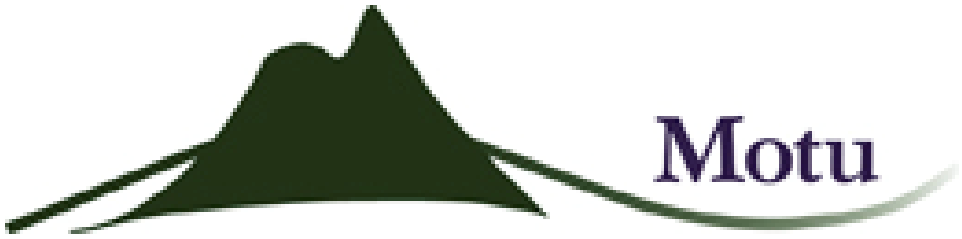

Patterns of population location in Auckland

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Information on the location of employment is drawn from Statistics New Zealand's prototype Longitudinal Business Database. Only people authorised by the Statistics Act 1975 are allowed to see data about a particular, business or organisation. The results in this paper have been confidentialised to protect individual businesses from identification. The results are based in part on tax data supplied by Inland Revenue to Statistics New Zealand under the Tax Administration Act 1994. This tax data must be used only for statistical purposes, and no individual information is published or disclosed in any other form, or provided back to Inland Revenue for administrative or regulatory purposes. Any person who had access to the unit-record data has certified that they have been shown, have read and have understood section 81 of the Tax Administration Act 1994, which relates to privacy and confidentiality. Any discussion of data limitations or weaknesses is not related to the data's ability to support Inland Revenue's core operational requirements.
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Abstract

This paper uses spatial statistical techniques to examine the economic determinants of residential location patterns in Auckland in 2006. The primary empirical focus of this paper is descriptive. We seek to establish the extent to which there are identifiable population subgroups that cluster together within the Auckland Urban Area, and further, to ascertain where these groups mainly live. It confirms previous findings of strong ethnic clustering and identifies clustering by qualification, income, and country of birth. It examines the interaction between incomes, land prices, and population density, and the relationship of land price with access to selected locational amenities.

JEL codes

R12 – Size and Spatial Distributions of Regional Economic Activity; R23 – Regional Migration; Regional Labor Markets; Population; Neighborhood Characteristics; R31 – Housing Supply and Markets

Keywords

Residential location choice; local amenities; residential sorting

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1 Introduction

"Cities teem with positive and negative externalities, all acting with different strengths, among different agents, at different distances … Together these many interactions, helped by history and a good deal of chance, produce the spatial structure that we see. Is it any wonder that spatial patterns are complex, that they occasionally display sudden change, or that tractable models can capture only a portion of their rich variegation?" Anas et al. (1998, p.1459)

The last fifty years have witnessed the devolution of the city. In the late nineteenth or early twentieth century, most cities could be characterized by a monocentric urban form, with firms clustered in a central location, normally around a port or transport hub, and residents located nearby or near public transport lines linked to the centre. But the truck and car have changed that. The availability of inexpensive means to transport goods have freed many manufacturing firms from the need to locate near their suppliers or customers, or near rail or shipping facilities, and allowed them to choose locations where land was inexpensive. The availability of cars enabled people to live in locations far from the central city where land was cheap, life was less crowded, and where new firms were locating. The result is the decentralized, often sprawling and seemingly unplanned modern city, frequently characterized by a polycentric form featuring many subsidiary sub-centres far from the traditional city centre.

Auckland is no exception to this trend, although changing geographic classifications make an exact comparison difficult. In 1956, the Auckland urban area had a population of 399,000, of whom 255,000 (64%) lived in the Central Auckland urban zone. [1] Fifty years later, the Auckland Urban Area had a population of 1,208,000, of whom 396,000 (33%) lived in the Central Auckland urban zone. These figures imply that over 80 percent of the increased population located itself outside the Central Auckland urban zone, in the Southern (from 55,000 to 371,000 people), in the Northern (from 53,000 to 248,000 people) and in the Western (from 36,000 to 192,000 people) urban zones.

The changing nature of the city raises many questions. Where do new businesses and new households choose to locate, and why? Do firm location decisions depend on

[1] The aggregate population data used in this paper are from Statistics New Zealand and correspond to the Auckland "Urban Area." The Auckland Urban Area comprises the Northern, Central, Western, and Southern Auckland urban zones. The definition of these zones, and the population statistics for these zones and for the Auckland Urban Area, are presented in Appendix A. Statistics New Zealand also publishes data for the Auckland "Statistical Area," which comprises the Auckland Urban Area and some outlying rural districts and islands. These data are also reported in Appendix A.

identifiable firm characteristics such as size? For what types of businesses is traffic congestion likely to be an important factor in location choice, and how is this affected by the construction of new highways and roads? What is the role of zoning? Do household location decisions depend on readily identifiable characteristics such as age or ethnicity, or do they mainly depend on income or unobserved preferences? And where should national and city governments locate new roads or public amenities such as greenbelts, swimming pools, or schools?

This paper is the first in a series that explores the factors that determine where households and firms locate within the Auckland Urban Area. The broad focus of this paper is on how the household decision-making process affects location patterns: in essence we try to address the question, "Why do people choose to live where they live?" In doing this, we first develop a theoretical framework to examine the main factors that should affect where people live. We then examine patterns of residential location in Auckland, giving particular emphasis to the extent to which different population subgroups tend to cluster together. Our quantitative analysis of revealed location choices complements existing studies that provide qualitative analysis of stated location preferences (e.g.: Saville-Smith and James, 2010).

2 Residential locations decisions: Preferences, incomes, neighbours, and location-based sorting

Big cities offer residents a huge variety of places to live. The resultant location patterns are of interest to city planners, government officials, and economists. City planners are often interested in the best places to build roads, public transport infrastructure, or new amenities. Government officials are often concerned about the effects of income-based sub-group clustering, particularly if poor people live near other poor people. Living in a poor neighbourhood may worsen school outcomes, or increase health risks, or lessen the chance of finding work, for instance, potentially jeopardizing the effectiveness of welfare programmes aimed at alleviating poverty. And economists are interested in the strength of the various economic forces that determine individual and aggregate location patterns.

When making their location choices, individual households tend to make a trade-off between a variety of factors: the suitability of a particular house; the accessibility of amenities in both the immediate region and the wider city; the cost of travelling to work; the people in the neighbourhood; and the cost of purchasing or renting housing, perhaps taking into account future resale value. Households typically consider a variety of locations, choosing that which provides the best value for money as their circumstances permit. Since

locations that have convenient access to amenities or workplaces save transport costs or lead to higher levels of satisfaction, other things being equal, land prices in these locations are typically higher than in inconvenient locations.

The traditional economic approach to residential location sorting has been to analyse a land price bid-rent gradient as a function of the distance to the central city. The basic argument, developed by Alonso (1964), Mills (1967), and Muth (1969), is that if people work in the central city, they will bid more for land located close to the centre than for land far from the centre, as living close lowers commuting costs. Since the quantity of land demanded is assumed to be a rising function of income and a declining function of its price, this approach suggests that land prices and density should both be a declining function of the distance from the centre. Moreover, if transport to the centre is particularly cheap in certain locations, possibly because of public transport or access to a highway, these locations should also have relatively high land prices and high population density. For this reason, older cities are often characterized by densely populated corridors around transport networks.

Figure 1 illustrates the concept of bid-rent gradients graphically. Urban locations are characterised in terms of their distance from a single centre, labelled *M*, that offers amenities or employment. Individuals are indifferent between all of the rent and location combinations on each of the bid-rent curves such as BR_1. Locations close to the centre offer them low-cost travel to the workplaces or amenities at the centre but at the cost of higher land rents. The lower land rents in more distant locations allow people to pay less for the same amount of land, or to consume greater amounts of land (lower density), but at the cost of more expensive travel to the central amenities and workplaces. The combinations on curve BR_3 are preferred to those on the higher curve BR_1 because they offer the same combination of travel costs and access to the centre but at lower rents. Higher travel costs would make the slope of the bid-rent curves steeper, since people would be more willing to pay higher rents near the centre to avoid the higher travel costs.

The insight that people will pay for convenient locations, other factors equal, is no doubt correct. But the relatively simple theoretical approach of Alonso, Mills and Muth has proved more suited to describing nineteenth and early twentieth century cities than modern cities characterized by multiple subsidiary centres, often on the edges of the city, with employment scattered throughout the city. While population density does decline with distance, Anas et al. (1998) observe that modern cities have several features that are not consistent with the traditional focus on land rent-gradients based on the cost of commuting to

a central city workplace. In particular, they argue that even though subcentres have not eliminated the importance of the city centre, they are prominent in all cities, and account for a large share of employment. If people like to live near where they work, the decentralization of employment partially explains why people live where they live. But it doesn't explain the second anomaly, the amount people commute, which is several factors higher than can be explained by traditional approaches.

At a common sense level, commuting patterns are reasonably easy to explain. People, and their children, enjoy a wide range of activities that must be enjoyed on site, such as going to the movies, eating at restaurants, walking along a beach, swimming in a pool, or shopping, and these activities all necessitate commuting. People also have vastly different preferences over the frequency with which they undertake these activities. When selecting a place to live, they choose a location that balances housing costs with the cost of commuting not only to a workplace but also to these various amenities. Even if they minimize commuting costs, the amount of commuting is likely to be large simply because people undertake a large variety of activities and these activities are spread out over space, particularly as they are often done with friends or relatives who live in different parts of a city. But most people do not have minimal commuting costs, for they swap their housing locations less frequently than they change tastes, household circumstances, and workplaces, inducing additional travel.

From this perspective, the demand to live in a particular location is more likely to be driven by the demand for enduring local amenities than the demand to live near a current workplace. In practice, many people commute less to work than they commute to other locations.[2] Surprisingly, formal theoretical analysis of within-city residential location patterns has largely ignored the role of multiple trips to use amenities.[3] At first glance, however, the demand for amenities seems able to explain both the proliferation of suburban sub-centres and the extent of commuting, particularly given the increasing importance of the service sector over time. Sub-centres providing a wide range of consumer services emerge to minimize the amount of commuting done by local residents; and in turn these subcentres attract ancillary business service providers, raising employment opportunities further. The virtuous circle is completed as the proliferation of suburban amenities and jobs attracts new residents to the neighbourhood. Commuting trips to the central city and other subcentres

[2] See the discussion in section 2.2 below for a summary of New Zealand patterns.
[3] See McCann (1995 and 1998) for analysis of trip frequency influences on the location of businesses.

remain frequent, however, not just because people like to use a wide range of amenities located all over the city, but because economies of scale mean that some amenities (such as large sporting arenas, for instance, or retailers specializing in infrequently purchased items) are not replicated right across a city.

While people like to choose convenient locations, where affordable, there is also a pronounced tendency for population subgroups to cluster together, with people of a particular age, race, or income oftentimes living in concentrated numbers in a particular area, while being almost wholly absent from other regions. This subgroup-clustering can occur for at least four reasons. First, households from one particular subgroup may choose to locate near to an amenity that has particular appeal ("amenity preference"). Maori may locate near a marae, for instance, while young households without children may choose to locate near an entertainment district. Secondly, people from a subgroup may choose to live near each other, because they share common interests and find it convenient and pleasant to be close to people similar to themselves ("positive association"). Thirdly, people from a subgroup may end up living by themselves because they are disliked by other groups, who choose to live in areas without them ("negative discrimination"). Fourthly, people from a subgroup may live together because they have similar income and find themselves not only priced out of more expensive neighbourhoods but making similar calculations about the costs and benefits of living in the neighbourhood in which they do live ("income sorting").

Since few houses remain empty, it is clear that land prices and rents adjust to sort households into different areas. What remains unclear, however, is the relative importance of income, transport costs, preferences and neighbourhood clustering effects in determining where people live. Logic suggests all of these factors could be important, but none need be.

2.1 Income

It is natural to suspect that income is an important determinant of where people live, because if land prices in a conveniently located area or an area with good amenities rise sufficiently high, low income people will be excluded. Moreover, most cities have easily identified rich and poor neighbourhoods.

A simple case of income sorting is illustrated in Figure 2. Bid-rent curves are assumed to differ across income groups, with the low-income group having a stronger preference for central living, and hence a steeper curve. This situation could arise if people on low incomes are more sensitive to travel costs or if high-income people put more value on

living on larger land areas. For the case that is illustrated, the low-income group will be concentrated in high-density central areas up to distance d_L from the centre, whereas the high-income group will be concentrated in lower density peripheral areas between d_M and d_h from the centre. Other configurations are possible – high-income people may have a stronger preference for frequent consumption of amenities at the centre, in which case their bid-rent curves would be relatively steep and they would be observed concentrating close to the centre.

Income based sorting need not be important. If areas have a mixture of large and small houses, located on different sized plots, and in various states of repair, poor people will be able to mix with the rich if they value the local amenities sufficiently highly that they are prepared to reduce their consumption of housing to obtain them. For this reason, the extent to which suburbs have a diverse income mix will depend on historic building patterns and the extent to which zoning regulations prevent intensification, perhaps by banning multi-story apartments that would otherwise allow low-income people to live in an area without using much land. Indeed, many new suburbs may have less income mixing than older areas, for their houses will be more uniform in age, and perhaps more uniform in size and type than houses in areas that were developed decades or centuries earlier. Moreover, since incomes were lower when older areas were developed, many of these houses will be smaller and less suited to modern taste than more recently constructed houses, lowering their attractiveness to high-income households despite their convenient locations.

2.2 Transport costs

The historic evidence strongly suggests that falling transport costs led to city decentralization (Baum-Snow, 2007; Glaeser and Kohlhase, 2004; Moses and Williamson, 1967). The effect of falling transport costs on land prices and within-city inequality patterns is difficult to establish, however, due to the complexity of the economic mechanisms. Several issues have been identified: the extent to which lower transport costs lead to economic decentralization; the extent to which lower transport prices lower or raise land prices across a city; the extent to which good access to transport infrastructure facilities is reflected in *local* land prices and rents; and the extent to which transport costs lead to income-based sorting, with higher income households living in areas with good transport access.

Moses and Williamson (1967) argued, largely in response to the historic development of Chicago, that the invention and popularization of the truck was the crucial

factor that led to industrial decentralization. In the late nineteenth century, the cost of moving goods around a city (by horse and cart) was so much greater than the cost of moving goods between cities (by rail or ship) or of moving people within a city (by streetcar) that most industrial firms found it uneconomic to locate in peripheral regions of a city despite low land costs. The truck changed that, first by allowing cheap transport within a city and subsequently by allowing direct links between companies located in different cities, once intercity highways were built. The highway network enabled residential decentralization as well, as households could locate near highway on-ramps far from the central city and speedily commute to workplaces located near other highway network exits, including those in the centre (Baum-Snow, 2007). The widespread of use of the motor car for workplace commuting has meant most people can live 15–30 miles from a workplace and still commute within 30 minutes (Glaeser and Kohlhase, 2004).

The reasons why it is difficult to uncover the effect of transport costs on land prices has been best demonstrated in a theoretical model by Fujita and Ogawa (1982). They extended the Alonso-Mills-Muth model by asking where people and firms would locate if both were free to choose locations. They showed that a variety of permutations were possible. When transport costs were high, firms would largely concentrate around transport hubs, typically the central business district, while people would be located in surrounding but nearby residential areas. As transport costs reduced, at some point a second industrial subcentre can form, or the city can move to mixed form with firms and residents intermingled in most areas. For a given population, the reduction in transport costs causes the total value of land to first increase and then decrease. This is because the total value of residential land depends on the interaction of both demand and supply factors. While households will pay a premium for land that reduces the cost of commuting to work or consumption amenities, transport improvements not only increase the convenience of land located near a city but also reduce the scarcity of convenient land. If the population remains fixed, the latter effect dominates, causing land prices to fall if transports costs fall sufficiently low. If the city population rises because lower commuting costs make it more attractive relative to other cities, however, the increased demand for land will tend to raise prices despite lower commuting costs.

While transport costs have an ambiguous effect on property prices overall, areas with good access to transport networks typically command price premiums. (See Grimes and Liang (2008) for evidence concerning the willingness to pay to be near motorway access in

Auckland.) This does not necessarily lead to income-stratified sorting, however, as the willingness to pay for commuting convenience depends jointly on income, the location of jobs, and tastes for consumption amenities.

Between 2006 and 2009, the average New Zealander spent 7–8 hours per week travelling, and travelled 230 km per week (Ministry of Transport, 2010a, 2010b). Eighty percent of this travel was undertaken in cars, 10–15 percent as a pedestrian, and 4 percent on public transport. Travelling to work accounted for approximately 16 percent of this time, and travelling for an employer a further 10 percent. Most of the remaining three-quarters of the time spent travelling was for shopping and personal business, social visits and recreation, or while accompanying someone else somewhere, often a child. Auckland and Wellington residents spent one to two hours longer per week travelling than residents of other cities, although they travelled a similar distance.

2.3 Amenities

Casual observation suggests that many households choose residential locations because of the amenities they offer. Formal analysis of the role of amenities in location decisions has, however, suffered from a failure of the literature to adequately define what amenities are and how they are valued.

This paper takes the broad view that a local amenity is any activity, the cost or convenience of which varies across locations. Sometimes these activities can be undertaken at home, if they are available; or people can travel to another location and do them. Locations thus differ in the convenience or cost of undertaking different activities. Consequently, in a North Shore beachside house, the amenity "looking at the sea" can be undertaken by lifting one's head; the amenity "taking a walk on the beach" can be undertaken in a minute or two by walking out the door and across the road; and the amenity "flying from the airport" can be undertaken by driving across town for an hour. The same activities may take an hour, an hour, or 15 minutes from a location in Otara. Since by this definition, people living in any location can do any activity that is available in any other location, locations primarily differ in how easy or costly it is to partake in different activities. The question of whether a place is convenient or inconvenient to amenities *in general* is therefore somewhat complex, as it depends on the number of trips to each amenity that people make.

The existence of amenities in multiple locations complicates the interpretation of observed patterns of densities and rents. Figure 3 extends the analysis of the basic bid-rent

gradient relationship that was shown in Figure 1 by allowing additional amenities at locations C_1 and C_2, at distances d_{C1} and d_{C2} from the centre. People will bid up rents in areas that are close to these additional amenities, leading to a non-monotonic relationship between rents and distance from the centre. One implication of this extension is that the same level of rent will be observed at more than one location. People can pay the same rent in different locations but what they are gaining varies across the locations.

It is probable that amenities have been growing in importance over time, as goods that are consumed at home become cheaper and less scarce, and people have more income to spend on other things. As many New Zealand families realize, this has raised the importance of location convenience: trips to the shopping centre, to schools, to sports practices and sports games, to the cinema, or to restaurants can take up more and more time. The extent to which this trend will have affected location decisions is unclear, as declining transport costs have reduced the "inconvenience factor" of many locations over the same period, and amenities located in suburban areas have become more common. Travel surveys suggest that most of the 10 percent increase in travelling that took place between 1989 and 2009 was because of an increase in trips for shopping and personal business (Ministry of Transport, 2010b).

If some non-natural amenities such as schools or shopping centres are used very frequently, it is most likely that it will be profitable to supply them to all neighbourhoods to reduce the inconvenience to locals. Paradoxically this means most neighbourhoods will have similar locational convenience to the most important amenities, and so amenities that may be thought to be the most important may have the least significance in determining land values. An exception to this rule could occur if zoning restrictions prevented businesses or organizations that supply frequently used services from setting up in certain neighbourhoods. In the empirical work we examine how distance to schools and shopping centres affects location decisions, and discuss this issue further.

