the census analysis of job opportunities along several useful dimensions.

First, we examined inter-census changes in ln*(JO)* and *EJS*, particularly over the period encompassing the global financial crisis (GFC) and subsequent recovery and expansion of the labour market. Secondly, using worker and employer characteristics, we accounted for the fact that the characteristics of jobs other than commutability affected whether workers could access a particular job. Specifically, we incorporated the matching of workers and firms on quality and allowed for the observed persistence of workers' jobs in industries that demand their skills. This accounting for heterogeneity in job availability, particularly along the dimensions of worker skill and firm quality, allowed us to more convincingly disaggregate differences in experienced job opportunities for low- versus high-skilled workers. The identification of trend differences in outcomes between different skill groups was particularly pertinent to discussions of spatial mismatch since low-income workers were more likely to be susceptible to such mismatch. Finally, we used the IDI data to explore the link between job opportunities and commute distance, which reemphasised the importance of thinking about potential trade-offs/optimisation between (residential and work) location and commute costs. In particular, we explored whether increasing job opportunities was correlated with shorter or longer commutes, and whether these patterns varied spatially in Auckland (which displays the greatest variation in job opportunities over time).

4.2 Data and method

The IDI analysis was based on the labour and commute datasets constructed by Fabling & Maré (2015; 2020), combining cleaned employer monthly schedule tax data on monthly jobs with business register data on employing business locations (plants) and cleaned administrative residential address data. This IDI commute dataset covers almost all employee jobs for the period 2005 to 2017 (ie not spanning the census periods exactly), with weighting applied to account for missing commutes so the resulting data was representative of the residential employed population.[25,26] We restricted this population to working age (18–

[25] Missing commute information is primarily a problem for primary and secondary school teachers, who are paid centrally and are not easily allocated to a particular work location because of the large number of schools each teacher potentially works at.

[26] Working proprietors are excluded from the analysis because their labour input is estimated from annual tax returns and, therefore, they are not included in the commute dataset. Employee jobs are not weighted by the full-time equivalent

75) individuals, and aggregated the data to quarterly which eased the computational burden of the analysis – the commute dataset has over 1billion rows – while still identifying seasonal variation in accessibility.

We followed the same method as the census analysis to define job opportunities, employing the modified exponential decay function for weighting potential commutes by distance. In the absence of time-varying information on the road network over the analysis period, commute distance was measured as meshblock centroid to meshblock centroid, and restricted to commute distances of 50 km or less. Initially, we compared both the job opportunities (ln*(JO)*) and mean exposure to job surplus (*EJS*) derived from the IDI commute dataset to census equivalent results, before focusing exclusively on the ln*(JO)* measure to derive skill-group specific job opportunity measures. Both the restriction to 50 km commutes and the focus on job opportunities are driven by computational requirements, since the introduction of heterogeneity in workers, firms and jobs substantially increases the dimensionality of the job opportunities calculation.

Specifically, to account for job sorting, we modified the *JO* metric to allow for different types of workers and firms, so that for a job of type B (E_{jB}), where 'job type' is a mix of worker and firm characteristics, we assigned a probability (p_{AB}) that such a job might be filled by a worker currently in a job of type A. Then the job opportunities of a worker currently in a job of type A can be expressed as the physical distance and job transition probability weighted sum across all jobs of type B, ie:

$$\text{Job Opportunities for worker type A by residential area } h \quad \text{(Equation 4.1)}$$

$$JO_{hA} = \sum_j g(dist_{hj}) p_{AB} E_{jB}$$

and aggregate job opportunities across all worker types is the simple summation of this measure across all job types currently held by residents in location h (or across any subset of the job type characteristics to yield, eg the job opportunities for workers with a specific characteristic within the job type).

$$\text{Job Opportunities by residential area } h \quad \text{(Equation 4.2)}$$

$$JO_h = \frac{1}{N_h} \sum_A N_{hA} \sum_j g(dist_{hj}) p_{AB} E_{jB}$$

It is immediately obvious from equation 4.2 that we should be concerned about the computational load of probability-weighting for each job, since the probability matrix scales with the square of the number of distinct worker-firm job types. To make this approach tractable, we placed restrictions on the number of job types, and we aggregated the commute data to the Statistics NZ statistical area 2 (SA2) level after first confirming that the SA2 level produced similar results (at the mean) to the meshblock level in the absence of allowing for heterogeneity in jobs.[27]

4.2.1 Worker 'skill' and firm 'quality'

To account for job sorting, we identified three job characteristics that were strongly predictive of the type of job transitions workers make: firm industry, firm quality and worker skill. The first of these measures is the

(FTE) measure available in the labour dataset, since the derivation of this measure largely relate to the characteristics of the incumbent worker in the job, implying that it is not necessarily a characteristic of the job that might carry over to a new holder of that job.

[27] SA2 boundaries do not necessarily align with urban area boundaries, so we used residential employment shares to allocate boundary-crossing SA2s to the predominant urban area.

employers' ANZSIC (2006) division, which includes 19 industry groups.[28] Firm quality and worker skill are estimated directly from the labour dataset using a two-way fixed effects regression of log wages on worker and firm fixed effects, together with time dummies and a sex-specific quartic in age (as in Maré et al. 2017). Firm quality was then defined as the four quartiles of the firm fixed effect distribution within industry and calendar year. Worker skill was similarly defined as within sex and year quartiles of the worker fixed effect plus the component of the wage attributable to age (which captured the combined effects of experience, tenure and cohort).

The average worker skill measure is non-stationary over time, and separately normalised for men and women, which motivated us to calculate skill quartiles within year and sex, ensuring that a quarter of male and female workers are in each skill group in each calendar year. Similarly, average firm quality (as measured by the firm fixed effect) increases over time, and the identification of firm quality within industry allows the firm quality measure to capture the component of firm quality (wage premium) orthogonal to industry (thus avoiding the possibility the majority of firms in, say, finance industries are deemed to be among the highest quality firms).

Combined, these three job characteristics yield 304 distinct job types. To populate the probability matrix (p_{AB}) between job types, we relied directly on the empirical distribution of job-to-job transitions, where we made a number of data restrictions to improve the signal in those transitions. Specifically, we excluded short-term (one to two month) jobs, and jobs that ended and then restarted with the same employer (within six months). We then focused on new jobs that started within six months of the old job finishing, counting the total number of transitions between the job type being left (job type A in the above notation) and the job type being started (job type B). The transition probability (p_{AB}) is, then, the number of transitions from job type A to job type B as a proportion of the total number of job types B that were started. Since we wanted to identify the potential of rare transitions with non-zero probability, we pooled job transitions over all time (ie p was assumed to be time-invariant) even though we observed time variation in the match rate of workers of different types and, indeed, changes in the composition over time of the types of workers and jobs that ended and started employment spells.

One issue with using worker skill defined from two-way fixed effects was that the measure is quasi-fixed for a given individual, meaning we did not observe transitions from job types at one worker skill level to job types in another worker skill level, except in a way that was economically unmeaningful, ie when workers were close to the quartile boundary and their age changed between jobs, or where the calendar year changed between jobs, resulting in the skill quartile boundary moving. In the real world, we would expect to observe some movement of workers between jobs that are generally held by tertiary qualified individuals and jobs held by unskilled workers. In this analysis, however, there are essentially four separate labour markets – one for each worker skill group – which mechanically reduces the overall job opportunities for workers (since, on average, a worker cannot access three quarters of jobs). Excluding across skill group transitions, the probability matrix (p_{AB}) potentially has 23,104 (=304x76) cells. In practice, almost all these cells have non-zero probabilities, but certain transitions are much more likely than others, particularly within industry job changes, with high-skill workers moving to high-quality firms and low-skill workers being stuck in transitions between low-quality firms. Overall, despite the limitations of the worker skill categorisation (ie the unnatural segregation of the labour market), the heterogeneity that the probability matrix (p_{AB}) adds to measured job opportunities seems likely to present a more realistic view of the real-world opportunities that individuals face.

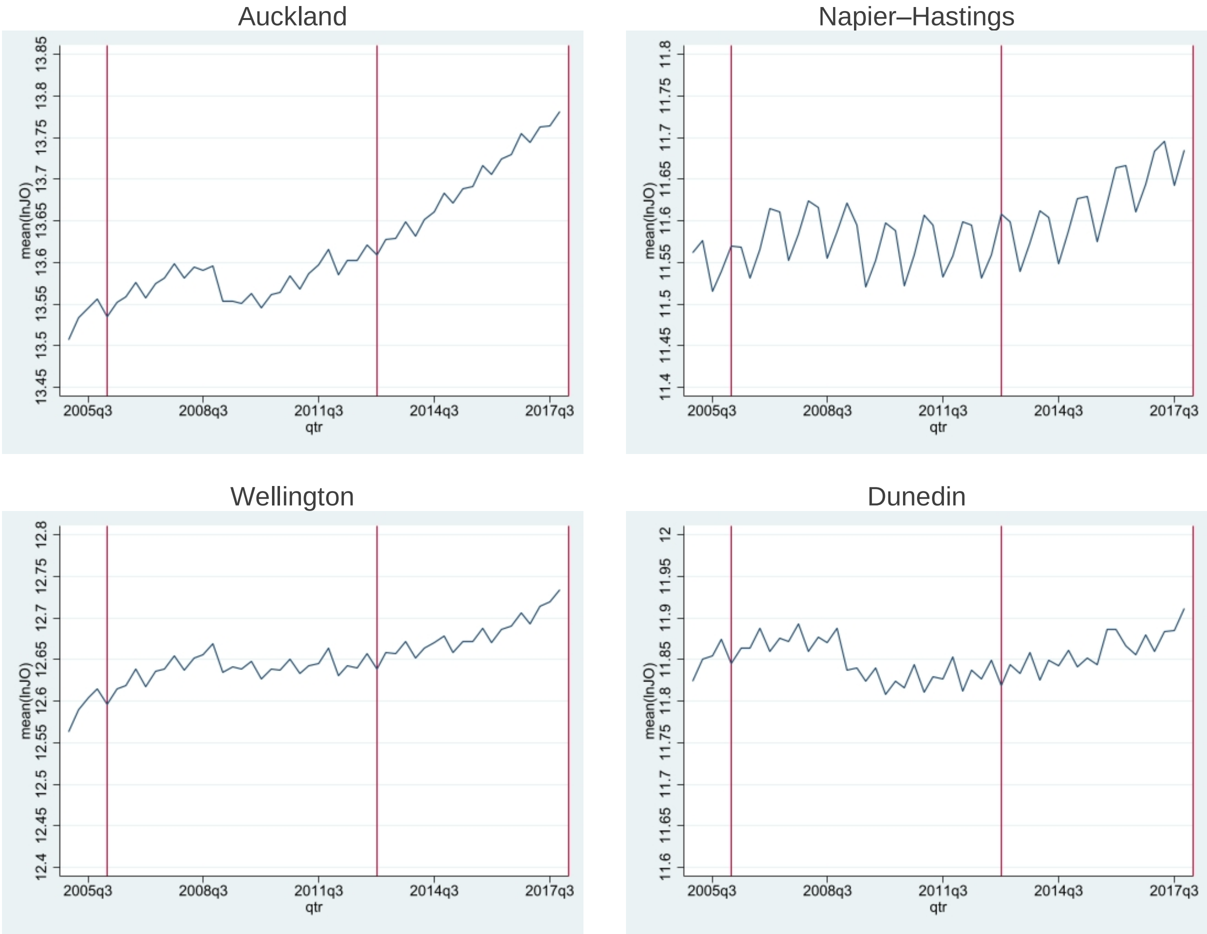
[28] Australian and New Zealand Standard Industrial Classification. https://www.stats.govt.nz/methods-and-standards/standards-and-classifications/

4.3 High-level results

Figure 4.1 and Figure 4.2 show mean job opportunities and mean exposure to job surplus for the four case study locations. Figure 4.3 shows changes in employment for the four locations.

The variation over time matches the census analysis, albeit with levels difference. The IDI shows variable effects of the GFC recession across regions (Auckland vs Wellington), seasonal variation due to agriculture in Napier–Hastings, and the relative size of student population in Dunedin. Overall, the change in JO is largely driven by changes in overall labour market size.[29] Exposure to job surplus has a slight trend in some regions, but it is second order compared with *JO*, confirming the findings in section 3.4. Thus we ignored it from here on.

Figure 4.1 Mean in(job opportunities) by study region (2005–2017)



[29] Note that official linked employer-employee data (LEED) statistics imply stronger growth in employment in Dunedin; 17 log points, rather than 5 in our analysis. Other regions show similar growth in total employment across the two analyses (noting that LEED relates to regional councils and our study areas are urban areas). Both the LEED and IDI datasets have issues around how the student population is tracked, which is a particular problem for Dunedin. LEED pays no attention to whether a commute is feasible when allocating to job locations whereas the IDI commute dataset assumes the residential address is correct.

Figure 4.2 Mean exposure to job surplus by study region (2005–2017)

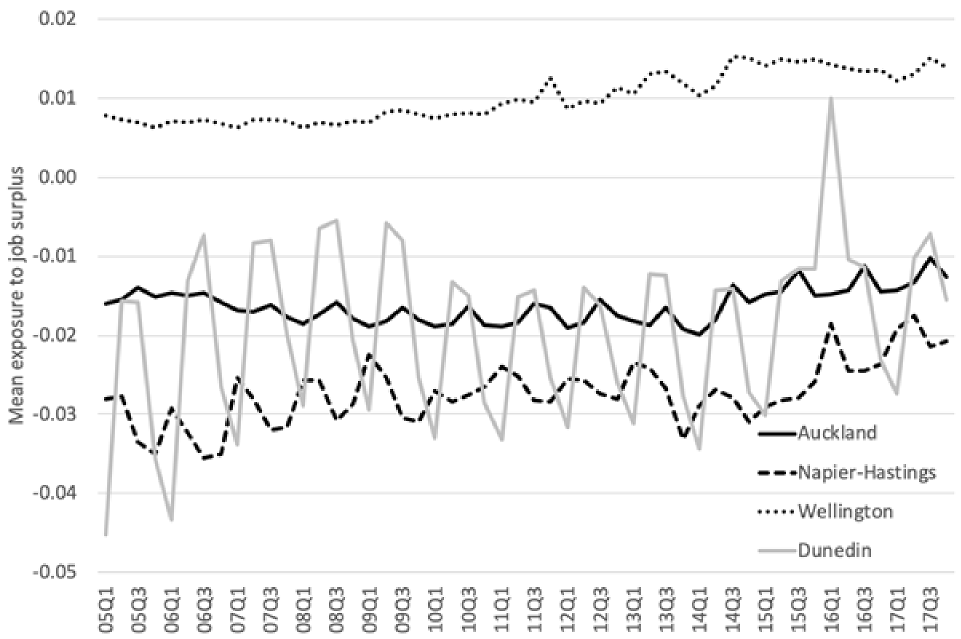


Figure 4.3 Log change in residential employment by study region (2005–2017)

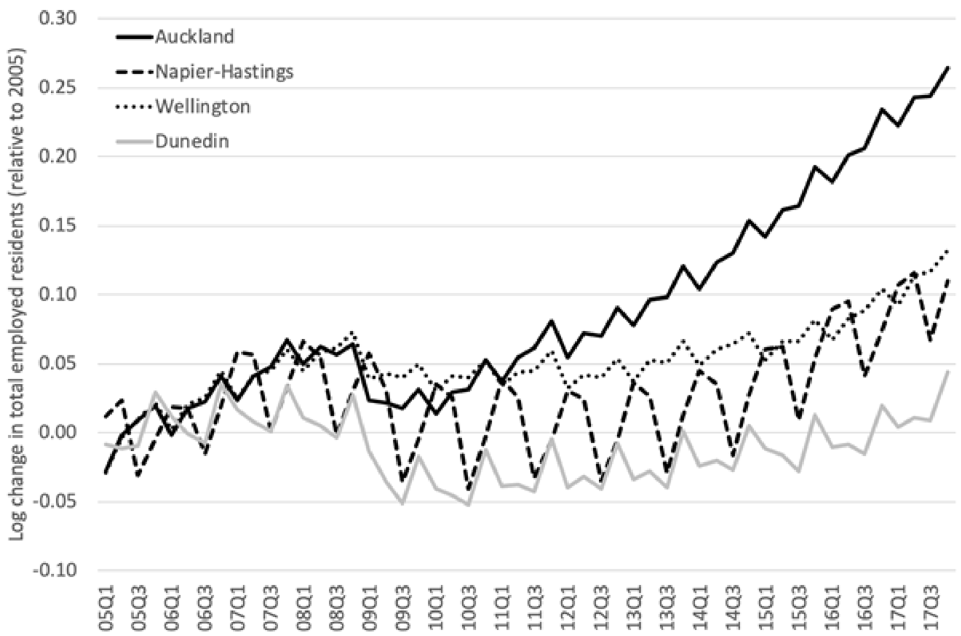
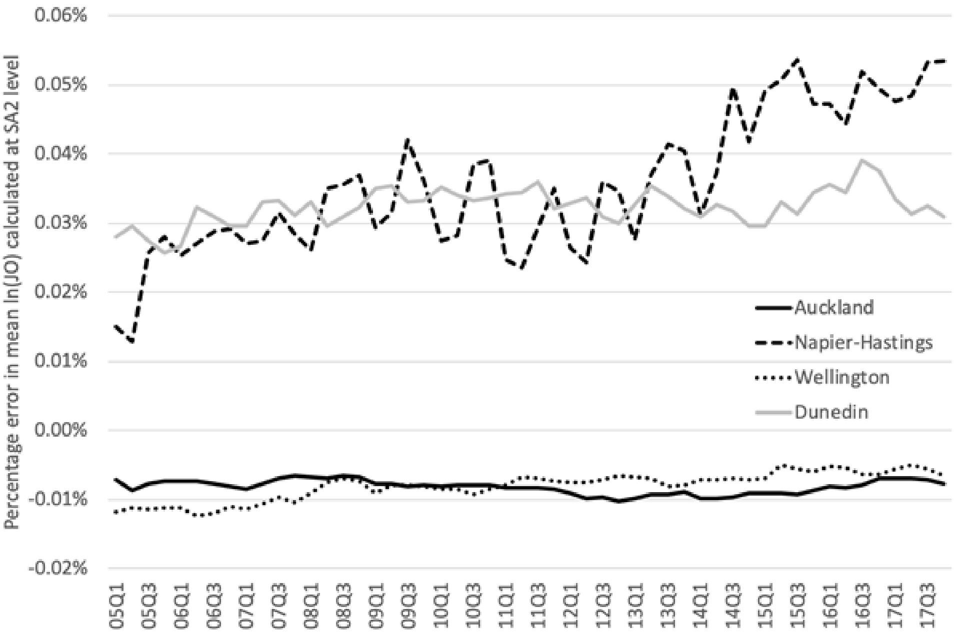


