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Residential Sorting Across Auckland Neighbourhoods

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Abstract

This paper addresses the extent to which people in Auckland exhibit residential location patterns that differ between groups, i.e. the extent to which they are spatially sorted. To measure patterns of residential location, the paper uses the index of segregation, an isolation index, Gini coefficients, Ellison & Glaeser and Maurel & Sédillot concentration measures, Moran's I and Getis and Ord's G*. Results are presented based on a classification of the population in different ways: ethnicity, income, education, age and country of birth. Both city-wide and local measures are considered. We find that ethnic-based sorting is the strongest indicator of residential sorting patterns, but sorting by income, education and age is also present. Sorting by income and qualifications is strongest at the top and, to a lesser extent, at the bottom of the income and qualifications range. Age segregation is most pronounced for older residents. Clustering is strongest within a range of up to one kilometre and declines significantly over greater distances. Local analysis by means of Getis and Ord's G* calculations suggest significant ethnic clustering. Apart from Māori and Pacific Islanders, ethnic groups tend to locate away from each other, as confirmed with cross-Moran's I calculations. When considering interactions between ethnicity and income we find that the location of ethnicity-income subgroups is more strongly related to neighbourhood ethnicity than to neighbourhood income.

The distribution of households and individuals across neighbourhoods arises through a complex process that is now commonly referred to as residential sorting (e.g. Clark & Morrison, 2012). When choosing areas to live, people make tradeoffs regarding the

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wide variety of housing and neighbourhood attributes associated with the options available (Bayer et al., 2004). Residential segregation can be defined generally as the degree to which groups live separately from each other (Johnston et al., 2007; Massey & Denton, 1988). The sorting of population subgroups into distinct areas may reflect heterogeneous tastes, with segregation supporting the provision of local public goods (Tiebout, 1956) or proximity to amenities valued highly by the subgroup. Alternatively, it may reflect income stratification within housing markets, with different groups making different tradeoffs between convenient locations and lower residential prices. Finally, social sorting may arise if groups prefer to live close to people similar to themselves, or separate from people who are different (see Maré et al., 2011 for further discussion).

The purpose of the current paper is to answer two key questions:

(i) what is the nature and strength of residential sorting in the Auckland urban area?

(ii) how does this differ between different groups?

It adds to a small existing literature on the topic, which to date has focused primarily on sorting by ethnicity (Johnston et al., 2003, 2007, 2011; Grbic et al., 2010). The paper makes three original contributions. First, it presents additional measures to summarise patterns of sorting. Second, it summarises residential sorting within Auckland by country of birth, income, qualification, and age, as well as by ethnicity. Third, it examines the interrelationship of sorting by ethnicity and by income.

In the next section, we discuss the relevance of residential segregation for urban and social policy, and refer to previous studies of the Auckland Urban Area. We then introduce the methods that we use to examine patterns of spatial sorting, and the data on which we base our measurement. After presenting key findings, we conclude by summarising the main insights of the analysis.

Background

With a resident population of about 1.4 million in 2012, Auckland is New Zealand's largest city. It is also one of the most culturally diverse cities among the Organisation for Economic Co-operation and Development (OECD) member countries, with almost 40 percent of the adult population born overseas at the 2006 Census. Auckland's population diversity has profound implications for the spatial distribution of the growing population. As in all major cities, there is considerable sorting of the population across neighbourhoods, along dimensions such as ethnicity, income, country of birth, and age. As Auckland continues to grow, by an anticipated 31 percent by 2031 (Statistics New Zealand, 2010, medium series), patterns of residential location will reflect the changing population composition, with growth pressures in areas currently housing groups that will increase most rapidly. Measuring and understanding existing patterns of residential sorting is vital for anticipating the future demands for housing, local transport and other infrastructure and community facilities.

Residential location patterns take on a greater significance if social and economic outcomes are also influenced by the composition of the neighbourhoods in which people live. Many studies present results consistent with such local spillovers and externalities, which operate by shaping the range of interactions that residents have in their neighbourhood.

In a study of United States urban ghettos, Cutler and Glaeser (1997) show that segregation can be positive if it increases the interactions that unskilled residents have with skilled and high income residents, and negative if segregation limits such interactions. Other studies have found that individual outcomes are affected by neighbourhood levels of education (Kremer, 1997; Borjas, 1995) and the quality of neighbourhood interactions (Ioannides, 2003). Even fertility can be inversely related with neighbourhood quality (Tumen, 2012).

Particularly relevant for Auckland is the extensive literature on the implications for immigrants of residential sorting. Segregated immigrants may not pick up host country skills and language, which can hinder their access to better jobs and can reduce long term earnings. On the other hand, sorting can provide access to employment opportunities and transportation, reducing the costs associated with assimilation into a host society and increasing the opportunity for gainful trade in the labour market or in business (Cutler & Glaeser, 2008; Edin et al., 2003; Warman, 2007; Andersson et al., 2009; Zhou, 1998).

Outcomes may be affected not only by clustering *per se*, but also by the type of locations in which different groups are clustered. Groups may be disadvantaged by being clustered in areas isolated from key amenities, job growth and transportation networks, giving rise to what has been termed 'spatial mismatch' (Cutler et al., 2008; Kain, 1968; Collins & Margo, 2000). Such clustering may arise from housing market discrimination or stratification, with income differences influencing the combinations of convenience and price that are feasible for different groups.

In Auckland, previous studies have highlighted the strength of ethnic residential segregation in Auckland, especially for the groups facing the worst housing and labour market outcomes. Johnston et al. (2005, 2008, 2009) and Grbic et al. (2010) document ethnic segregation, and hypothesise that segregation contributes to a cycle of poor education, poor labour market outcomes and poorer quality housing for Māori and Pacific residents (Johnston et al., 2007, 2005). The hypothesis is plausible, but the direction of causality is not clearly established.

Measuring Residential Sorting

After reviewing the research literature on residential sorting, Massey & Denton (1988) conclude that "segregation should be measured not with one index, but with several" (p.283). Our study follows this suggestion and summarises residential patterns in the Auckland Urban Area using a range of summary statistics. The chosen measures provide complementary perspectives, highlighting different features of observed patterns of sorting. We distinguish two broad approaches to the measurement, namely fixed boundary measures, which summarise patterns across different areas but do not take account of location, distance or scale; and spatial measures, which take into account the topological relationship of neighbourhoods to one another when considering the degree of clustering (Jargowsky & Kim, 2005). For each of these two approaches, we present global measures that summarise the degree of sorting across the Auckland Urban Area. For localised analysis, we present only a spatial measure. Table 1 presents the formulae used to calculate the various measures. In this section, we provide an overview of the measures and the insights that they provide.