Much of the previous literature on amenities has focused on the difference in factors such as crime, seaboard access and climate across different cities. The primary thesis of this literature is that people will migrate between cities until differences in the amenity quality of different locations are sufficiently reflected in land prices and wages that further migration is unattractive (Roback, 1982; Rappaport, 2008). In essence, locations with good amenities – for example, a pleasant climate, or good access to outstanding natural facilities – will have higher priced property and lower wages than locations with poor amenities. However, the literature demonstrates that the relationship between land prices and amenities

can be quite complex, for three reasons. First, as noted by Rosen (1974), the relationship reflects the distribution (across different people) of preferences for the amenity as well as the intensity of preference for an individual. Secondly, land prices will differ if the amenity is primarily prized by consumers, by exporters, or by producers of goods for local consumption. Thirdly, the effect of amenities on land prices will depend on the income tax system (Albouy, 2009).

If amenities are primarily prized by consumers or by producers of goods for which there is a large export demand, households or firms bid up the price of conveniently located land, so the price of land is higher than otherwise. The extent to which users will bid up prices depends on the tax system. Since firms are taxed on their profits, they will be willing to pay less than the amount they save by being in a particular location, as the money spent on the location is not generally tax deductible. In contrast, household will be willing spend more than the money they save by being conveniently located, as income but not convenience is taxed. If amenities are primarily prized by producers of goods for local consumption, land prices may not rise much, as the benefits of the amenities can be competed down as low prices for the final goods, rather than as high prices for land.

2.4 Neighbourhood clustering effects

Economists have a long history of examining neighbourhood clustering effects. Beginning with papers by Tiebout (1956) and Schelling (1969), economists have analysed how the composition of a neighbourhood affects the actual or perceived quality of life in an area, and how this affects whether people decide to settle in an area. A vast literature has examined the conditions under which neighbourhood clustering effects are important. This literature has identified three major reasons why clustering occurs. First, it can occur because people have preferences as to the characteristics of their neighbours, such as their age, race or income ("neighbourhood clustering"). Secondly, people have preferences over the quality of certain local services such as schools or over quality-of-life factors such as crime levels which are affected by the characteristics of the people living in the local neighbourhood ("amenities"). Thirdly, people have preferences over the quantity of amenities funded by local taxes, and they move to areas composed of people with similar preferences and incomes ("fiscal sorting"). In all cases, it is possible that relatively small differences in preferences can lead to significant clustering.

There is little doubt that neighbourhood clustering effects are important. The influence of local amenities and fiscal sorting are closely related. According to a leading recent review, "empirical evidence suggests strongly that residential location choices within metropolitan areas are made on the basis of many factors other than transportation and commuting costs, such as local schools, crime rates, and other public amenities" (Nechyba and Walsh, 2004, p. 183). Survey evidence supports this conclusion, demonstrating in particular that people are concerned about schooling, crime, and natural amenities as well as access to commercial facilities when making location decisions (Gottlieb, 1994; Florida, 2000). The impact of differences in preferences for particular amenities may be reinforced by fiscal sorting if the amenities are funded locally.

Casual observation, supported by careful statistical analysis, shows that ethnic clustering occurs in most cities. In a pair of influential papers, Cutler and Glaeser (1997) and Cutler, Glaeser and Vigdor (1999) analysed the causes and consequences of black segregation in U.S. cities in the twentieth century. They argued that there were three main possible explanations for the segregation that followed the mass movement of rural blacks to urban centres. First, it was possible that newly arriving blacks chose to live in established black neighbourhoods, for a mixture of cultural familiarity and security. If this is the case, one would expect migrants would be prepared to pay a premium to live in these areas compared with non-blacks or established blacks. Secondly, they argued that segregation could have been the result of legal or non-legal restrictive discrimination against blacks, preventing them from entering predominantly white neighbourhoods and thereby forcing them to live in black neighbourhoods. If this were the case, blacks would be likely to pay a premium for their housing, due to the limited choice. Thirdly, segregation could be caused by price sorting, with non-blacks paying a premium to move into neighbourhoods with few blacks. In this case, non-blacks would pay a premium for housing, while blacks might choose to live in relatively low cost black neighbourhoods. While they could not definitively distinguish these hypothesises, they argue that the first explanation was likely to be important before 1940, the second explanation up to 1970, and the third explanation in the post-1970 period as segregation became less intense. In particular, they note that while as late as 1970 some 56 percent of city neighbourhoods and 70 percent of suburban neighbourhoods in metropolitan areas had fewer than 1 percent black populations, in 1990 only 17 percent of central city and 40 percent of suburban neighbourhoods were so characterised.[4] Moreover,

[4] A neighbourhood was defined as a census tract, with approximately 4000 people.

property rents and prices in black neighbourhoods were lower in more segregated cities than less segregated cities in 1990, whereas they were higher in 1970.

Johnston et al. (2009) analysed neighbourhood clustering amongst Auckland's main ethnic groups between 1991 and 2006. They showed that there is considerable clustering for each of the four main ethnic groups, and that it increased significantly for Pacific Islanders and Asians over the period, a time of considerable inward migration. In 2006, for example, Pacific Islanders made up 17 percent of Auckland's population, but the average Pacific Islander lived in a neighbourhood that comprised 44 percent Pacific Islanders. Unlike black migrants to U.S. cities, however, who moved to the centre city, most Pacific Island migrants moved to South Auckland. We conduct a further analysis of clustering by different subgroups below.

The tendency of people to cluster complicates the analysis of residential location patterns, for several reasons. First, for a given set of people, transport costs, and amenities, location patterns are not unique. If high-income people like to cluster together, for instance, the location of the first few high-income people will form an "attractor" point that provides an incentive for subsequent high-income people to locate nearby, even if desirable amenities are located elsewhere. Such path dependency can mean that sometimes random initial conditions can determine subsequent settlement patterns; and that different patterns might have evolved if the initial conditions were different. The problem of non-uniqueness is most acute when neighbourhood effects are positive rather than negative: that is when people who have one particular characteristic are attracted to live near rather than far away from people with the same characteristic (Bayer and Timmins, 2005).

Secondly, path dependency means amenities that were important in one technological era can lead to the continued popularity or unpopularity of suburbs decades or centuries after the amenity became redundant (Arthur, 1989; Krugman, 1991). A neighbourhood conveniently located to a rail station may continue to be attractive even if the trains no longer run, simply because it was once desirable and built up a reputation as a nice place to live. Alternatively, a neighbourhood that was filled with low quality housing because of a disamenity such as a polluting industrial plant may be unable to attract higher income people when the plant is closed, because of a history of poorer quality schools.

Thirdly, it can become very difficult to untangle the extent to which a neighbourhood's popularity is due to its convenient access to amenities or due to the people

living in the neighbourhood. Even if the cost of travelling to different amenities can be accurately identified, if there is a tendency of neighbourhoods with more convenient access to attract people of a particular characteristic, it may be impossible to rigorously establish that a neighbourhood's popularity is due to its location rather than the people living in that location.

2.5 Aggregate demand

The interplay of income, transport costs, location convenience and neighbourhood clustering influences where individual households choose to live. In aggregate, however, people choose to live where houses are built. Consequently, a different approach to this question is to ask what determines where houses are built. Clearly this question is not independent of the question "Where do people choose to live?", because houses are built in the expectation that they can be sold at prices that cover land and construction costs. Nonetheless, an examination of aggregate housing patterns can be revealing about the overall preferences of the community.

The number of dwellings can increase in a city for two reasons: either an increase in the city's population, or a decrease in average household size. In either case, there are three possibilities for the new dwellings; they can built on new land at the edge of a city (outspill); they can be built on unoccupied land within the city (infill); or they can be built on already developed land, as taller buildings. In recent years, most cities around the world have expanded primarily through outspill, with the combination of infill and taller buildings accounting for approximately 20 percent of new dwellings (Sheppard, 2009). This clearly need not be the case, but appears to reflect three factors: a desire by many people to live in lower density neighbourhoods than those provided by a central city; the lower cost of building suburban low-rise dwellings rather than central high-rise dwellings, reducing the cost of suburban living; and sufficiently low transport costs that living in suburban areas is not too inconvenient or expensive. If people did not have these preferences, growing cities would be characterised by more infill and less outspill development.

The relative cost of infill and outspill housing reflects four major factors: the relative cost of building one- or two-storey buildings versus multiple-storey buildings, which depends on building technology and mandated building standards; the maximum legal height of multiple-storey buildings, which depends on zoning restrictions and natural geographic features; the availability of city-fringe land for residential purposes, which also depends on zoning restrictions; and the cost of city-fringe land, which depends on the value of rural land.

Given land and construction costs, builders will tend to supply the houses for which there is most demand relative to construction costs, and hence which are most profitable. Houses will be built in the suburbs rather than the centre only if, given construction costs, people prefer houses on large pieces of land in the suburbs to houses or apartments built on smaller pieces of land in the centre.

In their study of aggregate U.S. cities, Glaeser and Kohlhase (2004) argue that the preference for suburban living is sufficiently strong that high density housing and public transport are increasingly irrelevant to residential housing patterns. They note that single family housing is now the overwhelmingly dominant form of construction in the United States, whereas as recently as 1972 more apartments were built than houses. They further argue that the car and highway system has enabled this switch, by allowing most people to live within a 30 minute commuting trip to the city centre or to their workplace even as the cities expand geographically.

Auckland's expansion in the last thirty years is consistent with these overseas trends. Between 1976 and 2006, 45,000 new dwellings were built in central Auckland, an increase of 45 percent over the 1976 level. The number of dwellings in each of the northern, western and southern regions of Auckland doubled in the same period, accounting for 75 percent of the overall 175,000 increase. Consequently, it appears that Auckland residents have had a preference for suburban rather central living over this period. The extent to which this reflects the pattern of construction and transport costs rather than other factors such as building or zoning restrictions is unclear, however.

The aggregate residential construction patterns do not change the interpretation of individual location decisions, but they do suggest that at the margin Aucklanders have been more willing to pay for low-priced houses in the suburbs than higher priced houses in the centre. This suggests that empirical work should initially attempt to address two questions. First, are there distinctive demand patterns amongst different subgroups that, in combination with the growth in the size of each subgroup, can explain the overall pattern of new dwelling construction over time? Secondly, given the overall construction patterns, how much does neighbourhood clustering determine where different population groups choose to locate?

3 Empirical methods

The primary empirical focus of this paper is descriptive. We seek to establish the extent to which there are identifiable population subgroups that cluster together within the

Auckland Urban Area, and, further, to ascertain where these groups mainly live. As the literature has made clear, such clustering can occur for various reasons. We use techniques that show the extent to which income sorting occurs within Auckland, the extent to which people wish to locate near various types of amenities or commercial and social facilities, and the extent to which different population subgroups live in different parts of Auckland.

Consistent with the descriptive focus of this report, the presentation of the empirical patterns relies heavily on graphical presentation and mapping. In addition, we present a range of summary statistics to capture how patterns differ across different population groups. In this section, we introduce the three spatial statistics that we use to capture spatial patterns, and describe the method of spatially smoothing meshblock statistics.

3.1 Isolation index

We use an isolation index to capture the extent to which members of a population subgroup are disproportionately located in the same meshblocks as other members of their group. The formula comprises two parts. The first part is the isolation ratio, or the average fraction of members of the group who live in the same neighbourhood:

$$IR = Isolation\ ratio = \sum_j \frac{g_j}{G}\,\frac{g_j}{N_j}$$

where j refers to a meshblock, g_j/G is the fraction of the group living in meshblock j, and g_j/N_j is the fraction of the population in meshblock j that comprises the group. The second is the isolation ratio normalised by the group's share of the entire Auckland urban area population, as in Cutler et al. (1999):

$$Isolation\ index\ = \frac{IR - (G/N)}{1\ -\ (G/N)}$$

Both the isolation ratio and the isolation index measure the degree to which group members live in meshblocks in which their group is over-represented. The isolation ratio has a range of [G/N,1] while the isolation index takes on values from zero to one. If the isolation index equals 0, the group is distributed in proportion to the total population; if it has a value of 1, it means that all members of the group are in the same local area.

3.2 Moran's I

Moran's I statistic is used as a summary measure of neighbourhood clustering. It provides, for each group, a measure of whether meshblocks in which the group is over- or under-represented are located among other meshblocks with similar composition. It thus

conveys spatial information that complements the insights gained from the Isolation index, for which only within-meshblock composition is taken into account. We calculate Moran's Index of Global Spatial Association (Moran, 1950) using the following formula:

$$I = \frac{p'Wp}{p'p} \qquad (1)$$

where p is a vector of mean-centred population shares across meshblocks and W is a spatial weight matrix. The index provides a measure of how similar the population compositions of meshblocks are to the composition of the meshblocks surrounding them. We use a row-standardised spatial weight matrix that gives zero weight to meshblocks with centroids further than 1 km from the meshblock centroid and that weights 'close' meshblocks in proportion to their populations. Using a population-weighted, row-standardised weight matrix, the I statistic can be calculated as the coefficient on meshblock share in a regression of a group's share of 'neighbourhood' population on the group's share of meshblock population. The calculation of standard errors is more complicated. We calculate two sets of standard errors under the assumptions of randomisation and normality (Cliff and Ord, 1981; Pisati, 2001). All of the reported Moran index values are statistically significant using either set of standard errors.[5]

The Moran index lies between zero and one, with a value of one indicating strong spatial correlation. Whereas the isolation index reveals whether a group is strongly clustered *within* individual meshblocks, the Moran index indicates whether meshblocks in which a group is over-represented or under-represented are close together.

3.3 Getis and Ord G*

The same degree of spatial autocorrelation can reflect a range of different spatial patterns. There may be one or several distinct areas of concentration, and the areas of concentration may be at various locations. To investigate spatial patterns of concentration, we calculate, for each area, Getis and Ord's (1992) index of concentration (commonly referred to as G*), and display it on a map. The index measures a group's share of the population within a certain distance from each meshblock centroid and expresses it as a normally distributed test score. A high value of the test score indicates that the subgroup accounts for a larger

[5] In a companion paper, Pinkerton (2010) investigates a broader range of estimates of the Moran I statistic, varying the radius over which meshblocks are given positive weight. Values of the Moran's I for radii of more than 1 km are lower than those for 1 km, reflecting spatial decay. 290 meshblocks need to be dropped when calculating the 1 km Moran index, since they have no neighbours within 1 km. When using larger radii, these no longer need to be dropped and we are able to confirm that index values are very similar whether these omitted meshblocks are included or not. Pinkerton (2010) also provides a broader range of indicators of neighbourhood clustering, with discussion and analysis of the different insights that they provide.

share of the population in and around a meshblock than would be expected if they were randomly distributed. Using a row-standardised weight matrix (W), the formula for G^* at the j^{th} meshblock is:

$$G_j^* = \frac{\left(Wp_j - \bar{p}_\iota\right)}{S\sqrt{\frac{\left(N\sum_k w_{jk}^2 - 1\right)}{(N-1)}}}$$

where $S = \sqrt{\left(\sum_k \frac{p_j^2}{N}\right) - \bar{p}_J{}^2}$. We use a row-standardised weight matrix that gives zero weight to meshblocks more than 1 km from the centroid, with non-zero weights proportional to meshblock population. In contrast to the weight matrix for the Moran's I index, the weight matrix here includes the meshblock itself. This provides a test statistic that is normally distributed under the null hypothesis of no spatial association. A value of G^* for a meshblock that is greater than 1.96 indicates that there is less than a 2.5 percent chance that the high degree of concentration that is observed around the meshblock would be observed if location decisions were random. Similarly, a value of less than -1.96 indicates a significantly low degree of concentration.

4 Data

Our empirical analysis of residential location patterns focuses on the Auckland Urban Area. We require spatially linked information on the location of households and individuals, on the location of locational amenities, and on the relative costs of locating in different areas, as captured by land prices. Individual and household information needs to include demographic measures that reflect membership of different social groups and networks. All of this information needs to be in a form that can be spatially referenced, to support the measurement of the distance or travel time from each location to amenities, and to support the measurement of neighbourhood characteristics for areas around each household location.

The analysis presented in the paper combines data from three main sources. First, population information is drawn from the New Zealand Census of Population and Dwellings. Second, land price information is obtained from valuation summaries provided by Quotable Value New Zealand. Third, information on the location of amenities is assembled from Geographic Information System (GIS) files obtained from a variety of sources.

4.1 Population location – Census of Population and Dwellings

The New Zealand Census of Population and Dwellings is conducted every five years and collects a range of socio-demographic information on each member of the New Zealand population. In the current study, we restrict our attention to people aged 18 years of age and over, living in the Auckland Urban Area. Our focus on residential location requires information at a fine spatial scale. The finest geographic breakdown available for Census data is at the meshblock level. A meshblock is a relatively small geographic area. In urban areas, it is roughly equivalent to a city block. Within the Auckland Urban Area, there are 8,837 meshblocks, with a median usually resident total population in 2006 of 129 people. In order to access detailed geographic identifiers, we needed to access the Census data within Statistics New Zealand's secure data laboratory and under conditions designed to give effect to the security and confidentiality provisions of the Statistics Act 1975.[6] From this, we obtain counts of the usually resident population aged 18 and over for each meshblock – separately for individuals with particular characteristics, such as sex, age, ethnicity, and income band.[7]

We use 2006 Census data. Self-reported ethnic identification is collected in the census, with each person able to select multiple responses. We report ethnicity on a 'total response' basis, which is the approach recommended by Statistics New Zealand (2005). Individuals giving multiple responses are included in more than one ethnicity group. Total personal income is reported in 14 categorical bands, which we summarise at a higher level of aggregation. Where people do not provide a usable response to the census questions that we use, they are not included in subgroup counts.

Household income is estimated by aggregating incomes within a dwelling and adjusting for the number of people. Household income is equivalised by dividing total household income by the square root of the number of individuals, as in Atkinson et al. (1995). Where income is missing for some individuals within the dwelling, either because an individual was absent on census night or because a valid response was not recorded, the individual is assigned the mean income of other residents at the dwelling.

[6] See Statistics New Zealand (2007a) for more details on classifications and confidentiality protections.

[7] Statistics New Zealand provides access to a meshblock database that can be used outside the data laboratory. The meshblock database contains meshblock-level tabulations for the entire population rather than the population aged 18 and over, which is our focus. It also does not support the separate analysis of all the subgroups considered in this paper.

4.2 QVNZ land values

The land value measures used in this paper are based on valuation data obtained from Quotable Value New Zealand (QVNZ), which is New Zealand's largest valuation and property information company. QVNZ currently conducts legally required property valuations for rating (tax) purposes for over 80 percent of New Zealand local government areas (councils) – in earlier years QVNZ conducted valuations for all councils. The remaining councils use competing valuation companies to conduct their property valuations, but these data are purchased by QVNZ to create a complete database of all New Zealand properties. This database was matched by QVNZ to census meshblocks and made available to us in an aggregate form at the meshblock level on an annual basis. For each year, QVNZ assigns the most recent valuation to a property, and then aggregates all the properties at the meshblock level. Valuations are available using Statistics New Zealand's 2001 meshblock boundaries. These have been mapped to 2006 meshblock boundaries. Land value is measured as the total land value of all assessments divided by the total land area for all assessments. We restrict our attention to valuations for the Auckland Urban Area.

Observations are for a category of land use for a meshblock in a valuation year. Valuations are carried out on a three-yearly cycle, which varies across Territorial Authorities. Data are available from 1990 for Papakura and Franklin, from 1991 for North Shore, Auckland, and Manukau, and from 1992 for Rodney and North Shore. Observations are dropped where the recorded land area is zero or if the number of assessments is less than three (a combined loss of six percent of assessments, ten percent of land value). Some observations appear to be outliers in terms of changes in land value per hectare or land area per assessment. Outliers are identified by regressing each of these variables on a set of year and indicator variables for each combination of meshblock and category, and selecting observations with large regression residuals in *both* regressions. Affected observations account for around 0.1 percent of assessments and 0.3 percent of aggregate land value. For these observations, land area per assessment is replaced with the mean value for the meshblock-category combination and land price per hectare is replaced with the ratio of total land value to the imputed mean multiplied by the number of assessments. To reduce remaining volatility, land price per hectare was smoothed using a three-period moving average across valuation years.