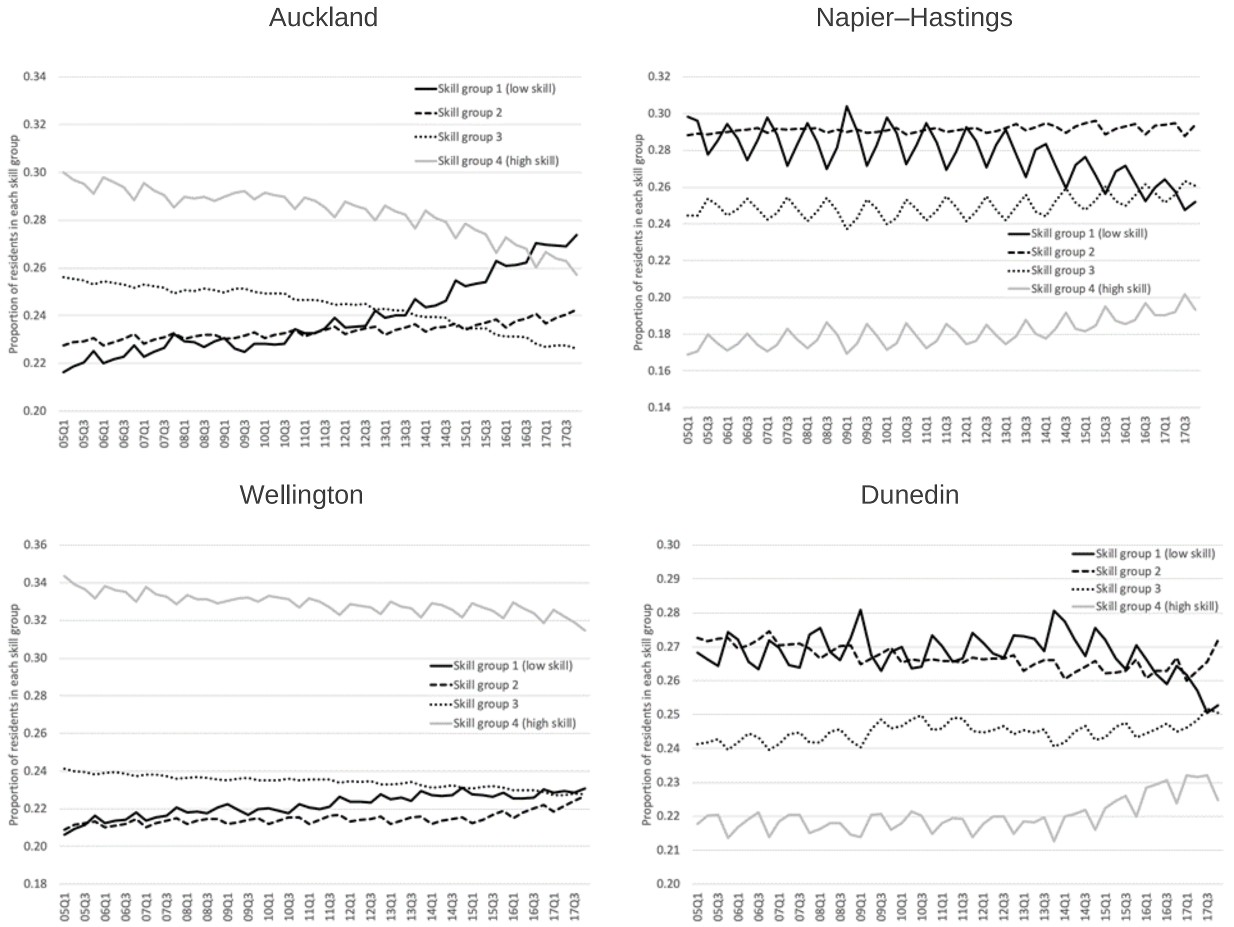
Figure 4.4 Percentage error in mean job opportunities from estimating at SA2 level instead of meshblock level



The error from approximating at the SA2 level (with SA2 to SA2 centroid distance) is minimal, as shown in Figure 4.4. There are some issues of comparability at the 25th percentile (not reported), but of little consequence as we focused on means.

Figure 4.5 shows substantial differences in trends across worker skill groups for all regions, although again this is partly driven by changes in aggregate job market size (see Figure 4.6). In particular, as the quartiles of skill are derived from all jobs, the skill mix in a particular region varies substantially from equal shares. For example, in Auckland, growth in total employment comes disproportionately from low-skill jobs leading towards a convergence in job opportunities for the lowest and highest skill groups over time. In contrast, the Wellington region has reasonably stable employment shares across the skill groups, with job opportunities greatest for high-skill workers throughout the period 2005 to 2017.

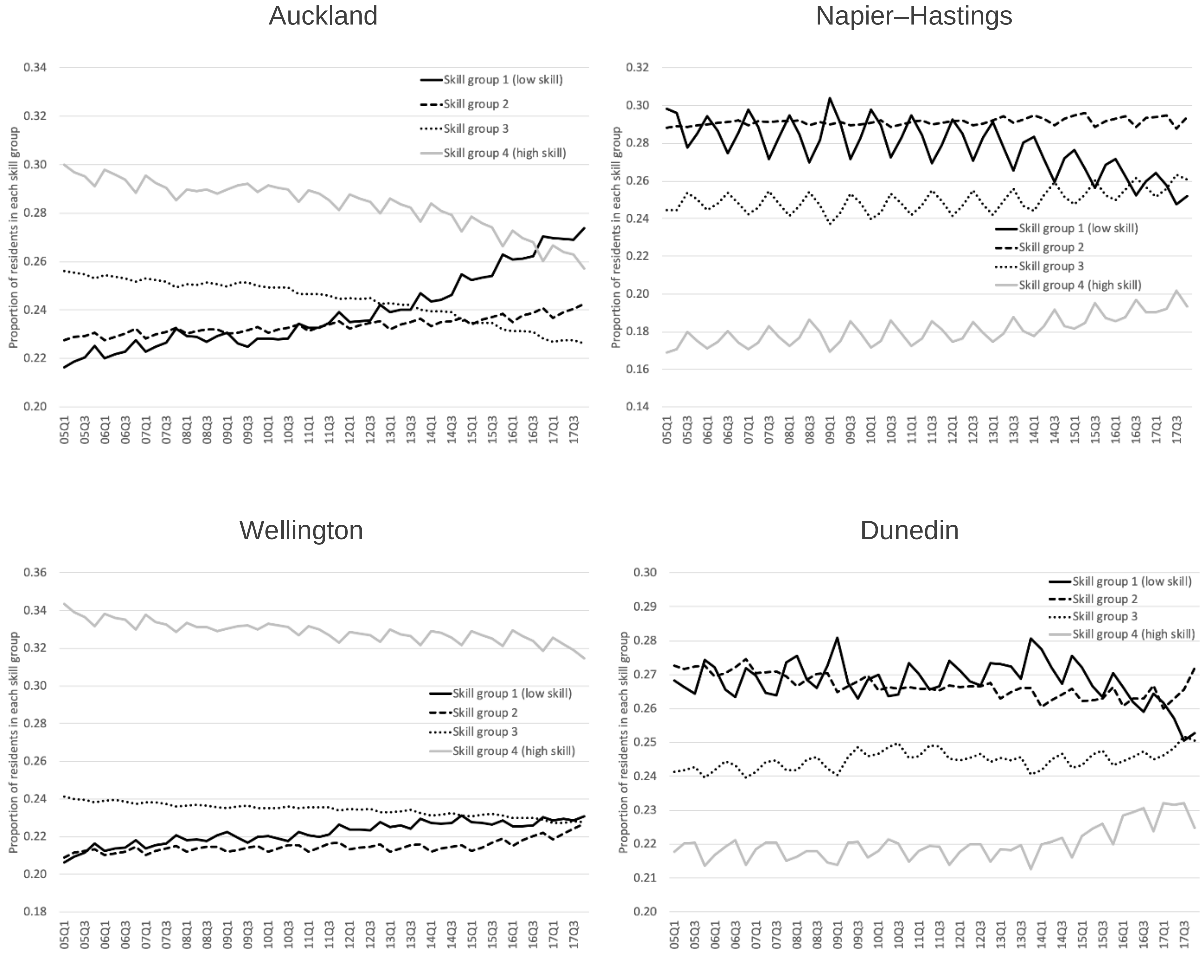
Figure 4.5 Mean ln(job opportunities) by study region and worker skill (2005–2017)



Seasonal variation in Napier–Hastings is concentrated almost entirely in the bottom half of the skill distribution, consistent with this variation being due to the substantial primary sector in the region.

Overall labour market conditions and economic growth have most likely been the prime determinants of access to job opportunities, but this finding could partly be an artefact of not having any variation in the commute network over time. The Auckland analysis below shows some interesting core/periphery geographic variation to that story.

Figure 4.6 Employment shares by study region and worker skill (2005–2017)



4.4 A closer look at Auckland

Here we take a closer look at the IDI results for Auckland as that region has the most variation in aggregate and skill-specific *JO*.

4.4.1 Job opportunities and commute distance over time and space

In Auckland, access to job opportunities and mean commute distance have both risen since 2009, following the GFC-induced decline in economic activity (Figure 4.7). Thus the relationship between job opportunities and mean commute distance is positive over time. However, as illustrated in Figure 4.8:

- Accessibility and commute distance are negatively related at any one time (as expected).
- There is not, however, a strong relationship between where ln*JO* grew and where the distance of commutes declined, suggesting there was no systematic pattern of change in where people commuted to, or at least in the distance taken to get to any new work destination for any job changes.

Figure 4.7 Auckland job opportunities and commute distance (annual averages)

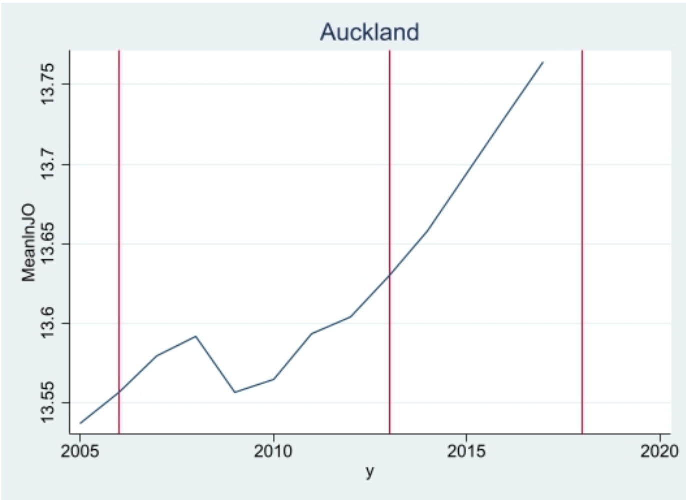
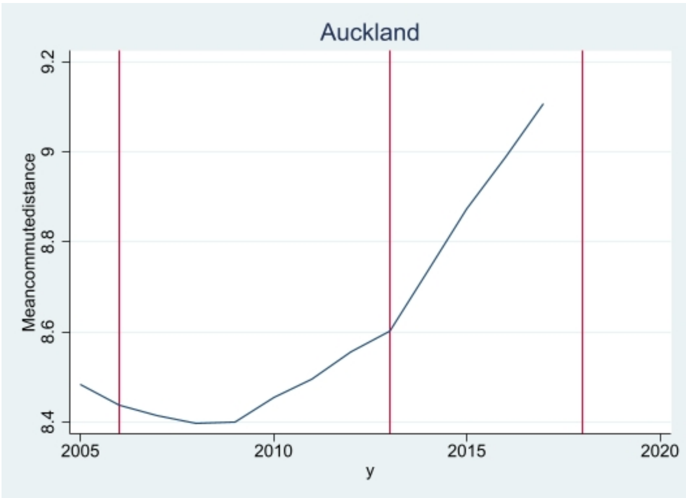
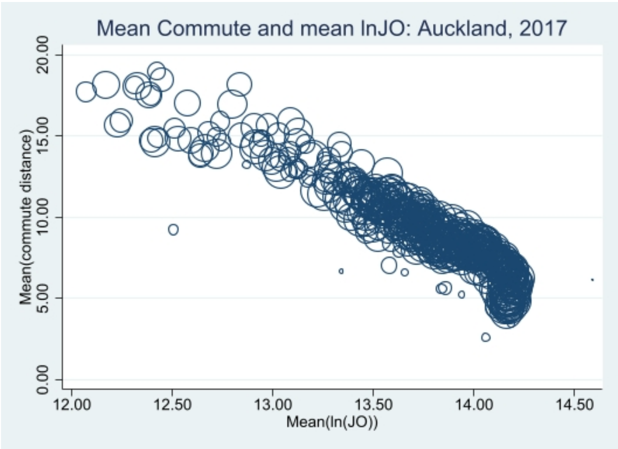
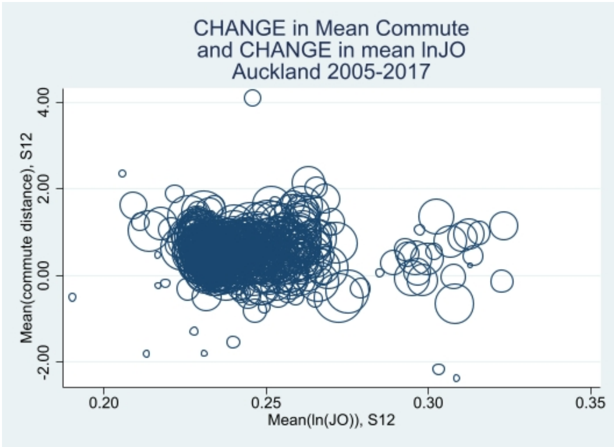
Annual lnJO	
Annual commute distance (km)	
Note: Vertical lines indicate census years.	

Figure 4.8 Levels and changes in ln*JO* and commute distance



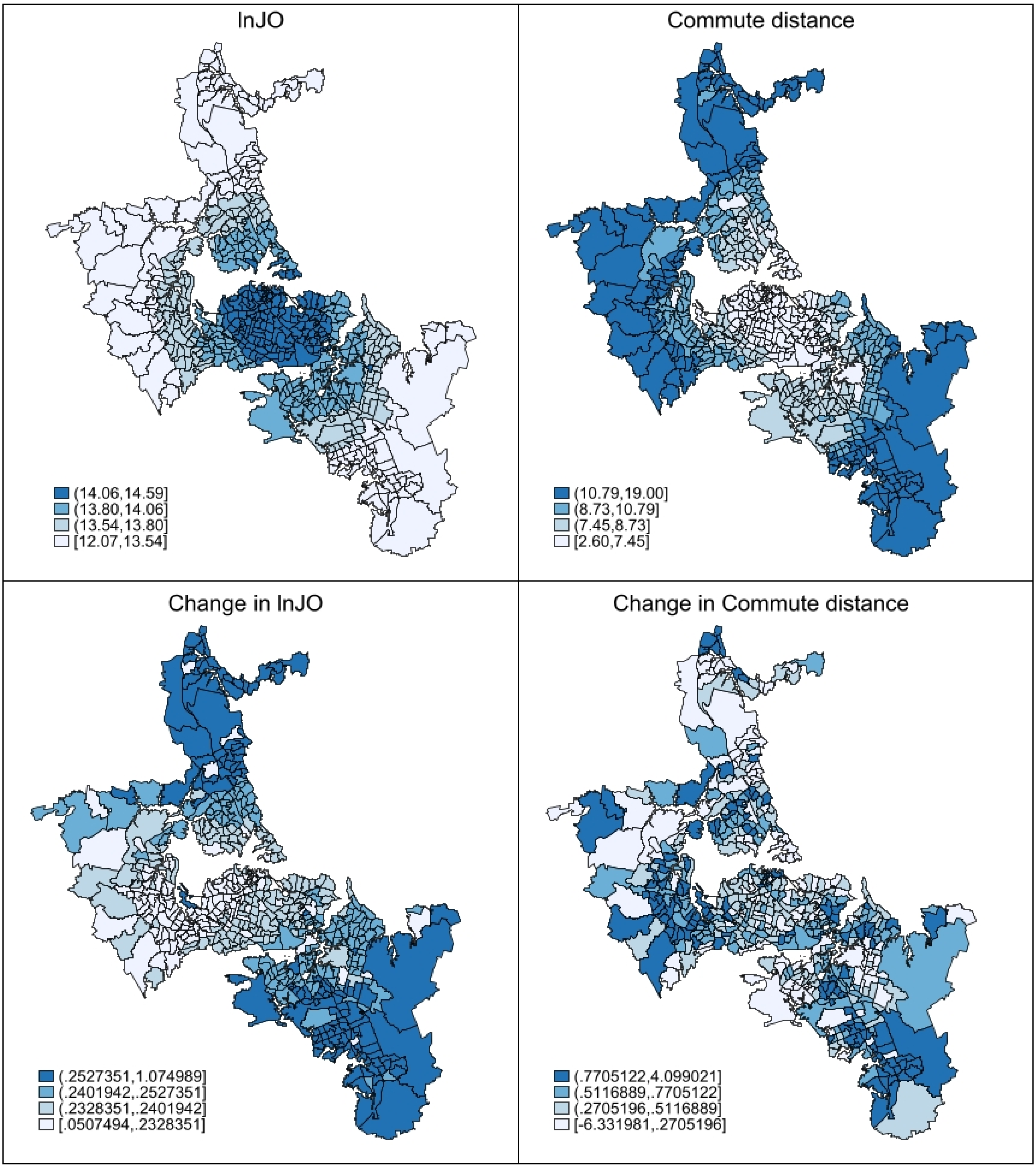


Note: Each circle represents an SA2 area, weighted by population

The spatial patterns evident in Figure 4.9 reinforce the above observations:

- Between 2005 and 2017, ln*JO* increased most in the south and north of the city.
- Commute distance did **not** necessarily drop where ln*JO* increased (not known from this data is whether the commute *cost* changed).
- Average commute distance increased near the outskirts of the city, consistent with newly developed residential areas having relatively few new jobs locally.