Table 1: Summary measures of residential sorting

A. Global Measures	
A.1 Fixed Boundary Measures	
Segregation index	$S_g = \frac{1}{2}\sum_{a=1}^{A}\left\lvert\frac{P_{ga}}{P_{g\bullet}} - \frac{(P_{\bullet a}-P_{ga})}{(P_{\bullet\bullet}-P_{g\bullet})}\right\rvert$
Adjusted segregation index	$AS_g = \frac{1}{2P_{\bullet\bullet}}\sum_{a=1}^{A}\left(\left\lvert P_{ga}-P_{g\bullet}\frac{P_{\bullet a}}{P_{\bullet\bullet}}\right\rvert + \left\lvert (P_{\bullet a}-P_{ga}) - (P_{\bullet\bullet}-P_{g\bullet})\frac{P_{\bullet a}}{P_{\bullet\bullet}}\right\rvert\right)$ $= 2\frac{P_{g\bullet}}{P_{\bullet\bullet}}\left(1-\frac{P_{g\bullet}}{P_{\bullet\bullet}}\right)S_g$
Isolation index	$IsI_g = \frac{IsR_g - \frac{P_{g\bullet}}{P_{\bullet\bullet}}}{1-\frac{P_{g\bullet}}{P_{\bullet\bullet}}}$; where $IsR_g = \sum_{a=1}^{A}\frac{P_{ga}}{P_{g\bullet}}\frac{P_{ga}}{P_{\bullet a}}$
Gini coefficient	See main text
Ellison-Glaeser concentration index	$\gamma_{EG} = 1{,}000 * \frac{\frac{\left\{\sum_{a=1}^{A}\left(\frac{P_{ga}}{P_{g\bullet}} - \frac{P_{\bullet a}}{P_{\bullet\bullet}}\right)^2\right\}}{\left(1-\sum_{a=1}^{A}\left(\frac{P_{\bullet a}}{P_{\bullet\bullet}}\right)^2\right)} - \frac{1}{P_{g.}}}{\left(1-\frac{1}{P_{g\bullet}}\right)}$
Maurel and Sedillot concentration index	$\gamma_{MS} = 1{,}000 * \frac{\frac{\left\{\sum_{a=1}^{A}\left(\frac{P_{ga}}{P_{g.}}\right)^2 - \sum_{a=1}^{A}\left(\frac{P_{.a}}{P_{\bullet\bullet}}\right)^2\right\}}{\left(1-\sum_{a=1}^{A}\left(\frac{P_{\bullet a}}{P_{\bullet\bullet}}\right)^2\right)} - \frac{1}{P_{g\bullet}}}{\left(1-\frac{1}{P_{g\bullet}}\right)}$
A.2 Spatial Measures	
Moran's I	$M_g = \sum_{a=1}^{A}\frac{\left(\frac{P_{ga}}{P_{g\bullet}}-\frac{1}{A}\right)\left(\sum_{n=1}^{N_a} w_{an}\left(\frac{P_{gn}}{P_{g\bullet}}-\frac{1}{A}\right)\right)}{\sum_{a=1}^{A}\left(\frac{P_{ga}}{P_{g\bullet}}-\frac{1}{A}\right)^2}$ $= \frac{p_1' W p_1}{p_1' p_1}$
Cross-group Moran	$Cross\ M_g = \frac{p_1' W p_2}{p_1' p_1}$
B. Localised measures	
Getis and Ord G*	$G^*_{ga} = \frac{\left(W\frac{P_{gn}}{P_{\bullet n}} - \overline{\frac{P_{ga}}{P_{\bullet a}}}\right)}{S\sqrt{\frac{(A\sum_{n=1}^{A} w_{an}^2 - 1)}{(A-1)}}}$ Where $S = \sqrt{\left(\sum_{n=1}^{N_a}\frac{\left(\frac{P_{ga}}{P_{\bullet a}}^2\right)}{A}\right) - \overline{\frac{P_{ga}}{P_{\bullet a}}}^2}$

Note: P_{ga} refers to the population of group g (=1,2,...,G) in area a (=1,2,...,A). A subscript dot refers to the sum over that particular subscript. $\overline{\frac{P_{ga}}{P_{\bullet a}}}$ refers to the mean share of group g in an area, averaged across all areas. Each area a has a set of neighbourhood areas that are indexed by n and numbered from 1 to N_a. w_{an} is an element of an A by A spatial weight matrix W, row standardised by population shares. For the Moran indices, p_i is an A-vector of population shares of group i.

Global fixed boundary measures

One of the most common global fixed boundary measures cited in the literature is the index of dissimilarity (Duncan & Duncan, 1955). The index measures the proportion of people in a population subgroup that would have to relocate in order to make their distribution identical to that of a reference group. When the index is computed between one group and all other groups combined, it is known as the *index of segregation*. Such segregation indices for ethnic groups in Auckland have been calculated by Johnston et al. (2009). The segregation index is simple to calculate, present and interpret but, as with other global indices, provides very limited information on clustering patterns. It does not reveal whether the areas in which a group is over-represented are clustered together, or whether they are spatially dispersed, as on a checkerboard (Brown & Chung, 2006; Johnston et al., 2009). Interpretation of the segregation index is problematic where groups are of different sizes, as the equalizing reallocation of people may then lead to large changes in the populations of areas. We focus on a variant of this index, the *adjusted segregation index*, which indicates the number of "swaps" required to create a spatial distribution for both the target group and non-target group to be equal to the average distribution (van Mourik et al., 1989), while maintaining the size of each area.

Isolation indices provide a different perspective on residential sorting patterns. They measure the extent to which people locate with other members of their own group. We present an index based on the average group-share experienced by members of a group. Consider a group accounting for 5 percent of the population. If spatially segregated, group members may on average live in areas in which, say, 10 percent of the population belongs to the group. Normalising this measure so that it equals 0 when the group accounts for the same proportion of each area, and 1 when they live only in areas where they account for the entire population, we have an isolation index (*IsI*), as in Cutler et al. (1999).

The degree of spatial sorting can be captured by examining how unequal group shares are across areas. The *Gini coefficient* is a commonly-used inequality measure in this context. A Lorenz-type location curve is constructed through plotting the cumulative percentage of group population in an area on the vertical axis and the cumulative percentage of the total population from that area on the horizontal axis, where observations are ordered from the smallest group proportion to the largest group proportion. If a group is identically distributed to the total population, the Lorenz-type curve would coincide with the 45 degree line. The total area between the realised Lorenz-type curve and the 45 degree line gives the Gini coefficient of segregation.

The two final global concentration measures that we consider are the closely-related Ellison & Glaeser (1997) and Maurel & Sédillot (1999) *concentration indices*, denoted EG and MS respectively. Both are derived as the correlation between location decisions made by members of a particular group, which can be positive or negative. The measures were originally derived to capture the geographic concentration of firms within an industry. The formulae shown in Table 1 differ from the original formulations to reflect the focus on people rather than firms. Unlike firms, which differ in size, all people carry equal weight, so that the final term in both the numerator and denominator is $1/P_g$ rather than a Herfindahl index, as in the unweighted index of Maurel & Sédillot (1999). A value of zero for either of these indices would indicate a lack of residential sorting. The two indices differ only in the term shown in parentheses in Table 1. The EG index has a more positive value for groups that are concentrated in areas with higher shares of the overall population, as described in Maré (2005).

Global spatial measures

The measures presented so far do not reflect whether areas of concentration are spatially close to each other, or are in isolated pockets. *Moran's I* is a common global measure of spatial autocorrelation which indicates whether spatial dispersion is random or not. It measures the correlation between individual observations and spatially weighted neighbouring observations.[1] It ranges between -1 and 1. The index can be calculated for various definitions of neighbourhood, to capture the strength of correlation over different distances. Moran's *I* can be calculated as the coefficient on area composition in a regression of neighbourhood composition on area composition (Anselin, 1995; Gibson, 2006), though the standard errors differ from the regression standard errors due to spatially correlated errors.

An analogous *Cross-Moran's I* can be calculated to reflect correlation between a group's concentration in an area and the concentration of another group in the surrounding neighbourhood. The cross-Moran's index may be greater than one in absolute value.