To create an annual land price series from the three-yearly valuation data, we use annual data on property sales by area unit. (There are approximately 25 meshblocks in each

area unit.) For each valuation year, we calculate the ratio of land price per hectare to median sales price, and linearly interpolate (and extrapolate for initial and final years, where necessary) this ratio. Multiplying the observed annual median sales price by this ratio generates an annual series for land price per hectare. To reduce remaining volatility, land price per hectare was smoothed using a three-year moving average. Land price per hectare for each Area Unit was calculated by aggregating land value and land area to AU level and then calculating a ratio.

4.3 Amenity data

The proximity of a meshblock to an amenity is measured as the straight-line distance from the meshblock centroid (geographic centre) to the nearest amenity.

We consider two measures of retail accessibility – the distance to the nearest supermarket and the distance to the nearest bank. Even though access to bank branches *per se* may not be a significant amenity for many people, banks are generally located in retail areas and it is for this reason that we include distance to banks. We also include the distance from the Central Business District (CBD) to capture access to central city amenities.[8] Locations and contact details of bank branches around New Zealand were obtained from www.zenbu.co.nz, using information collected before 20 May 2008. Information on the location of supermarkets was also obtained from Zenbu, using data that were imported in 2008. The supermarket data were filtered to identify only major supermarkets, defined as those that belonged to the four major supermarket chains (New World, Foodtown, Pak'nSave, and Woolworths).[9]

As an indicator of access to community facilities, we include a measure of proximity to schools. For each meshblock, we calculate the distance to the nearest school, using school data obtained from Zenbu using data from June 2008. We also include a measure of the distance from the centroid of each meshblock to the nearest coast, to capture the amenity value of coastal access.[10]

Transport accessibility is captured by measures of distance to three major transport facilities – the nearest railway station, the nearest motorway ramp, and Auckland

[8] The reference point for the CBD was the geographic centroid of the three area units contained in the CBD (au06 values 514101-514103).
[9] The processing of the data was done by Andrew Rae and Mairéad deRoiste of Victoria University.
[10] The GIS data on the coast exist as a line file. This is converted to a point file with points every 50 metres. The "distance to coast" variable is the straight-line distance from each meshblock centroid to the nearest point on the coast.

International Airport. The railway station data are from a 2005 version of the LINZ Topographic Database.

We include a measure of population density as a potential amenity. The measure is the average number of people aged 18 years and over per square km. For a given meshblock, the average is calculated over all meshblocks whose centroids lie within 2 km (straight-line distance) of the given meshblock's centroid.

A measure of proximity to employment is derived from Statistics New Zealand's prototype Longitudinal Business Database (LBD). See the disclaimer at the front of this paper for the conditions of access. Employment Accessibility is measured as the ratio of employment within two km of a meshblock to resident population aged 18 and over. As for population density, this is calculated over all meshblocks within a 2 km distance. Employment in each firm is measured as the annual average number of employees in each firm at the fifteenth of each month. The meshblock measure of employment is the sum of employment in plants within the meshblock.

5 Population location patterns in Auckland

This section documents patterns of residential location within the Auckland Urban Area, and the relationship between land prices and proximity to selected locational amenities. The summaries provide guidance on the net impact of interactions between various determinants of residential location but, as discussed in section 3 above, are consistent with more than one explanation. A fuller understanding of the relative strength of particular determinants requires more formal multivariate modelling. This is undertaken in a companion paper (Maré and Coleman, 2011).

Four sets of findings are presented. First, we document the degree of clustering that occurs for a range of population subgroups. The strength of association varies across groups. This may reflect that members of some groups prefer to locate near to fellow group members (or away from other groups), or that groups have different preferences or income levels and are choosing locations that balance the perceived attractiveness of areas with their willingness to pay for land price costs associated with the areas.

Second, we examine whether there are systematic differences in how close different groups locate to selected amenities. Again, differences may arise for a number of reasons. Groups may differ in the strength of their preference for being near particular amenities. Alternatively, even if all groups have the same preferences for amenities, the

bidding up of land prices close to amenities may lead to residential sorting on the basis of income.

To gauge the potential role of land price variation in shaping residential locate choices, the third and fourth sets of results show the land price gradient associated with proximity to amenities, and differences in rent distributions for different groups.

5.1 The overall picture: basic location patterns around Auckland.

Until 2010, when the Auckland Council was established, Auckland comprised four main political divisions, corresponding approximately to the four main geographic and statistical regions: North Shore City, the area north of Waitemata Harbour; Waitakere City, encompassing western Auckland; Auckland City, encompassing central Auckland and the inner-city and eastern suburbs; and Manukau City, to the south. In 2006, 33 percent of the 1,208,000 residents of the Auckland Urban Area lived in the Central Auckland zone, while 31 percent lived in the Southern, 20 percent lived in the Northern, and 16 percent lived in the Western urban zones. Employment was more centrally concentrated, but not overwhelmingly so: 55 percent of employment was in the Central Auckland zone, 19 percent in the Southern, 17 percent in the Northern, and 9 percent in the Western urban zones. While 80 percent of the employed Central Auckland residents worked in the Central Auckland urban zone, only 30 percent of Northern, 43 percent of Western, and 36 percent of Southern zone residents in employment worked in central Auckland. Most of the remaining workers were employed in the regions in which they lived, suggesting that most people avoid cross-suburb commutes. This pattern is consistent with international evidence that while suburban subcentres provide much employment, they do not replace the central area.

Auckland expanded geographically as its population increased. In 1956, Auckland had 399,000 residents, of whom 36 percent lived outside the Central Auckland urban zone. In 1976, the population had increased to 743,000, of whom 61 percent lived outside central Auckland, while by 2006, 67 percent of Auckland residents lived outside central Auckland.

A different perspective can be obtained by examining the number of dwellings in Auckland. In 1976 there were 225,000 dwellings in the Auckland urban area, of which 43 percent or 97,000 were in the Central Auckland urban zone. In 2006, the number of dwellings had increased to 400,000. Of the 175,000 new dwellings, 30 percent were located in the Southern Auckland zone, 25 percent each in the Northern and Central Auckland zones, and 20 percent in the Western Auckland urban zone; consequently, Central Auckland's share fell

to 35 percent of the total. Since 75 percent of new dwellings have been built outside Central Auckland since 1976, it is hardly surprising that 77 percent of Auckland's population growth took place outside the central city.

Auckland's development was not uniform over this period (see Figure 4). Between 1976 and 1986, the number of dwellings in Central Auckland increased by only 4,200, or by 10 percent of the city wide increase of 43,000. This was a period where, given preferences, property prices, and transport costs, people voted to move from central Auckland and developers built very few dwellings there. In contrast, between 1996 and 2006, 30 percent of new dwellings were built in central Auckland, and the population increased by 27 percent of the total increase in Auckland's population. During this decade, developers clearly thought it worthwhile to expand central Auckland's housing stock in response to the increased demand to live there.

Figure 5 shows how land prices and population density vary across Auckland. The figures show that land prices are most expensive in central Auckland and along the North Shore, are moderate in the northern, eastern and western suburbs, and are lower in the south of the city. Population density is also high in most of the central city, but there are pockets of high and moderate density in all regions.

Figure 6 and Figure 7 show scatterplots of the same data. Each "point" represents a single meshblock. Figure 6 shows the relationship between population density and the distance from Auckland's Central Business District (CBD), and the relationship between land price and the distance to the CBD. Figure 7 shows a scatter plot of density against land price.

The graphs confirm that on average land prices decline with distance to the central city, as is the case in most other cities in the world. The data suggest considerable heterogeneity in land prices, however, conditional on the distance from the centre: at any distance from the centre, land can be found at a large range of prices. Population density shows similar heterogeneity, with some low- and some high-density meshblocks found at all distances from the downtown area. As distance increases, the density of the most dense regions decreases, however, leading to a gradual decrease in average density with distance.[11]

The relationship between prices and density is upward sloping. All the most densely populated regions have high prices. Nonetheless, a key aspect of the relationship

[11] Previous studies of Auckland have also shown a higher density of population and employment closer to the centre of Auckland. (Maré, 2008; Williamson et al, 2008)

between density and price is again its heterogeneity. Figure 7 indicates that a large range of population densities exist at all prices. In line with traditional theoretical perspectives, some high-priced areas are relatively crowded, and some low-priced areas are sparsely populated; but there are also many high-priced areas with moderate densities (for example Mission Bay) and low-priced areas with high densities (for example Manurewa). Similarly, for any population density land can be found at a wide range of price levels.

5.2 Patterns of neighbourhood clustering – who lives near whom?

We use two main indicators to analyse clustering patterns across a range of socio-demographic dimensions The first is the isolation index. If members of a population subgroup were randomly located within Auckland, they would, on average, live in a meshblock where they accounted for the same proportion of the meshblock population as their group does of the Auckland population. If there is any spatial clustering, they will be observed in meshblocks in which their group has a higher than average population share. For instance, people of Pacific ethnicity in Auckland account for 11.1 percent of the population aged 18 and over (2006 data). However, the average Pacific person lives in a meshblock where over 35 percent of the population is of Pacific ethnicity. This gives an isolation index of ((0.356-0.111)/(1-0.111) =) 0.28. Similarly, people with a university degree account for 19.4 percent of the population aged 18 and over, yet on average live in a meshblock where 26.6 percent of the population has a university degree, giving an isolation index of 0.09. The second measure is the Moran I statistic, which indicates the extent to which meshblocks that have relatively high or relatively low concentrations of the subgroup are in contiguous areas.

It is tempting to interpret such observed patterns as evidence that group members prefer to locate together or suffer discrimination that forces them to locate together. While this remains a potential explanation, co-location may also arise as a result of shared preferences for locational amenities or due to similarity in income levels within groups.

Recent studies of residential segregation in Auckland focus on ethnic segregation (Ho and Bedford, 2006; Johnston et al. (2003, 2007, 2008, 2009); Grbic et al., 2010). Collectively, these studies present a wide range of summary measures that capture different aspects of residential segregation, including indices of segregation, concentration, isolation, and exposure. They have also highlighted the insights to be gained by looking at local indicators of spatial association to reveal the spatial patterns behind the global summary measures. The studies generally find that Pacific peoples have the most atypical residential

location pattern. They are relatively highly concentrated as a group, with relatively high exposure to Maori but not to other ethnic groups. The majority New Zealand European group has relatively low exposure to other ethnic groups.

Table 1 summarises the strength of neighbourhood clustering for a selection of population subgroups. The first three columns provide the relevant measures for the "isolation index" described above – each group's share of the Auckland urban area population, the isolation ratio, and the isolation index itself. The Moran index is included in the fourth column. The final two columns contain information on differences in the median land prices faced by different groups and in personal incomes, which are discussed in section 5.3 below.

As expected, there is almost no geographic clustering by gender. The isolation index is close to zero, implying that each group is geographically distributed roughly in proportion to population, and the Moran's *I* index is small (0.07), implying that there is only a weak relationship between the gender composition of a meshblock and that of nearby meshblocks. There is somewhat more concentration by age, with younger adults (18-29 years old) and older people (aged over 65) disproportionately living in meshblocks with others in their own age group. The isolation index values are 0.07 for young adults and 0.11 for older people. The Moran's *I* statistics, however, show different spatial patterns for these two groups. For older people, there is relatively weak spatial autocorrelation ($I = 0.20$) whereas for younger people, the correlation is higher ($I = 0.49$). Meshblocks with a high proportion of young adults are likely to have other young-adult meshblocks nearby. Meshblocks with a high proportion of older people are less likely to appear close to each other. This may reflect the presence of aged care or retirement centres that raise the proportion of older people in particular meshblocks, but which are not necessarily located very near other such centres.

Consistent with previous studies of residential segregation in Auckland, there is evidence of strong neighbourhood clustering by ethnicity. Residents identifying their ethnicity as Pacific are highly clustered, with an isolation index of 0.28 and a high Moran index of 0.74. The Moran index reflects two different aspects of clustering: first, that Pacific peoples are clustered together in contiguous meshblocks in certain parts of Auckland; and secondly, that Pacific peoples are absent from many contiguous areas of Auckland. The first panel of Figure 8 provides a map of Auckland urban area, with the darkest areas showing where the Pacific ethnic group is most strongly clustered. The strongest concentrations are in Manukau City in the south and, to a lesser extent, in a few pockets of Waitakere City in the

west. Conversely, Pacific peoples are under-represented in northern and central Auckland, eastern suburbs such as Howick, and isolated other areas such as Titirangi.

The spatial distribution of Maori is similar to that of Pacific peoples, with areas of concentration in Manukau, extending to Papakura in the south, and also in Waitakere. The strength of clustering is not, however, as strong. The isolation index is only 0.09 and the Moran Index of 0.58, while still high, is lower than that for Pacific people.[12]

Residents claiming Asian ethnicity are also highly clustered, although less so than Pacific people. The average person identifying as Asian lives in a meshblock that is 32 percent Asian. The areas with relatively few Asian people are diverse, including areas such as Devonport and Titirangi that are largely European, and areas such as Manakau that are largely Pacific Island and Maori. A map showing the spatial concentrations of the Asian ethnic group is shown as the third panel of Figure 8.

Clearly, ethnicity categories are very broad. The next set of summary statistics in Table 1 provides comparable measures for groups defined by country of birth. Statistics are provided for the ten largest (by population) country-of-birth groups. Concentration measures are generally smaller for country-of-birth groups than for the broader ethnicity groups. For instance, the values for the isolation index and Moran's *I* for Samoan-born (0.13 and 0.64) and Tongan-born (0.09 and 0.50) are lower than for the Pacific ethnic group (0.28 and 0.74). This suggests that concentrations of Samoans, Tongans, and other Pacific groups occur in close proximity to each other. Similarly, index values for residents born in the People's Republic of China (0.11 and 0.44), the Republic of Korea (0.07 and 0.39) and India (0.07 and 0.38) are all below the corresponding figures for the Asian ethnic group (0.16 and 0.54), suggesting some co-location of Asians from different countries of birth. For the foreign-born, concentration is slightly higher for recent migrants, who have arrived in the previous five years, than for longer-settled migrants. However, migrants who have been in New Zealand for more than 15 years are more concentrated than those who have been in the country between 6 and 15 years.

[12] The values of the Moran index presented here are considerably higher than those presented by Johnston et al. (2009), whose study also uses 2006 Census data for the Auckland Urban Area. Our study measures spatial association at a smaller spatial scale of 1 km, whereas they use a scale of around 4 km to ensure that all meshblocks have at least one neighbour. We are grateful to Mike Poulsen and Ron Johnston for their generous assistance in identifying the reasons for the differences.

Among people who have moved into Auckland within the previous 5 years, recent migrants[13] are the most geographically concentrated group, with an isolation index of 0.08 and Moran's *I* of 0.40. This is moderately high, but not greatly different from the patterns for returning New Zealanders, earlier migrants, or even New Zealand-born residents who have not moved. Despite this similarity in the *degree* of geographic clustering, the groups are clustered in somewhat different areas, as shown in the maps in Figure 10. Figure 10 maps the location of returning New Zealanders and foreign-born recent migrants (those who were living out of New Zealand five years earlier). The spatial pattern of returning New Zealanders is similar to that of the highly qualified population, though less widespread in the Auckland city and North Shore areas. In contrast, the spatial pattern of foreign-born recent migrants is similar to that of people stating Asian ethnicity. This is perhaps not surprising given that over half of the people entering Auckland from being overseas five years earlier were of Asian ethnicity (calculations from tables in Statistics New Zealand, 2008).

Relatively strong spatial concentration is also evident on the basis of qualifications. People reporting no qualifications are concentrated, as are those with high (university level) qualifications. For these two groups, the isolation index is 0.07 and 0.09 respectively, and the Moran index values are 0.65 and 0.71. As emphasised by Johnston et al. (2009), these global summary measures do not reveal whether the neighbourhood clustering is in one or in many different areas of Auckland, nor whether the two concentrated qualification groups are concentrated in the same or in different areas. These patterns can, however, be seen in the maps that are included as

Figure 11. The "no qualifications" and "high qualifications" groups are concentrated in very different areas of Auckland. The highly qualified group is most concentrated in and around the high land-price areas of central Auckland and on the East Coast and the south part of the North Shore. In contrast, people reporting no qualifications are concentrated in the low to medium rent areas of Manukau in the South and Waitakere to the West.

Table 1 summarises concentration measures on the basis of personal income, and also on the basis of household income. The patterns are similar, though we will focus on household income as a more appropriate indicator for understanding household location decisions. The strongest geographic concentration is for the high household income group, with an isolation index of 0.13 and a Moran's *I* of 0.53. The maps in Figure 13 show the concentration of residents with high household income – around the inner-city suburbs and along the East Coast both north and south of the Waitemata harbour. There are also many

[13] "Recent migrants" are defined as people who are foreign-born and were living out of New Zealand five years earlier.

contiguous areas where there are relatively few high household income residents. In contrast, the spatial patterns for low and middle income groups are less distinct, and overlap in many areas.

There is also evidence of clustering on the basis of labour force status. The isolation index indicates that this clustering is most pronounced for full-time employed residents (0.05) and those who are not in the labour force (0.06). The unemployed group, however, has the highest value of Moran's *I* index (0.27), indicating that meshblocks with high unemployment rates tend to be located near each other, even though there is a mix of labour force statuses in any given meshblock. This interpretation is confirmed by the maps in Figure 12, which show less dispersion of high-unemployment areas than is the case for other labour force status groups. The observed patterns are consistent with a range of different characterisations of labour market functioning, but do point to the importance of understanding spatial aspects of labour markets, as noted in Martin and Morrison (2003).

The final breakdown in Table 1 is for groups defined by housing tenure. Both renters and owners show moderately high isolation and spatial autocorrelation (isolation index of 0.14 and 0.17 respectively, and Moran's *I* index values of 0.38 and 0.47). The maps in Figure 14 show that there is a concentration of renters in the high-land price central city and inner suburbs, and also in lower priced areas in the South. Residents living in owner-occupied dwellings have concentrations in a range of areas, especially in coastal locations.

5.3 Who pays higher land prices?

The final four columns of Table 1 show, for each social grouping, what the median land price is in the meshblocks where they live, the median personal and household income for each group, and relative population density. Each of these measures is expressed as a percentage of the overall population median, as shown in the top row of the table.

There is a generally positive relationship between the median land price paid by a group and the group's median household income. Figure 15 illustrates this relationship for selected subgroups.[14] Groups with higher median incomes pay higher land prices, reflecting their ability to secure property in more desirable locations. There is, however, also evidence that residents are making tradeoffs between the price that they pay for land and the amount of land that they use. The points on the figure are delineated according to whether the land

[14] The selected groups are those that have incomes or land prices that differ most from the population medians. This has the effect of removing a large cluster of points from the centre of the graph.

density for the group is high (more than 3 percent above median), medium, or low (more than 3 percent below median). Groups paying high land prices are also using less land, as captured by the fact that they also live in areas with higher population density.

There are, of course, exceptions to this general pattern. Residents born in Korea have relatively low incomes and live in areas with relatively high land prices, so we would expect them to economise on land use by selecting areas with high population density. The median density of the areas where they reside is actually slightly below the population median (97%). Similarly, groups defined by current household income or current labour force status live in areas with close to median density, despite income-land price combinations that suggest otherwise. Those with high household income or in full time employment appear to be paying lower than median land prices, given their income level, yet their use of land is not lower than the overall median. Their population densities are 103 percent and 100 percent of the overall median respectively. Those with low household income and those who are unemployed appear to be paying high land prices given their income level, yet their land use is not lowered. They have population densities of 100 percent and 101 percent of the overall median respectively. A likely explanation of these exceptions is that residential location choices are based on longer-run expected incomes. Defining groups based on current income or labour force status as measured on census night will overstate the difference of these groups' long run incomes from the median. For the Korean-born group, it may be that their current household income is a relatively poor proxy for their longer term income or wealth.

