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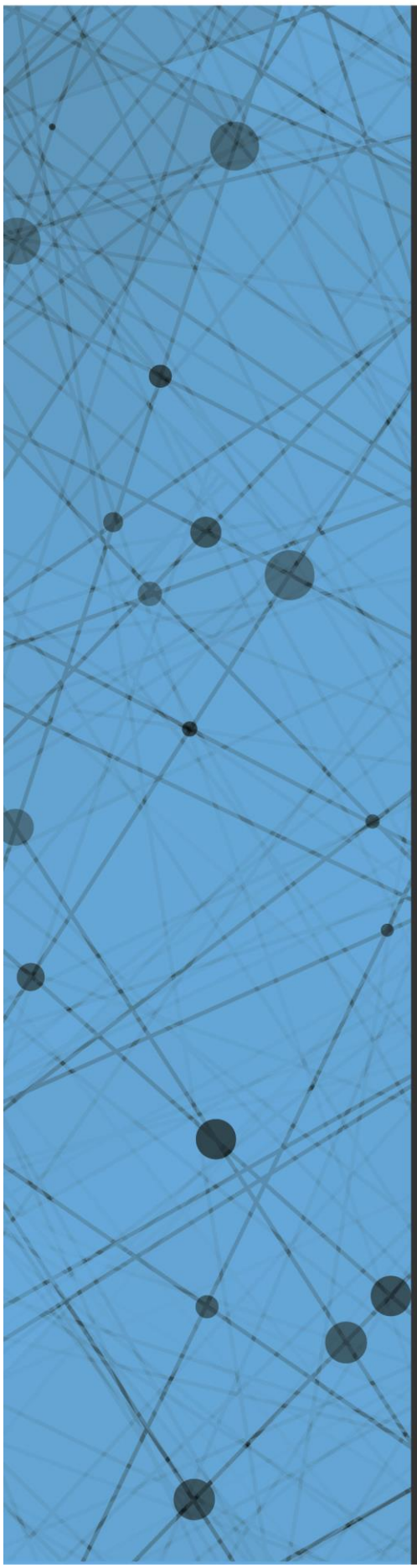

Commuting to diversity

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Disclaimer

Access to the data used in this study was provided by Statistics New Zealand under conditions designed to give effect to the security and confidentiality provisions of the Statistics Act 1975. All frequency counts using Census data were subject to base three rounding in accordance with Statistics New Zealand's release policy for census data. The views, opinions, findings and conclusions or recommendations expressed in this paper are strictly those of the authors and do not necessarily represent, and should not be reported as, those of the organizations at which the authors are employed.

Abstract

Does commuting increase workers' exposure to difference and diversity? The uneven spatial distribution of different population subgroups within cities is well documented. Individual neighbourhoods are generally less diverse than cities as a whole. Auckland is New Zealand's most diverse city, but the impacts of diversity are likely to be less if interactions between different groups are limited by spatial separation. Studies of spatial sociodemographic diversity generally measure the diversity of local areas based on who lives in them. In this study, we examine measures of exposure to local cultural diversity based on where people work as well as where they live. Our measure of cultural diversity is based on country of birth, with ethnicity breakdowns for the New Zealand (NZ) born. The study also examines whether the relationship between commuting and exposure to diversity differs between workers with different skills or types of job. The study focuses on diversity and commuting patterns within Auckland, using 2013 census microdata, and using local diversity measures calculated for each census area unit. We find that commuters who self-identify as NZ-born Europeans and residents born in England (together accounting for close to half of all commuters) are, of all cultural groups, the least exposed to diversity in the neighbourhoods where they live. Overall, commuting to the workplace raises exposure to cultural diversity, and to the greatest extent for these two groups.

JEL codes

J15, R23

Keywords

Cultural diversity; exposure to difference; exposure to diversity; residential segregation; commuting; Auckland

Summary haiku

You travel to work
and meet people unlike you.
Pākehā gain most.