Localised spatial measures

Global measures provide "no information with which to identify the location, size, number and intensity of each group's clusters" (Johnston et al., 2009, p.6). To provide a richer summary of concentration patterns, it is necessary to use localised measures, which can then be projected onto maps to show the geography of concentration. We rely on Getis and Ord's G* index to identify areas of neighbourhood clustering significantly different from the average situation in the total study area (Ord & Getis, 2001; Johnston et al., 2009). The index is a normally distributed *z* score under the null hypothesis of no spatial clustering. A value of G* for an area 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 in a neighbourhood around (and including) an area would be observed if location decisions were random. As with other spatial measures such as Moran's *I*, the distance used for analysis of the neighbourhood can be altered to model clustering at varying definitions of neighbourhood.

Alternative localised measures are possible, but not included in the current study. A localised Moran's LI_{ga} decomposes the global Moran's I into the contributions of each individual area. The sum of all LI_{ga}'s is therefore equal to the global Moran's I value (when the weights matrix has been row-standardized). The Location Quotient (LQ) is another commonly used localised measure based on fixed boundary areas rather than neighbourhoods. The LQ index compares the percentage of a group living in an area to the percentage of that group living in the total study area (Brown & Chung, 2006), indicating whether a group g is over-represented or under-represented in each individual area analysed. We prefer Getis and Ord's G* because it has a clear statistical interpretation, and captures correlations across area boundaries.

Random and systematic segregation

Carrington and Troske (1997) point out that substantial segregation can arise when location is observed across small spatial units, and for groups that account for a small proportion of the overall population. They suggest a modification to standard segregation measures, which they refer to as an 'index of systematic segregation'. This index captures the amount of segregation that occurs in excess of what would occur if allocation across areas were random. For each of the segregation indices listed above, we calculate an analogous measure of systematic segregation. For each population subgroup, we simulate a random allocation using a binomial distribution where the number of group members in an area is simulated based on the actual area population and expected probability equal to the group's share of the total Auckland population. We calculate the value of each segregation measure (Z) in each of 25 independently simulated random allocations. We use the average of these 25 simulations as the estimate of the segregation that would be measured with random allocation (Z_R), and present an index of systematic segregation using the following formula: $Z_{Systematic} = (Z - Z_R)/(1 - Z_R)$. The form of the Isolation Index is already similar to this, so the systematic version is calculated by replacing the actual population share with the Isolation Ratio that would be observed with random allocation, using the following formula: $IsI_{Systematic} = \left(ISR_g - ISR_{g,R}\right)/\left(1 - ISR_{g,R}\right)$.

Data

We used data from the 2006 Census of Population and Dwellings. Unit record data were accessed in the restricted environment of the Statistics New Zealand Data Laboratory under conditions designed to meet the confidentiality and security provisions of the Statistics Act 1975. We examined residential location at the finest available spatial scale – meshblocks. These vary in size, from part of a city block to large areas of rural land. The Auckland Urban Area contains 8629 meshblocks, with an average population size of 137 people. In accordance with strict confidentiality rules, all summary statistics and counts are based on data randomly rounded to base 3.

Our analysis is restricted to people aged over 18 years and living in the Auckland Urban Area, and distinguishes subgroups defined in terms of self-reported ethnicity, age, income, highest qualification, and country of birth.

The variable ethnicity is self-identified, reflecting the group or groups to which people feel that they belong. The main ethnic groups defined in the 2006 Census by Statistics New Zealand are New Zealand European, Pacific Peoples, Māori, Asian and Other. One person can belong to multiple ethnic groups. When we analyse sorting by ethnicity, people stating multiple ethnicities are counted in more than one ethnic group. Grbic et al. (2010) show that the difference between using mutually exclusive ethnic categories and non-mutually exclusive categories as defined here is very small.

Although ethnicity is a standard dimension along which to measure segregation, it is very broad. Asian ethnicity, for instance, encompasses a wide range of different cultures and country groups. Similarly, Pacific ethnicity refers to a number of distinct cultural groups. We therefore also analysed sorting on the basis of country of birth, which provides a somewhat more detailed breakdown. It complements the ethnicity analysis, since country of birth classification masks the diversity and sorting within the New Zealand-born population, and conflates the possibly distinct sorting patterns for recent and established immigrants. Country-of-birth analyses are presented for each of the 10 largest source countries, including New Zealand.

We used two measures of income – personal and household. For each measure, we divide the population into three groups. Personal income was classified as high if over $50,000 per year, low if below $20,000 per year, and medium otherwise, with a quarter to a third of people in each category. Data on personal income was missing for 11 percent of individuals.

Household income was estimated by aggregating incomes within a dwelling and adjusting for the number of people, and was equivalised by dividing total household income by the square root of the number of individuals, as in Atkinson et al. (1995). Where income was 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 was assigned the mean income of other residents at the dwelling. Data on household income was missing for 6.6 percent of individuals. Non-missing values were classified as low if annual household income was below \$20,000 (18 percent of residents), and high if it was above \$55,000 (33 percent of residents).

To measure educational attainment, qualification variables were created based on Statistics New Zealand's highest qualification indicator which combines highest school and post school qualifications. Our results focus on two qualification groups – those with no qualifications, accounting for 17 percent of the population, and those with a degree qualification, referred to as 'high' qualifications (19 percent of individuals).

Age was classified into four general categories: young (18-29), early middle age (30-49), late middle age (50-65) and retired (65 plus).

Geographical coordinates for the centroids of meshblocks were calculated in ArcGis (for meshblocks with multiple shapes, the centroid of the largest shape was used). For the calculation of spatial measures such as Moran's *I,* a row-standardised spatial weight matrix was used. This gives zero weight to meshblocks with centroids further than a defined distance (one kilometre in our main results) from the meshblock centroid and weights 'close' meshblocks in proportion to their populations. Weighting by population ensures that spatial lags of population shares represent the neighbourhood composition. Using a population-weighted, row-standardised weight matrix, the *I* statistic can be calculated as the coefficient on group 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 calculated standard errors under alternative assumptions of standardisation and normality (Cliff & Ord, 1981; Maré, 2005; Pisatio, 2001). All Moran's *I* statistics reported in the paper are statistically significant.

We classified the population on the basis of individual characteristics. Household income was treated as a (shared) characteristic of individuals within a household. Focusing on individuals is a common approach in studies of residential location (Andersson et al., 2009; Cutler & Glaeser, 1997; Eberts & Gronberg, 1981; Reardon et al., 2008), although comparable studies have focused on household characteristics, reflecting the relevance of household decision making for location choice (Bayer & McMillan, 2012; Jargowsky & Kim, 2005; Iceland et al., 2010). Our measures of residential sorting thus included the influence of the sorting of individuals into households, as well as sorting across areas.

Results

The Auckland Urban Area contains a diverse population mix. The first column of Table 2 summarises the composition of the adult population along six key dimensions – ethnicity, age, country of birth, qualification, individual income and household income. Compared with New Zealand overall, Auckland had a high proportion of people identifying themselves as of Asian ethnicities (19.1 percent compared with around 9 percent nationally), and also a low proportion of people born in New Zealand (57.6 percent, compared with 73.2 percent nationally). Aucklanders also had higher incomes and higher qualifications than average.

The remaining columns of Table 2 present global measures of residential segregation, as described above. The overall picture is of relatively strong ethnic sorting, with people identifying with Pacific ethnicities having the highest level of segregation on most measures. These findings are consistent with the findings of Johnston et al. (2009) and of Grbic et al. (2010), who find Pacific to be the most segregated group, with Māori and Asians experiencing lower segregation in more recent times.[2] We extend these previous findings to show evidence of sorting of immigrants by country of birth. We also document less pronounced sorting by personal and household income, by qualification, and by broad age group.