The patterns in Figure 15 shed some light on the distinctive patterns of geographic concentration identified by the isolation and Moran's indices. The concentration of Pacific groups, defined by ethnicity or by country of birth, reflects low incomes, and occurs in areas with low land prices and low population density. Other groups are concentrated in relatively high-priced areas, though the concentrations are not solely a result of high-income groups bidding up prices for access to desirable locations. Groups concentrated in high-priced areas include relatively low-income groups such as those born in PRC, as well as relatively high-income groups such as the degree-qualified and returning New Zealanders. It may be that the different groups have common location preferences and are making different trade-offs to secure access to desirable, and therefore high-priced, locations. Alternatively, different groups may be paying similarly high prices to locate in quite different areas, reflecting differences in what the groups find attractive.

Before examining, in the next section, whether groups end up locating near different sorts of amenities, we first examine whether the distribution of land prices paid by different groups provides any indication of distinct location patterns. Although it is a useful summary measure, the median land price does not capture possible differences in the distribution of land prices paid by different groups. Conversely, differences in median land prices may arise even when there is considerable overlap in land price distributions.

To provide a fuller picture of variation in the land prices paid by different groups, Figure 16 shows, for selected groups, the full distribution of land prices. By contrasting the distribution for a particular group with the distribution of land prices for the whole of Auckland, the graphs highlight the groups that have atypical land price distributions.[15] The figures show that there are only small differences in the land price distributions of people classified by age, income, housing tenure, family type (except for solo-parent families) or labour force status. However, they also confirm that many more Pacific peoples, Maori, and people with low qualifications lived in low priced areas than average, and far fewer lived in high priced areas. Conversely, far fewer returning New Zealanders and high qualified people lived in low priced areas, and far more lived in high priced areas than average. Ethnic Asians were only slightly less likely to live in most low land price areas, but there is a noticeable peak in areas with slightly above average prices. Differences for country-of-birth groups highlight the highly peaked distributions for two Pacific countries (Samoa and Tonga), concentrated in low-priced areas, and for other countries of birth (South Africa, PRC, India and Korea) with peaks at higher prices. The distribution of land prices for residents born in Fiji is bimodal, perhaps reflecting the mix of Fijian and Indian ethnic groups born in Fiji. Overall, however, differences in median land prices provide a reasonable summary measure for differences in the full distributions of land prices.

5.4 Patterns of proximity – who lives near what?

As noted in section 2.3, areas of high population density and high rent may occur at many different locations if there are amenities in more than one location. For New Zealand as a whole, Pearce et al. (2006) demonstrate substantial variation across space in accessibility to community resources. There is also a well established New Zealand literature, reviewed by Stevenson et al. (2009), that investigates the relationship between health outcomes and

[15] Wilcoxon-Mann-Whitney tests were used to test the hypothesis that a particular group's distribution was different to the whole of Auckland distribution. The groups highlighted in the next paragraphs had distributions that were statistically different. Results are available from the authors.

neighbourhood characteristics. Unequal access or exposure to locational amenities can result from variation in preferences for particular amenities, as a consequence of neighbourhood clustering, or because income differences enable higher income people to bid their way into desirable neighbourhoods.

In Table 2, we summarise variation in different groups' proximity to selected locational amenities. The first row of the table shows the median value for each amenity measure – calculated as the distance experienced by the median resident. Half of all residents in the Auckland urban area live within 1.08 km of a supermarket, half live within 1.13 km of a bank branch, and half live within 0.48 km of a school. We also measure access to the CBD, for which the median distance is 11.37 km. Most locations in Auckland are close to the coastline, with a median distance of only 1.03 km.

Access to transport networks also varies across the Auckland urban area. Half of all residents are within 2.64 km of a motorway ramp. Half of all residents live within 3.68 km of a railway station. Half of Auckland urban area residents live within 16.01 km of Auckland's only major airport, the Auckland International Airport.

The two final locational factors that we examine are population density, and the average number of jobs per resident aged 18 and over as a broad measure of labour market accessibility. Both of these measures are calculated for a 2 km radius area around each meshblock. By this measure, median population density in Auckland is 1,834 per square km and half of Aucklanders live in meshblocks with more than 0.52 jobs per resident within 2 km.

The rows of Table 2 show which groups experience higher or lower levels of access to amenities, for the same set of population subgroups as included in Table 1. The median value for each group is expressed as a ratio to the overall population median in the first row. A value greater than one implies a higher median value for the group.

Consistent with the summary measures of concentration presented in the previous section, distinctive patterns of proximity to amenities are observed for groups defined in terms of ethnicity, qualifications, mobility, and country of birth. However, the patterns in the table are perhaps best understood in terms of variation in population density. Groups that have a higher-than-average median population density include the highly qualified (relative density = 1.08); returning New Zealanders and recent migrants (1.05); and the Asian ethnic group (1.06). By country of birth, particularly high density is observed for residents born in PRC (1.10) and India (1.09). Associated with these dense areas are shorter than average distances to supermarkets and banks (0.79 to 0.97), relatively high employment to population ratios (1.06 to 1.12), and relative closeness to the CBD

(0.71 to 0.91). Proximity to the CBD is particularly high for the highly qualified and for return New Zealanders, as was evident in Figure 10 and

Figure 11.

Recent migrants and Asian groups are atypically close to both the CBD and to the Airport, reflecting population concentrations not only close to the city and the North Shore but also in the southeast areas from Howick to Botany Downs, which are closer to the airport.

The fact that distance to supermarkets and banks is shorter in densely populated areas is perhaps not surprising given that such services tend to locate close to their customer base. The distribution of schools differs in that the distance to school is also relatively short for Maori, Pacific, and no-qualifications groups (relative distance of 0.85 to 0.96), which have among the lowest median population densities (relative density of 0.92 to 0.95). Among the groups in dense areas, the most highly qualified, and returning New Zealanders, live slightly further away from schools than average (relative distance of 1.01).

5.5 Location costs – which locations are costly?

Land prices play a central role in shaping residential location patterns. Land prices in desirable locations are bid up until the location's relative attractiveness is offset by its relative expense. The people who locate in the most desirable locations are those who have the strongest preferences for the benefits it offers, those with the highest incomes, who will be willing to spend greater amounts to secure the location, or those with the weakest preference for high land use, who are not deterred by high population density.

We expect land price to be higher in locations closer to an amenity. The observed land price gradient reflects the strength and mix of preferences for the amenities that can be accessed from each location. In this section, we illustrate the existence of land price gradients around selected locational amenities. Figure 17 contains plots of land prices at varying distances from amenities, together with upper and lower quartile lines to indicate variation around the overall pattern.

For each amenity, the population is ranked according to the amenity measure and then divided into 20 equal groups. For each of these groups, we calculate the mean amenity value (distance, density, or employment-population ratio), and the log of the median land price. The results show a clear gradient for distance to supermarkets and banks. Land prices are higher for locations closer to these retail services.

Table 3 reports the regression estimates of the slope of the land price gradient for the selected amenities, corresponding to the graphs in Figure 17. The first graph in the first column of Figure 17 provides evidence that proximity to schools appears to attract a land price premium. In the first column of Table 3, the land price gradient for distance to the nearest school is shown as -0.303. This means that a location that is 10 percent closer to a school than another will have land prices that are 3.03 percent higher. However, most people live close to schools, so that systematic differences in land prices are evident only for areas more than about 1 km from school, where land prices are somewhat lower. Differences in school quality, and the influence of school zoning, may also serve to weaken the observed relationship between land prices and distance *per se*.[16]

As shown in the second column of Figure 17, there is a similarly-sized gradient for access to supermarkets and bank branches. Table 3 shows that the land price gradient for distance to the nearest supermarket is -0.470 and to the nearest bank is -0.604. There are also significant gradients for proximity to the CBD (slope of -0.920) and population density (slope of 0.768). Land prices are higher for areas close to the CBD and for areas with relatively high population density. Closeness to the railway station, the airport, the coast and motorway ramps do not appear to be strongly linked to land prices in Figure 17, yet are estimated to have a significant gradient in the regressions in Table 3. This in part reflects the influence of some high-land price areas that are outliers in the regressions. The low explanatory power of the regressions, as shown by the R-square measure in Table 3, also indicates considerable variation around the fitted relationship.

6 Discussion

6.1 Links between neighbourhood clustering, proximity to amenities, and location costs

This paper addresses the question "What determined where Aucklanders lived in 2006?" by asking the separate questions "Where did different groups of Aucklanders live?" and "What did they value there?" As studies of most other modern, decentralised and sprawling cities have found, the answers are complex.

A somewhat trite answer to the question "Where did Aucklanders live?" is "Where the houses were built." In 2006, only a third of the Auckland's dwellings were in central Auckland urban zone; it follows that only approximately a third of Aucklanders lived there.

[16] See Gibson et al. (2005) and Rehm and Filippova (2008) for evidence on the land price effects of school zoning in New Zealand.

The more interesting question is “Why were houses built where they are located?” Since dwellings are built where, given demand patterns and construction costs, it is profitable to build them, it is possible to make some inferences about demand patterns by examining the location of dwellings. In Auckland, this approach is informative. Between 1976 and 1986, for instance, less than 10 percent of Auckland’s new dwellings were constructed in the Central Auckland urban zone, revealing a marked preference, at then-prevailing construction prices, for suburban living. In the decade to 2006, 30 percent of new dwellings were constructed in Central Auckland, suggesting an increasing demand for more central living. Nonetheless, since 70 percent of new dwellings were in suburban areas, particularly in the Southern Auckland urban zone, it is clear that at the margin there was greater demand for the big houses constructed in lower density suburban areas than for houses and apartments in Central Auckland.

The changes in aggregate building patterns reflect not just the different cost of constructing dwellings in more densely populated Central Auckland urban zone than the less densely populated suburbs, but also changes in demand patterns. Many of these patterns can be attributed to changes in the composition of the population and the different demand patterns of different subgroups. The data clearly show a tendency of different ethnic groups to cluster in different places – Pacific peoples and Maori in south and west Auckland, Asian peoples in the North Shore, and eastern suburbs – but also a tendency of returning New Zealanders and people with degree qualifications to cluster together in central suburbs. The decade to 2006 was characterised by a large increase in the size of the Asian, Pacific, and degree-qualified population subgroups – up by 140,000, 62,000, and 103,000 respectively – and it is plausible that these aggregate population trends are behind the observed changes in residential location patterns during the decade.

The analysis of clustering by population subgroups has extended our knowledge of clustering in Auckland in several dimensions. The patterns of ethnic clustering noted by Johnston et al. (2009) are broadly confirmed, although we estimate that clustering is much stronger than they report by analysing clustering over a much smaller radius, namely 1 km. Both Maori and Pacific peoples are shown to be significantly over-represented and clustered in low priced and slightly low density areas of southern and western Auckland, and to be significantly under-represented in higher priced areas such as central Auckland and North Shore City. The average Pacific person lives in an area that is 36 percent Pacific Island, even though Pacific people are only 11 percent of the Auckland population. This paper confirms

that Pacific peoples have lower than average incomes and that these clusters are in areas where land prices are lower than average. There is a wide range of low priced areas, however, and further analysis is needed to establish whether, conditional on purchasing out of the subset of Auckland areas that have similar land prices, Pacific peoples are more clustered than could be expected given their income profile.

Asian people are also highly clustered, though in areas characterised by higher than average density and price. This clustering is notable not only because of the areas with very low Asian presence, which include both low and high income neighbourhoods, but because incomes of ethnic Asians are lower than average, yet the clustering takes place in places with higher than average land prices. Given than many Asian residents of Auckland are recent migrants, this may indicate a desire by new migrants to live in areas over-represented with other Asians, and a willingness to pay a premium to do so. Thus this clustering could be motivated by quite different reasons from those behind the clustering of Maori and Pacific peoples.

The paper also establishes the existence of clustering along dimensions other than ethnicity. Prominent among these is the analysis of clustering for groups defined by country of birth and by income, and the clustering of high and low qualified people.

Degree holders, residents with high household income, and returning New Zealanders have high incomes, live in areas with higher than average land prices and densities, live in meshblocks where their groups are over-represented, and have low representation in areas of Auckland with low land prices. They also tend to live in central Auckland, the North Shore, and selected other areas such as Titirangi. The association of high income, high density, and high land prices suggests that these areas are the most desirable in Auckland; but the statistical analysis cannot distinguish whether this is because these area have favourable natural amenities or because they have high concentrations of people considered desirable as neighbours. The proximity of these areas to the sea, nice beaches or other desirable natural phenomena suggests the former. The clustering of people with few qualifications, who typically have low incomes, in areas with low land prices is suggestive of income-based sorting.

While subgroup clustering by qualification and ethnicity suggests income-based sorting may have some importance in Auckland, it is notable that clustering by income alone is not particularly strong. In particular, the isolation indices for low- and middle-income

groups are 0.06 while that for high-income people is 0.13. The high-income group is the most clustered, with more missing among low- and middle-income groups. The Moran index value for high-income people is also reasonably high (0.59), indicating that there are sizeable contiguous areas with more than usual, or less than usual numbers of high income people, even though each area has a lot of people who don't have high incomes.

We demonstrated the interaction between land prices and population density. For a given income, high land prices are associated with higher population density, as residents respond to higher prices in part by using a smaller amount of land. Low income groups tend to be geographically concentrated in low land price, low density areas. Exceptions include people born in PRC and in Korea, who report low household incomes but who nevertheless pay relatively high land prices to locate in high-density areas. High-density areas not only command higher land prices, but also offer more convenient access to a range of locational amenities. Whether different groups that pay high land prices are attracted to the same local amenities or pay a premium for access to amenities that place a particularly high value on remains a challenge for subsequent multivariate analysis.

In addition to establishing the extent to which different groups cluster, the paper has also tried to ascertain the value generally placed on having a location convenient to different types of amenities and commercial facilities. Our theoretical perspective, which emphasises the growing importance of being located near to amenities and facilities that are consumed on site, is supported by New Zealand-wide survey data indicating that up to three quarters of all travel is undertaken for non-work purposes, particularly for the use of commercial and recreational facilities. Two aspects of the analysis suggest that short distances to commercial centres (supermarkets or banks) and community services (schools) are valuable. First, for each type of facility, a 10 percent increase in the distance from the facility is associated with a 4–5 percent decrease in land price. Secondly, the median distance to each facility is very low, approximately 1 km for banks and supermarkets, and 500 metres for schools, while three quarters of Aucklanders live within 2 km of a supermarket and 700 metres of a school. This suggests that not only are people prepared to pay a reasonable premium to avoid inconvenient locations, but that investors (and the Ministry of Education) provide these facilities so that their customers and clients are not inconvenienced. Consequently, such facilities are found in all regions, and commercial facilities probably play little role in determining location patterns. Anecdotal evidence suggests that school quality is

an important determinant of location decisions, but we have been unable to classify schools by quality in this analysis and cannot confirm this statistically.

The analysis also shows the size of the premium paid to be close to downtown Auckland: land prices decline by 9 percent for every 10 percent increase in the distance from the CBD. This premium is sizeable, and partially explains the high densities in areas close to downtown. In line with the results from the international literature, however, it has not been established the extent that this premium is because of the quality of the natural amenities in downtown Auckland, the quality of the commercial and social facilities, because of clustering effects, or because central Auckland is an unusually job-rich location. The simultaneous collocation of all of these facilities and effects means the spatial analysis conducted in this paper has been unable to answer this question, even though it has determined the magnitude of the overall premium.

6.2 Next steps

The current paper is extended in a subsequent paper (Maré and Coleman, 2011) that uses multivariate methods to tease out the contributions of different effects. In that paper, we focus on the location patterns of people who have moved into or within Auckland in the previous five years. By concentrating on people who have moved recently we reduce the potentially confounding effect of endogenous amenity location – people may be observed living near amenities not because the amenities influence their location choices but because amenities are located in the areas where people already live. However, as we illustrated in the current paper, the location patterns for recent migrants and New Zealanders returning from overseas are atypical. We will need to distinguish the location patterns of these groups from other groups of people who have changed location.

Our multivariate analysis of location choices provides a clearer indication of the relative strength of different determinants of residential location. It shows, for example, how strong the patterns of neighbourhood clustering are once we control residential sorting by income levels, with which they are related. Separate analyses are carried out for selected subgroups to identify whether there are distinct patterns of location behaviour across groups.

We are also undertaking related work on the determinants of business location patterns. The combined impact of our analyses of residential and business location will be to provide valuable guidance for evaluating the likely impacts of urban policy issues such as

land-use zoning, policies to encourage mixed-income neighbourhoods, the public provision of locational amenities, and the provision of transport infrastructure.