Figure 4.9 Spatial illustration of ln*JO* and commute distance for Auckland, 2017 levels and change 2005–2017

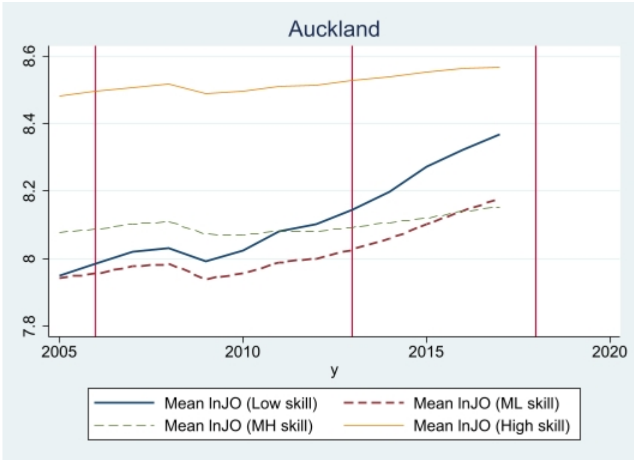


4.4.2 Changes in ln*JO* and commute distance by skill group

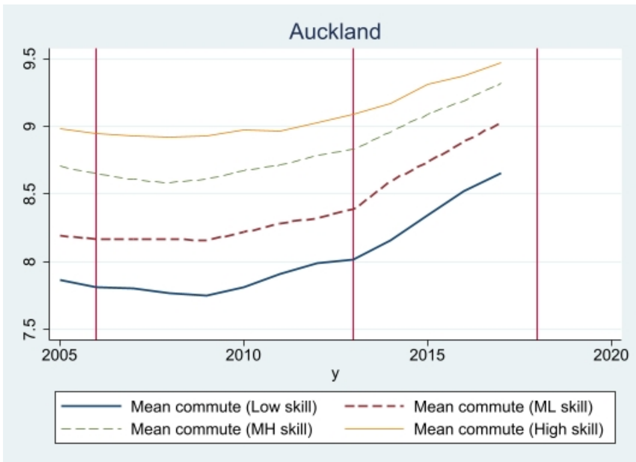
We now turn to how these relationships might differ for skill groups within Auckland. Figure 4.10 shows the changes over time in job opportunities and commute distance disaggregated by skill group as described in section 4.2. It was apparent that higher-skilled workers not only lived in areas with relatively high accessibility (job opportunities), but also had the longest commute distances. Low job accessibility for low-skill workers did not result in long commutes, as would be expected if spatial mismatch were a major labour market problem. Over the study period, accessibility generally increased for all groups, but increased particularly strongly for low-skilled workers. At the same time, commuting distances increased for all groups, but proportionally slightly more for low-skill workers.

Figure 4.10 Median ln*JO* and average commute distance for Auckland 2005–2017 by skill group (annual)

<table>
<tr><td>Annual lnJO</td><td>



</td></tr>
<tr><td>Annual commute distance</td><td>



</td></tr>
</table>

The cross-sectional relationships are presented in Figure 4.11 for levels and Figure 4.12 for changes. In essence the skill-disaggregated differences in the negative relationship between ln*JO* and commute distance add no further insights to the aggregate relationship. The within skill-group change in commute and change in ln*JO* seems uncorrelated.

Figure 4.11 Ln*JO* and commute distance at 2017 by skill group for Auckland SA2s

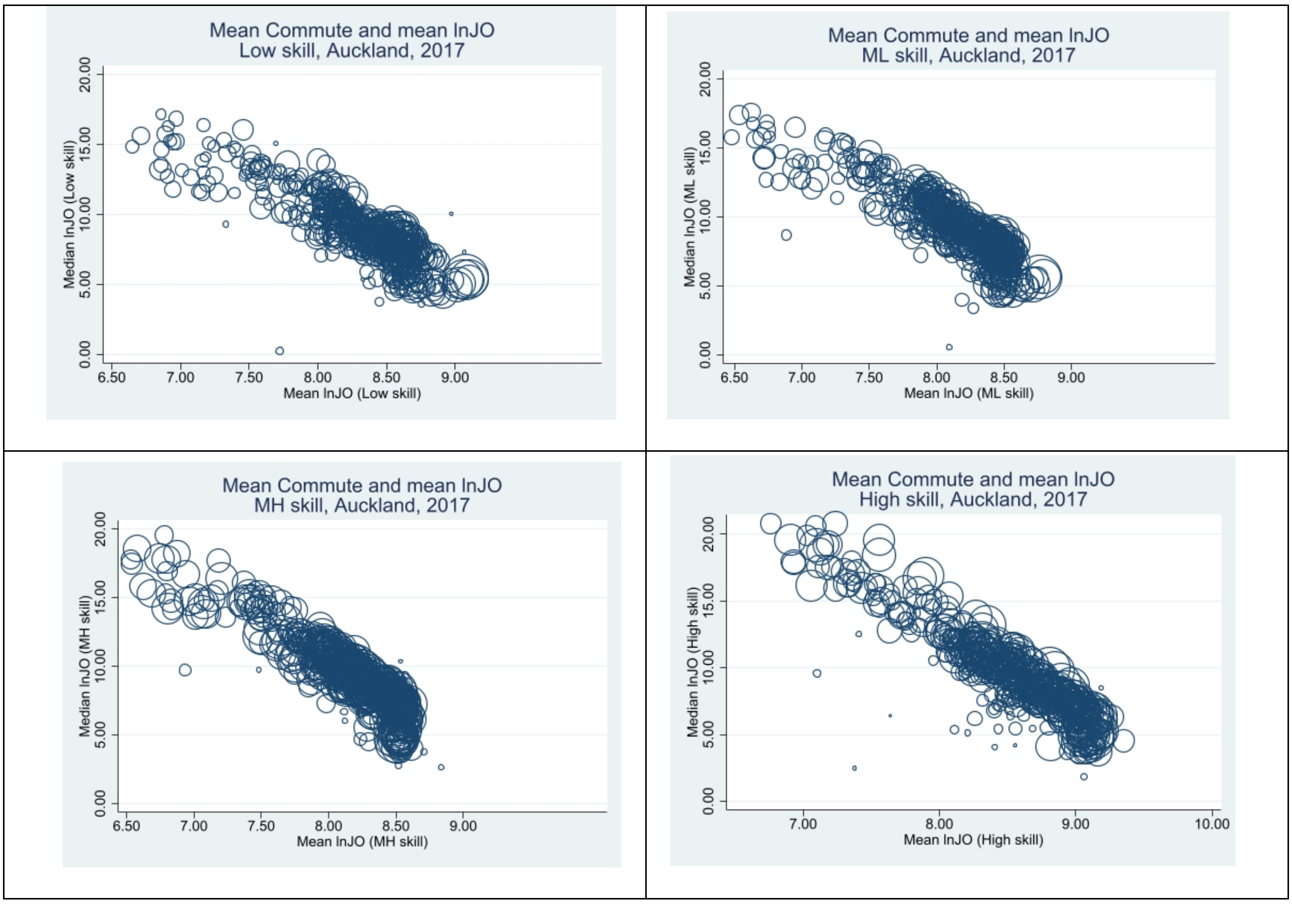
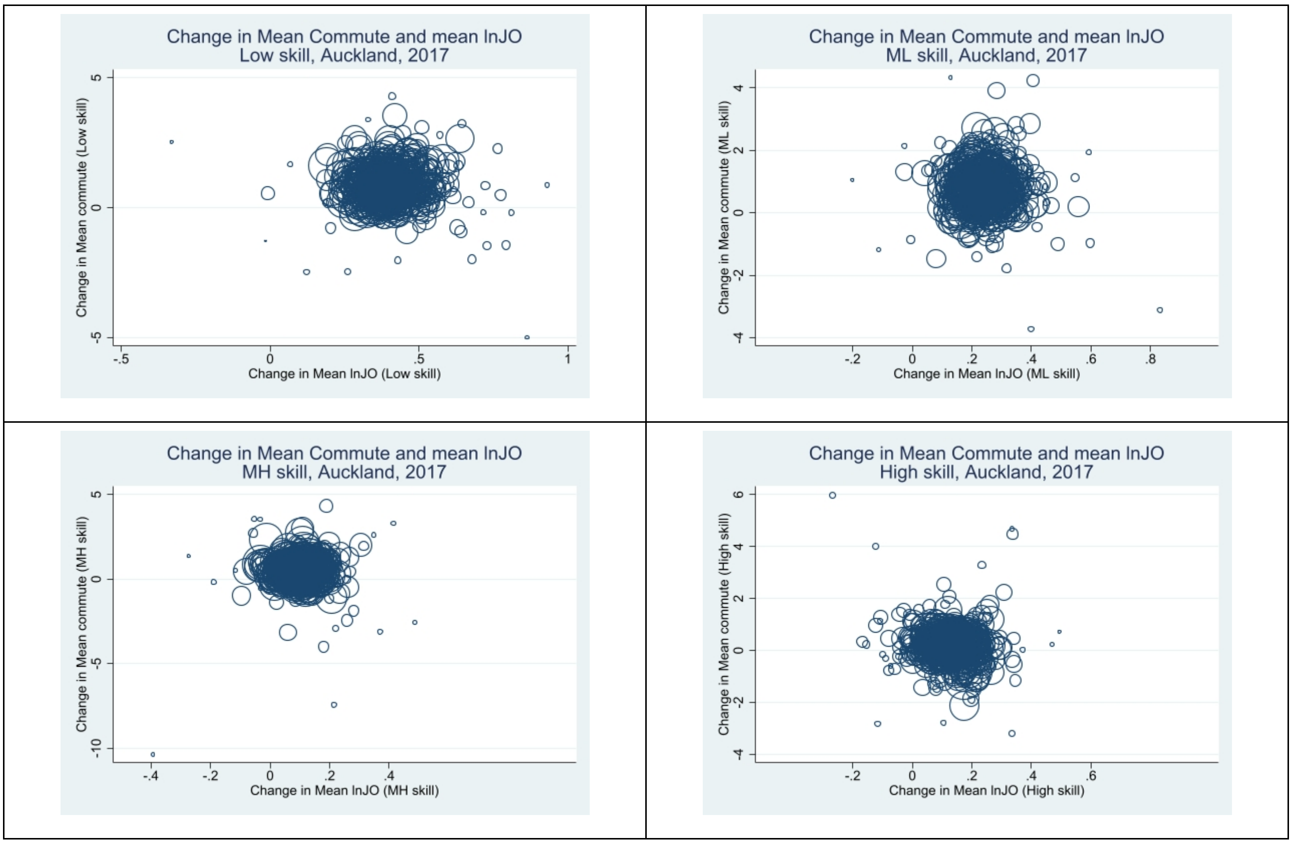


Figure 4.12 Changes in ln*JO* and commute distance 2005–2017 by skill group for Auckland SA2s



4.4.3 Spatial distribution of changes in lnJO and commute distance by skill group

The patterns documented in the previous section did not occur uniformly across Auckland. In this section, we document where in Auckland ln*JO* (Figure 4.13) and commute distance (Figure 4.14) changed for different skill groups. It is useful at this stage to consider Auckland as four urban zones, namely the northern, western, central and southern zones.

- First, there was a wide growth dispersion, both between zones and between SA2s within zones.
- For lower-skilled workers, there was stronger ln*JO* growth in the north-west but there was strong job opportunity growth within all four zones.
- Stronger ln*JO* growth for higher-skilled workers occurred in the north.
- The average commute distance lengthened for lower-skilled workers in all zones, whereas for higher-skilled workers the average distances tended to stay the same and in many cases declined.

Figure 4.13 Distribution of changes in ln*JO* by skill group

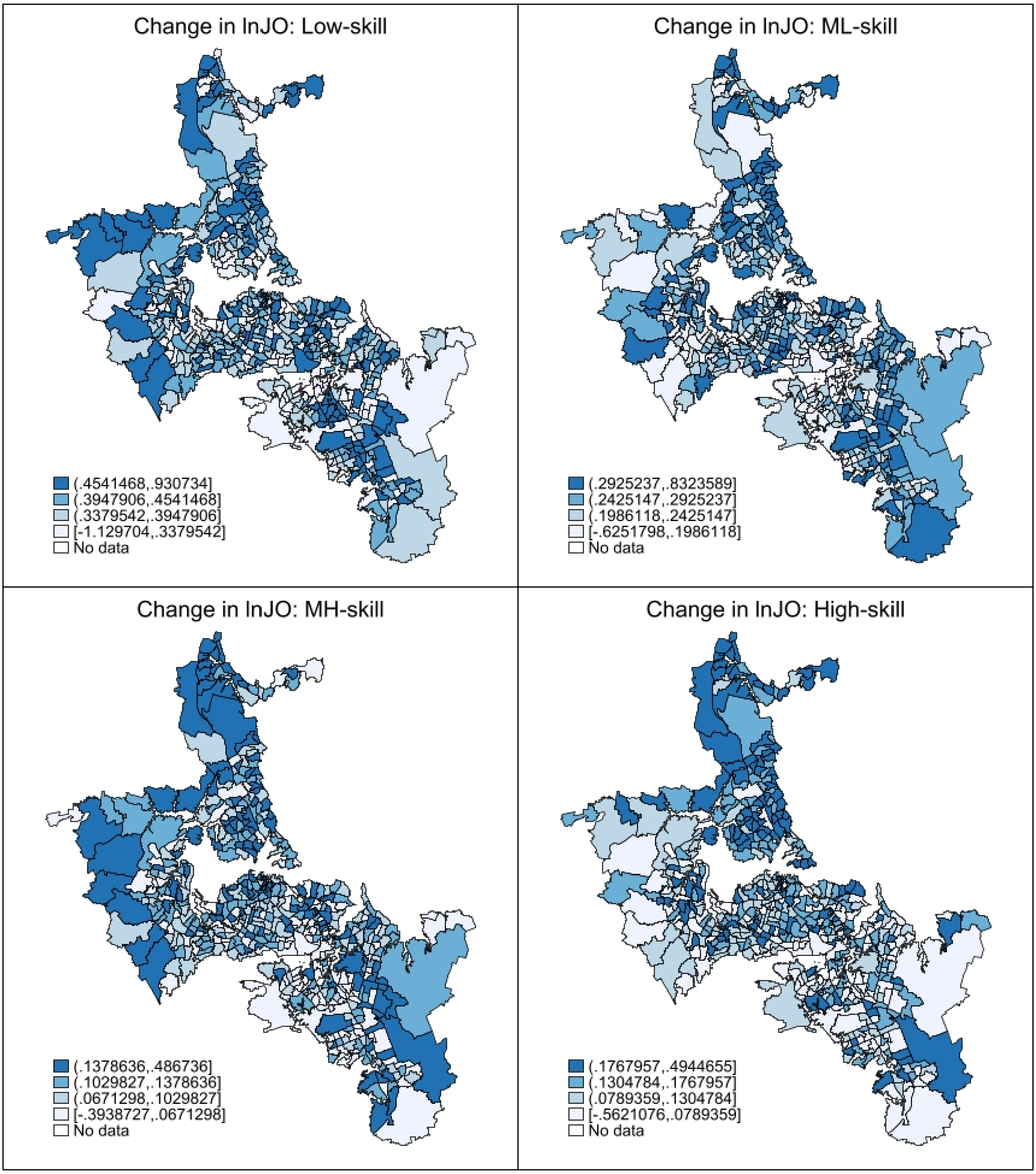
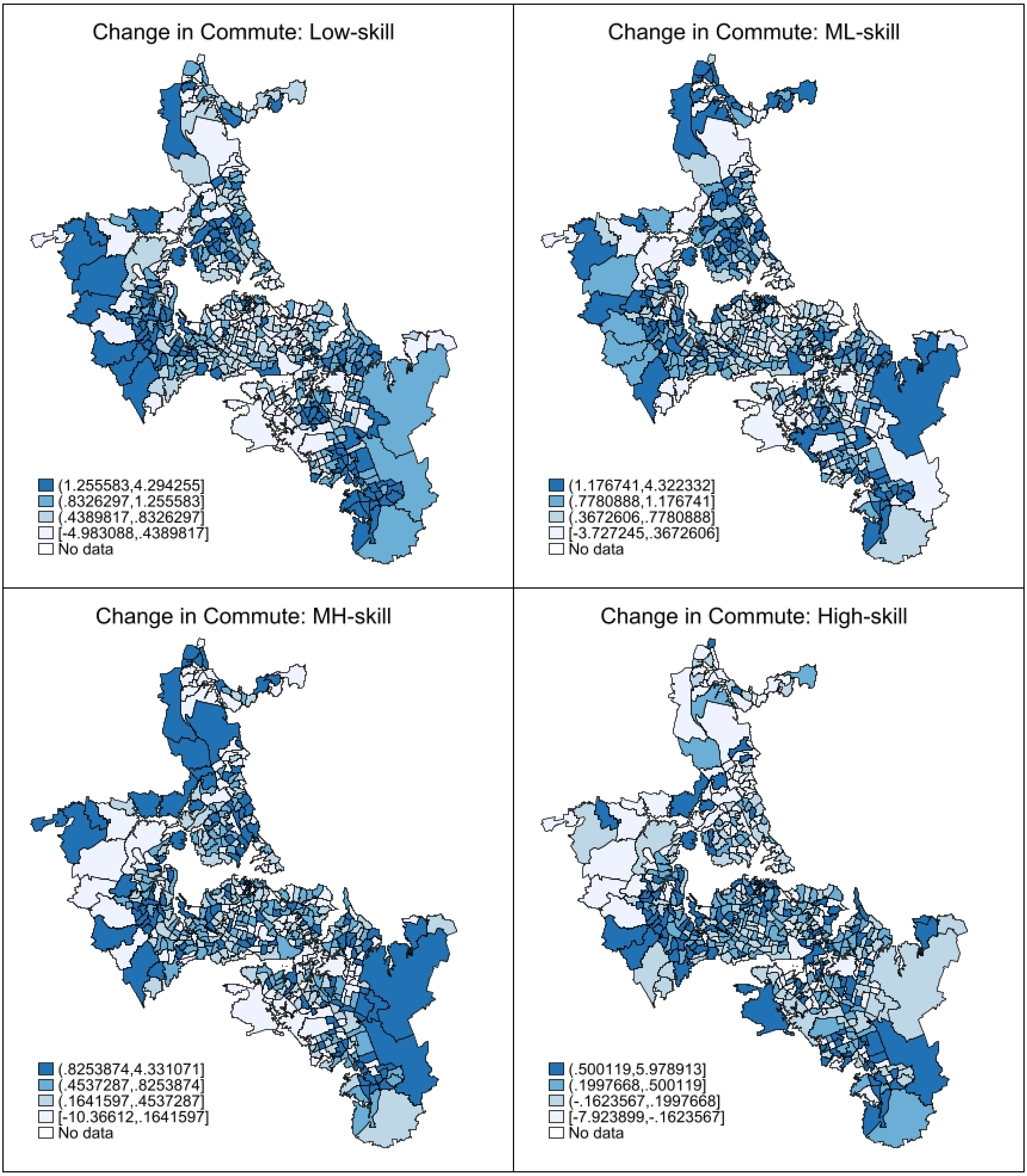


Figure 4.14 Distribution of changes in commute distance by skill group



4.5 Results from other centres

Both similarities and differences occurred among the results for the other three study areas, which are presented here in summary form.