Table 3 contains analogous information to that in Table 2, adjusted for the degree of segregation that would be measured if groups were randomly allocated across meshblocks. Appendix Table 1 shows the index values arising from random allocation. Some of the measures suggest substantial segregation even when there is none. The overstatement is particularly pronounced for small population groups, and for the segregation index, Gini coefficient, and Maurel-Sédillot index. Given these biases, and our interest in small groups such as country-of-birth subpopulations, our presentation and interpretation will rely primarily on the measures reported in Table 3.

Table 2: Global segregation measures: Auckland Urban Area

	Percent of population 18yrs + (%)	Isolation ratio (%)	Isolation index (×100) (%)	Segregation index (%)	Adj Segregation index	Ellison-Glaeser index (×1000)	Maurel-Sedillot index (×1000)	Gini (%)	Weighted Moran (1km)
Ethnicity									
European	60.5	70.5	25.2	42.9	20.5	0.02	0.02	19.5	0.72
Asian	19.1	32.1	16.1	41.5	12.8	0.11	0.15	47.6	0.54
Pacific	11.1	35.6	27.5	58.4	11.6	0.28	0.27	66.0	0.74
Māori	8.3	16.5	8.9	38.4	5.9	0.12	0.11	45.6	0.58
Birthplace									
NZ	57.6	61.3	8.7	24.3	11.9	0.01	0.00	7.0	0.51
UK	7.9	12.4	4.9	31.3	4.6	0.07	0.08	39.1	0.57
PRC	5.5	15.5	10.6	52.7	5.5	0.32	0.39	68.2	0.44
Samoa	3.5	15.8	12.8	63.6	4.3	0.43	0.43	76.7	0.64
India	2.8	9.9	7.3	55.0	3.0	0.34	0.40	72.0	0.38
Fiji	2.7	10.4	7.9	56.5	3.0	0.38	0.43	72.5	0.45
S.Africa	2.0	7.0	5.1	53.4	2.1	0.27	0.34	70.2	0.49
Tonga	1.7	10.9	9.4	70.1	2.4	0.55	0.58	82.6	0.50
Korea	1.6	8.5	7.1	65.4	2.0	0.67	0.80	82.1	0.39
Australia	1.5	3.8	2.3	37.1	1.1	0.04	0.10	49.0	0.15
Income									
Below $20k	33.7	36.3	3.9	15.9	7.1	0.01	0.02	10.2	0.30
$20k - $55k	25.6	27.4	2.4	13.6	5.2	0.01	0.01	8.3	0.26
Above $55k	29.7	35.8	8.7	26.4	11.0	0.03	0.02	21.7	0.59
Household income									
Below $20k	18.1	23.4	6.5	25.6	7.6	0.04	0.05	26.6	0.30
$20k - $55k	42.0	45.6	6.2	19.8	9.6	0.01	0.01	10.8	0.32
Above $55k	33.3	42.2	13.4	31.6	14.1	0.04	0.04	25.8	0.53
Qualification									
None	16.9	22.9	7.2	28.9	8.1	0.04	0.04	29.5	0.65
High	19.4	26.6	9.0	30.6	9.6	0.05	0.05	32.2	0.71
Age									
18-29	24.5	29.7	6.9	21.4	7.9	0.05	0.08	19.6	0.49
30-49	42.1	44.4	4.1	15.2	7.4	0.01	0.00	6.3	0.20
50-65	21.1	23.9	3.6	17.9	6.0	0.02	0.01	18.4	0.29
Over 65	12.3	22.3	11.5	31.5	6.8	0.17	0.18	37.2	0.20

Table 3: Systematic global segregation measures (Carrington & Troske, 1997): Auckland Urban Area

	Percent of population 18yrs + (%)	Isolation ratio (%)	Isolation index (×100) (%)	Segregation index (%)	Adj Segregation index	Ellison-Glaeser index (×1000)	Maurel-Sedillot index (×1000)	Gini (%)	Weighted Moran (1km)
Ethnicity									
European	60.5	70.5	25.2	38.9	17.9	0.02	0.02	19.0	0.72
Asian	19.1	32.1	16.1	36.3	10.5	0.11	0.14	45.4	0.54
Pacific	11.1	35.6	27.5	53.6	9.8	0.28	0.26	63.3	0.74
Māori	8.3	16.5	8.9	30.3	4.2	0.12	0.10	39.8	0.58
Birthplace									
NZ	57.6	61.3	8.6	19.0	9.0	0.01	0.00	6.3	0.51
UK	7.9	12.4	4.9	22.0	2.9	0.07	0.07	32.2	0.57
PRC	5.5	15.5	10.5	44.9	4.1	0.32	0.37	63.1	0.44
Samoa	3.5	15.8	12.7	55.9	3.1	0.43	0.41	70.9	0.64
India	2.8	9.9	7.3	44.1	1.9	0.34	0.37	63.5	0.39
Fiji	2.7	10.4	7.9	45.6	2.0	0.38	0.40	63.8	0.45
S.Africa	2.0	7.0	5.1	39.5	1.2	0.27	0.30	57.8	0.49
Tonga	1.7	10.9	9.3	60.2	1.5	0.55	0.53	74.2	0.50
Korea	1.6	8.5	7.0	53.4	1.2	0.67	0.75	72.9	0.39
Australia	1.5	3.8	2.2	14.4	0.3	0.04	0.05	21.4	0.15
Income									
Below $20k	33.7	36.3	3.8	9.8	4.2	0.01	0.01	8.4	0.30
$20k - $55k	25.6	27.4	2.3	6.7	2.4	0.01	0.00	5.6	0.26
Above $55k	29.7	35.8	8.6	20.8	8.3	0.03	0.02	19.8	0.59
Household income									
Below $20k	18.1	23.4	6.4	18.8	5.2	0.04	0.05	23.2	0.30
$20k - $55k	42.0	45.6	6.2	14.2	6.7	0.01	0.01	9.5	0.32
Above $55k	33.3	42.2	13.3	26.6	11.4	0.04	0.04	24.2	0.53
Qualification									
None	16.9	22.9	7.2	22.2	5.8	0.04	0.03	26.0	0.65
High	19.4	26.6	8.9	24.5	7.2	0.05	0.04	29.4	0.71
Age									
18-29	24.5	29.7	6.9	15.0	5.3	0.05	0.07	17.0	0.49
30-49	42.1	44.4	4.0	9.2	4.3	0.01	0.00	5.0	0.20
50-65	21.1	23.9	3.5	10.8	3.4	0.02	0.01	15.3	0.29
Over 65	12.3	22.3	11.4	24.0	4.8	0.17	0.18	32.8	0.20

Sorting by ethnicity

Residents with Pacific ethnicity accounted for 11.1 percent of the adult population in the Auckland Urban Area. The isolation ratio shows that, on average, they lived in areas where 35.6 percent of the population was Pacific, giving an isolation index value of 27.5. The next-most isolated ethnic group, with an isolation index value of 25.2, was European. On average, they lived in areas that were 70.5 percent European, despite being only 60.5 percent of the population. Although the geographic concentration of minority ethnic groups has been the focus of prior studies, the distinct location patterns of the majority European group are an equally relevant factor in Auckland's population geography. This fact is further reinforced by the adjusted segregation index, which indicates that 17.9 percent of Auckland residents would have to swap places to achieve equal distribution of European and non European populations across meshblocks. Lesser changes would be needed for Asian (10.5 percent) Pacific (9.8 percent) or Māori (4.2 percent).