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Table 1: Residential segregation measures for Auckland Urban Area – by demographic group

	Percent of Population	*Isolation ratio*	*Isolation Index*	*Weighted Moran (1 km)*	*Relative Median Landprice*	*Median Income*	*Median Household Income*	*Population density*
2006 Usually Resident Population	100.0%	100.0%			14.99	$28,700	$43,000	1,834/ km^2
Male	47.7%	48.2%	0.01	0.07	100%	123%	103%	100%
Female	52.3%	52.8%	0.01	0.07	100%	79%	96%	100%
Age 18–29	24.5%	29.7%	0.07	0.49	102%	72%	101%	103%
Aged 30–49	42.1%	44.4%	0.04	0.20	98%	128%	103%	99%
Aged 50–65	21.1%	23.9%	0.04	0.29	100%	117%	110%	98%
Aged over 65	12.3%	22.3%	0.11	0.20	104%	55%	60%	100%
Maori Ethnicity	8.3%	16.5%	0.09	0.58	62%	94%	92%	92%
European Ethnicity	60.5%	70.5%	0.25	0.72	108%	120%	117%	99%
Pacific Ethnicity	11.1%	35.6%	0.28	0.74	52%	79%	80%	95%
Asian Ethnicity	19.1%	32.1%	0.16	0.54	109%	59%	72%	106%
Other Ethnicity	1.4%	5.1%	0.04	0.15	105%	67%	77%	104%
Overseas-Born	42.4%	47.4%	0.09	0.51	101%	80%	85%	102%
New Zealand Born	57.6%	61.3%	0.09	0.51	99%	115%	112%	99%
Born in UK	7.9%	12.4%	0.05	0.57	106%	120%	112%	97%
Born in PRC	5.5%	15.5%	0.11	0.44	119%	34%	50%	110%
Born in Korea	1.6%	8.5%	0.07	0.39	117%	36%	44%	97%
Born in India	2.8%	9.9%	0.07	0.38	106%	93%	86%	109%
Born in South Africa	2.0%	7.0%	0.05	0.49	106%	134%	127%	94%
Born in Australia	1.5%	3.8%	0.02	0.15	117%	118%	123%	103%
Born in Samoa	3.5%	15.8%	0.13	0.64	45%	74%	74%	95%
Born in Fiji	2.7%	10.4%	0.08	0.45	79%	88%	89%	97%
Born in Tonga	1.7%	10.9%	0.09	0.50	54%	65%	65%	96%

Table 1: (continued)

	Percent of Population	*Isolation ratio*	*Isolation Index*	*Weighted Moran (1 km)*	*Relative Median Landprice*	*Median Income*	*Median Household Income*	*Population density*
Returning New Zealander	2.1%	4.9%	0.03	0.32	139%	153%	145%	105%
Recent Migrant	14.5%	21.3%	0.08	0.40	108%	67%	77%	105%
NZ-born: Moved within NZ in last 5 years	24.1%	28.3%	0.06	0.38	100%	120%	116%	98%
Earlier Migrant	27.9%	31.5%	0.05	0.45	98%	86%	88%	100%
NZ-born: Did not move in last 5 years	31.4%	35.6%	0.06	0.33	96%	107%	107%	99%
0–5 Years in NZ	16.0%	22.9%	0.08	0.42	106%	66%	77%	105%
6–10 Years in NZ	7.4%	11.4%	0.04	0.35	103%	77%	82%	102%
11–15 Years in NZ	3.7%	6.8%	0.03	0.23	107%	80%	86%	101%
More than 15 Years in NZ	15.3%	18.2%	0.03	0.34	92%	94%	93%	98%
No Qualification	16.9%	22.9%	0.07	0.65	73%	67%	74%	94%
School Qualifications	23.0%	24.9%	0.02	0.27	104%	77%	93%	101%
Post-School Qualifications	30.0%	32.1%	0.03	0.44	97%	116%	106%	97%
High Qualification	19.4%	26.6%	0.09	0.71	137%	151%	134%	107%
Income below $20,001	33.7%	36.3%	0.04	0.30	97%	32%	54%	100%
Income $20,001 to $50,000	25.6%	27.4%	0.02	0.26	94%	106%	95%	98%
Income over $50,000	29.7%	35.8%	0.09	0.59	114%	211%	154%	102%
HH income below $20k	18.1%	23.4%	0.06	0.30	93%	35%	29%	100%
HH income $20k–$55k	42.0%	45.6%	0.06	0.32	91%	94%	86%	98%
HH income above $55k	33.3%	42.2%	0.13	0.53	120%	177%	177%	103%
Household Type: Couple with Dependents	28.5%	32.8%	0.06	0.36	94%	113%	96%	97%
Household Type: Single with Dependents	5.7%	9.5%	0.04	0.40	75%	80%	53%	95%
Household Type: Couple, no Dependents	33.7%	37.5%	0.06	0.32	104%	107%	122%	99%
Household Type: Single, no Dependents	32.1%	38.3%	0.09	0.43	107%	83%	90%	104%

Table 1: (continued)

	Percent of Population	*Isolation ratio*	*Isolation Index*	*Weighted Moran (1 km)*	*Relative Median Landprice*	*Median Income*	*Median Household Income*	*Population density*
Employed Full time	51.4%	53.9%	0.05	0.25	102%	147%	123%	100%
Employed Part time	12.3%	14.0%	0.02	0.23	105%	56%	90%	101%
Unemployed	3.4%	5.6%	0.02	0.27	89%	30%	61%	101%
Not in Labour Force	28.5%	32.8%	0.06	0.20	97%	41%	59%	100%
Renter	29.6%	39.1%	0.14	0.38	101%	89%	79%	103%
Owner	60.0%	67.0%	0.17	0.47	100%	110%	109%	98%

Table 2: Proximity to amenities – by demographic group

	Distance to								*Log of pop density (2 km)*	*Empl. To Pop ratio (2 km)*
	nearest School	*nearest Super-market*	*nearest Railway station*	*nearest Bank*	*Auckland Airport*	*CBD*	*Coast*	*nearest Mway ramp*		
Median	0.48 km	1.08 km	3.68 km	1.13 km	16.01 km	11.37 km	1.03 km	2.64 km	1834/ km^2	0.52
2006 Usually Resident Population	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Male	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Female	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Age 18-29	0.97	0.94	0.90	0.94	0.98	0.92	1.10	0.89	1.03	1.08
Aged 30-49	[1]	1.02	[1]	1.03	1.00	1.02	1.03	1.01	0.99	0.99
Aged 50-65	1.04	1.05	1.09	1.03	1.02	1.04	0.92	1.07	0.98	0.96
Aged over 65	1.01	0.99	1.10	0.95	1.03	[1]	0.85	1.04	1.00	0.97
Maori Ethnicity	0.94	1.02	0.87	1.13	0.91	1.18	0.97	0.97	0.92	0.98
European Ethnicity	1.07	1.05	1.12	1.01	1.08	0.97	0.92	1.02	0.99	0.97
Pacific Ethnicity	0.85	0.97	0.80	1.09	0.68	1.16	[1]	1.04	0.95	[1]
Asian Ethnicity	0.96	0.90	0.98	0.88	0.92	0.88	1.22	0.95	1.06	1.09
Other Ethnicity	0.98	0.95	0.92	0.94	0.98	0.89	1.23	0.94	1.04	1.04
Overseas-Born	0.97	0.97	1.01	0.97	0.97	[1]	1.07	1.02	1.02	1.01
Born in New Zealand	1.02	1.03	0.99	1.02	1.03	[1]	0.94	0.99	0.99	0.99
Born in UK	1.10	1.07	1.35	1.05	1.14	1.05	0.84	1.12	0.97	0.89
Born in PRC	0.93	0.84	[1]	0.79	0.95	0.76	1.20	0.95	1.10	1.12
Born in Korea	1.04	0.90	1.83	0.94	1.38	0.98	1.20	0.74	0.97	1.23
Born in India	0.92	0.90	0.84	0.87	0.83	0.83	1.36	1.05	1.09	1.06
Born in South Africa	1.12	1.05	1.92	1.08	1.15	1.19	[1]	1.18	0.94	0.85
Born in Australia	1.04	[1]	[1]	0.96	1.07	0.85	0.90	0.97	1.03	[1]

Table 2: (continued)

	Distance to								*Log of pop density (2 km)*	*Empl. To Pop ratio (2 km)*
	nearest School	*nearest Super-market*	*nearest Railway station*	*nearest Bank*	*Auckland Airport*	*CBD*	*Coast*	*nearest Mway ramp*		
Born in Samoa	0.84	0.97	0.80	1.15	0.65	1.21	[1]	1.06	0.95	0.98
Born in Fiji	0.94	0.97	0.83	1.06	0.72	1.16	1.13	[1]	0.97	1.02
Born in Tonga	0.80	0.99	0.79	1.04	0.66	1.10	0.94	1.12	0.96	1.06
Returning New Zealander	1.01	0.97	0.94	0.88	1.05	0.71	0.94	0.85	1.05	1.09
Recent Migrant	0.96	0.90	0.97	0.89	0.97	0.90	1.15	0.93	1.05	1.08
NZ-born: Moved in NZ in last 5 yrs	1.03	1.02	0.97	1.02	1.03	1.01	[1]	0.94	0.98	1.02
Earlier Migrant	0.98	1.00	1.04	1.01	0.97	1.04	1.03	1.06	1.00	0.98
NZ-born: Did not move in last 5 yrs	1.01	1.05	[1]	1.03	1.02	1.01	0.91	1.03	0.99	0.96
0–5 Years in NZ	0.96	0.91	0.96	0.90	0.96	0.91	1.14	0.93	1.05	1.08
6–10 Years in NZ	0.97	0.97	1.10	0.97	0.96	[1]	1.13	1.05	1.02	1.01
11–15 Years in NZ	1.01	0.99	1.15	[1]	0.98	[1]	1.09	1.07	1.01	[1]
More than 15 Years in NZ	0.99	1.02	1.01	1.04	0.97	1.06	0.96	1.07	0.98	0.96
No Qualification	0.96	1.01	0.95	1.07	0.94	1.15	0.97	1.05	0.94	0.97
School Qualifications	[1]	0.99	1.05	0.98	1.01	0.98	1.04	[1]	1.01	1.00
Post-School Qualifications	1.04	1.05	1.09	1.04	1.03	1.05	0.95	1.06	0.97	0.95
High Qualification	1.01	0.97	0.98	0.88	1.02	0.72	1.07	0.89	1.07	1.08
Income below $20,001	0.98	0.98	[1]	0.98	0.98	1.01	1.03	1.02	[1]	[1]
Income $20,001 to $50,000	[1]	1.01	[1]	1.03	0.99	1.05	1.02	1.02	0.98	0.99
Income over $50,000	1.06	1.04	1.08	0.99	1.05	0.91	0.95	0.99	1.02	0.99
HH income below $20k	0.95	0.95	0.96	0.95	0.97	1.02	1.04	[1]	[1]	1.02
HH income $20k–$55k	0.99	1.01	1.01	1.04	0.99	1.07	1.03	1.04	0.98	0.98
HH income above $55k	1.06	1.03	1.05	0.97	1.05	0.87	0.95	0.95	1.03	1.01

Table 2: (continued)

	Distance to								*Log of pop density (2 km)*	*Empl. To Pop ratio (2 km)*
	nearest School	*nearest Supermkt*	*nearest Railway station*	*nearest Bank*	*Auckland Airport*	*CBD*	*Coast*	*nearest Mway ramp*		
Household Type: Couple with Dep	[1]	1.06	1.07	1.07	0.98	1.09	1.02	1.09	0.97	0.94
Household Type: Single with Dep	0.93	1.02	0.94	1.09	0.94	1.13	1.03	1.05	0.95	0.97
Household Type: Couple, no Dep	1.05	1.02	1.10	1.01	1.03	[1]	0.94	1.04	0.99	0.97
Household Type: Single , no Dep	0.97	0.93	0.88	0.90	0.99	0.87	1.03	0.87	1.04	1.09
Employed Full time	1.01	1.02	1.01	1.01	1.01	0.99	1.02	[1]	[1]	[1]
Employed Part time	1.02	1.03	1.08	[1]	1.03	0.98	0.98	1.04	1.01	0.98
Unemployed	0.94	0.95	0.89	[1]	0.95	1.04	1.07	0.96	[1]	1.02
Not in Labour Force	0.98	0.98	[1]	0.98	0.98	1.02	0.96	1.01	[1]	[1]
Renter	0.94	0.93	0.89	0.91	0.96	0.90	1.07	0.89	1.03	1.10
Owner	1.04	1.05	1.12	1.04	1.03	1.04	0.96	1.08	0.98	0.94

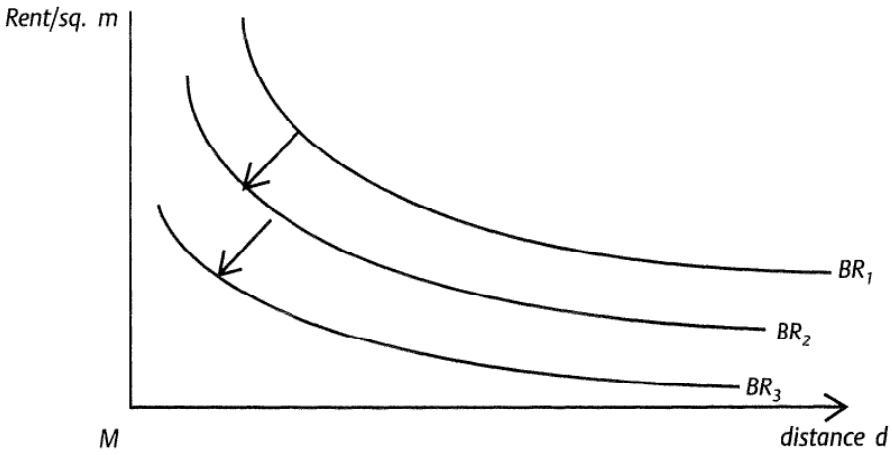
Note: Index numbers in brackets indicate cases where the group median is not statistically significantly different from that of the overall population. The difference is considered significant if the p-value from a Wilcoxon-Mann median test is less than one percent.

Table 3: Rent gradients for amenities

Dependent Variable: Log of Landprice	*Distance to nearest School*	*Distance to nearest Supermarket*	*Distance to nearest Railway station*	*Distance to nearest Bank*	*Distance to Auckland Airport*	*Distance to CBD*	*Distance to Coast*	*Distance to nearest Motorway ramp*	*Log of population density*	*Empl. To Population ratio*
Landprice gradient	-0.303***	-0.470***	-0.111***	-0.604***	0.194***	-0.920***	-0.0817***	-0.279***	0.768***	0.334***
	[0.0158]	[0.0149]	[0.0129]	[0.0126]	[0.0240]	[0.0121]	[0.0103]	[0.0123]	[0.0129]	[0.0131]
Constant	14.74***	15.00***	15.13***	15.01***	14.45***	17.09***	14.97***	15.22***	9.420***	14.73***
	[0.0168]	[0.0104]	[0.0199]	[0.00979]	[0.0672]	[0.0289]	[0.0111]	[0.0149]	[0.0943]	[0.0146]
Observations	8517	8517	8517	8517	8517	8517	8517	8517	8517	8516
R-squared	0.042	0.105	0.009	0.213	0.008	0.405	0.007	0.057	0.293	0.071

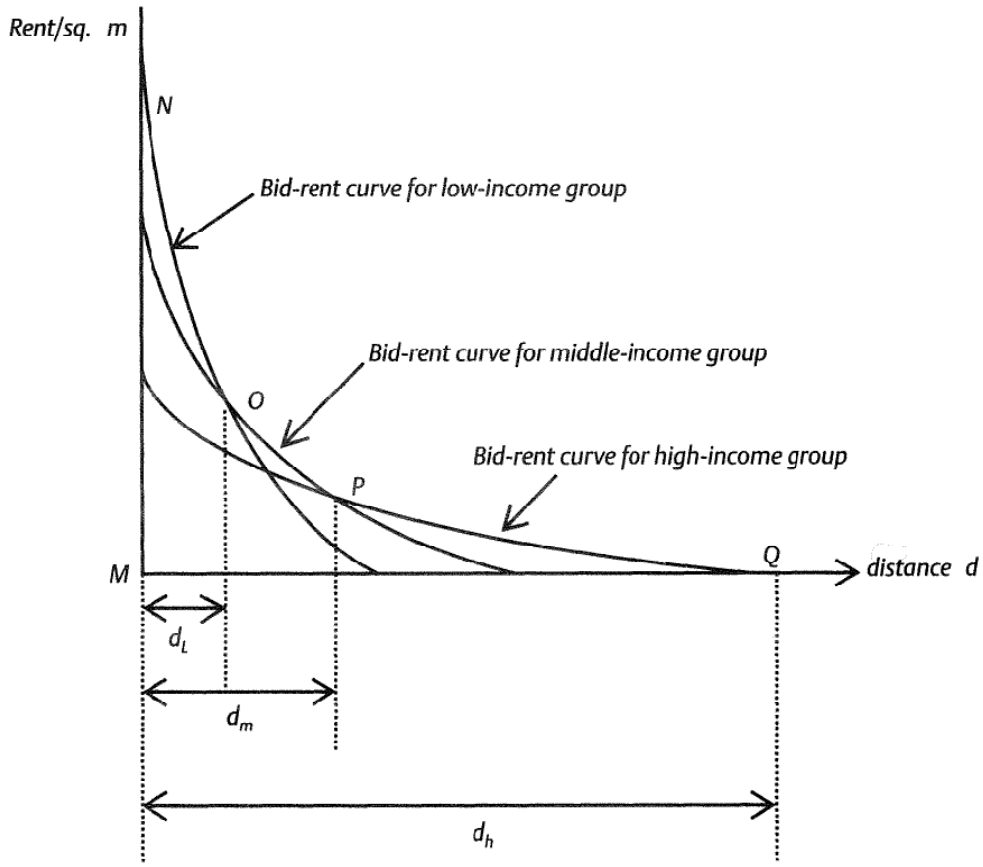
Standard errors in brackets;*** p<0.01, ** p<0.05, * p<0.1

Figure 1: Bid-rent curves



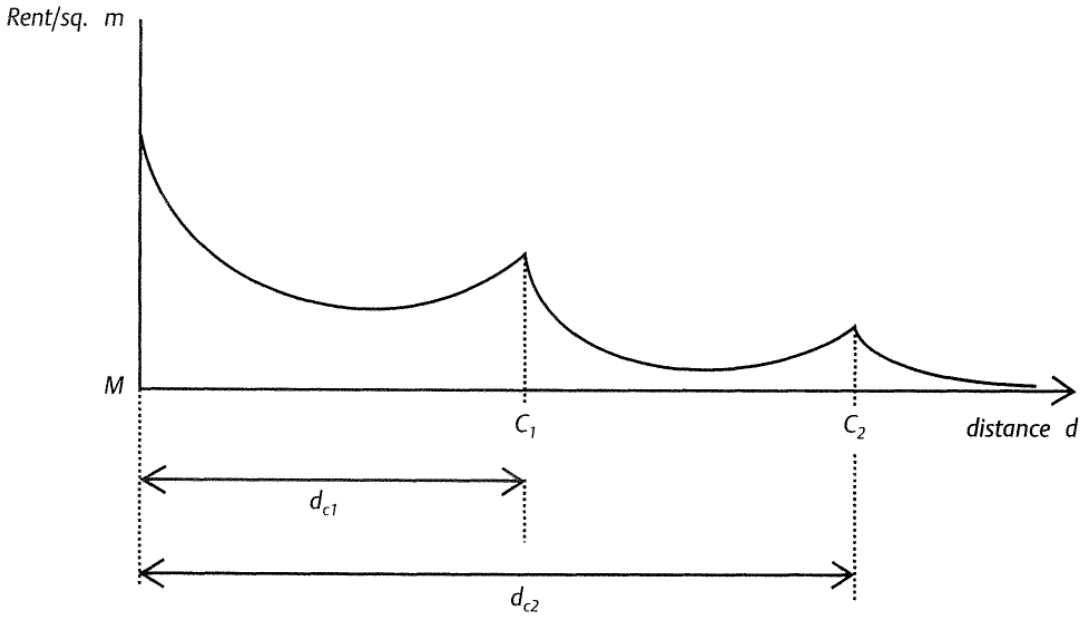
Source: McCann (2001, Figure 3.10)

Figure 2: Bid-rent curves – income sorting



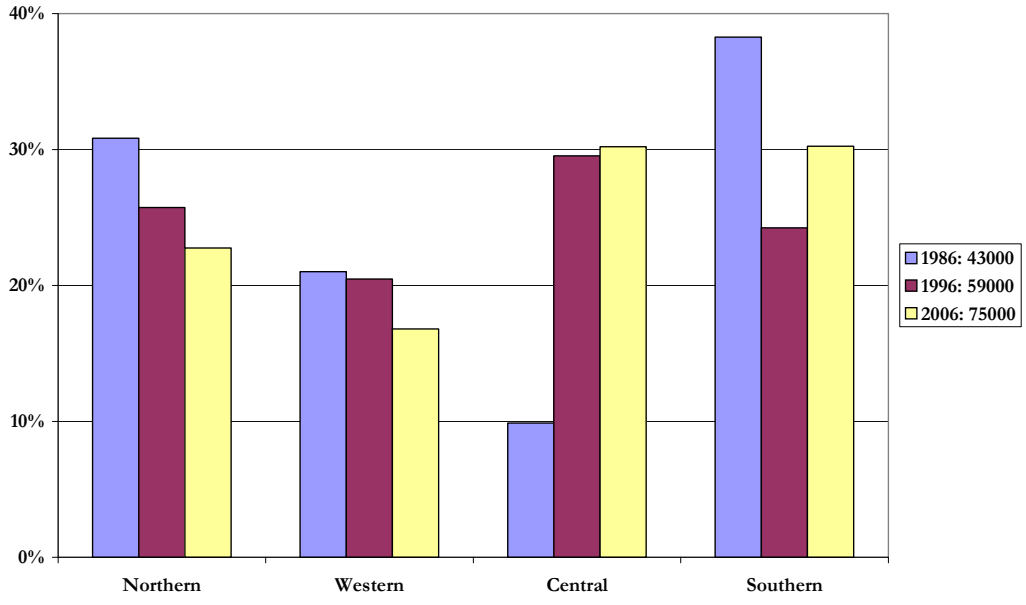
Source: McCann (2001, Figure 3.11)