- Job opportunity growth and change in average commute distance was higher among high-skilled people in Napier–Hastings.
- Job opportunities increased a similar amount in Wellington for the low- and high-skilled groups but the average commute distance tended to increase for low-skilled workers.
- In Dunedin there were generally more job opportunities for high-skilled workers but generally fewer job opportunities for low-skilled workers while the average commute distance changed little on average.

4.6 Commuting distance and skills

The descriptive IDI results provide a general picture of the relationship between accessibility to job opportunities and commute distance. Here we present an econometric investigation of that relationship using the annual panel data for each study area. We look at equations with (logged) commute distance as the dependent variable, initially without fixed SA2 effects.

Specifically, we report estimates of the following two regression specifications:

$$\ln(Commute_{ist}) = \beta_s * \ln JO_{it} * 1(skill_{it} = s) + \gamma_t Year + \alpha_s + \delta_i \quad \text{(Equation 4.3)}$$

$$\ln(Commute_{ist}) = \beta_s * \ln JO_{it}^{sk} * 1(skill_{it} = s) + \gamma_t Year + \alpha_s + \delta_i \quad \text{(Equation 4.4)}$$

Each observation is for an area (*SA2=i*), skill group (*s*), and year (*t*). The main coefficient of interest is β – the coefficient on $\ln JO_{it}$, which in some specifications we allowed to vary by skill group. This coefficient reflects the nature and strength of the relationship between accessibility and commuting distance. If β is negative, workers in accessible areas face shorter commutes. The difference between equations 4.3 and 4.4 is that the measure of job opportunities in equation 4.4 is skill specific, whereas in equation 4.3 we include overall job opportunities.

The results are summarised in Table 4.1 and Figure 4.15 and Figure 4.16. In Table 4.1, the upper panel reports estimates that exclude SA2 fixed effects (δ_i), whereas the lower panel includes these fixed effects. The first four columns report estimates of equation 4.3 and subsequent columns report estimates of equation 4.4. In each panel, the first row shows the overall slope from a simple regression of ln*(Commute)* on ln*(JO)*, including only a time trend.

Figure 4.15 and Figure 4.16 plot the coefficients from columns 1 and 5 of the upper panel of Table 4.1.

The descriptive summary presented above has shown that, in all locations, mean commute distance has increased over time, especially in Auckland. Furthermore, in all locations mean commute distance is inversely related to (logged) access to job opportunities. This negative relationship also shows up in the regression estimates, with the strongest negative relationship in Dunedin and the weakest in Auckland.

For Auckland:

- The negative relationship between job opportunities and commuting distance is stronger for higher-skilled workers, irrespective of whether job opportunities are disaggregated by skill.
- On average a 1% higher *JO* is associated with a 0.63% lower commuting distance.
- Controlling for the effect of job opportunities, lower-skilled workers have shorter commutes (intercepts not shown in Table 4.1).

For Napier–Hastings:

- The same relationships for Auckland also exist for Napier, although with a low slope for the effect of overall job opportunities for skill group 3.
- On average a 1% higher *JO* is associated with a 1.04% lower commuting distance.

For Wellington:

- The relationships are again consistent with those for Auckland, but with a low slope for high-skilled workers' response to skill-specific ln*(JO)*.
- On average a 1% higher *JO* is associated with a 1.09% lower commuting distance.

For Dunedin:

- There is not a systematic relationship across skill groups for the relationship between commuting distance and ln*(JO)*.
- Commuting and job opportunities are still negatively related, but less systematically across the skill groups than in the other three locations.
- However, on average a 1% higher *JO* is associated with a 1.83% lower commuting distance – larger than in the other three locations.

We expect there are issues with the Dunedin analysis that stem from the quality of the student address data, which could lead to some moderate underestimation of total employment growth in the region.

For Auckland, Napier and Dunedin the responsiveness of commuting to changes in access to job opportunities is lower when those opportunities are skill specific. This is somewhat surprising as it suggests that commuting is more responsive to overall job opportunities than it is to skill-specific opportunities.

In Wellington, however, the effect of adjusting for skill group is very small and even in the opposite direction from what would be expected. We infer that the way the skill groups are defined might not adequately capture skill differences among Wellington workers, or perhaps the workforce is more homogeneous than elsewhere – possibly related to the size of the government sector in Wellington.

Overall there is a strong negative relationship between (logged) job opportunities and commuting (whether logged or not), confirming the results from analysis of the census data.

Figure 4.15 Elasticity coefficient of mean commute v mean overall job opportunities

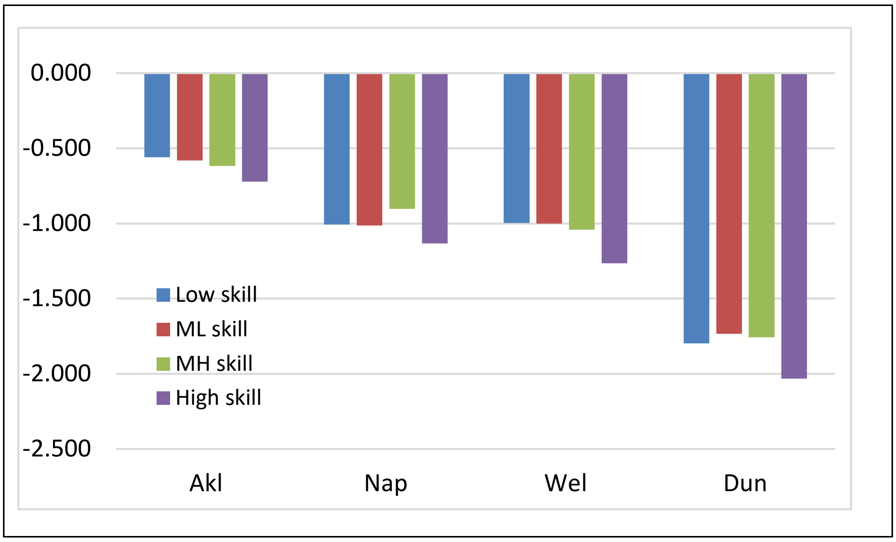
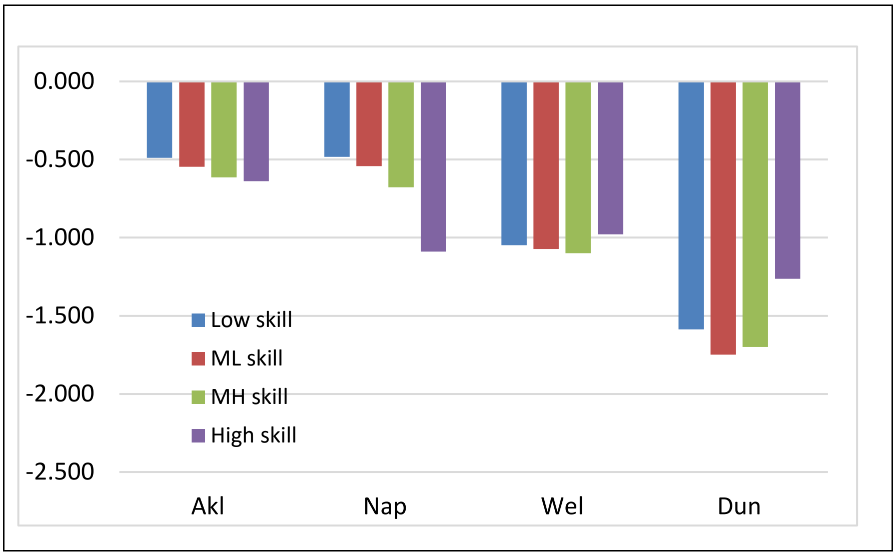


Figure 4.16 Elasticity coefficient of mean commute vs skill-specific job opportunities



In the lower panel of Table 4.1, SA2 fixed effects are included, meaning the relationship captured by the slope parameters is between the within-SA2 variation in commuting and the within-SA2 variation in job opportunities over time. As suggested by the lack of strong relationships in Figure 4.12, the overall slope is variable. However, the same pattern of relative slopes across skill groups remains, with slopes for high-skilled workers generally more negative (or less positive) than for low-skilled workers.

Thus it would seem residential location within a city has a considerable influence on mean commute length and also picks up some of the measured effect of access to job opportunities. However, the choice of residential SA2 is likely to be at least partly influenced by the implied commuting distance. That is, the choice of residential location is not exogenous to the transport infrastructure. People locate in areas with good transport links to centres of employment (and vice versa), with transport infrastructure playing an enabling role – without going so far as saying 'build a road and they will come'.

We expect the results in the lower panel of Table 4.1 understate the effects of job opportunities on commute distance, even if those in the upper panel may overstate them.

Table 4.1 Summary of regression results at SA2 level

	Relationship of ln(commute) with overall ln(JO)				Relationship of ln(commute) with skill-specific ln(JO)			
	Auckland	Napier–Hastings	Wellington	Dunedin	Auckland	Napier–Hastings	Wellington	Dunedin
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean ln(JO)				(a) No SA2 fixed effects				
β pooled	-0.630***	-1.035***	-1.089***	-1.833***	-0.455***	-0.333***	-0.577***	-1.452***
	(0.02)	(0.16)	(0.08)	(0.13)	(0.01)	(0.07)	(0.04)	(0.08)
β low skill	-0.560***	-1.007***	-0.997***	-1.798***	-0.489***	-0.482***	-1.049***	-1.587***
	(0.02)	(0.15)	(0.08)	(0.15)	(0.02)	(0.14)	(0.08)	(0.10)
β ML skill	-0.581***	-1.013***	-1.001***	-1.735***	-0.547***	-0.542***	-1.072***	-1.748***
	(0.02)	(0.14)	(0.08)	(0.12)	(0.02)	(0.14)	(0.09)	(0.11)
β MH skill	-0.618***	-0.902***	-1.042***	-1.757***	-0.615***	-0.677**	-1.100***	-1.699***
	(0.02)	(0.17)	(0.08)	(0.11)	(0.02)	(0.20)	(0.09)	(0.11)
β high skill	-0.721***	-1.133***	-1.266***	-2.032***	-0.638***	-1.090***	-0.979***	-1.264***
	(0.03)	(0.22)	(0.09)	(0.14)	(0.02)	(0.15)	(0.06)	(0.10)
				(b) With SA2 fixed effects				
β pooled	0.294***	-0.138	0.093	-0.008	0.135***	-0.123***	-0.025	-0.280***
	(0.01)	(0.10)	(0.07)	(0.09)	(0.01)	(0.03)	(0.02)	(0.04)
β low skill	0.376***	-0.128	0.240**	0.106	0.220***	0.116	-0.122*	-0.031
	(0.02)	(0.12)	(0.08)	(0.08)	(0.02)	(0.09)	(0.06)	(0.06)
β ML skill	0.343***	-0.123	0.190**	0.068	0.192***	0.050	-0.204***	-0.084
	(0.01)	(0.11)	(0.07)	(0.09)	(0.02)	(0.08)	(0.05)	(0.06)
β MH skill	0.288***	-0.065	0.091	-0.039	0.135***	0.063	-0.296***	-0.198**
	(0.01)	(0.10)	(0.06)	(0.11)	(0.02)	(0.08)	(0.05)	(0.06)
β high skill	0.202***	-0.347**	-0.063	-0.205	0.040*	-0.282**	-0.329***	-0.290***
	(0.01)	(0.12)	(0.06)	(0.12)	(0.02)	(0.08)	(0.03)	(0.04)

Note: Standard errors in parentheses, clustered by SA2. Regressions are all weighted by the size of the resident population.

4.7 Affordable housing areas

The above analysis shows there has been a variety of job opportunity situations in New Zealand’s major centres, that people will generally commute further when local job opportunities are fewer, but that the change in job opportunities and any commuting response, in terms of average distance travelled, has been mixed. The question now turns to whether the patterns differ among nearby areas for those SA2s that might be considered ‘affordable’. As shown in chapter 3, people choose their residential location for many reasons other than job opportunity.

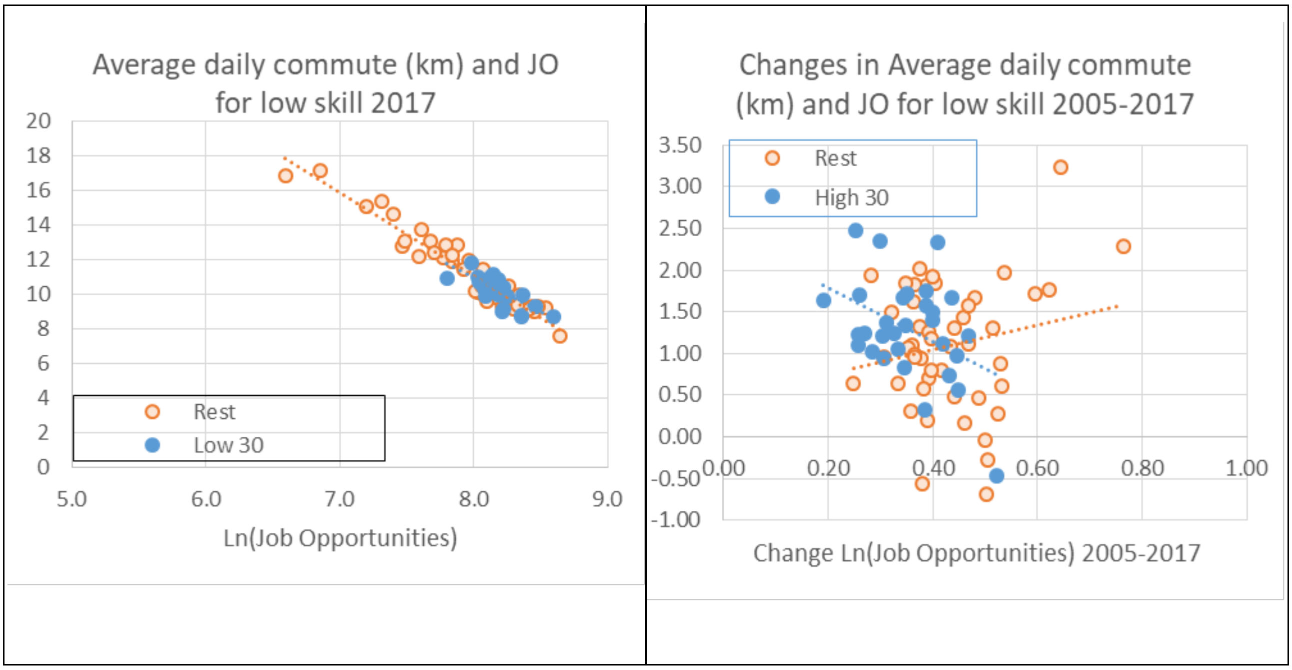
This raises the issue of what is meant by affordable? There is a relative dimension: an amenity mix on offer in a block of residences that has a low price relative to blocks with a similar mix of amenities could be considered as affordable. Then there is an absolute dimension: any mix of some minimum standard of amenities that is low priced could be deemed affordable. For this study, the notion of absolute affordability was applied and the above types of analyses were repeated to see whether a cross section of the 30 SA2s in each study area, or zone within study area, with the lowest average rents, showed different commute patterns from the other SA2s. We expected spatial mismatch to show up as residents of low-*JO* areas having longer commutes (and lower employment rates)[30] If spatial mismatch were a particularly large problem in low-rent areas, we would expect residents of such areas to face especially long commutes and low job opportunities.

As an example, the pattern of average commute distance to (logged) job opportunities is shown in Figure 4.17 for the western zone of Auckland, where each SA2 is represented by a dot (not weighted by population) and the results are shown in level form for 2017 and in change form for 2005 to 2017. In this case, the affordable SA2s tended to be on average closer to job opportunities and hence less travel was required but the commute-job opportunity relationship is similar for the 30 ‘affordable’ and remaining 48 ‘less affordable’ SA2s. There was a wide variety of experiences when it came to the change between 2005 and 2017 which weakened any generalisation. In spite of the mixed outcomes, the standard negative commute-job opportunity relationship persisted for the low-skilled workers in affordable SA2s. Both the level and change outcomes were interpreted as low-skilled workers in affordable areas being able to extend their commute distance when faced with fewer job opportunities, and hence provided no evidence of spatial mismatch in West Auckland.

A variation of the West Auckland result which reached the same conclusion is shown in Figure 4.18 for Wellington. Low-skilled workers in the most affordable 30 Wellington SA2s tended to have fewer nearby job opportunities than their peers in the remaining 119 SA2s but they also tended to commute further, again showing the standard commute-job opportunity relationship. On a change basis, there was little discernible difference between the two groups and again low-skilled workers in affordable areas tended to travel further when job growth (for their skills) was not as high. As above, these results offered no evidence of spatial mismatch.