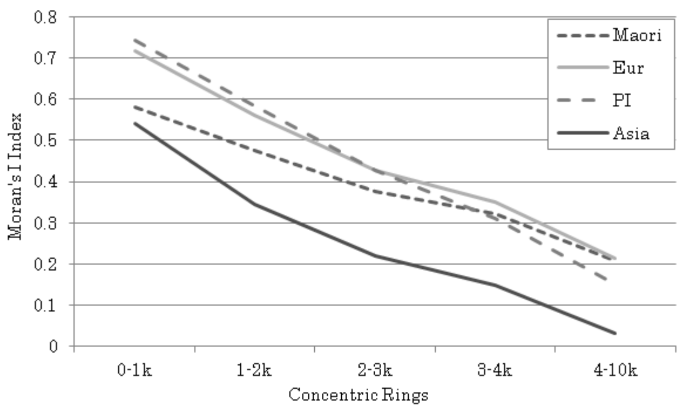
The closely related Ellison-Glaeser and Maurel-Sédillot indices capture the relatively strong correlation between location choices among Pacific peoples. The scale of the indices is affected by the number of spatial units used in the calculations. Due to the fine spatial scale, with over 8,000 meshblocks, the values presented here are much smaller than those reported for industry clustering by Ellison & Glaeser (1997), Maurel & Sédillot (1999) or Maré (2005). We multiplied the index values by 1,000 to improve readability, and we focused on relative index sizes. In contrast to the indications from the isolation and adjusted segregation indices, the correlation of location choices among European residents was much lower than for other groups. The measured isolation of Europeans, and the strength of their segregation, thus reflect the fact that they were numerically dominant, and is not a result of correlated location choices. Asian and Māori ethnic groups had intermediate levels of concentration.

The Gini coefficient shows moderately strong inequality of population shares for all groups, confirming the insights from the other measures. Shares were more unequally distributed across areas for Pacific than they were for Māori or Asian ethnic groups, and least unequal for the European ethnic group.

The final columns of Table 2 and Table 3 present Moran's *I* index, which summarise the extent to which concentrated meshblocks were located close to each other. It thus provides quite different information from that provided by the other global indices. The highest spatial autocorrelation measured by Moran's *I* (0.74) is for the Pacific ethnic group. The value of 0.74 indicates that meshblocks where a relatively high proportion of residents are of Pacific ethnicity are likely to have other high-Pacific meshblocks within one kilometre. The index value for European ethnicity is similar (0.72), indicating that concentrations of Europeans are also likely to extend across contiguous meshblocks. Moran's *I* values for Māori (0.58) and Asian (0.54) groups are not as high, but still suggest strong spatial correlation.

The values of the Moran index presented here are considerably higher than those presented by Johnston et al. (2009), whose study also used 2006 Census data for the Auckland Urban Area. Our study measured spatial association at a smaller spatial scale of one kilometre whereas they used a scale of around four kilometres to ensure that all meshblocks had at least one neighbour.[3] Figure 1 shows the relationship between Moran's *I* and the distance at which neighbourhoods are measured. Results are compared for neighbourhoods defined as concentric rings of varying width around, and distance from, each meshblock. The strength of spatial autocorrelation declined as we captured more distant neighbourhoods and calculated a weighted average across a larger number of meshblocks.[4]

Figure 1: Distance decay in Moran's *I* by ethnicity



The Māori values of the Moran's I index suggest that each ethnic group is concentrated in one or more clusters of neighbouring meshblocks. A single index value is, however, consistent with a broad range of spatial patterns. To understand the patterns that lie behind the global measure, we use a localised measure of concentration – the Getis and Ord G^* index, which is mapped in Figure 2. The darkest shaded areas reveal where each group is most strongly clustered and the lightest shades show areas in which a group is significantly underrepresented. The strongest concentrations of Pacific Peoples and Māori were in the south of Auckland urban area and pockets in the west. Māori clusters extended further down to Papakura. These two groups were underrepresented in northern and central Auckland, as well as in the east. The Asian population was strongly clustered in the eastern suburbs such as Howick, non-coastal North Shore and in central Auckland, most probably due to the large student population in this area. Asian people were largely absent from those areas with high Pacific Island, Māori or European populations such as Titirangi and Devonport (which are largely European areas) and Manukau. European clustering appears to be of a more dispersed form, in addition to Titirangi and Devonport; pockets of clusters occur at Mission Bay and along coastal North Shore.

The maps indicate that people of Māori and Pacific ethnicities have similar spatial distributions. The strength of such relationships can be measured using the Cross-Moran index. Table 4 presents the values of the cross-group Moran index for ethnicity groups.

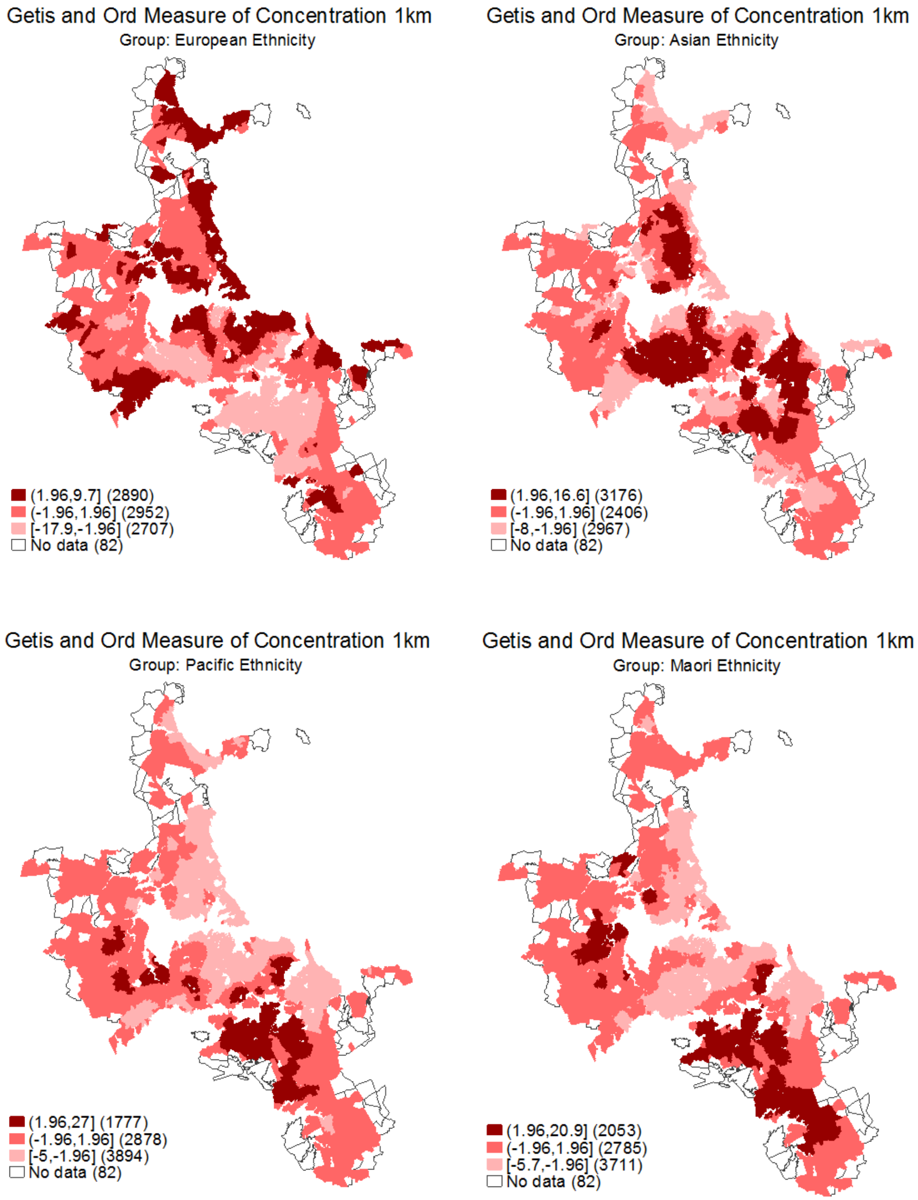
Table 4: Co-location indices – Cross-Morans by ethnicity

	Neighbourhood %			
Meshblock %	European	Asian	Pacific Island	Māori
European	0.716	-0.176	-0.400	-0.112
Asian	-0.426	0.541	-0.078	-0.089
Pacific Island	-0.867	-0.074	0.742	0.204
Māori	-1.000	-0.335	0.843	0.580

Note: Highlighted cells are Own-group Moran's I indexes, as shown in Table 2.