Figure 3: Bid-rent curves – Multiple amenities



Source: McCann (2001, Figure 3.18)

Figure 4: The fraction of new dwellings located in Auckland, by region



Source: Census of Population and Dwellings

Figure 5: **Maps of population density and land prices**

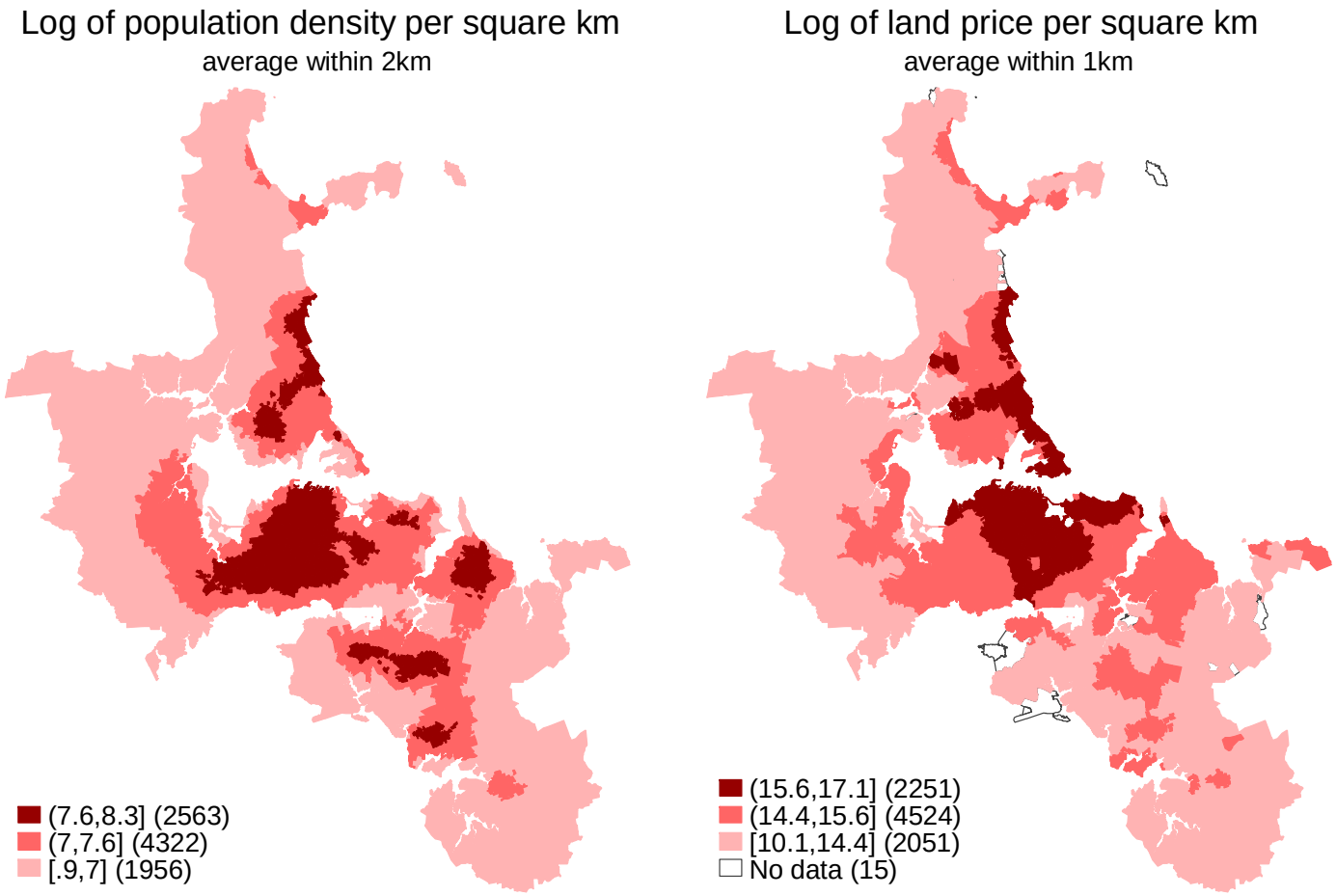


Figure 6: Proximity to CBD: land prices, population density and distance to CBD

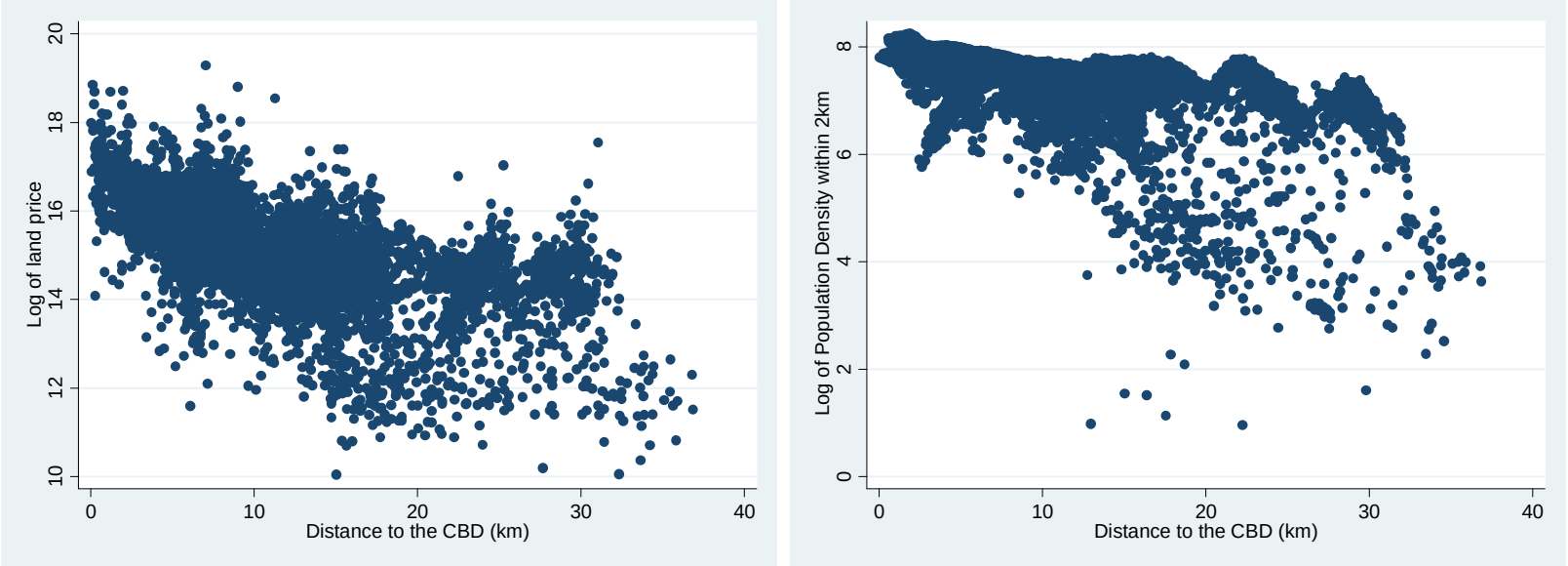


Figure 7: Population density and land prices (Population aged 18+)

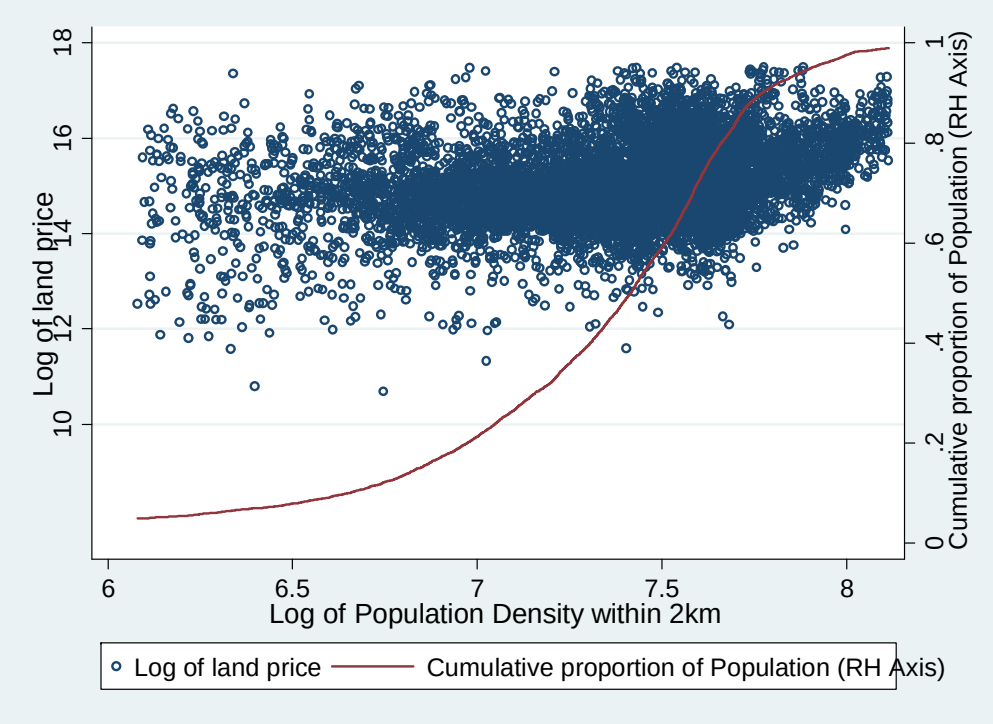


Figure 8: Maps of residential segregation – by ethnicity

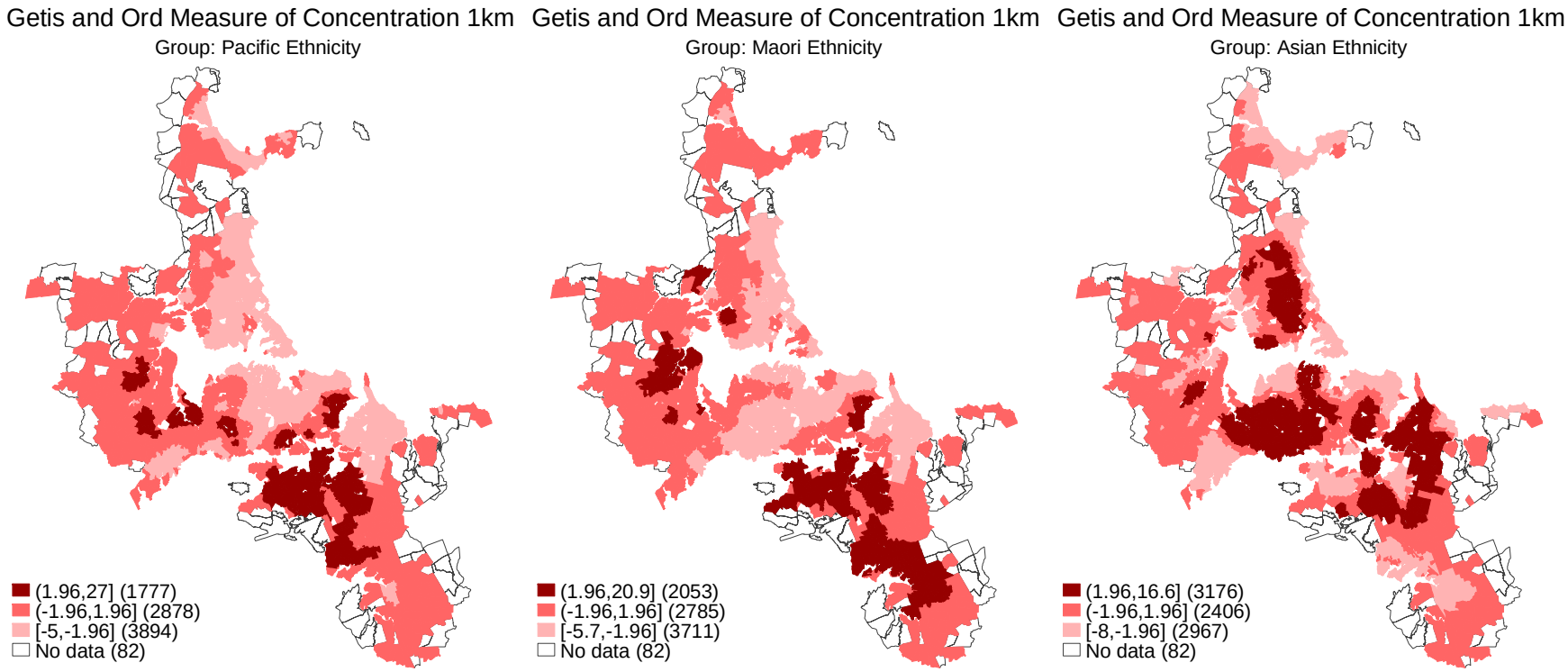
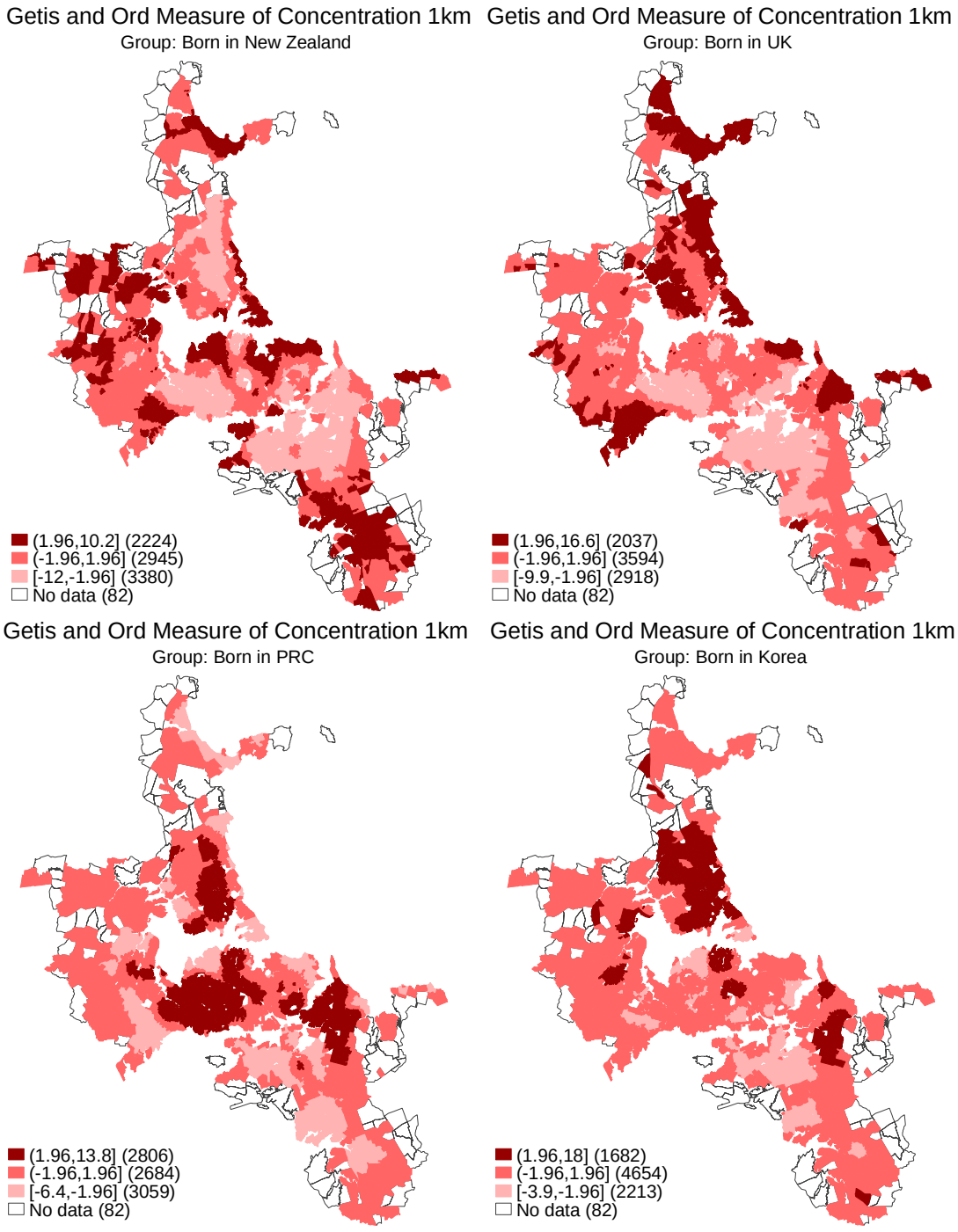
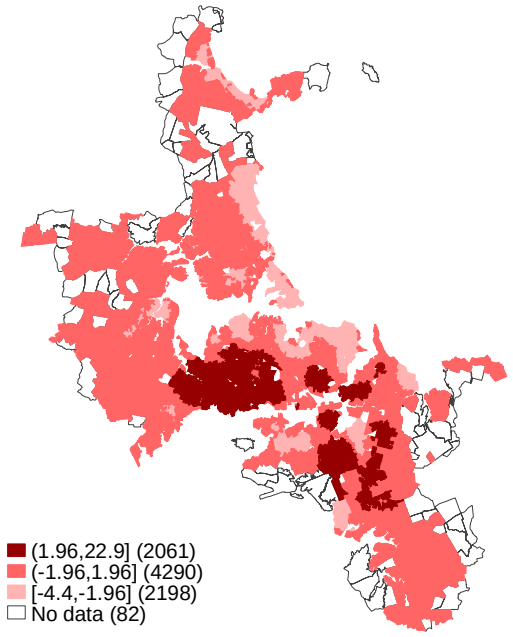


Figure 9: Maps of residential segregation – by country of birth



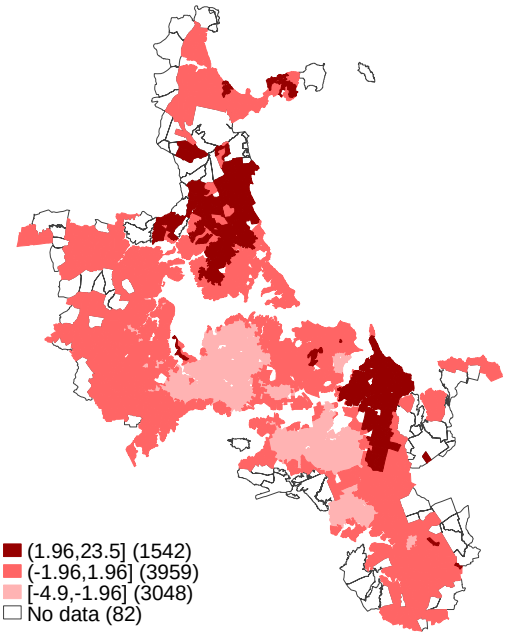
Getis and Ord Measure of Concentration 1km

Group: Born in India



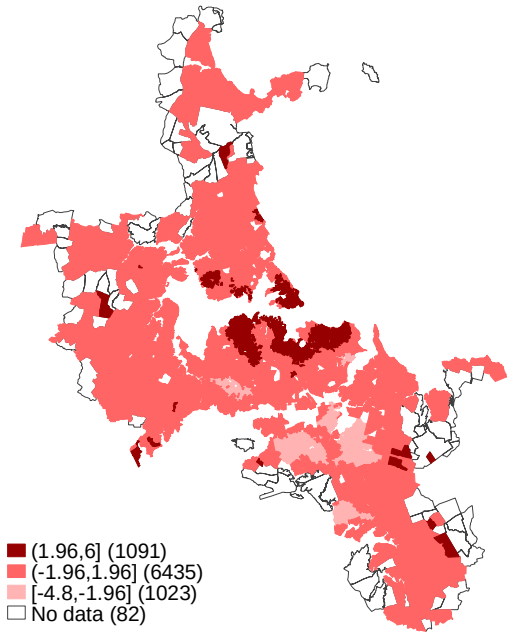
Getis and Ord Measure of Concentration 1km