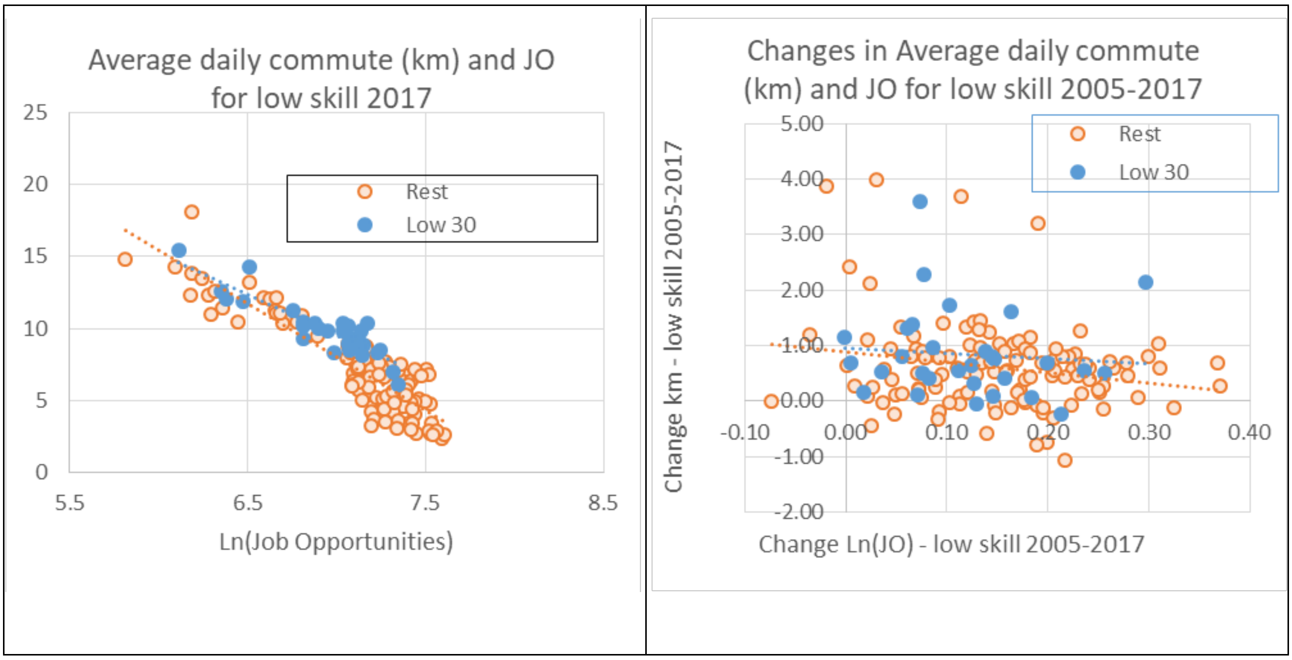
[30] If the spatial mismatch were reinforced by housing market discrimination, as found by Kain (1968), rents in low-accessibility areas would not be low enough to compensate residents for the longer commutes.

Figure 4.17 Mean commute vs job opportunities for low-skilled workers in the western zone of Auckland



Note: 'Low 30' in these figures refers to the 30 SA2 areas with the lowest rents

Figure 4.18 Mean commute vs job opportunities for low-skilled workers in Wellington



Note: 'Low 30' in these figures refers to the 30 SA2 areas with the lowest rents

The same exercise repeated for the other three zones of Auckland and for the other two study areas came to the same conclusion; no evidence of spatial mismatch exists, in that low-skilled workers in affordable areas showed the standard adaptation to different nearby job opportunities.

4.8 Summary and next steps

The results of this chapter are consistent with the results of the previous chapter. Furthermore, they show job accessibility measures that match the skills of the resident population do differ and the skill-based accessibility measures better capture the relationship between job opportunity and commute distance.

These figures also provide some indications of whether low-skilled workers in affordable areas experience a spatial mismatch. No such evidence was found although this is not proof. For instance, the response measure here is the average distance commuted, but this does not measure how many people were able, or more importantly not able, to commute. This is a matter for further research. However, given the results of chapter 3, where no effect between job opportunities and unemployment was discernible, it is reasonable to infer there is widespread ability to commute in New Zealand's major centres.

Before bringing these results together with the research objectives, the following chapter looks more closely at large transport investment that would be expected to affect commuting patterns.

5 Transport's role in accessibility

The research objectives included determining what transport barriers existed between areas of high affordability and those locations of high job opportunities, and hence what policy response would be appropriate. The previous two chapters have shown that New Zealand workers in general appear able to adapt their situations to undertake their employment. This does not preclude the possibility that some groups may indeed face constraints on either commuting or changing their home-work locations. This also does not preclude the possibility that transport policy changes could be made to improve welfare, either for any constrained groups or for people more generally.

This chapter makes use of the low-skill job opportunity data from chapter 4 to consider how transport and accessibility interact to improve welfare for low-skill persons, and then uses examples within the study centres to explore issues with applying accessibility measures to improve welfare.

The chapter is largely exploratory, given the literature on the link between accessibility and welfare is still evolving and the use of accessibility measures in New Zealand urban and transport policy is relatively new. The chapter, though, does provide insight into how the model and data results revealed in the previous two chapters integrate with policy and also set a platform for recommendations in the following chapter.

5.1 Applying accessibility in New Zealand urban and transport policy

Better access has been an implicit objective in transport policy for many years in New Zealand, as elsewhere, but has more formally entered transport and urban policy recently. The current Government Policy Statement on land transport (GPS) now sets four priorities, including 'better transport options' and lists two of 31 KPIs that directly relate to access: KPI #10, 'access to jobs'; and KPI #11, 'access to essential services' (including education and shops). These priorities and KPIs thus feed into individual transport investment decisions of Waka Kotahi, and hence also affect many local government transport investments, via projects being scored as to their (a) alignment to the GPS strategy, (b) effectiveness in achieving GPS priorities, and (c) efficiency, with efficiency determined by the benefit–cost ratio.

Accessibility is now more formally recognised in the setting of urban policy among New Zealand major urban centres. Local partnerships of key policy and infrastructure providers are being formed to plan for local urban growth. For example, Auckland City now has the Auckland Housing and Urban Growth Joint Programme which includes land-use plans out to 2050 and a 30-year Auckland Transport Alignment Project, the latter including targets for the number of jobs that can be accessed within a 45-minute peak public transport trip and within a 30-minute peak drive.

This coordination of urban and transport policy is likely to eventuate in more people living closer to their employment and, in turn, higher population densities where employment is expected to become more concentrated (eg Auckland). However, it should be noted that a higher measure of job accessibility for an urban area can be achieved by reducing travel times but can also – and is more likely to – come from where the growth of jobs and residents occurs.

5.2 From improved access to higher welfare

MRCagney (2019) provides an extensive review of the costs and benefits associated with urban development. The issues are many and complicated but key channels between better accessibility and higher welfare are discussed below.

First, a closer home-work location mix offers the potential of less transport resource use and, as shown in chapter 4, people also value being closer to work centres for reasons over and above any lower transport costs. However, there are two key factors that can reduce these implied welfare gains. First, the transport resource reduction will be less if non-work travel is increased (say home-work now further from school) and/or if congestion is increased. Second, while people value being closer to job centres, they are also willing to trade off some of this benefit for cheaper housing and a longer commute if costs are unfavourable to residing near work. These factors imply there is unlikely to be a consistent relationship between accessibility and community welfare, whether it be for all people or for low-skilled people only.

These considerations have two implications for transport policy: travel costs will be reduced if extra transport supply matches the demand, as usual, but there is also the risk that transport investment which is inconsistent with the planned home-work intensification will undermine the accessibility objective. However, and beyond the scope of this research project, it is acknowledged that the practical application of this logic is complicated by (a) different agencies planning the urban forms (b) the uncertainty as to whether these plans will then be delivered, especially given uncertain costs and the uncertainty as to whether the initial plans were indeed optimal, both of which could lead to land-use plans being changed, and (c) the uncertainty about public response – all good reasons to test and challenge the urban plans that transport agencies and departments are expected to facilitate.

The second channel of potential effect from a more concentrated home-work network is the likely wider choice of transport options available, such as rideshare, walking/cycling and public transport. This channel is directly aligned with this research project, given the international literature noting that secondary earners and low-income earners can be more sensitive to the transport costs inherent in any spatial home-work mismatch. However, there is also likely to be an increase in housing costs, especially if the improved home-transport-work connection attracts more residents and jobs to the area. Thus the net effect on low-income households can be ambiguous. From a policy perspective, this points to the need to monitor the distributional effects of transport interventions if improved accessibility for low-income households is to be an objective.

The third potential channel of effect is via economies of scale. There is the potential for higher PT demand to cross thresholds that bring PT economies of scale into effect, leading to lower transport costs more generally.

Both the second and third channels are likely to show as a higher PT share, which is another New Zealand transport KPI.

In sum, there remains the likelihood that general transport improvements aimed at addressing demand issues will benefit low-income earners. There is also the potential for targeted improvements in job accessibility to reduce travel costs and improve job outcomes for low-income earners, especially when more travel options are made available and when scale drives individual PT costs down. However, it is ambiguous whether the general targeting of higher job accessibility, or any specific targeting of higher accessibility of low-skill jobs for people living in low-cost housing will improve the welfare of these householders, as any initial travel cost savings risk being undermined by higher housing costs. This risk will be lower where low-income earners own or share in the ownership of local properties and higher for those renting who do not have long-term rental agreements.

5.3 New Zealand examples of transport improvements and responses

This section considers three transport infrastructure improvements of recent years. Of interest is the relationship between job opportunities, employment and rents, and in particular, whether (a) low-rent areas lack job opportunities and (b) whether increases in low-skill job opportunities over time have translated into a higher proportion of the working age population being employed. Evidence of low-rent areas lacking job opportunities would be consistent with a spatial mismatch although other explanations can also exist; likewise failure of more job opportunities for low-skilled workers translating into higher employment. The exercise is largely descriptive and aims to identify transport issues where further research is required.

The study areas are the Napier–Hastings area, where the two urban areas have experienced significantly improved road access due to the Hawke's Bay Expressway, the 'North Shore' of Auckland, or more literally the northern zone urban area of Auckland City, which has grown rapidly and has relied heavily on an expanded bus network for its PT services; and Wellington City, which consists of four urban areas that are well connected by train.

The data presented below is for the areas defined as New Zealand statistical area 2 (SA2) unless otherwise stated. Job opportunity data is as per chapter 4. Proxies used for rent costs are the average rent for a three-bedroom dwelling derived from the 2006 and 2018 censuses. The proportion of people employed is also from the census data, with employment taken to be either full or part time and age confined to 15 to 64 years.

5.3.1 Hawke's Bay Expressway

The Napier–Hastings area has low population densities, has an above average proportion of the population considered highly deprived[31] and is an urban area dominated by private vehicle travel. The previous chapters showed Napier–Hastings have the following links between job opportunities, commuting and other variables. In general there was little evidence to suggest a spatial mismatch was a problem in the Napier–Hastings labour markets.

Table 5.1 Summary of results reported above for Napier–Hastings

Higher job opportunities	Weakly associated with lower wages received, especially for women
	Associated with lower rents although the relationship is changing over time
	Weakly associated with a higher rate of employment although not for highly qualified residents
Job opportunities	Seasonal pattern within a modest upward trend over time
	Lowest, but increasing, for the high-skilled residents and becoming relatively fewer for low-skilled residents
Mean commute distance	Declined by 0.5% for each 1% increase in low-skilled job opportunities, ranging to a 1% decline for a 1% increase in high-skilled job opportunities

Travel within the Napier–Hastings area has been significantly improved by the Hawke's Bay Expressway in recent decades. Built over 43 years and still not finished, recent significant changes were:

- 2003: improved link to the airport, with more changes in 2020

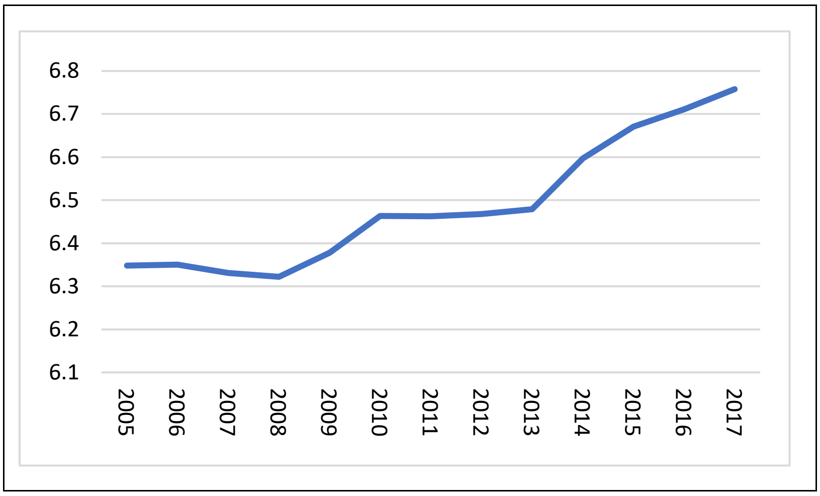
[31] Taken to be a score of 9 or 10 here using the University of Otago 2018 Index of Deprivation (www.otago.ac.nz/wellington/departments/publichealth/research/hirp/otago020194.html#2018)

- 2007: replacement of the Meeanee intersection with an overbridge
- 2011: better linking to SH2 at the southern end.

Many other changes to adjoining roads and intersections have also occurred sporadically since 2007.

Figure 5.1 shows how mean commuting distance in the Napier–Hastings conurbation has changed since 2005. There is a notable increase in the mean distance in 2008 which may well be a reaction to the Meeanee overpass opening in 2007, although the effect of recovery from the GFC is probably also present here. The next significant increase in mean commuting distance occurred in 2013, but this looks more like the effect of general growth in the labour market (see earlier Figure 4.3 which shows job opportunities) than further improvements in the expressway.

Figure 5.1 Napier–Hastings mean commute distance



The following section does not try to tie changes to the expressway directly but simply notes that the expressway has been a major transport improvement, that the improvement was largely based around private vehicles and that the expressway is used heavily today for commuting, as well as for other travel demands.

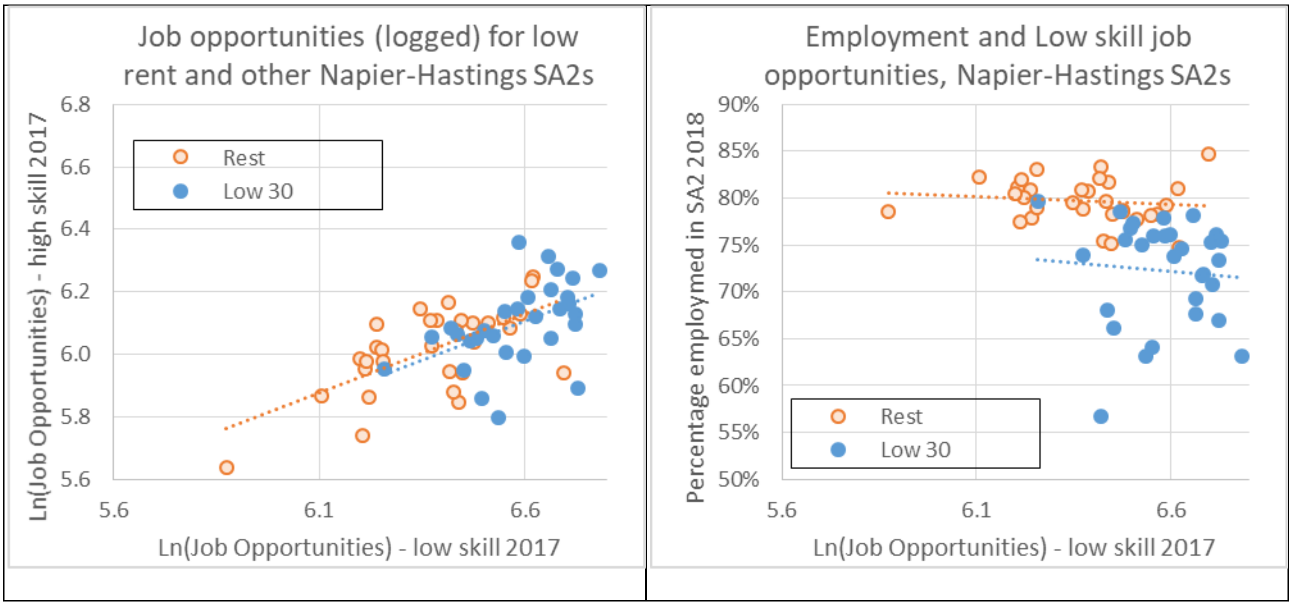
The reporting proceeds by splitting off the 30 lowest rent areas[32] from 31 remaining SA2s that make up the Napier–Hastings zones (excluded were another eight SA2s that were missing rent data).

The following observations are made about the levels of activity:

- All areas have more low-skill job opportunities than high-skilled (Figure 5.2, left)
- The relationship between low-skill job opportunities and the rate of employment is weak (right graph).
- However, the rate of employment is generally lower in low-rent areas in spite of similar or higher low-skill job opportunities – this last point is important as it suggests the lower rate of employment is not due to fewer job opportunities, as per the international spatial mismatch literature, but could be due to any number of socio-economic factors, of which access to transport could be one.

[32] The 30 SA2s with the lowest rents included all areas (17) that had a deprivation score of 9 or 10.

Figure 5.2 Recent relationship with low-skill job opportunities in Napier–Hastings

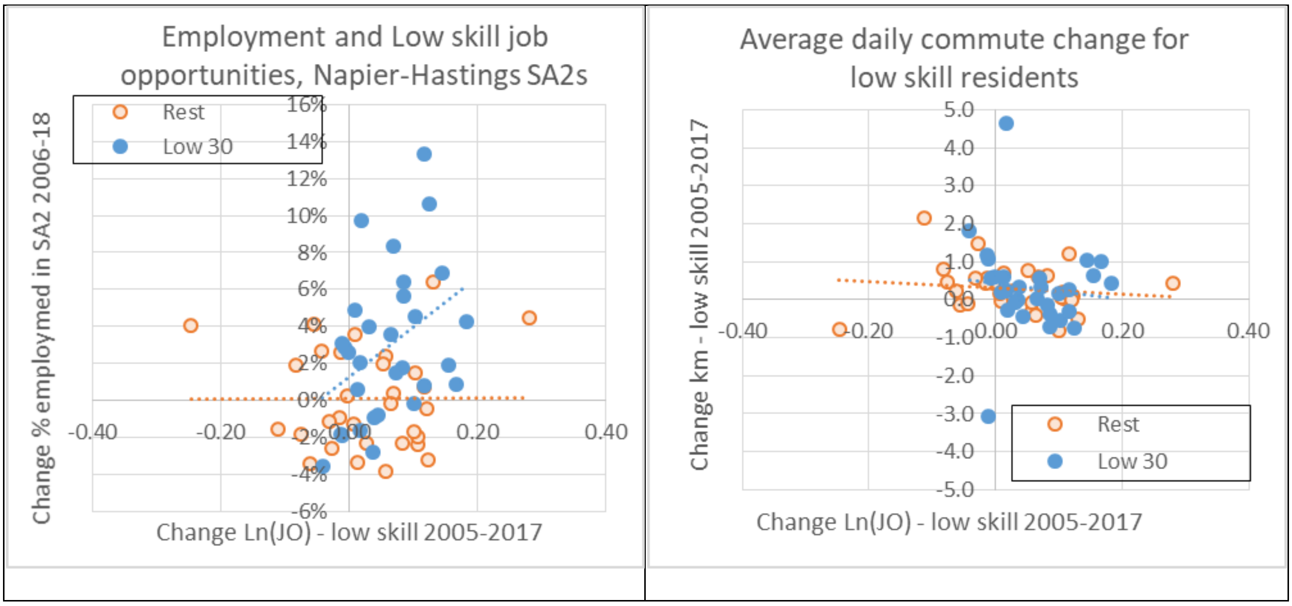


Note: 'Low 30' in these figures refers to the 30 SA2 areas with the lowest rents.