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Tables and Figures

1 Introduction

Auckland is New Zealand's largest city, and one of the most diverse cities in the world. According to the 2013 Census of Population and Dwellings, roughly 40 percent of Auckland's population was born overseas, and Auckland was host to more than 200 different ethnic groups (Mondal, Cameron, & Poot, 2019). Studies of the economic impacts of diversity have identified a range of ways that such diversity might improve economic performance through innovation and productivity, and might improve the quality of life experienced by residents (Kemeny & Cooke, 2018; Ottaviano & Peri, 2006; Page, 2007). However, realising these potential gains may be contingent on other factors such as institutional quality or social capital (Kemeny & Cooke, 2017). It also depends on meaningful interactions taking place between dissimilar people. Previous research has documented residential segregation within Auckland, by ethnicity (Johnston, Poulsen, & Forrest, 2011) and by country of birth (Maré, Pinkerton, Poot, & Coleman, 2012), which could limit the realisation of gains from diversity.

The current study re-examines the spatial mixing of populations within Auckland, using data from the 2013 Census of Population and Dwellings.[1] It focuses on how location patterns affect people's exposure to difference and exposure to diversity. Whereas previous studies have relied on measures of isolation or segregation to summarise the degree of non-randomness of the spatial distribution of the population, we report measures that capture the probability that people live or work in areas where interactions are likely to be between a diverse range of cultural groups.

There are three novel aspects of our study. First, we measure diversity based on a combination of birthplace and ethnicity, and second, we measure diversity not only in the areas where people live but also in the areas where they work. The third novelty is that we examine the contribution of commuting patterns to peoples' exposure to diversity.

Section 2 summarises the existing literature on Auckland's residential sorting patterns, and key insights from the international literature that looks at exposure to diversity from both the residence and workplace perspective. Section 3 introduces the 2013 census data that we use, and the measures of exposure to difference and diversity that we analyse in section 4. The key insights from our analysis are discussed in section 5.

[1] Corresponding data from the 2018 Census were not yet available at the time of writing.

2 Literature Review

2.1 Residential location patterns in Auckland

More than a dozen empirical papers have been written in the past 16 years documenting the patterns of residential segregation and sorting in Auckland, mostly focused on ethnic segregation.[2], A recurrent finding is that, as in most urban areas, there is pronounced spatial sorting. A consequence of this sorting is that the degree of diversity experienced by any ethnic group is strictly less than city-level diversity – their local interactions are disproportionately with other members of their own group. The broadly defined Pacific ethnic group is generally found to be the most strongly clustered group, as measured by various measures of segregation.

All of the papers listed in footnote 2 use data from the Census of Population and Dwellings, from some subset of the five censuses from 1991 to 2013. A strength of the census data is that residential location is observed for very small geographic areas (meshblocks) with an average population of around 100. It also contains detailed coding of relevant indicators of socio-cultural groups, including ethnicity, and country of birth. There is, of course, a drawback of analysing small groups in small areas, in that counts of group members can be very small or zero in many meshblocks, yielding high variability in summary measures of residential segregation. This problem is magnified by the confidentiality requirement to randomly round or suppress small counts of groups within meshblocks. Most studies have therefore relied on very broad ethnic groupings (European, Māori, Pacific, Asian), or have focused attention on only the largest ethnic or country-of-birth groups, or have analysed patterns across larger 'area units', with an average population size of around 2,000 (Ishizawa & Arunachalam, 2014; Maré, Pinkerton, & Poot, 2016; Mondal et al., 2019).