As expected there was a very high index value between Māori and Pacific Peoples of 0.84, indicating that a meshblock with a high Māori proportion will be highly likely to have a neighbourhood strongly represented by Pacific Islanders. Interestingly, the reverse is less true. A meshblock with a high Pacific Islander proportion was not surrounded by a neighbourhood strongly represented by Māori. Both groups tended to locate away from Europeans, as reflected by the negative index values of -1 and -0.867 respectively. Cross-Moran results also confirm that Asians tend not to locate close to European, Pacific or Māori. These results echo the findings of Johnston et al. (2009), who found considerable overlap between Māori and Pacific clusters: three-quarters of meshblocks where Pacific Islanders were over-represented also showed Māori over-representation. Similarly, Johnston et al. (2005) found that 20 percent of Māori lived in meshblocks that were at least 40 percent Pacific in their composition.

Figure 2: Maps of residential segregation in Auckland, by ethnicity, 2006



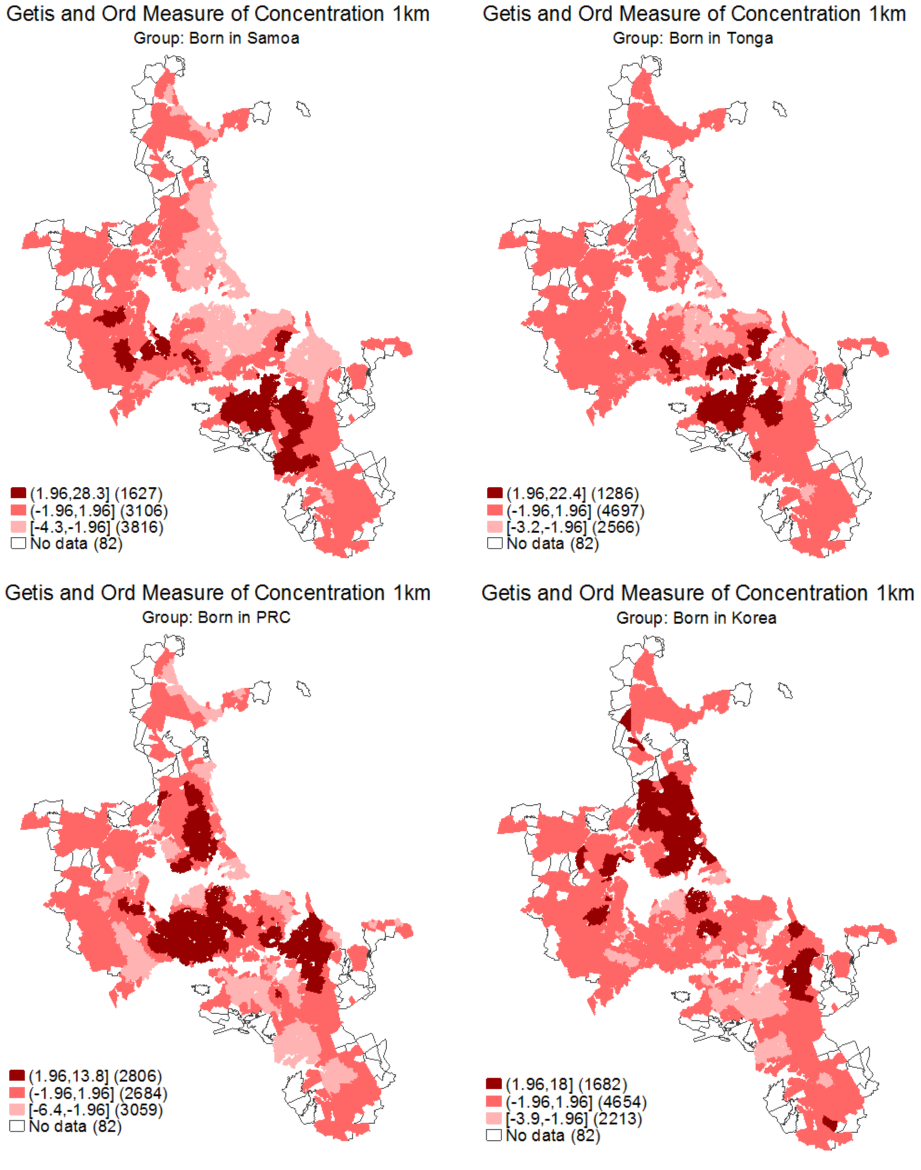
Sorting by other characteristics

One major limitation of measuring sorting on the basis of ethnicity is that ethnic classification are very broad, and may obscure patterns of sorting within or between ethnic subgroups. To complement the analysis of ethnic sorting, we therefore present summary measures of sorting by the 10 main countries of birth.

There is not a simple relationship between ethnic and country of birth classifications. All ethnicities are represented among the New Zealand born, and other countries also have more than one dominant ethnic grouping, as in the case of Fiji, which contains substantial subpopulations of Asian (Indian) and Pacific ethnicity. Furthermore, sorting by country of birth will reflect the residential patterns of recent migrants, which may differ from those of their more established compatriots.

The country-of-birth patterns presented in Table 3 show residential segregation of immigrants from each of the 10 main source countries. The strength of segregation is, however, particularly strong for Samoan and Tongan immigrants, and for Korean and Chinese (PRC) immigrants, consistent with the ethnicity results for Pacific and Asian groups. The value of the isolation index is highest for Samoan (12.7) immigrants and also high for Tongan (9.3) immigrants. These groups also have high values of EG and MS indices. Furthermore, both Samoan and Tongan neighbourhoods extend over adjacent meshblocks, with values of Moran's I index of 0.64 and 0.50 respectively, though neither is individually as spatially correlated as the Pacific ethnicity group overall, reflecting that Samoan and Tongan neighbourhoods tend to be close to each other. The similarity of Samoan and Tongan spatial distributions to each other, and to the distribution of residents of Pacific ethnicity, is shown in the upper panels of Figure 3.