Turning to the effect of changes in low-skill job opportunities:

- Residents in low-rent areas have tended to take on more employment as job opportunities increase, a pattern not observed among the other SA2s although the variation within both sets of areas is wide (Figure 5.3, left).
- This positive employment-job opportunity relationship among low-rent areas is consistent with the results of chapter 3 and potentially with a spatial mismatch hindering employment for low-skilled workers but there could be other factors contributing to this effect, as seems likely to be the case given the level results above.
- The average commuting distance has generally increased although largely independent of any change in job opportunity and rent categorisation (right).

Figure 5.3 Recent relationships with changes in low-skill job opportunities in Napier–Hastings



Note: 'Low 30' in these figures refers to the 30 SA2 areas with the lowest rents.

As for inferences about transport effects, it is difficult to attribute past changes in access to job opportunities or commute distance to transport interventions. The observed changes documented above and in the previous two chapters are caused largely by variation in overall labour market size and growth, rather than by the (sought-for) alternative of jobs and residences moving closer together – spatial sorting, although faster commuting may well allow longer commuting distances.

Of course one might argue that it is not until all the segments and interchanges of the expressway have been completed that the full network gains become evident (the hose blockage analogy). And even then its effects may be difficult to discern. As noted in the literature review, an analysis by Overman (2015) found only three high-quality OECD studies that showed positive effects on employment, productivity or income from road improvements – and none on the employment effect of rail, buses and active modes. Another insight from the literature review is that the main moderator of accessibility is the road network for private vehicles.

On a cautionary note, the investment in transport may not deliver an employment benefit (reducing spatial mismatch) if land-use restrictions prevent the establishment of new workplaces or new housing areas. However, given the redevelopment of the land formerly used by the Whakatu meat processing plant, which is on the Hastings edge of the expressway, and the land for commercial activities at the northern end of the expressway, we infer that employment growth in the Napier–Hastings area is not particularly constrained by land-use regulations.

While the general results of this research project do not point to a widespread labour market issue due to spatial mismatch and the results of this section provide an example of where a network heavily reliant on private vehicles is mediating spatial mismatch, there is scope for a more nuanced interpretation. The figures reported above for Napier–Hastings also indicate that rates of employment are lower in low-rent areas within the region and that employment outcomes have improved within these areas over a period that coincided with the expressway. This points to future research questions:

- Did better roads contribute to job growth for low skilled?
- Can transport reduce the employment gap in low-rent areas? Why and how?

5.3.2 Auckland northern busway

Auckland is of interest to this study as it is the biggest New Zealand city and it offers contrasting transport systems which create a type of natural experiment. It is the latter that raises our interest in the northern zone of Auckland. But first, a recap of results reported in earlier chapters which, as above, fail to show evidence of a problematic spatial mismatch.

Table 5.2 Summary of results reported above for Auckland

Higher job opportunities	Significantly associated with lower wages received, especially for women, but not for low qualification jobs
	Significantly associated with lower rents
	Weakly associated with a higher rate of employment across sexes and qualifications
Job opportunities	Increasing rapidly over time
	Although more slowly for high-skilled residents
Mean commute distance	Declined by 0.5–0.6% for each 1% increase in job opportunities generally

The northern zone of Auckland is fast growing, separated from the Auckland CBD by a harbour, does not have a train service and has expanded its bus service significantly in recent years.

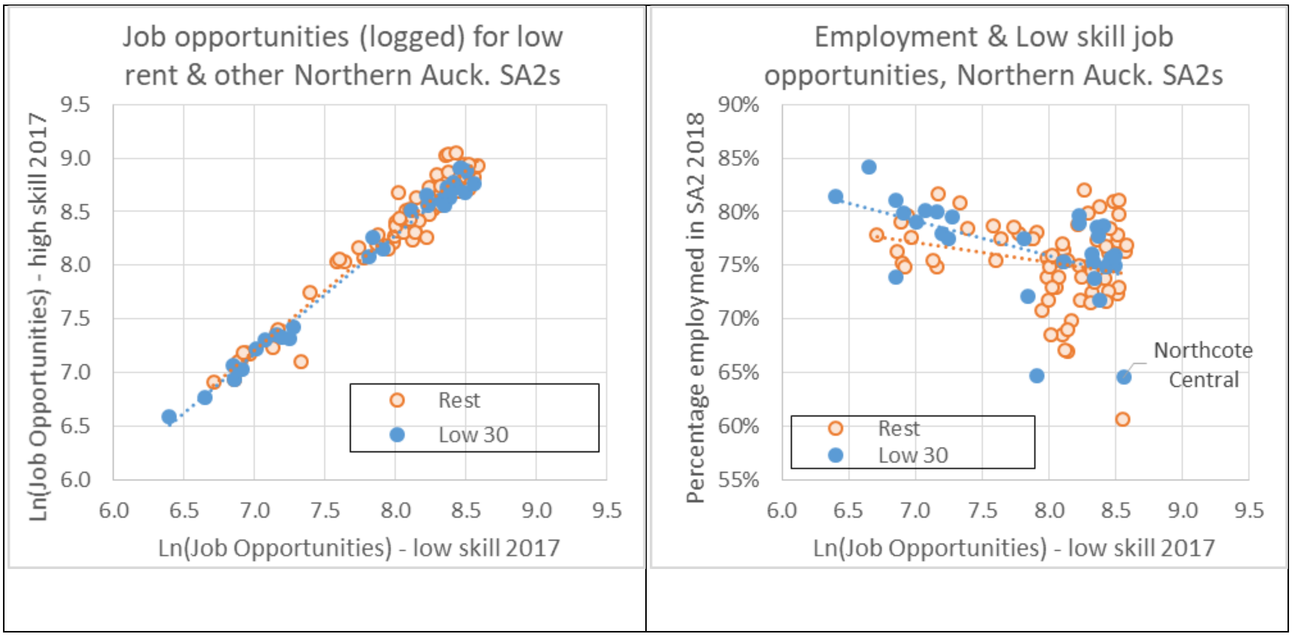
The Northern Busway is a spine network between the Hibiscus Coast in the north and the Auckland Harbour Bridge near the Auckland CBD. The busway was officially opened in 2008 and has gone from early patronage around one million per annum to nearly six million today.

Again the figures below split off the 30 SA2s with the lowest rents from the remaining 71 SA2s (with another three excluded due to missing rent data).

The following observations are made about the levels of activity:

- The northern Auckland areas have slightly more high-skill job opportunities in each SA2 than low-skill job opportunities (Figure 5.4, left).
- The rate of employment at an unweighted SA2 level is generally negatively related with low-skill job opportunities.
- Both relationship are similar for the 30 low-rent areas and the remaining 71 areas alike.
- As an example pointing to wider socio-economic issues, rather than just transport costs, being important, Northcote Central had the highest access to low-skill job opportunities among the low-rent areas, plus had the lowest rent, but it also had the lowest rate of employment.

Figure 5.4 Recent relationship with low-skill job opportunities in the northern zone of Auckland

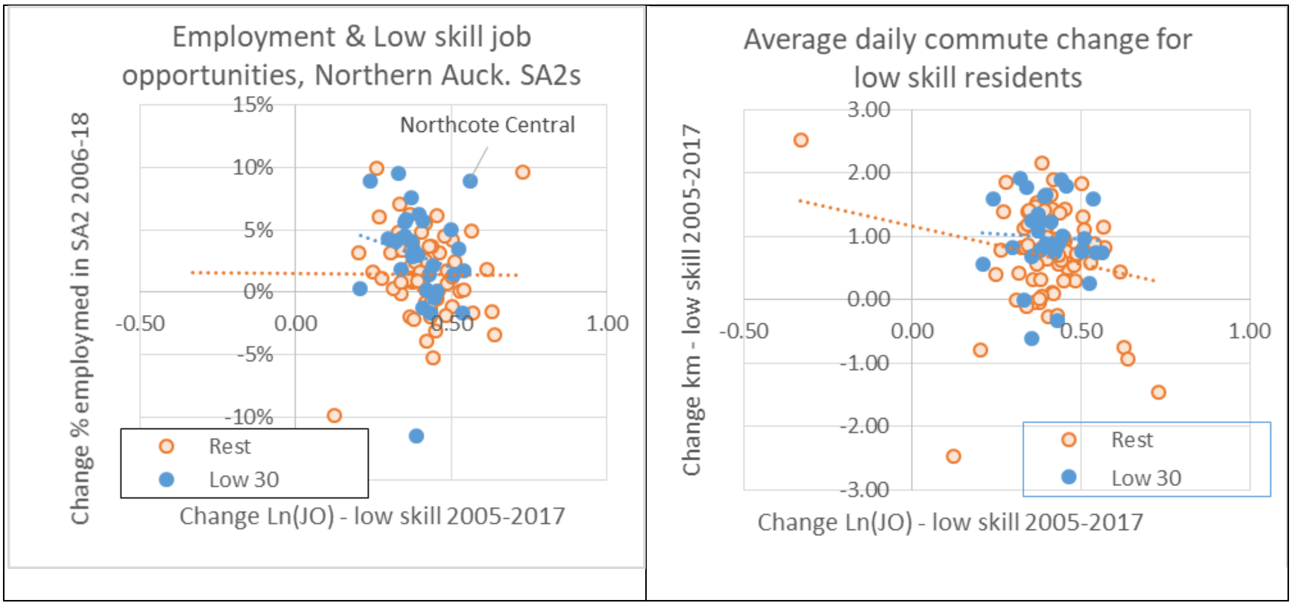


Note: 'Low 30' in these figures refers to the 30 SA2 areas with the lowest rents.

Turning to the effect of changes in low-skill job opportunities:

- Northcote Central, as it turns out, also had the largest increase in low-skill job opportunities between 2005 and 2017, and one of the largest improvements in the rate of employment.
- Otherwise there was no general pattern among the low-rent areas and all areas of northern Auckland to suggest relatively more low-skill job opportunities led to relatively higher rates of employment (Figure 5.5, left); likewise for the average commute (right).

Figure 5.5 Recent relationships with changes in low-skill job opportunities in the northern zone of Auckland



Note: 'Low 30' in these figures refers to the 30 SA2 areas with the lowest rents.

The example of Northcote Central illustrates the twofold nature of accessibility and the potential for ambiguous effects. First, it is an example of where proximity and existing transport links (and not a transport intervention) are enabling residential growth in an area with high job opportunities, the suburb being near the northern end of the Harbour Bridge and hence close to the Auckland CBD and the suburb now (since 2018) undergoing strong re-development. Second, though, the re-development also significantly changes the costs and character associated with the suburb and it is a matter of ongoing study whether changes will benefit the incumbent residents.

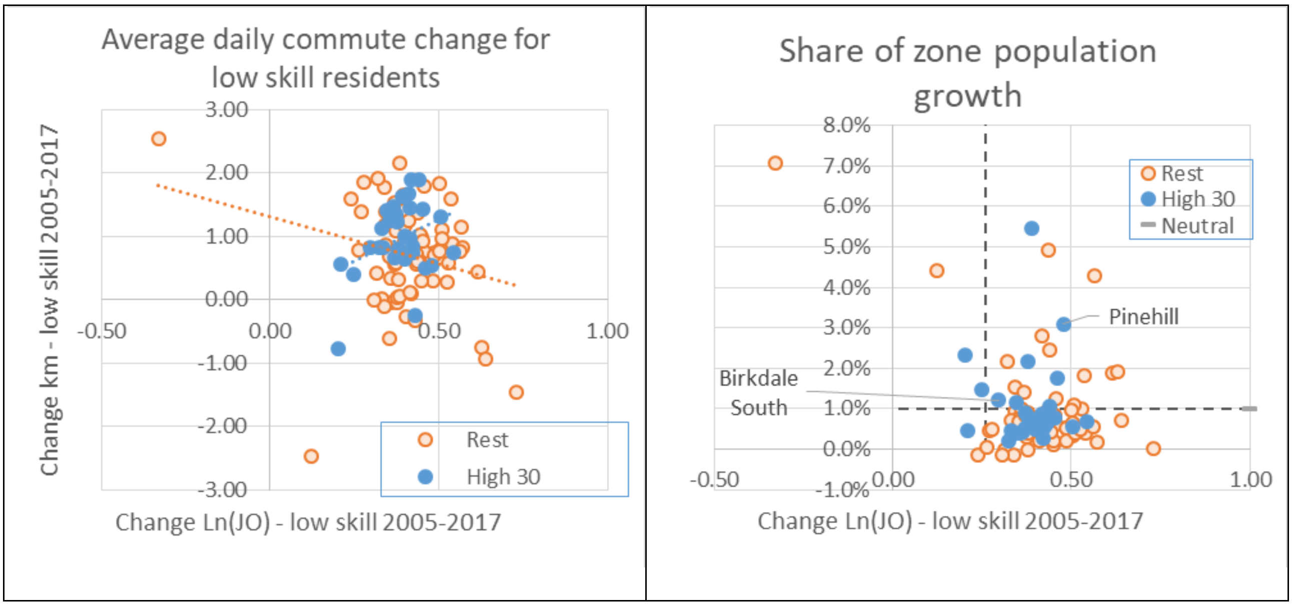
Another interest in northern Auckland is the effect of the improved bus services. The literature implies an important role for transport in improving accessibility for low-skilled people is to increase transport options, eg those without access to a private vehicle are likely to require active modes, public transport and ridesharing.

Below the SA2s are split between those 30 with the highest proportion of workers commuting by public bus being identified from the remaining SA2s. These 'high bus use' areas have the proportion of people using public buses to commute to work ranging from 10.2% to 20.2%, with an unweighted average of 13.3%. The remaining areas range from 0% to 10.2% and average 5.3%.

The effect of changes in low-skill job opportunities show:

- Most areas experienced more low-skill job opportunities and a slightly longer commute, with the high bus SA2s only slightly different on average (Figure 5.6, left). These results are not conclusive, but again fail to suggest transport in general is hindering the labour market.
- The share of resident population growth between 2006 and 2018 was not biased towards those areas with high bus use or high low-skill job opportunity growth (right graph), eg Birkdale South, which has a high proportion of workers taking the bus to work (14.4%) and was among the low-rent areas, did experience an approximate 30% increase in low-skill opportunities and made up 1.2% of zone population growth, but otherwise few high bus use areas were part of the above-average right quadrant below.

Figure 5.6 Average low-skill commute distance (left) and share of population growth (right) versus change in logged job opportunities for high bus use SA2s in the northern zone of Auckland



Note: 'High 30' in these figures refers to the 30 SA2 areas with the highest bus use.

Before elaborating on these results, further evidence of the multi-faceted nature of the challenge to policy makers is Pinehill, one of the SA2s that has combined population growth, good access to PT and jobs. While the PT share was a relatively high 10.2% in 2018, population growth also led to other transport demands for the 58.3% that travelled to work by car, including to areas below the Auckland CBD. There are also the 43.9% who travel to education by car, mostly nearby, but including to the Auckland CBD (see Figure 5.7).

Figure 5.7 2018 travel departure for work (left) and education (right) from Pinehill (green), Auckland

Source: https://commuter.waka.app/

The results for the northern zone of Auckland point to a transport network that is mediating spatial mismatch, including with a large bus network. Again a more detailed look points to future research questions:

- Is the improved bus service benefiting incumbent low-skill residents (as opposed to incoming residents)?
- Likewise, is new housing development in high job opportunity areas benefiting incumbent low-skill residents?
- Can total welfare be increased further by concentrating population growth near public transport?
- What thresholds exist to enable a lower average cost per ride?

5.3.3 Wellington train network

Wellington is also of interest because it is a large city but it is also the New Zealand city with the largest urban train service. A recap of results reported in earlier chapters is tabled below.

Table 5.3 Summary of results reported above for Wellington

Higher job opportunities	Significantly associated with lower wages received across sexes and skills
	Significantly associated with lower rents
	Associated with a higher rate of employment, especially for low-qualified workers when faced with more low-qualified job opportunities
Job opportunities …	Increasing modestly over time
	Although more slowly for higher-skilled residents
Mean commute distance …	Declined around 1% for each 1% increase in own-skill job opportunities

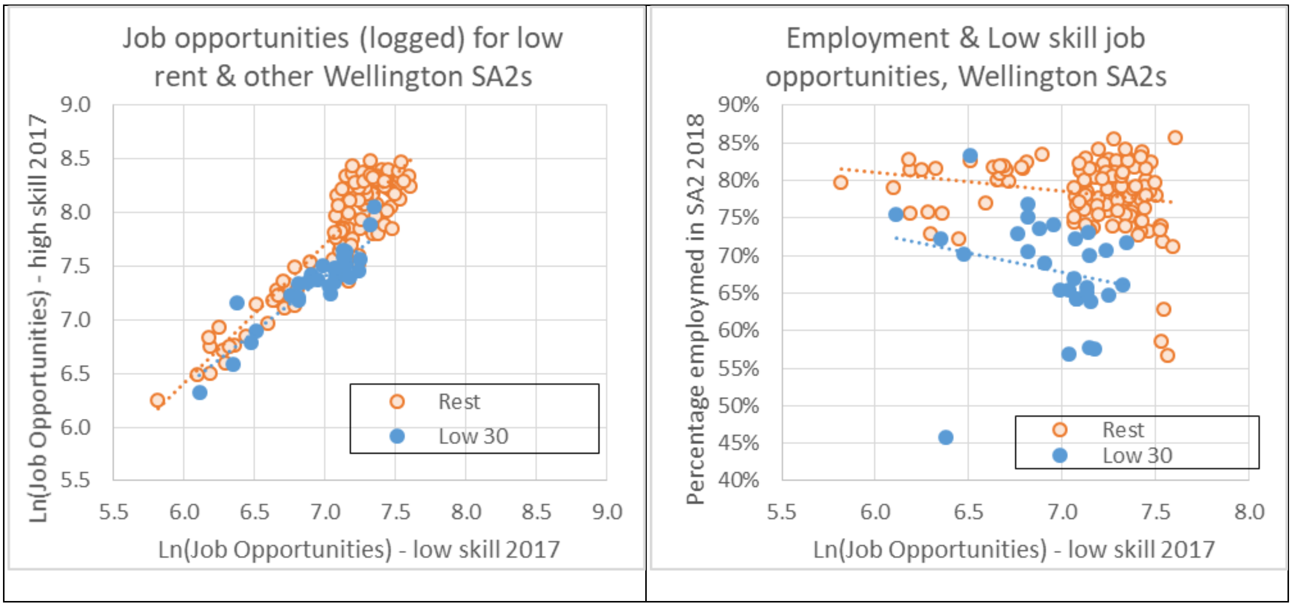
The Wellington urban area includes four zones: Porirua to the north, Wellington, Lower Hutt, Upper Hutt. The two rail spines that connect Wellington zone with the three other zones have existed for many decades. Patronage has increased from around 11 million per annum in 2006 to over 14 million pre-Covid.