One of the limitations of the existing studies is that they analyse data that are classified by administrative or statistical boundaries. As a result, they face the 'modifiable areal unit problem' (Gehlke & Biehl, 1934; Openshaw, 1984), with the implication that the patterns that they show may not occur at different spatial scales. Only a few of the Auckland studies have investigated the spatial scale of segregation, reporting statistics such as Moran's I, mapping Getis and Ord's G* LISA measure (Johnston et al., 2011; Maré et al., 2016, 2012), or comparing measures at different spatial scales (Manley, Johnston, Jones, & Owen, 2015). Internationally, recent studies have developed methods to addressed the spatial scale of segregation more directly. Olteanu et al (2019) capture the spatial scale of segregation by measuring how quickly the population composition of a location converges to the city-wide composition, as segregation is measured over gradually increasing circles. They propose an index (named a "distortion coefficient") that

[2] See (Grbic, Ishizawa, & Crothers, 2010; Ishizawa & Arunachalam, 2014; Johnston, Poulsen, & Forrest, 2002, 2003, 2005, 2007, 2008, 2011; Manley, Johnston, Jones, & Owen, 2015; Maré & Coleman, 2011; Maré, Coleman, & Pinkerton, 2011; Maré, Pinkerton, & Poot, 2016; Maré, Pinkerton, Poot, & Coleman, 2012; Mondal, Cameron, & Poot, 2019; Poulsen, Johnston, & Forrest, 2000)

summarises, for each location, how close the convergence trajectory is to what would result from complete separation of sub-groups (distortion=1), relative to random allocation of all groups (distortion=0). This novel approach captures spatially varying patterns of segregation but has not yet been extended to fully capture spatial variation in exposure to diversity, which depends on the diversity of the city-wide population, as well as the degree of residential segregation. In the illustration provided by Olteanu et al., population composition is identified on the basis of four ethnic groups, which provides only a limited view of diversity.Even among studies that rely on aspatial (boundaried) areal units, the focus is often on segregation rather than exposure to diversity, and often for a small number of distinct groups. Following the segregation focus of Massey and Denton (1988) and Lieberson (1981), some studies have considered pairwise exposure of particular groups to other groups (Johnston, Poulsen, & Forrest, 2003, 2008; Maré et al., 2012), or to the dominant (European) group (Grbic, Ishizawa, & Crothers, 2010), but have not translated this into exposure to diversity *per se*. Reardon et al (2008) take an explicitly spatial approach to measuring pairwise exposure, calculating pairwise segregation indexes across four ethnic groups, using bespoke neighbourhoods. The strength of segregation at each location is calculated based on employment composition in the surrounding neighbourhood, where the size of the surrounding neighbourhood is varied – from a radius of 500 metres, to a radius of 4 kilometres. They show clearly that the comparison of measures at different radii provides richer information about the spatial configuration of segregation. However, there is a high (0.92-0.99) correlation between measures taken at different radii, suggesting that cross-area comparisons based on one spatial scale provide a meaningful indication of relative exposure to diversity.

In our study, we follow the aspatial approach of relying on administrative boundaries, extending the existing literature by focusing on exposure to diversity, using a more detailed breakdown of cultural groups that combines country of birth and, for the New Zealand born, ethnicity as well.

Our study is also only the third study to use 2013 census data (the others are Mondal et al (2019) and Manley et al (2015)). Finally, our study extends the New Zealand literature on residential segregation not only by examining its implications for exposure to diversity, but also by jointly looking at exposure at place of residence and exposure at workplace. Combining residential and workplace segregation or exposure to diversity has not been examined in New Zealand, but is an active area of research internationally, which we review in the next sub-section.

2.2 Non-residential exposure to diversity

The hypothesised benefits of diversity are contingent on social interactions actually occurring, particularly face-to-face, because this permits tacit knowledge exchange and the building of trust

(e.g. Page, 2007). As noted by Ellis et al. (2004), the literature on segregation has privileged residential location over other spheres of potential interaction, such as workplace, commuting, shopping, church, or sports and recreational areas. This limitation of focus reflects not only data availability but also empirical tractability.