Figure 3: Maps of residential segregation in Auckland by selected countries of birth, 2006

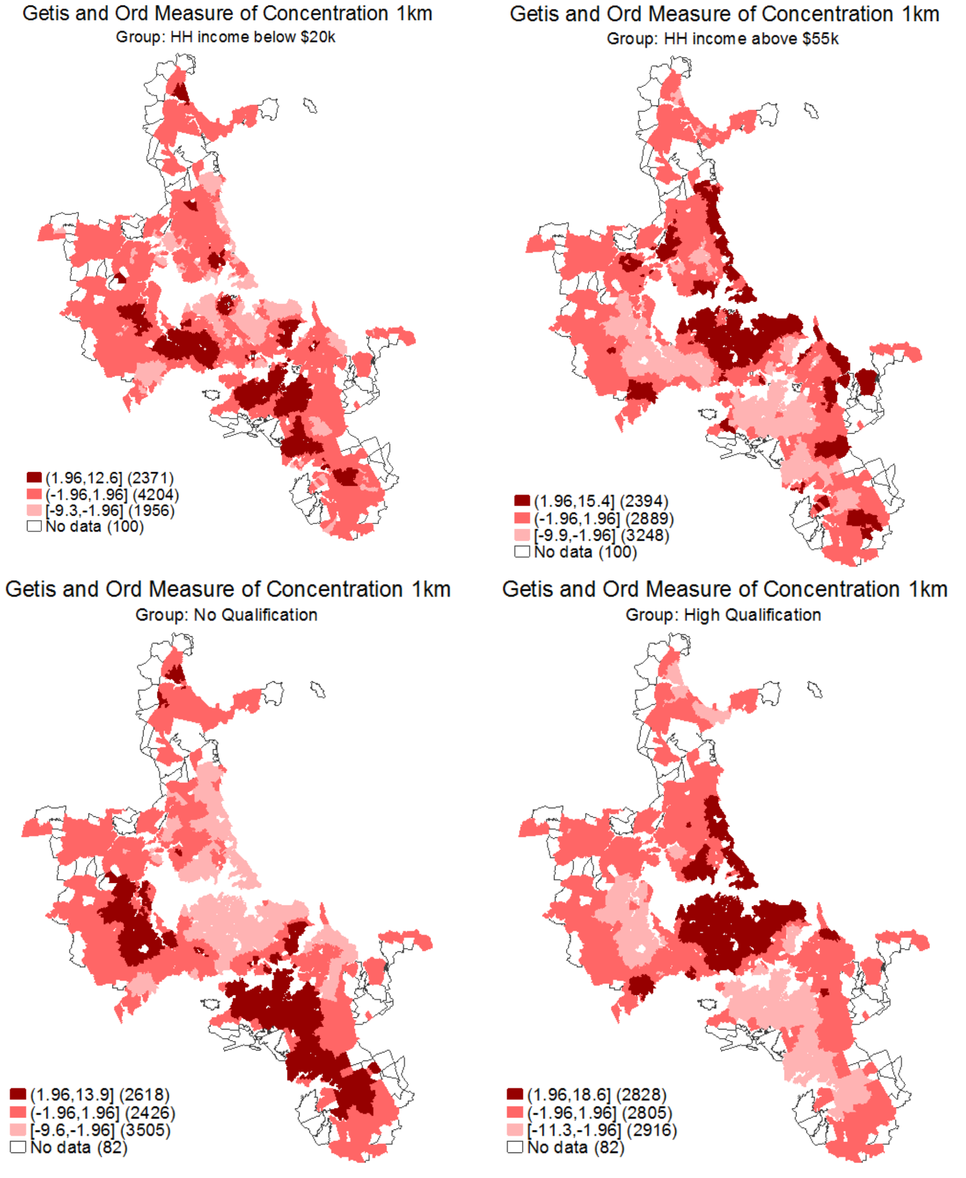


Korean immigrants showed the strongest correlation of location decisions, as measured by the EG and MS indices, though the degree of spatial autocorrelation (Moran's *I* of 0.39) was not as strong as for other country of birth groups. This suggests that Korean immigrant segregation may occur in a number of spatially separate pockets (see Figure 3). The spatial distributions for two of the main source countries for the Asian ethnic group, Korea and the People's Republic of China, differ markedly. The distribution of immigrants from India (not shown), another significant source country for the Asian ethnic group, has a distinct pattern that overlaps with but does not coincide with either the Chinese or Korean patterns. The distribution of the Asian ethnic group therefore provides a poor indication of the distribution of the distinct country-of-birth communities that it contains. Finally, immigrants from the UK and from South Africa displayed relatively low levels of isolation, segregation and concentration, but they sorted into neighbourhoods that were spatially close to each other, as indicated by relatively high values of Moran's *I*.

Sorting on the basis of ethnicity and country of birth is considerably stronger than sorting on other factors tabulated in Table 3, such as income, qualification and age. Residents with high or low levels of personal or household income were more segregated than those with intermediate income levels. High income earners and those in households with high equivalised household income displayed the greatest sorting, and the highest degree of spatial autocorrelation. Sorting on the basis of income is consistent with housing market stratification – an interpretation that is reinforced by the fact that sorting on household income is more pronounced than that on personal income. There is also consistent evidence of sorting on the basis of education. A person's highest qualification is correlated with lifetime income, and is a less volatile measure than annual income, and may thus be more correlated with housing choices. Segregation was somewhat stronger for residents at the upper end of the qualification and personal and household income distributions than for low-income residents and those with no qualifications.

The maps in Figure 4 show the similarities between the distribution of residents with low household income and those with no qualifications, and between the degree-qualified and those with high household income.

Figure 4: Maps of residential segregation in Auckland by household income and highest qualification, 2006



The final panel of Table 3 show patterns of sorting by age. The most pronounced sorting is evident for residents over the age of 65 years, who showed moderately strong isolation, segregation and concentration. However, in contrast with other concentrated groups, the degree of spatial autocorrelation is particularly low for older residents. A likely explanation for this pattern is the existence of small geographic retirement villages and communities that house a larger number of older citizens. In addition, the older members of the 65+ group often move to be close to facilities such as hospitals and social services (see e.g. Baxendine et al., 2005). At a meshblock level, this is picked up by the fixed boundary global indices. However because these are usually small compact areas, clustering at a neighbourhood level, as reported by a Moran's *I,* will undoubtedly be much lower.

Ethnicity and income

Actual patterns of residential sorting are, of course, more complex than is implied by group-specific measures. Particular individuals may belong to more than one subgroup shown in Table 3, and may potentially belong to groups with quite different patterns of residential sorting. The groups may have different degrees of sorting as well as being concentrated in different areas. A fuller understanding of residential patterns in the Auckland Urban Area could be built from examining the interactions and relative strengths of the different influences. In this section, we confine ourselves to a comparison of sorting by ethnicity and by income.

Māori, Pacific and Asian ethnic groups have relatively low average personal and household incomes. Table 5 provides a summary of the differences. Median incomes for Asian residents are 60 to 70 percent of the overall Auckland median. Comparable figures for Pacific and Māori residents are around 80 percent and 90 percent respectively. There is, however, considerable income diversity within each ethnic group. Thirty percent of Auckland residents have incomes over $50,000. Although Asian, Pacific and Māori ethnic groups have lower median incomes, there is still a sizeable proportion of each ethnic group with high incomes (17 percent, 14 percent, and 24 percent respectively). We examine whether members of these ethnic groups live near neighbourhoods that reflect their income or their ethnicity.

Table 5: Income distribution by ethnicity, 2006

	Total popn	Euro (%)	Asian (%)	Pacific (%)	Māori (%)
Median income	$28,700	120	59	79	94
Median hhold income	$43,000	117	72	80	92
Personal income (%)					
Low (below $20k)	34	30	50	38	34
Medium ($20-$50k)	26	26	25	33	33
High (over $50k)	30	40	17	14	24
Missing	11	4	8	15	10

The maps in Figure 2 to Figure 4 highlight similarities between the location patterns of Pacific ethnicity, and country of birth groups and those of low personal income or low qualification groups. We will examine whether high-income Pacific residents had similar locational distribution to the Pacific ethnic group generally. There is a less clear visual similarity between ethnic-based and income-based sorting for Asian residents. Although the Asian ethnic group had the lowest median incomes, the locations of concentrations of Asian residents bore some similarity to those of high-income residents. The lack of clear concordance may reflect the cultural and country diversity within the Asian ethnic group, particularly combining low income tertiary students with households of skilled migrants.