Again the figures below split off the 30 SA2s with the lowest rents from the remaining 119 SA2s (with another nine excluded due to missing rent data).

The following observations are made about the levels of activity:

- Generally more high-skill job opportunities exist than low-skill (Figure 5.8, left).
- Low-rent areas are not generally among the areas with the largest job opportunities.
- As in Napier–Hastings, a lower rate of employment among low-rent areas exists for any given level of low-skill job opportunities (right graph)
- The employment-*JO* relationship is similar for low and other rent areas alike.

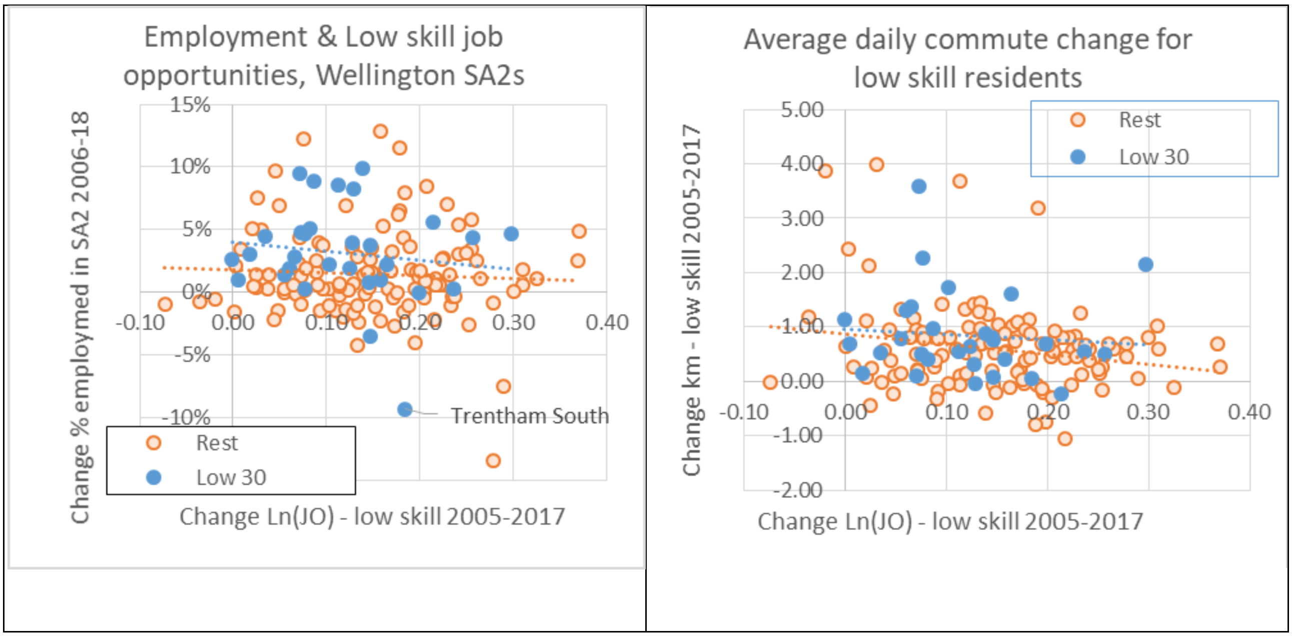
Figure 5.8 Recent relationship with low-skill job opportunities in the Wellington area



Turning to the effect of changes in low-skill job opportunities:

- There was little discernible difference between the low-rent areas and the rest when it came to changes in employment rate (Figure 5.9, left) and change in commute difference (right).

Figure 5.9 Recent relationships with changes in low-skill job opportunities in Wellington



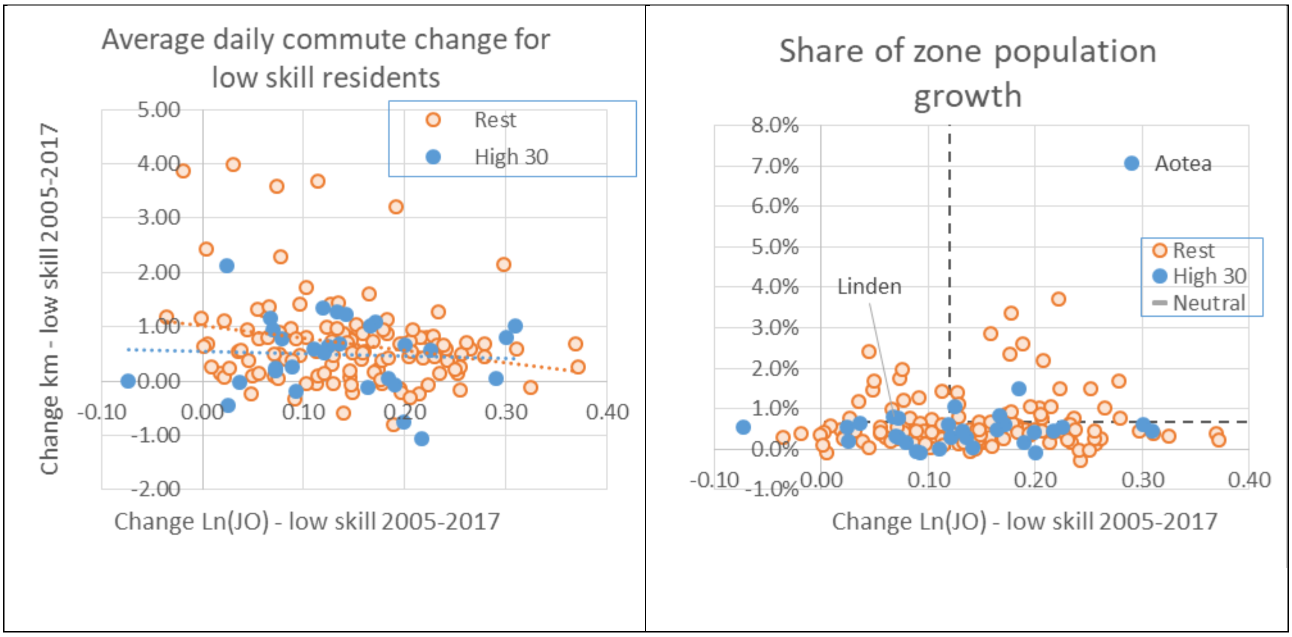
Note: 'Low 30' in these figures refers to the 30 SA2 areas with the lowest rents.

As in Auckland, the interest here is how patterns have changed in the presence of a rail network. The 30 SA2s with the highest share of commute by rail to work were split from the remaining 119 SA2s. These 'high train use' areas have the proportion of people using trains to commute to work ranging from 17.8% to 36.0%, with an unweighted average of 23.0%. The remaining areas range from 0% to 17.5% and average 5.9%.

The effect of changes in low-skill job opportunities show:

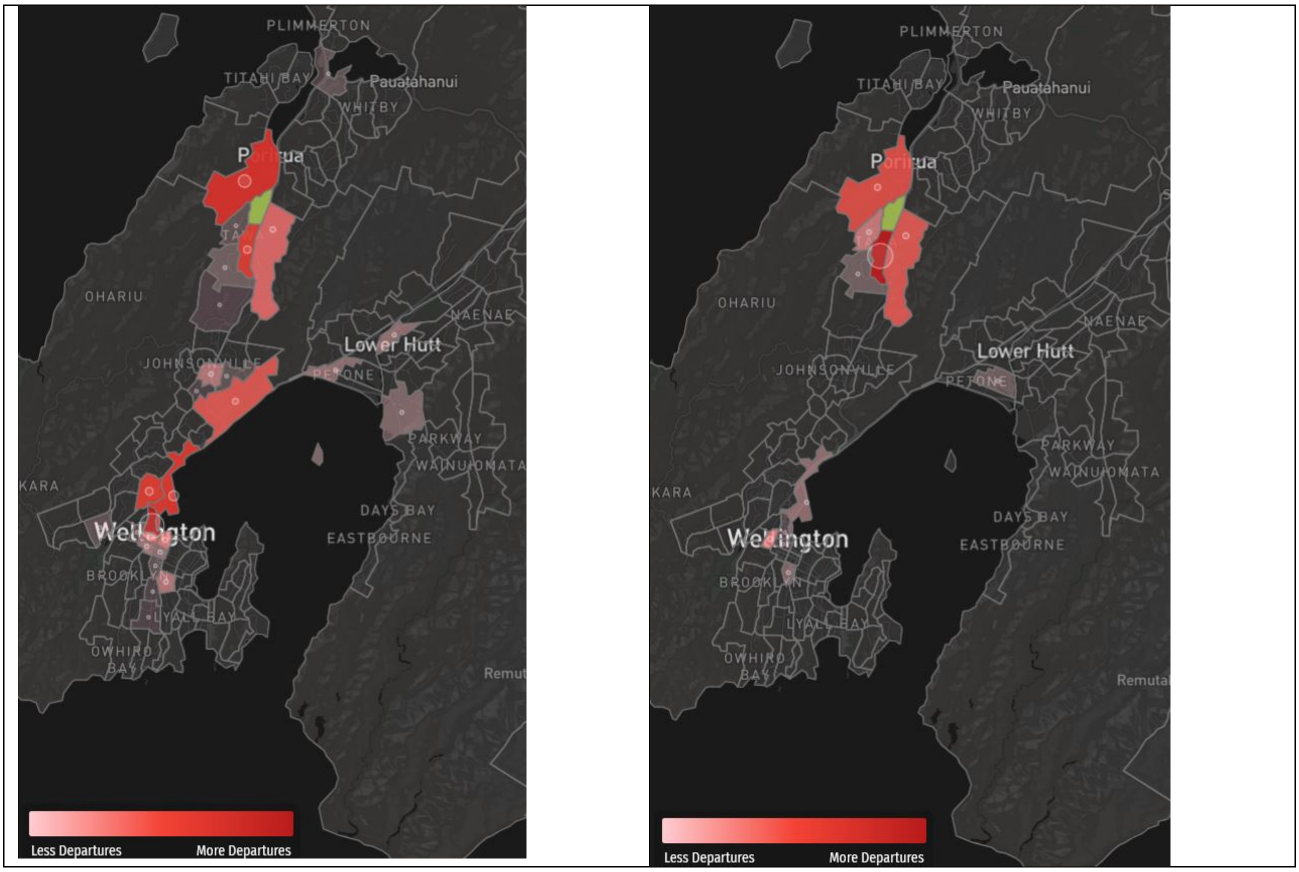
- The change in commute distance for the high train use SA2s was similar to the bulk of the remaining SA2s (Figure 5.10, left)
- As with northern Auckland, the growth in population has not been biased towards high train use areas (right graph). Between the 2006 and 2018 Censuses, the usually resident population of the Wellington urban area increased by 42,726. If this growth was evenly shared across the 101 SA2s then each SA2 would have just around 0.7% share of this growth. The right-hand graph in Figure 5.10 shows that four of the 30 'high train use' SA2s were in the upper right quadrant, experiencing both above average job opportunity growth and strong resident population growth.
- Also, as in Auckland, population growth in 'high train use' areas generates other travel demands. For example, in Linden, where train share for the work commute is 31.7%, 41.8% drive to work and 39.1% drive to education, although the general pattern of travel is less dispersed than in Auckland.

Figure 5.10 Average low-skill commute distance change (left) and share of population growth (right) versus change in logged low-skill job opportunities for high train use SA2s in Wellington



Note: 'High 30' in these figures refers to the 30 SA2 areas with the highest train use for work commute.

Figure 5.11 2018 travel departure for work (left) and education (right) from Linden (green), Wellington



Source: https://commuter.waka.app/

As previously, there is little to suggest a lack of job opportunities causes lower rates of employment, but again there are matters for further research:

- Can transport initiatives reduce the employment gap in low-rent areas? Why and how?
- Is there an opportunity to improve welfare by further concentrating population growth around public transport nodes?

6 Implications for policy and conclusion

6.1 Spatial mismatch

The aggregate inverse relationship between commuting distance and job opportunities might be termed a 'mismatch' as a simple observation of fact, but it tells us little about why there is a mismatch or whether anything should and could be done to alleviate it.

As noted in the literature review in chapter 2, section 2.6, Morris & Zhou (2018) found no association between wellbeing and commute duration. There may be spatial mismatch in a purely geographic sense, but under the hypothesis of utility maximisation people are balancing the costs of longer commuting with the benefits it delivers – higher wages and higher rates of home ownership.

People may choose to live in areas that are not close to particular types of industries or not in a dense CBD surrounded by tall buildings. Similarly the attractions and amenities of a particular residential area such as a larger house and proximity to schools (and the cost of housing) may outweigh the disbenefit of the consequent commute to work. In addition, preferences are likely to change with life stage, and there may also be a cohort effect which in New Zealand's case involves a relative shift towards inner city living.

Consistent with this diversity, an alternative explanation offered by Morris & Zhou (2018) is that the costs and benefits of commuting are relatively minor factors within the overall wellbeing regimen – job satisfaction, family life, health, the local environment and so on.

The results presented here are generally consistent with the interdependent nature of the residence-work place choice. They show that people value living closer to work, but this need not mean they subsequently earn higher wages. In fact, many people are willing to trade-off proximity to work against travel costs. Specific findings from our analysis are as follows:

- Accessibility is associated with higher rents and lower wages, consistent with accessibility being a positive local amenity that residents are willing to pay for.
- Greater accessibility to job opportunities tends to be associated with lower wages (net of commuting costs) and higher house prices. The effect varies in strength across gender and worker skill.
- We failed to find a strong relationship between accessibility and employment rates, which we might expect if spatial mismatch were problematic.
- Commuting distance is negatively related to accessibility to job opportunities, with the strength of the relationship increasing with worker skill. It appears that higher-skilled workers wish to, and can more readily afford to, live further from work.
- However, changes in the level of employment seem to relate more to general economic conditions than to job accessibility, although a lack of general variation in transport networks over the sample period could be masking a stronger effect.
- It is likely that reducing transport costs to an affordable area will improve the welfare of local residents. However, there are second-round effects to consider and our research here provides no evidence that persons living in affordable areas have not already adapted to the current transport network.
- One particular second-round effect is through higher house prices – a benefit to existing property owners, but the combined lower transport costs and higher housing costs may end up being a disbenefit to residents who are renting.

- Overall, it seems that in New Zealand the labour market and transport network function fairly well to mitigate the worst effects of spatial mismatch. The housing market functions less well.

6.2 Transport mediation

Whatever lies behind the residence–job choice taken, we should not infer that commuters would not welcome a reduction in the time (and cost) of commuting, which may or may not involve a reduction in distance – as for the Roads of National Significance with major road changes such as the Waikato Expressway and the Tauranga Eastern Link. Commuting is an equilibrating mechanism between choice of work location and choice of residential location. It generally confers no utility but does involve a cost, as in the pilot spatial general equilibrium modelling in Byett et al. (2017). One of the most fundamental reasons for any transport investment is to reduce travel time and/or cost, even though travel time benefits may eventually morph into other types of benefit such as higher wages or a different residential location.

However, a not inconsequential share of the benefits from improvements in accessibility to jobs is capitalised into land values, as implied by the results of our census analysis on rents, and consistent with literature reported in chapter 2, which implies the beneficiaries of an intervention may not be those to whom the intervention was targeted, and it may well be to their detriment.

Seen from this perspective, transport has the potential to undermine other policy objectives that may exist. For example, if a higher population density is desired to optimise non-transport infrastructure costs then new investment in roads can impact on population density. Likewise, improving transport links to affordable areas may change the nature of the affordable areas in unintended ways.

On balance, lower transport costs will generally lead to improved productivity and utility but not always in the manner that might be preferred for other reasons.

6.3 Transport barriers in affordable areas

Transport is always a barrier in that it imposes a cost for trade and interaction more generally. But fundamental spatial differences do exist which have their own value and these are sometimes preserved by the existence of transport costs.

It is likely that reducing transport costs to an affordable area would improve the welfare of local residents. However, there are second-round effects to consider and our research has provided no evidence that persons living in affordable areas have not already adapted to the current transport network. One particular second-round effect is through higher house prices – a benefit to existing property owners, but the combined lower transport costs and higher housing costs may end up being a disbenefit to residents who are renting.

6.4 Policy response

In chapter 2, we noted Angel & Blei (2016) show that because larger cities tend to be denser than smaller ones, they are also more productive, leading to two broad policy implications:

1 For transport, policies should increase overall regional connectivity by promoting metropolitan-wide commuting that is efficient – that is, faster and more convenient. The Hawke's Bay Expressway and Waterview tunnel in Auckland meet this recommendation.

2 For land use, policies should reduce barriers to the locational mobility of workers' residences and workplaces, to further enhance accessibility. The redevelopment of the Whakatu area in Hastings is an example of land-use change that facilitates the effects of better transport infrastructure. We expect more

development in that area and in other areas adjacent to the expressway in future. The situation should be similar for the urban redevelopment in New Lynn in Auckland.

The last point raises another interesting issue in that transport investments have a retrospective component – amelioration of existing spatial mismatch which is less reliant on current land use, and a prospective component that looks to the likelihood of future spatial mismatch and tries to forestall it. In that context land-use policies are much more important.