The simple idea of people 'bumping into each other' is relatively straightforward to capture if we restrict attention to a single spatial (residential) sphere of interaction. More generally, because people are mobile, identifying potential interactions requires tracking of *all* people across space and time. Hägerstrand (1970) characterised this challenge as "a hard nut to crack", and established a conceptual and analytical framework that has underpinned subsequent studies of 'time geography' in social sciences, ecology, and biological science. In the context of segregation and social exposure, there continues to be active development of methods and measures to realise the promise and challenges of analysing spatial, temporal, and socio-demographic dimensions of 'social interaction potential' (Farber, O'Kelly, Miller, & Neutens, 2015). Marcińczak et al (2015) provide a good summary of the relevant literature.

Empirical studies of segregation exemplify the challenges of engaging with the complexity of interaction patterns that vary simultaneously across space, over time, and between socio-demographic groups. There are three main strands of the empirical literature, reflecting different data collection approaches – space-time surveys, mobile phone data collection, and analysis of register data.

There is a well-established literature using space-time surveys to capture the range of locations in which people spend their time, and hence in which they may be exposed to other groups (Janelle & Goodchild, 1983; Le Roux, Vallée, & Commenges, 2017; Park & Kwan, 2018; Wong & Shaw, 2011). Such studies often combine sample information about location and demographic characteristics with external data about the sociodemographic characteristics of locations. The common finding is that residential segregation is more pronounced than the segregation that people experience when they are away from home.

Recent advances in data availability and computing have supported a number of innovative studies. Data from social media platforms can be used to identify and analyse diversity within friendship networks (e.g. Barker, 2012; Seder & Oishi, 2009), though such studies have generally focused on small samples, and lack a geographic focus. Large datasets of mobile phone locations and movements provide exceptionally rich information on 'activity-spaces'. Östh et al (2018) analyse the changing geographic locations of approximately 1.2 million phones in Sweden over a 24 hour period. Each phone is associated with a 'home' location, based on the phone mast nearest its location between midnight and 7:20am, and is allocated the socioeconomic characteristics of a bespoke (800 nearest neighbours) neighbourhood around the home location. These data enable the authors to track each phone's exposure to other phones not only at the home location, but throughout the day, taking into account who else was at the

same location at the same time. The study finds that diurnal mobility reduces segregation by poverty and wealth.

Galiana et al (2018) use mobile phone data for selected French cities and examine segregation in social networks, as captured by phone calls made between locations with the same median incomes. Geocoded person-level income information is aggregated to bespoke neighbourhood cells of 500m by 500m. As in Östh et al (2018), the focus is on segregation, with personal characteristics proxied by areal averages or medians.

Other studies using mobile phone data capture person-level characteristics from sources such as phone language-settings that are available from the phone tracking data (Silm & Ahas, 2014), or from phone apps, which enable the collection of some additional personal or locational information by survey. To date, such studies have been limited by fairly small sample sizes (Palmer, 2013; Yip, Forrest, & Xian, 2016), and also rely on external data sources for data on neighbourhood characteristics. Methods for summarising and analysing the data from phone apps and phone tracking continue to evolve as these data are increasingly used (Palmer, 2013).

As with the diary studies, the consistent conclusion from mobile-phone-based studies is that residential (night-time) segregation is more pronounced that segregation at other times of day, with segregation measured along a variety of dimensions such as ethnicity, income, wealth, or language.

The strand of the empirical literature that is closest to our own is the use of population register data. The advantage of these studies is that they capture information for a full population, usually coded to fine (100m by 100m grid) location information. However, compared with the survey and mobile-phone approaches, register-based studies contain more limited information on space-time movements. Data are generally available for residential contexts (neighbourhood, family) and workplace only.

Tammaru et al. (2016), for instance, uses Swedish population register data to examine immigrant men's and women's exposure to native-born Swedes at their workplace as well as in their neighbourhood of residence and within their household. They find that employed immigrants have greater exposure (lower segregation) in residential neighbourhoods than at their workplaces. This finding contrasts with the findings from travel diary studies, which find the reverse. The difference may reflect the different urban contexts of the studies, or may be a result of restricting attention to employed residents, whose composition and residential location patterns may differ from that of the full resident population.