Group: Born in South Africa



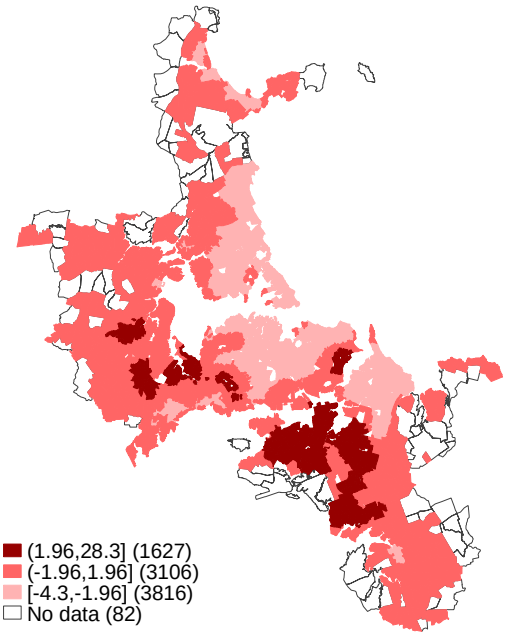
Getis and Ord Measure of Concentration 1km

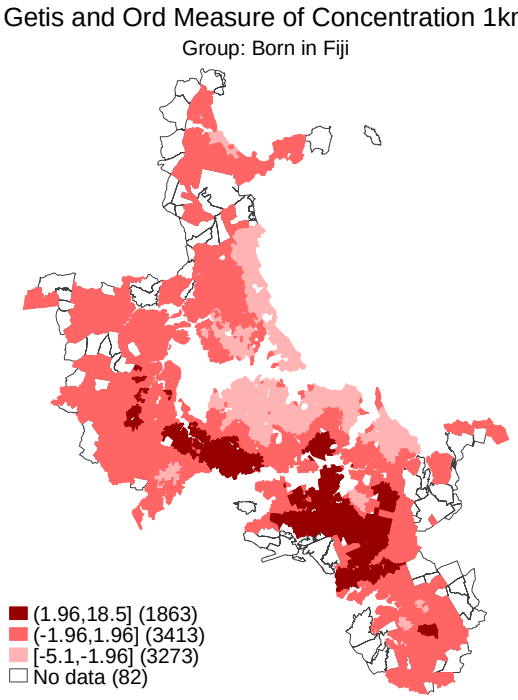
Group: Born in Australia



Getis and Ord Measure of Concentration 1km

Group: Born in Samoa




Getis and Ord Measure of Concentration 1km
Group: Born in Fiji
(1.96,18.5] (1863)
(-1.96,1.96] (3413)
[-5.1,-1.96] (3273)
No data (82)

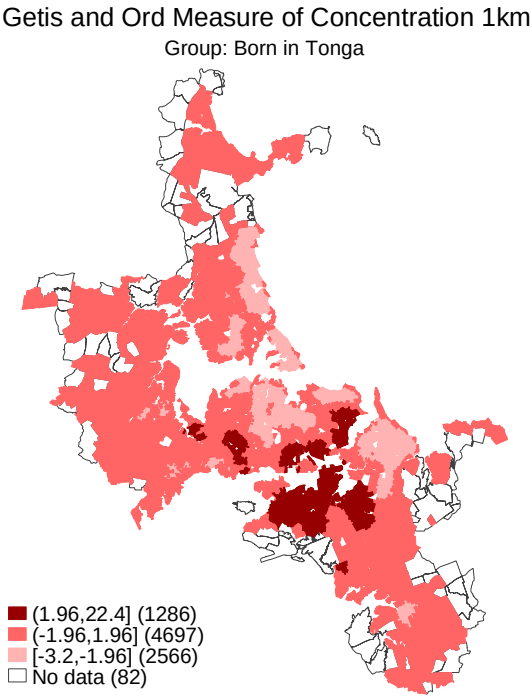

Getis and Ord Measure of Concentration 1km
Group: Born in Tonga
(1.96,22.4] (1286)
(-1.96,1.96] (4697)
[-3.2,-1.96] (2566)
No data (82)