Table 6 presents values of Cross-Moran indices for sub-populations defined by ethnicity and income. The first column shows the strength of correlation between the ethnicity-income groups and the presence of people of similar ethnicity in surrounding neighbourhoods. The indices are strong and positive for all ethnicity-income groups. The first block shows the patterns for Asian residents. The first entry is the Moran's I index, shown in Table 4, for the relationship between the concentration of Asian residents in a meshblock and the presence of Asians in surrounding meshblocks (within one kilometre). The relationship is even stronger when we consider the relationship between the presence of low-, medium- or high-income Asian residents in a meshblock and the prevalence of Asians in surrounding meshblocks. A similar pattern is evident for the other ethnic groups.

Columns 2 to 4 of Table 6 show whether the subgroups locate near residents with similar income levels. The relationships are relatively weak, with no strong evidence of income sorting within any of the ethnic groups.

The most notable pattern is that while high income Asian residents are surrounded by high income neighbourhoods, this is not the case for Māori and Pacific Islanders. The final three columns of the table show a starkly different pattern, with uniformly positive index values. These suggest that co-location near other members of one's ethnic group is a strong pattern, regardless of personal income level of a meshblock or of the surrounding neighbourhood.

Table 6: Co-location indices – Cross-Morans by ethnicity and income

Meshblock %		**Neighbourhood % (Income)**					
Asian		Low-	Med-	High-	Low-Asian	Med-Asian	High-Asian
Total Asian	0.54	0.13	0.02	-0.11	0.29	0.13	0.09
Low-income	0.90	0.23	-0.02	-0.18	0.49	0.21	0.13
Med-income	1.62	0.34	0.06	-0.39	0.82	0.42	0.26
High-income	2.01	0.22	-0.10	0.11	0.98	0.49	0.42
Pacific		Low-	Med-	High-	Low-Pacific	Med-Pacific	High-Pacific
Total Pacific	0.74	0.09	0.09	-0.40	0.30	0.24	0.06
Low-income	1.62	0.21	0.17	-0.86	0.66	0.52	0.14
Med-income	2.05	0.26	0.26	-1.12	0.82	0.67	0.18
High-income	4.60	0.50	0.67	-2.52	1.81	1.52	0.45
Māori		Low-	Med-	High-	Low-Māori	Med-Māori	High-Māori
Total Māori	0.58	0.08	0.21	-0.61	0.22	0.21	0.07
Low-income	1.16	0.24	0.39	-1.34	0.46	0.41	0.12
Med-income	1.33	0.20	0.51	-1.40	0.50	0.48	0.16
High-income	1.31	-0.17	0.52	-0.77	0.45	0.48	0.22

Summary

The purpose of this paper was to answer three key research questions: First, what is the nature and strength of residential sorting in Auckland? Second, how does this differ for different socio-economic groups? Third, what is the relative strength of sorting by income and by ethnicity?

We have presented a range of empirical indicators to capture different aspects of residential location patterns across the Auckland Urban Area in 2006. We showed that, especially for small population groups and small geographic areas, some of these indices identified segregation even when population groups were randomly allocated across areas. Our main table of results (Table 3) therefore presents measures of 'systematic segregation', which control for this bias, adopting the approach of Carrington and Troske (1997).

Our main findings with respect to ethnic segregation in Auckland confirm and extend the findings of previous studies. We confirm relatively strong residential sorting for the Pacific ethnic group, and for residents of Asian ethnicity, and a tendency of Māori and Pacific ethnic groups to co-locate. There is also evidence of pronounced sorting of the numerically dominant European ethnic group, although the Ellison and Glaeser (1997) and Maurel and Sédillot (1999) concentration indices show that this does not reflect strong correlation of location choices. We present new evidence on the segregation of immigrants, classified by country of birth. This reveals particularly strong sorting for Korean immigrants, though with less strong spatial autocorrelation than is observed for other groups. The residential patterns of Samoan and Tongan immigrants are characterised by strong isolation, segregation, concentration, and spatial autocorrelation.

We also report measures of sorting by personal and household income, by highest qualification, and by age. None of these groupings shows sorting of the same strength as seen for ethnic and country-of-birth groups. There is evidence of moderate residential segregation by income and qualifications, which is strongest at the top and, to a lesser extent, at the bottom of the income and qualifications ranges. Finally, age segregation is most pronounced for older residents, who are concentrated within meshblocks, though with relatively weak spatial clustering of high-concentration meshblocks.

We explore the relative strength of sorting by income and sorting by ethnicity, through the use of Cross-Moran indices of co-location. Asian, Pacific and Māori ethnic groups are sub-classified according to personal income levels. The location of ethnicity-income subgroups is more strongly related to neighbourhood ethnicity than to neighbourhood income composition.

We will be examining further the patterns of residential segregation by country of birth, to test for evidence that immigrants become more spatially dispersed over time as they become more integrated. We also hope to extend our work to look at the consequences of residential segregation in Auckland on socioeconomic outcomes. This further work will be able to highlight potential policy responses that may be considered in response to our findings.

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Notes

1 Formally, Moran's *I* is calculated as a covariance, scaled by the variance of individual area values, although it is referred to as a measure of spatial autocorrelation.

2 Johnston et al. (2009) estimate an index of isolation, index of segregation, Moran's *I* and G* to the four main ethnic groups over the last four census years from 1991-2006. Grbic et al. (2010) examine the levels of segregation between ethnic minority groups and Europeans using an index of dissimilarity and index of exposure, another basic global index which has not been presented in this paper.

3 We are grateful to Mike Poulsen and Ron Johnston for their generous assistance in identifying the reasons for the differences. In our calculations, 290 meshblocks have no neighbours within one kilometre, and so are omitted from our calculations.

4 Using a one kilometre radius, neighbourhood composition is based on an average of 42 meshblocks. Circle geometry leads to larger numbers for more distance concentric rings: 105 meshblocks within 1-2 kilometres, 191 meshblocks within 2-3 kilometres, 289 meshblocks within 3-4 kilometres, and 1785 meshblocks within 4-10 kilometres. The total number of meshblocks in the Auckland Urban Area is 8,629.

Appendix Table 1: Segregation Indices calculated based on random allocation

Subgroup share of total population (%)	Isolation Ratio	Isolation Index (*100)	Segreg-ation index (*100)	Adj Segreg. index	Ellison Glaeser index (*1000)	Maurel-Sedillot index (*1000)	Gini	Moran (1km)
%	%		%	%			%	
1	1.1	0.06	32.4	0.6	0.00	0.08	44.0	0.00
2	2.1	0.06	23.0	0.9	0.00	0.04	29.2	0.00
5	5.1	0.06	14.8	1.4	0.00	0.02	14.9	0.00
10	10.0	0.05	10.8	1.9	0.00	0.01	8.2	0.00
15	15.0	0.06	9.0	2.3	0.00	0.00	5.4	0.00
20	20.0	0.05	8.1	2.6	0.00	0.00	3.9	0.00
30	30.0	0.04	7.0	2.9	0.00	0.00	2.3	0.00
60	60.0	0.03	6.6	3.2	0.00	0.00	0.7	0.00

Note: Index values are calculated by randomly allocating population subgroups of varying sizes to meshblocks within the Auckland Urban Area, using total meshblock population as observed in 2006. The reported values are based the average of values from 25 independent random allocations using a binomial (n,p) distribution with n=meshblock population and p=subgroup population share.

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