Boterman and Musterd (2016) use register data from the Netherlands, and examine exposure to diversity in residential neighbourhoods and workplaces. Neighbourhood diversity is calculated for areas of around 3,000 people and workplace diversity is identified from co-workers in the same firm. In addition, the authors combine register data with information on mode of transport from a large transport survey, to capture exposure to diversity while

commuting. They measure diversity across nine groups defined by income level (three groups) and birthplace (three groups). As in Tammaru et al. (2016), they find that, for employed residents, exposure to diversity is greater in residential neighbourhoods than at workplaces, although there is greater variation in workplace exposure. They also find that high-income native-born Dutch people are the most 'cocooned' – having lower exposure to diversity than most other groups (except for low-income native-born Dutch), and more likely to travel by car.

Our study is most similar in scope to the register-based studies, using full-coverage data, and focusing on only two activity-spaces – residential neighbourhood and workplace neighbourhood, both captured at the individual level, with detailed geographic location information. Like Boterman and Musterd (2016), we analyse exposure to diversity in each place. We also examine the combined exposure that employed residents experience.

3 Data and methods

3.1 New Zealand census data

We use data from the 2013 Census of Population and Dwellings. In order to analyse detailed birthplace and ethnicity data at a fine spatial scale, analysis was undertaken using census microdata available in the Statistics New Zealand Datalab.[3] Birthplace and ethnicity information is available for each person, and residential information is available at a fine geographic level – (census meshblock). There are 10,415 meshblocks within the Auckland urban area, with a median area of around 3.6 hectares (190m by 190m), and mean population of around 125. In most cases, workplace is also captured at the meshblock level, enabling commuting times to be calculated for over 20,000 potential origin-destination pairs. As described below, diversity measures are calculated by grouping meshblocks into larger administrative units, 'census area units', with median area of 4169 hectares (1.3km by 1.3km) and mean population of around 3,600. These are similar in size to the definition of neighbourhoods used by Boterman and Musterd (2016), and at the small end of the size range of 'local environments' considered by Reardon et al (2008).

3.1.1 Sample selection

In order to examine the effect of work-related commuting on a person's isolation or exposure to diversity, we focus on employed residents of the Auckland urban area who also work within the Auckland urban area. As shown in Table 1, there were 1,035,150 adult usual residents of the Auckland urban area in 2013. Measures of residential diversity are based on this full population. Workplace diversity is measured using information on the 531,117 workers who are employed

[3] Access to census microdata is subject to strict conditions and requirements. See the disclaimer footnote at the start of the paper.

in the Auckland Urban area. This number includes 30,108 workers who commute into the Auckland urban area from elsewhere.

In order to examine the interaction of residence and workplace diversity, we focus more narrowly on a subset of the 501,009 Auckland urban area residents who also work in the Auckland urban area.[4] The subset we consider are those for whom we have non-missing income and dwelling information, and sufficiently precise (area unit or meshblock) workplace location information. Omitting 68,184 observation with missing information, 473,559 employed residents remain in our main analysis data set.

3.1.2 Capturing cultural diversity

We create measures of cultural diversity based on Aucklanders' reported country of birth and ethnic self-identification. Such statistical measures of cultural diversity will always be imperfect. There can be cultural diversity among people who have the same birthplace and ethnic identity, based on e.g. language, ancestry, religion or customs. Conversely, people from different birthplaces and with different ethnic identities can be culturally very similar. Nevertheless, like most of the literature, we use these observable characteristics as reasonable proxies for true but unobserved dimensions of cultural diversity.