Where transport investment addresses existing congestion and/or lack of accessibility, one would expect standard cost–benefit analysis of travel time savings to be a reasonable first order valuation of reduction in spatial mismatch even if some benefits are later captured in land values – which may generate equity issues. This would not be the case, however, when transport investment is pre-emptive and seeks to influence, or may potentially undermine, future locational choices. Explicit modelling of avoided spatial mismatch is then essential.

More generally as discussed in section 2.4.1, the UK Department for Transport has a mandatory requirement that the distributional effects of any transport intervention (that they approve) are included in an appraisal. From an accessibility perspective the focus is on PT interventions and how different groups – children, older people, people with a disability, minority communities, people without access to a car and people on low incomes – could be affected, although the people affected initially might not be the same as those affected later.

6.5 Concluding comments

The literature on spatial mismatch is dominated by US studies, but US cities have experienced patterns of development that are not so common in New Zealand (or in Australia – Dodson (2005) – or in European countries). In particular the hollowing-out of city centres with jobs migrating outwards, leaving only low-quality dwellings, is not evident in New Zealand. Hence our view is that spatial mismatch as used in the literature is not a term with widespread applicability to New Zealand – at least not in the US sense. Even there, debate occurs over whether 'space or race' (or indeed skills) is the core impediment limiting access to job opportunities.

The idea of 'mismatch' can carry a subjective or pejorative tone. Alleviating it must be more than just reducing commuting time (or cost), which most people would welcome irrespective of their current job-residence geographic configuration.

Spatial mismatch, if the term is to be more than just a truism, would seem to be applicable to situations where there is a fundamental lack of transport options (be it private car or PT frequency) that significantly limits the employment opportunities of people (or particular sub-populations) who live too far (in some sense) from major employment centres.

We cannot infer from our research that this sort of spatial mismatch is absent in New Zealand, although whether that is because it truly does not exist or because our models are not sophisticated enough is unclear. Nevertheless we did find evidence that accessibility to job opportunities with particular skill requirements are more relevant to women and lower-skilled workers. Presumably lower-skilled workers face more restricted employment opportunities, whereas for women the effect is probably caused by many women being secondary income earners with less access to the family car or wanting jobs with easier access to home and school. We also found that commuting distances are longer for lower-skilled workers.

Thus we might infer there are situations with the opportunity for transport interventions to raise economic wellbeing by more than the usual value of travel time savings, but care is required. As discussed above, the ultimate beneficiaries of a transport intervention may not be those to whom the intervention is targeted.

6.6 Next steps

Better understanding of spatial mismatch in the broader sense of work-home separation requires a more refined analysis. Measurement of job opportunities and commutes could be improved substantially through the use of peak commute time instead of meshblock centroid distance. Furthermore, the presence of multiple commute time observations over a number of years would enable the possibility of assessing the direct impact of changes in commute time on access to jobs. Even further potential exists to extend the job opportunities methodology if multiple commute modes are available in this commute time data, as low- and high-skilled individuals have different propensities to access public transport.

Based on the above we see a number of interesting research projects:

1. A longitudinal IDI-based case study of an area that has seen a significant and discrete transport intervention, plus richer data on accessibility and commuting (value of time and direct outlays), employment, housing, education and other demographics. This would enable better attribution of changes in labour market status, commuting and residential location to specific transport interventions – something that proved difficult in this study.

We originally thought the Hawke's Bay Expressway would be in this category, but in fact it has been too spread out over time with too many small incremental components and only a few major components. The Kapiti Expressway in the Wellington region is a possible candidate, even though its full benefit in terms of accessibility to job opportunities may not be realised until the Transmission Gully road is finished.

As noted at the end of chapter 3, in estimating the labour market and housing market impacts of job accessibility, we have been challenged by the lack of variation in the data. Accordingly we recommend:

2. A repeat of the census analysis after the next census (2023), which will likely lead to more precise estimates of the relationship between accessibility to job opportunities, and rents, wages and commuting.

In relation to the four research questions posited at the beginning, we have not been able to fully address the third one: *What transport barriers do workers living in affordable housing areas face in travelling to high employment opportunity centres/areas?*

The data has not enabled us to identify transport barriers as such, although the analysis has demonstrated that low job accessibility for low-skilled workers does not result in long commutes, as would be expected if spatial mismatch were a major labour market problem. It is now clear that answering this question requires an altogether different type of study that identifies in much more detail individual access to a private vehicle and public transport options (cost, frequency, reliability, hours of operation). We therefore suggest:

3. Analyse results from a household survey that enquires about access to transport for the purpose of commuting to work, including the possibility that a household may have members who choose not to work or that the household may have moved locations because of difficulties of access to employment.
4. This would also enable explicit consideration of other dimensions of accessibility beyond job accessibility, notably non-work trips by residents.
5. It would also perhaps allow for an analysis of the effects of accessibility and commuting on health and wellbeing (as per Morris and Zhou, 2018) especially in cases of people with a disability.

The fourth research question asked: *How might central and local government respond to such issues and what transport initiatives can be implemented and funded*? We have discussed what initiatives governments can undertake in principle, but we have not covered funding. In fact it should have been evident from the start that funding is a research topic in its own right. All we can state is the usual advice that any initiatives should be subject to a CBA and assessment of wider economic benefits – and then implemented or not, as appropriate.

There is no theoretical challenge in addressing spatial mismatch in a CBA once it is identified. It merely broadens the scope of CBA to include future changes in where people live and work that could occur in response to the initiative being implemented or not being implemented. That is, avoided spatial mismatch needs to be explicitly considered, including the change in the distribution of benefits over time.

Our final recommendation then is not really a research project in the traditional sense.

6 Produce guidelines or a template that transport analysts would use to ensure that any effects on spatial mismatch or potential spatial mismatch (positive or negative) are well understood, especially if some groups of workers are more affected than others.

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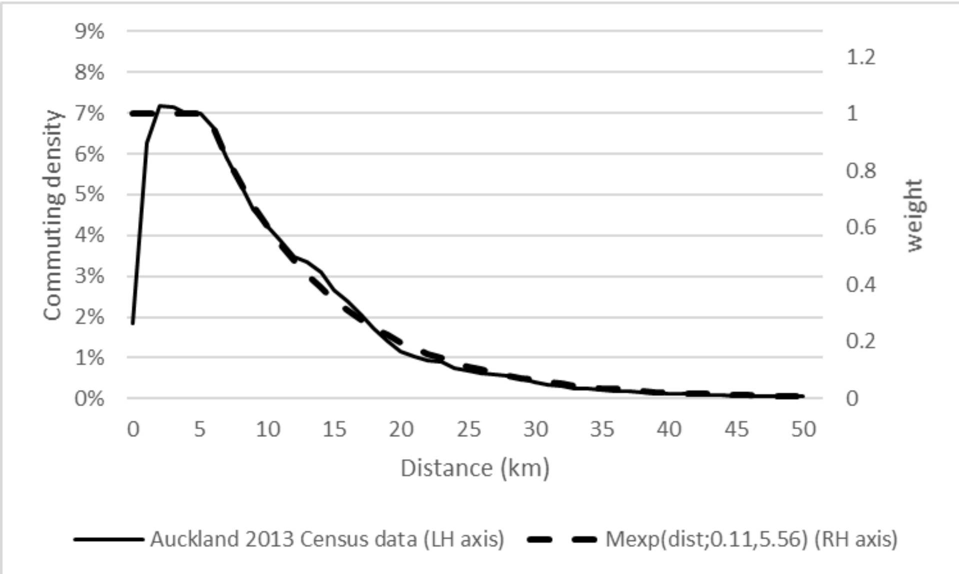
Appendix A: Choice of weighting function

We used a modified exponential decay function for weighting potential commutes by distance. The function has the following form (equation (Equation 3.7 in the text)

$$g^{Mexp}(dist_{rw};\gamma,\delta) = \exp\left(-\gamma \max\,(0, dist_{ij} - \delta\right).$$

We chose parameter values of $\gamma = 0.1$ and $\delta = 5km$. The following figure compares the distance weighting function with the actual distribution of commutes within Auckland, using the 2013 Census commuting data documented in Fabling & Maré (2020). The census data shows relatively few very short distance commutes of less than 2 km, due in part to the use of meshblock centroids as a proxy for location. There is, however, evidence of a flat portion of the density up to about 5 km. Beyond that, exponential decay with $\gamma = 0.1$ matches the decay in commuting density fairly well and thus provides a plausible proxy for distance deterrence in commuting.

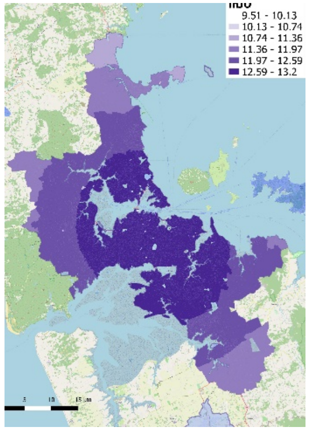
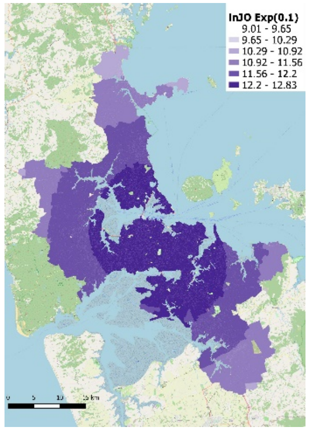
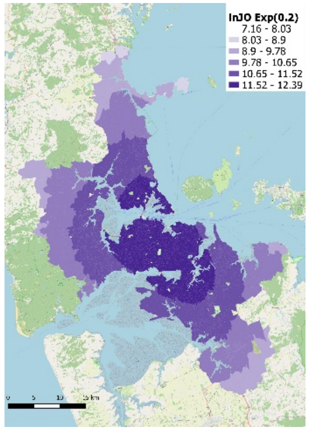
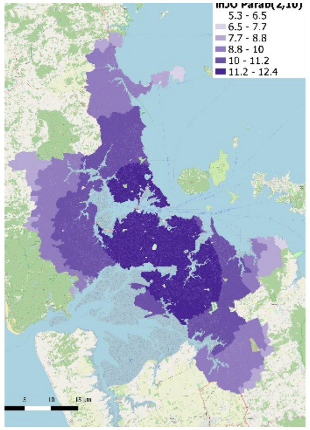
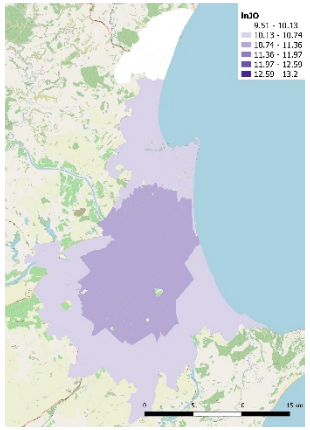
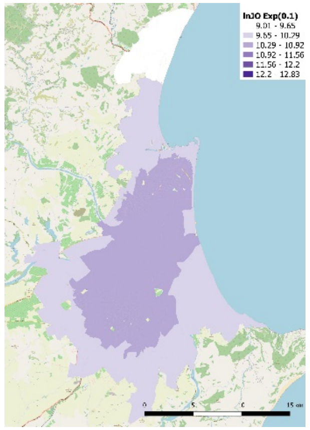
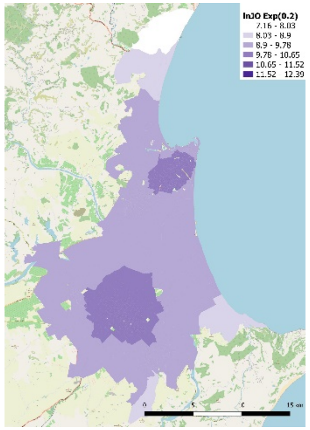
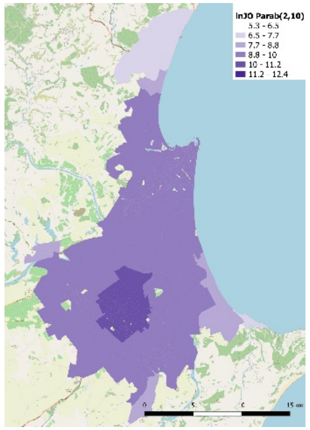
Figure A.1 Auckland commuting density and the choice of weighting function

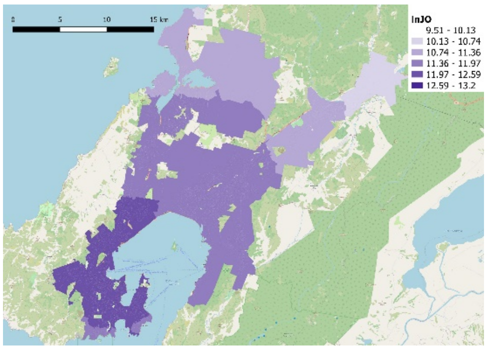
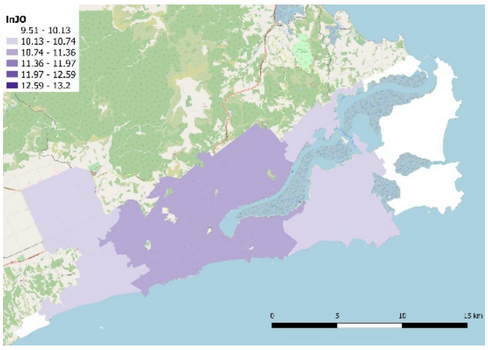


Source: 2013 Census commuting data documented in Fabling & Maré (2020).

Fitting the modified exponential function by non-linear least squares to the census data, excluding the values for density at 0 km and 1 km, yields estimates of $\gamma = 0.112$ (s.e.=0.002) and $\delta = 5.556km$ (s.e.=0.133).

Appendix B: Comparison of job opportunities with alternative weightings

	Mexp(0.1,5)	Exp(0.1)	Exp(0.2)	Parab(2,10)
Auckland				
Napier–Hastings				

<table>
<tr><th></th><th>Wellington</th><th>Dunedin</th></tr>
<tr><td>Mexp(0.1,5)</td><td>
</td><td>
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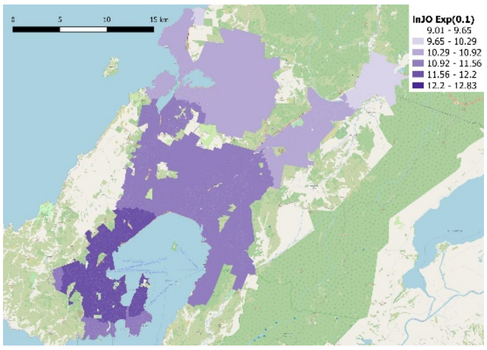
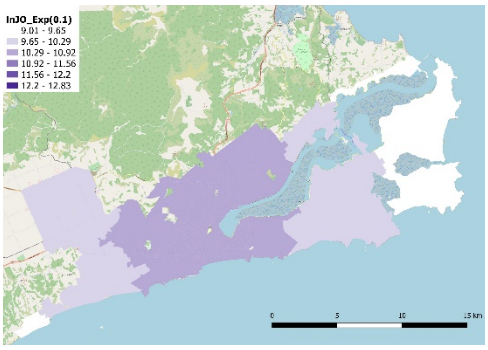
<tr><td>Exp(0.1)</td><td>
</td><td>
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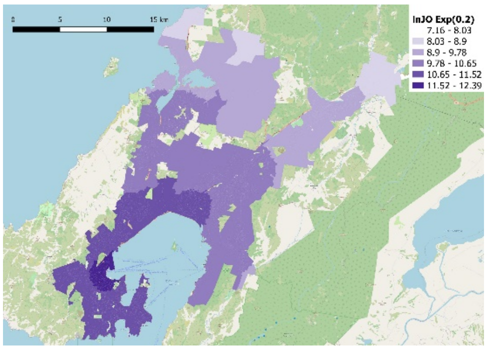
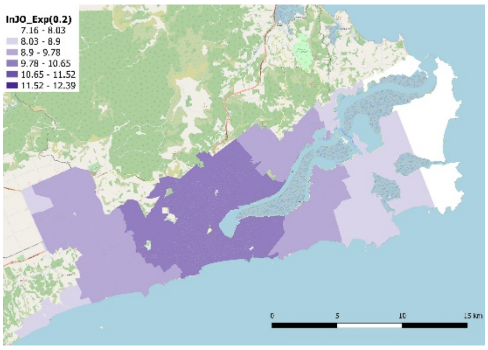
<tr><td>Exp(0.2)</td><td>
</td><td>
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Appendix C: Glossary

AHURI	Australian Housing and Urban Research Institute
ATAP	Auckland Transport Alignment Project
DfT	Department for Transport (UK)
EJS	exposure to job surplus – a component of job accessibility, as defined in section 3.3. An index of the availability of job opportunities, relative to the number of people who can also access those job opportunities
GFC	global financial crisis
GPS	Government Policy Statement on land transport
HQ	high-qualification skill group (people with tertiary qualification)
IDI	Integrated Data Infrastructure managed by Statistics NZ
IV	instrumental variable estimation: a statistical method for reducing the bias from mis-specification, as described in section 3.3.4.
JO	job opportunities – a component of job accessibility, as defined in section 3.3. A distance-weighted sum of jobs accessible from a meshblock ln*(JO)* refers to the natural logarithm of JO.
LQ	low-qualification skill group (people with less than tertiary qualification)
MB	meshblock: The smallest level of geographic area coding available in census data. The census analysis is based on 2013 meshblock boundaries. The IDI analysis is based on 2018 meshblock boundaries.
$NJA\ (= A_c)$	net job accessibility: the sum of ln*(JO)* and EJS
PT	public transport
SA2	statistical area 2 (2018 version): Geographic areas used in the IDI analysis. These areas are based on groupings of 2018 meshblocks.
TfL	Transport for London
V_c^w	the value to a worker of living in area c
V_c^f	the value to an employer of locating in area c
$\ln r_{mt}$	the natural log of monthly housing rental costs in meshblock *m* (for non-owner-occupied private dwellings)
$\ln w_t^h$	the natural log of annual incomes for people living in home-meshblock *h* (based on full-time employed workers)

$\ln w_t^j$	the natural log of annual incomes for people working in job-meshblock *h*. (Based on full-time employed workers)
h_d	the hazard function (conditional probability of finding of job) for exit from non-employment, as a function of duration *d*