Figure 10: Maps of residential segregation – by mobility groups

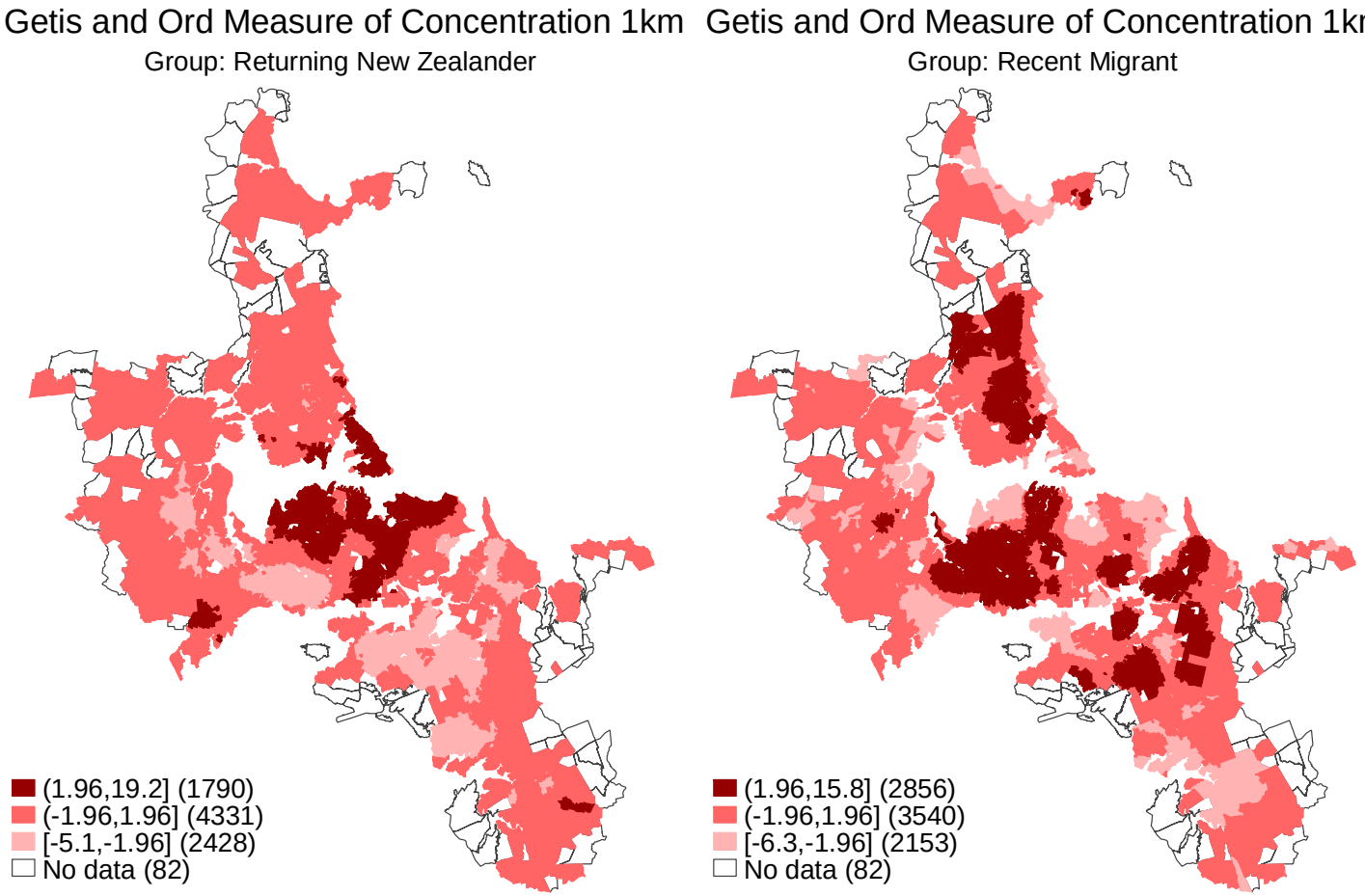


Figure 11: Maps of residential segregation – by highest qualification

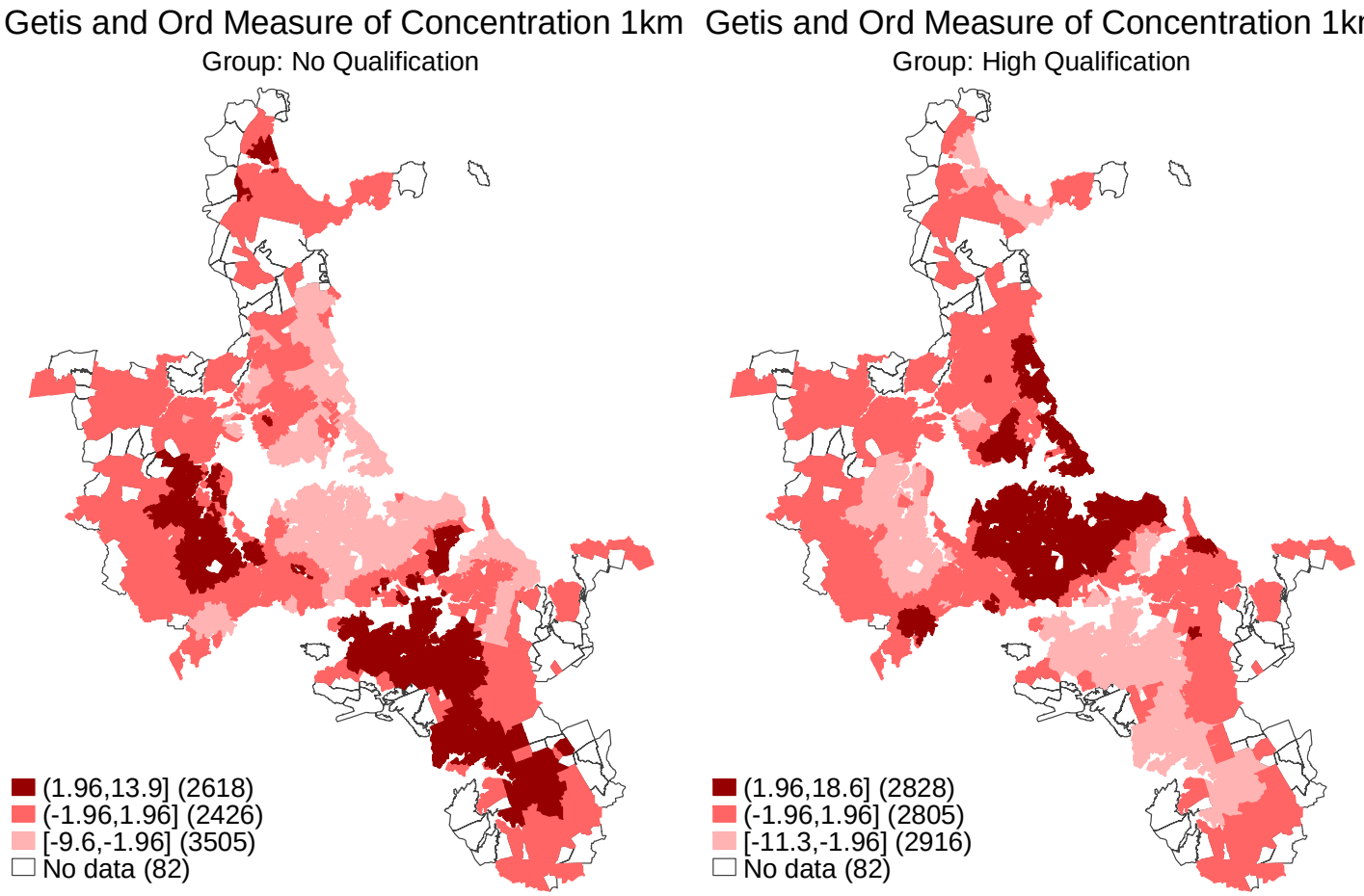


Figure 12: Maps of residential segregation – by labour force status

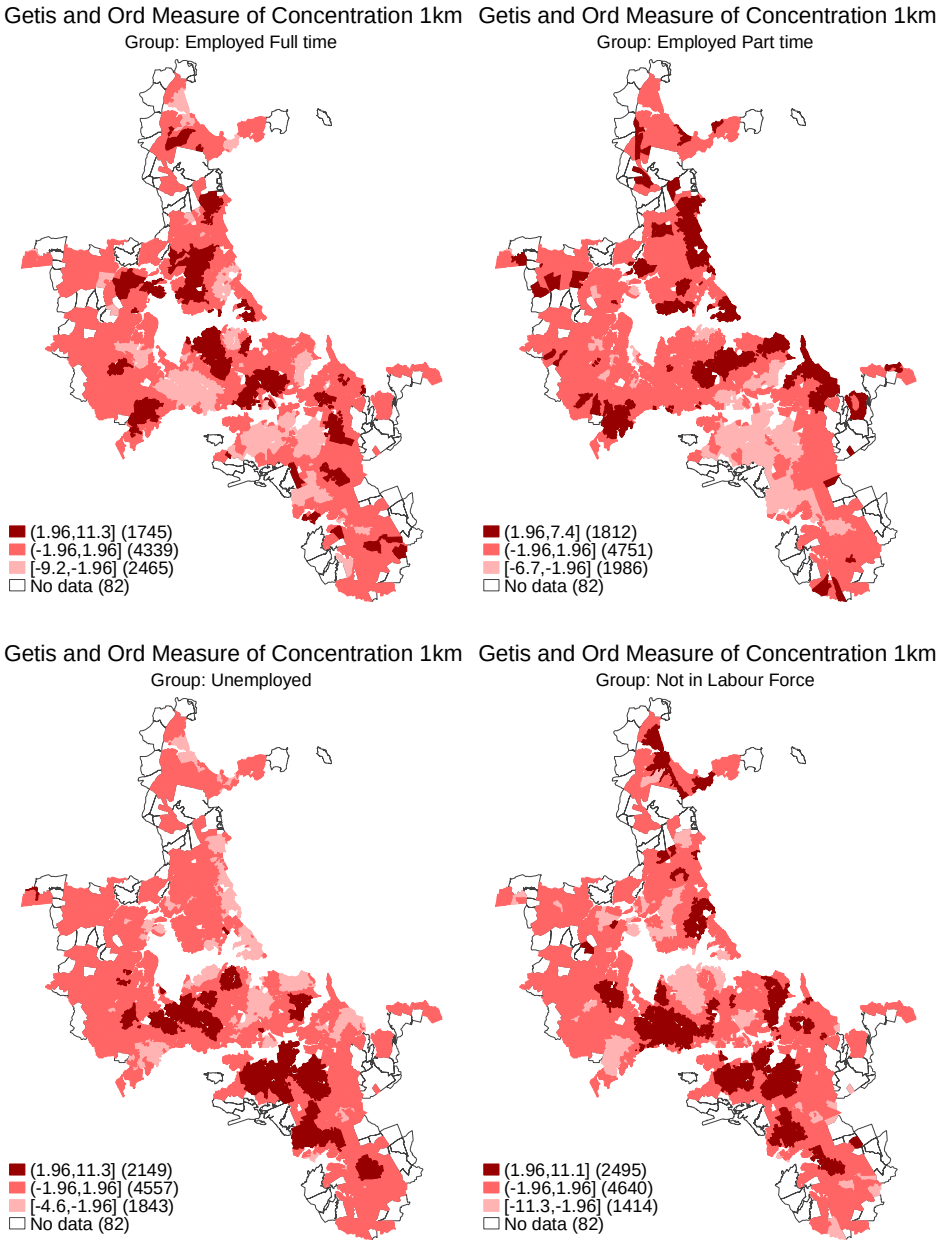


Figure 13: Maps of residential segregation – by income

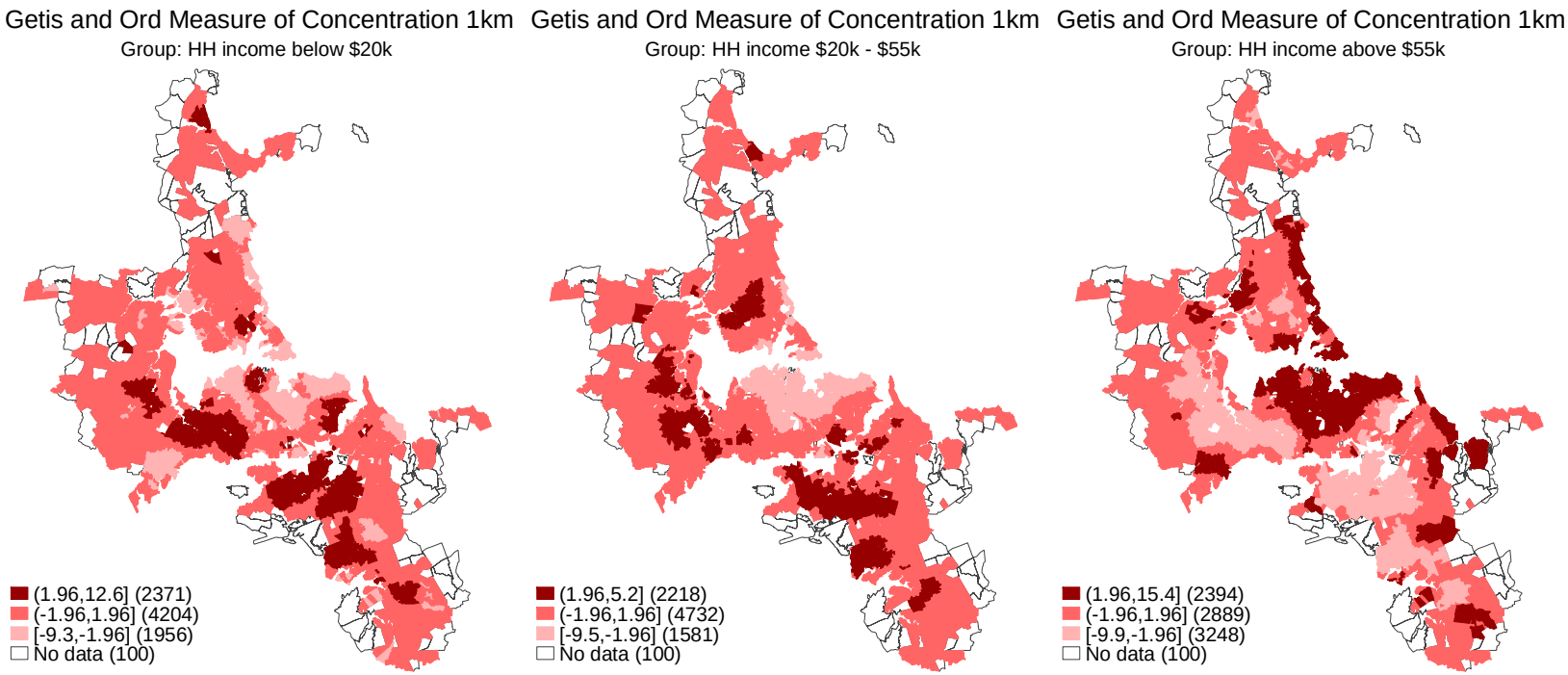


Figure 14: Maps of residential segregation – by housing tenure

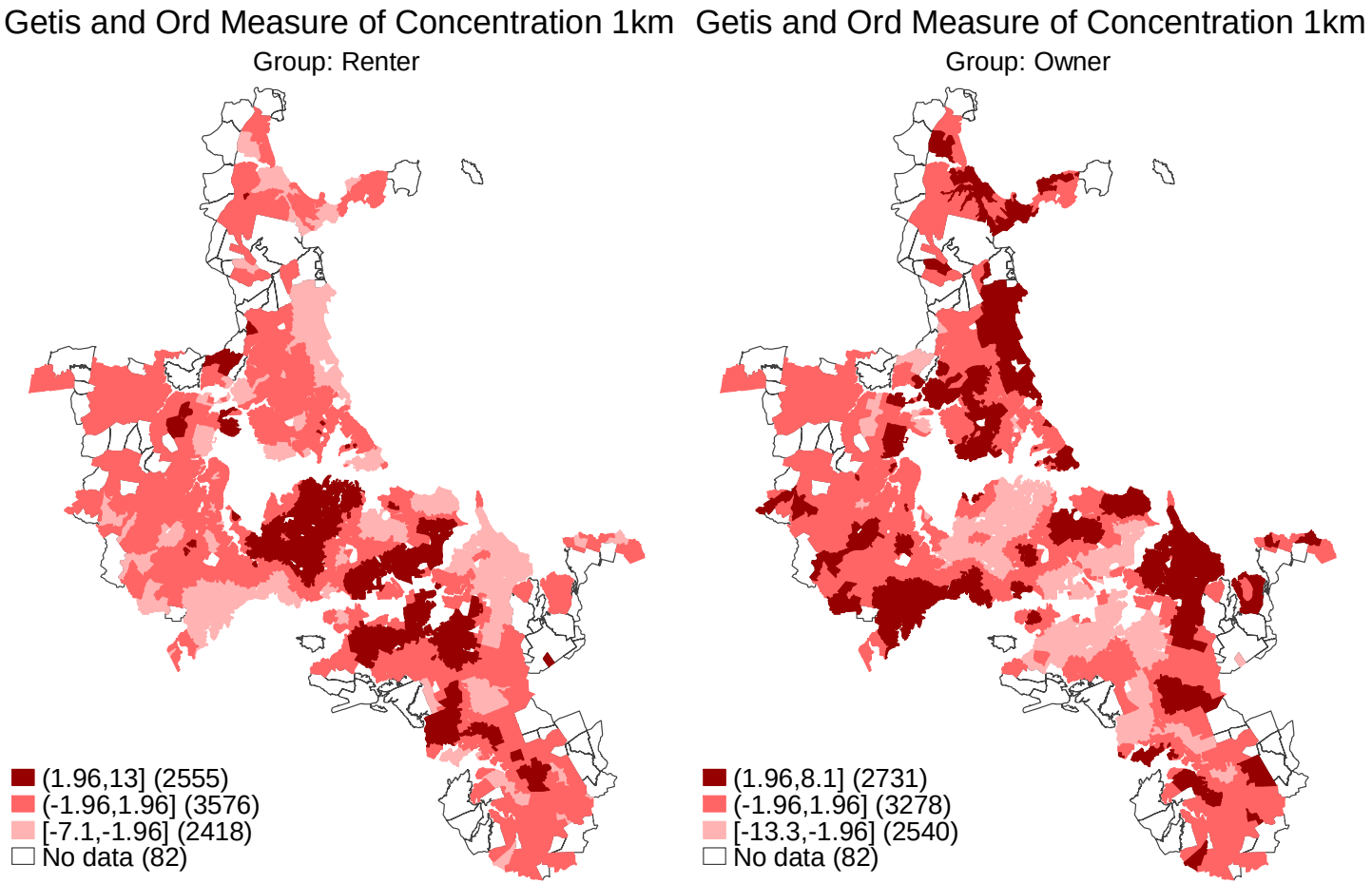


Figure 15: Land price, density and income – by subgroups

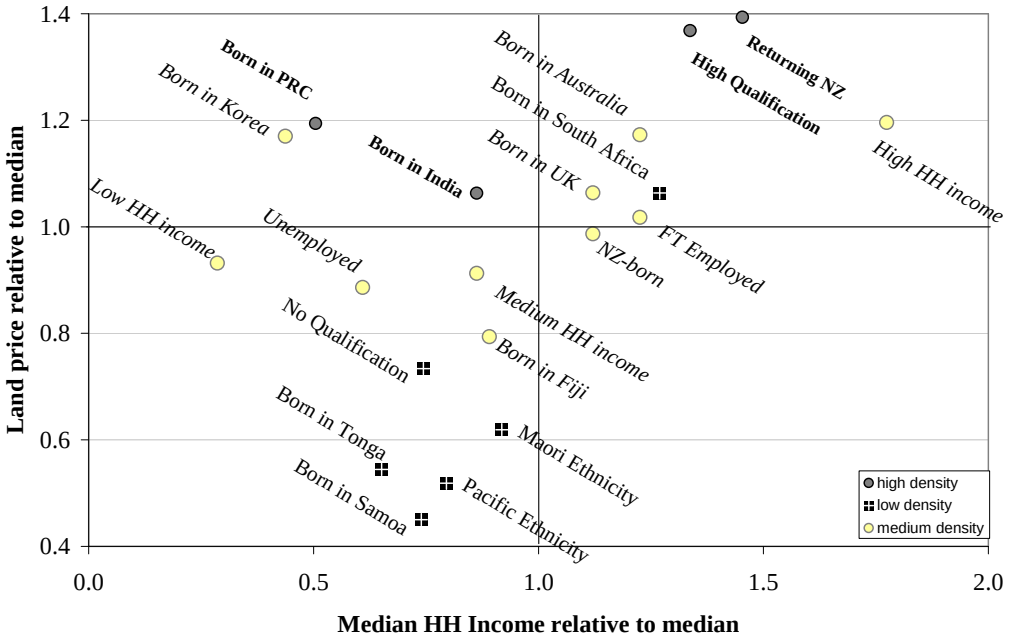
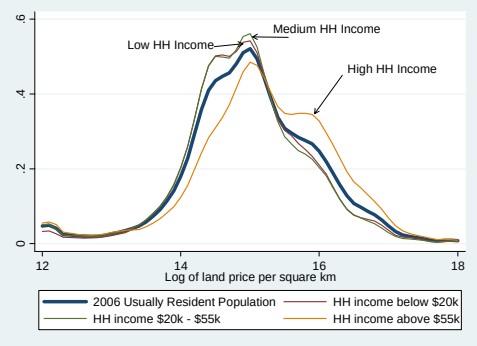
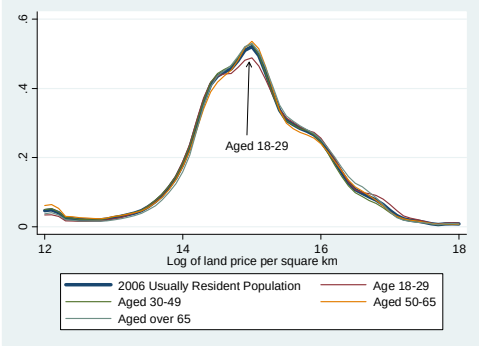


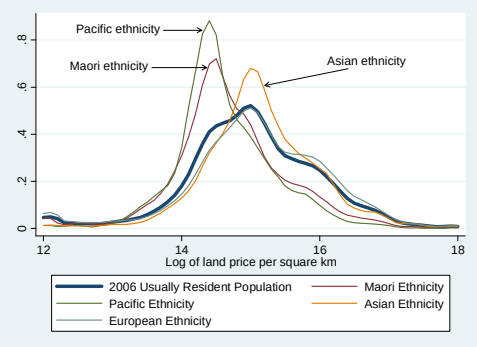
Figure 16: Rent distributions



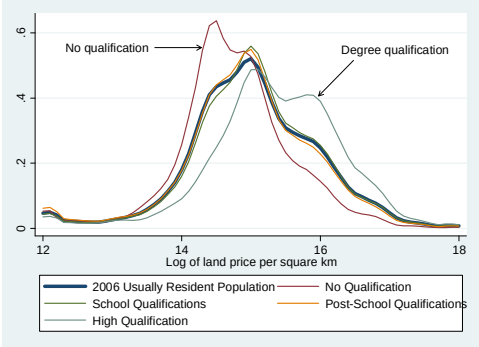
(c) Ethnicity



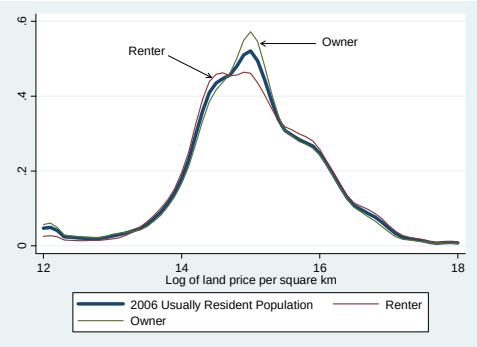
(d) Highest qualification



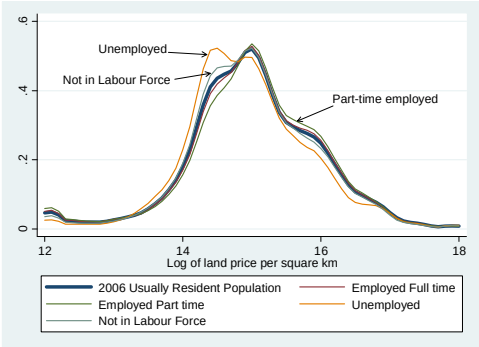
(e) Housing Tenure



(f) Labour Force Status



(g) Country of birth



(h) O'seas Born Years since migration

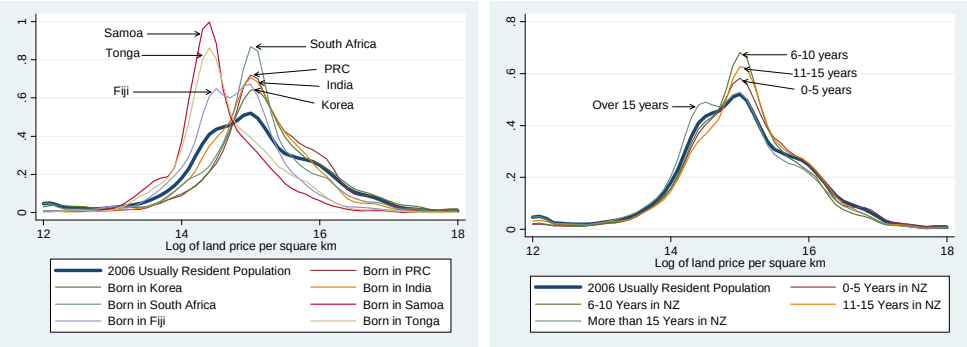


Figure 16: (continued)

(i) Mobility groups ***(j) Family type***

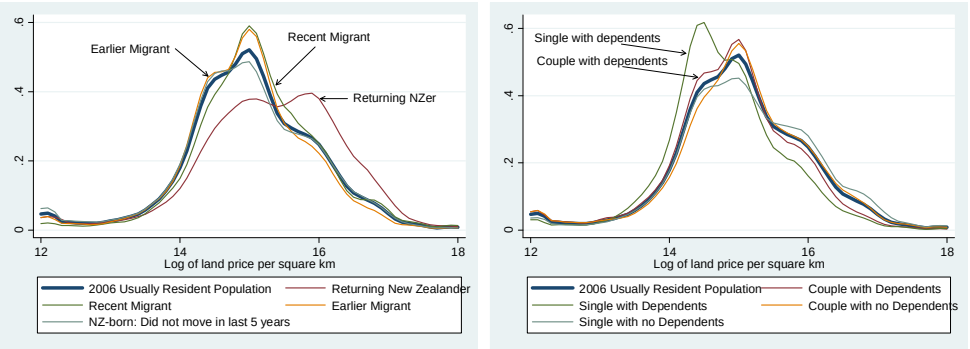
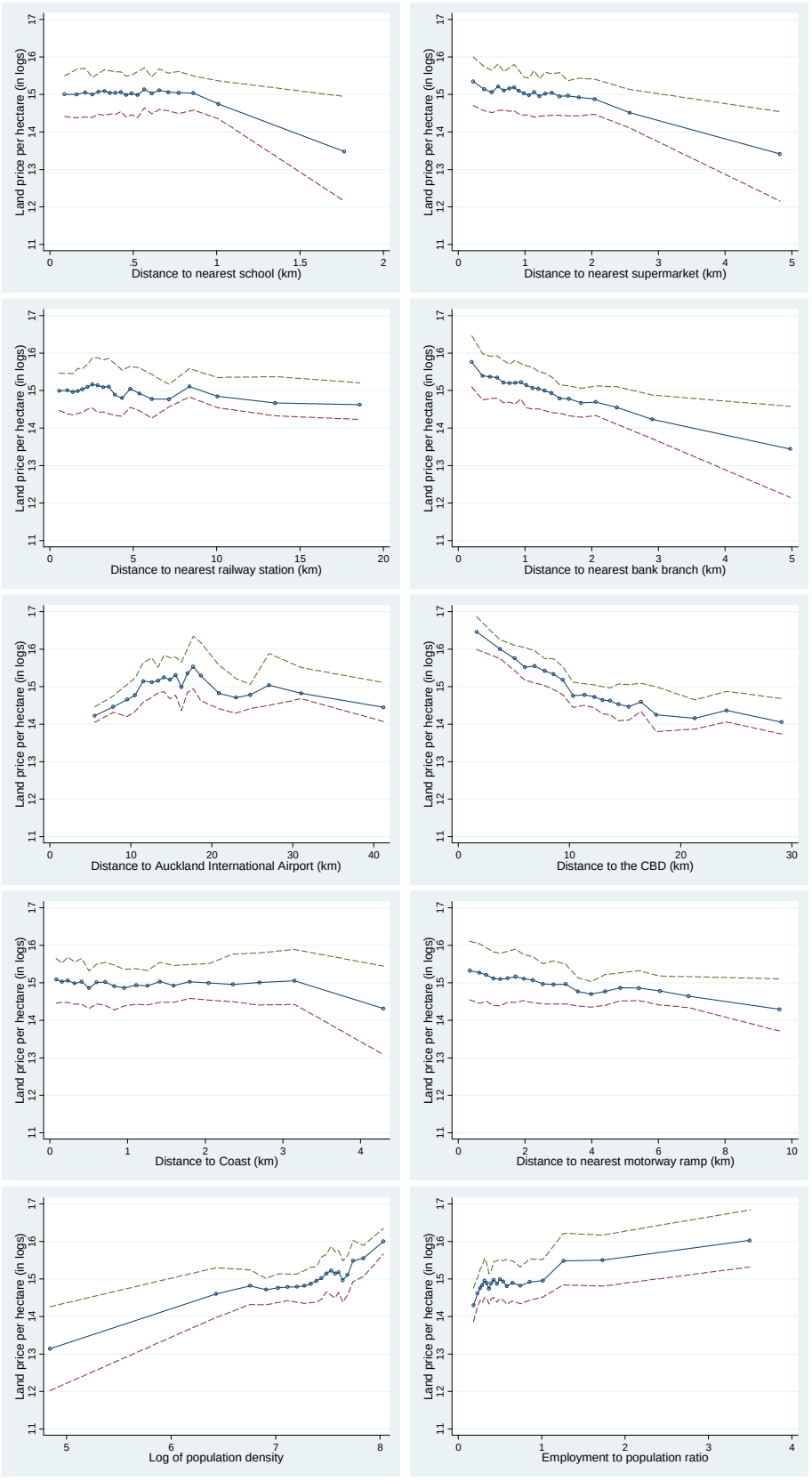


Figure 17: Land price gradients for amenities



Appendix A: Auckland population, 1926–2006

Over time, Statistics New Zealand has published several measures of Auckland's population, which differ slightly terms of the precise boundaries of the city area. The Auckland urban area comprises four zones – Northern, Central, Western, and Southern, defined as follows.

Northern Auckland Urban Zone:

- the part of Rodney District known as the Hibiscus Coast, from Waiwera south, including Orewa and the Whangaparaoa Peninsula;
- all of North Shore City.

Western Auckland Urban Zone:

- the part of Rodney District around Kumeu;
- the urban part of Waitakere City.

Central Auckland Urban Zone:

- Auckland City, excluding the Hauraki Gulf islands.

Southern Auckland Urban Zone:

- the urban part of Manukau City;
- Papakura district;
- Whangapouri Creek and Runciman in Franklin District.

The Auckland Statistical area comprises these four zones and some additional outlying areas including Helensville, Pukekohe Borough, and various islands.

In this paper we primarily use the "Auckland Urban Area" measure. We define population using the "usually resident population" definition of population, which enumerates people based on their usual place of residence rather than where they were on census night. This measure is not available prior to 1976. Some 1986 and 1991 census tables use a definition of "Usually resident population" that refers to people usually resident in New Zealand (ie: excluding overseas-born) but enumerates them according to where they were on census night.

The following table shows available statistics on the population of the Auckland Urban area (and zones within it) and the Central Auckland Statistical Area for each census year, 1926–2006.

Table A1: Auckland population, 1926-2006

	Urban Areas					
	Northern Auckland Zone	*Western Auckland Zone*	*Central Auckland Zone*	*Southern Auckland Zone*	*Total: Auckland Urban Area*	*Central Auckland Statistical area*
	Census night total population					
1926	23,538	9,373	164,863	16,507	214,281	236,274
1936	26,601	12,794	175,458	21,491	236,344	265,996
1945	34,770	17,008	216,389	29,938	298,105	331,994
1951	43,807	23,230	235,568	38,941	341,546	382,014
1956	53,201	36,029	254,667	55,362	399,259	441,069
1961	64,278	55,217	269,315	80,726	469,536	514,507
1966	86,297	75,792	281,192	124,886	568,167	613,671
1971	107,965	89,946	286,787	165,048	649,746	698,400
1976	137,421	108,139	289,125	208,101	742,786	797,406
1981	149,321	116,407	275,914	227,916	769,558	829,519
1986	162,614	125,282	285,097	247,761	820,754	889,225
1991	175,944	140,250	308,505	260,874	885,573	963,111
1996	202,014	158,313	346,125	291,525	997,980	1,087,413
2001	220,617	173,277	371,313	321,948	1,087,152	1,184,574
	Resident population (=census night, excluding usually resident overseas)					
1986	160,716	124,368	278,703	245,589	809,379	876,999
1991	173,140	138,972	299,226	257,814	869,169	945,507
	Usually Resident Population					
1976	138,002	108,866	285,111	208,481	740,460	793,704
1981	150,450	117,054	271,002	229,026	767,526	824,958
1986	162,888	125,998	288,874	238,168	816,928	882,175
1991	176,254	140,959	299,625	261,398	878,236	952,974
1996	202,281	159,771	338,160	291,600	991,812	1,078,893
2001	219,894	173,640	359,454	321,462	1,074,450	1,169,868
2006	248,106	192,342	395,982	371,658	1,208,088	na

Data Sources:

Total population on census night

Urban Areas

- *1926-1971: NZ Department of Statistics (1972): Book 1, Table 8, p. 23.*
- *1976-86: NZ Department of Statistics (1986): Table 3, p. 13*
- *1991-2001: Statistics New Zealand (2002)., Table 3, p. 23*

Statistical Areas

- *1926-1966: NZ Department of Statistics (1967) Table 3, p11.*
- *1971: NZ Department of Statistics (1972): Book 1, Table 9, p. 24*
- *1976-86: NZ Department of Statistics (1986): Table 3, p. 12*
- *1991-2001: Statistics New Zealand (2002)., Table 3, p. 23*

Resident Population (Census night population, excluding people usually resident overseas)

Urban Areas & Statistical Areas

- *1986: NZ Department of Statistics (1987): Table 2, pp. 17-18.*
- *1991: Statistics New Zealand (1992), Table 1, p.15.*

Usually Resident Population

Urban Areas

- *1976-1981: NZ Department of Statistics (1982) Part C, Table 4, p.59*
- *1986-91: Statistics New Zealand (1997): Table 6*
- *1996-2006: Statistics New Zealand (2007b), Table 1*

Statistical Areas

- *1981: NZ Department of Statistics (1982) Part C, Table 4, p.59*
- *1986: Statistics New Zealand (1997): Table 6*
- *1991-2001: Statistics New Zealand (2002)., Table 3, p. 23*