Birthplace diversity is calculated based on detailed country of birth coding. In most cases, a specific country of birth is recorded. However around 6 percent of adults failed to specify any country of birth, and others reported birthplace ambiguously or regionally. When coding birthplace, we aggregate countries that individually account for less than 0.2 percent of the national adult population, which we combine with region-of-birth codes. Our final birthplace codes identify the most common 24 individual countries of birth, which account for 87 percent of the Auckland adult resident population. A further 6.6 percent of the population are classified into one of 13 aggregated groupings, with the 6.5 percent who did not state a birthplace treated as a separate category.[5] There are thus 38 distinct birthplace categories.

New Zealand born residents account for 49 percent of the adult population in the Auckland urban area. We disaggregate this group into 12 distinct subgroups based on ethnic identification (5-digit coding[6]). The 2013 census codes up to 6 responses for each person. We treat each unique combination of responses as a distinct ethnic classification.[7] Any classification accounting for fewer than 0.2 percent of the adult population nationally is aggregated

[4] These 'intra-urban commuters' account for 92 percent of those whose workplace could be coded to an area unit. This calculation excludes 57,612 employed residents of the Auckland urban area whose workplace cannot be coded to a specific area unit. Many but not all of these excluded workers are likely to work within the Auckland urban area. For instance, 22,455 residents were recorded as working the Auckland Territorial authority, most of which falls within the urban area boundary.

[5] We replicated all of our analyses with the 'not-stated' group omitted from diversity calculations and the results were not meaningfully different.

[6] "New Zealander" is recoded as "New Zealand European".

[7] Where a person reports more than 3 ethnic identifications, we use 3 randomly chosen responses. For our analysis, this an innocuous restriction, since all responses of 3 or more ethnicities are combined.

hierarchically using Statistics New Zealand's standard country classification. Remaining small groupings are aggregated based on the number of responses. When examining the ethnicity of New Zealand-born adult residents of the Auckland urban area, we use distinct codings for the 11 largest ethnic groups, and combine all other responses into a single residual group.[8] The combined birthplace-ethnicity classification we use thus has 49 distinct groups – 38 distinct birthplace codes, with New-Zealand-born separated into 12 codes. We will refer to the groups identified by this 49-way classification as 'cultural' groups.

3.2 Measures of exposure

Using the cultural classification described in the previous section, we calculate two different measures to capture each person's exposure to cultural diversity[9] The first is a measure of exposure to difference, which captures the probability that a randomly selected person of a given group results in this individual meeting, in a random interaction, someone from a group other than their own. The measure is calculated for each group g as:

$$Exposure\ to\ Difference_g = 100 * \sum_{a=1}^{A} \left(\frac{P_{ga}}{P_g}\right) * \left(1 - \frac{P_{ga}}{P_a}\right) \quad (1)$$

where P_{ga} is the number of people from group g located in area a where g is one of the 49 cultural groups, P_g is the number of members of group g, and P_a is the total number of people in area a. We will denote P to be the number of people in Auckland. Exposure to difference is closely related to the commonly used index of isolation, which captures own-group exposure (Bell, 1954; Lieberson, 1981).[10] The index of isolation is simply 100-minus the index of exposure to difference.

The spatial units used as areas in this calculation are census area units (AU), which are similar in size to the neighbourhoods used by Boterman and Musterd (2016). Although diversity can be calculated for smaller geographic units (meshblocks), we consider that area units provide a more appropriate scale for capturing the diversity of potential interactions. A total of 358 area units within the Auckland Urban area were analysed, with an average usually resident adult population of around 2,900 and average employment of around 1,500. The index was calculated separately for AU of residence (using total adult population) and workplace AU (using total employment). Exposure to difference is calculated separately for each of the 49 groups, but tabulated for only the largest 11.

[8] The full classification that we use is summarized in Appendix Table 1. The table also shows, for each country of birth code, the ethnicity classifications that account for either 10,000 people or at least 15 percent of the country of birth group.

[9] For a review of a wide range of measures of segregation and diversity, see e.g. (Nijkamp, Poot, & Bakens, 2015).

[10] In the extended notation of Lieberson (1981), our measure is ${}_gP^*_{\tilde{g}}$, the exposure of group g to residents from other groups ($\tilde{g}$), where ${}_gP^*_{\tilde{g}} = 1 - {}_gP^*_g$. Subsequent studies of segregation often also examine exposure of groups to the majority (M) group ${}_gP^*_M$

If a group is completely segregated, living only in areas where no other groups are present $\left(\frac{P_{ga}}{P_a} = 1\right)$, exposure to difference takes the value of 0. The maximum exposure to difference (equals minimum exposure to own group, or minimum isolation) occurs when the group is proportionally distributed in all areas $\left(\frac{P_{ga}}{P_a} = \frac{P_g}{P}\right)$, in which case the measure of exposure would be $\left(1 - \frac{P_g}{P}\right)$. The maximum exposure to difference is clearly lower for large groups – a group that accounts for 90 percent of the population can have, at most, an exposure to difference of 10 percent.

If exposure measures are to be used as a measure of segregation, the literature has recommended the use of a modified own exposure or isolation index $\left(mII_g = \frac{II_g - \frac{P_g}{P}}{1 - \frac{P_g}{P}}\right)$, to make exposure measures comparable for groups of very different sizes. This modified index has been calculated previously for Auckland (Johnston et al., 2008; Maré et al., 2016, 2012; Mondal et al., 2019). This index summarises how close the spatial distribution of a group across areas is to a random allocation in which the probability of a person being assigned to an area is proportional to the area's total population $(mII_g = 0)$, or to complete isolation $(mII_g = 1)$. For the current study, where our focus is on exposure rather than segregation *per se*, we focus primarily on the unmodified index, which reflects the fact that larger groups are less exposed to difference, rather than relying on an index that represents how far from randomly distributed the different groups are.

The second measure of exposure that we examine is exposure to diversity. This provides additional information about different groups' exposure to a mix of other groups. A group that has low exposure to difference will tend to have relatively low exposure to diversity, since limited exposure to other groups implies limited exposure to a mix of other groups. However, high exposure to difference does not necessarily imply high exposure to diversity. A relatively small population group living in an area (e.g. Maori) with only one other group represented (e.g. NZ born Europeans) will have high exposure to difference, but low exposure to diversity.

Diversity is measured by the commonly used fractionalisation index:

$$FR_a = 1 - \sum_{g=1}^{G} \left(\frac{P_{ga}}{P_a}\right)^2 \tag{2}$$

The measure has a simple interpretation: it measures the probability that in a meeting of two randomly selected individuals in area *a* of the city the two belong to different groups. This measure takes its maximum value $\left(FR_a^{Max} = \frac{G-1}{G}\right)$ when all groups are of equal size, whereas a

value of 0 arises when everyone belongs to the same group.[11] The *FR* index is calculated for each area. We calculate the index separately for AU of residence (FR_r) using total adult population, and workplace AU (FR_w) using total employment.

We also calculate the diversity associated with each combination of residence and workplace (FR_{rw}), to capture the diversity of interactions that occur either at home or at work, using the following formula.

$$FR_{rw} = \frac{FR_r + FR_w}{2} \quad (3)$$

In the absence of information on the proportion of time spent in each location, exposure to residential and workplace diversity are given equal weight. A group's exposure to diversity is calculated as the average value of FR_a experienced by group members, where a could refer to residence (r), workplace (w), or a combination of residence and workplace (rw).

$$Exposure\ to\ diversity_g = 100 * \sum_{a=1}^{A} \left(\frac{P_{ga}}{P_g}\right) FR_a \quad (4)$$

This measure has the appealing interpretation that it captures whether group members live or work in areas where random meetings would generate a high proportion of cross-group interactions. Exposure is measured separately for residence diversity for workplace diversity, and on average across residence and workplace.

Table 2 shows the average exposure to diversity for the employed population who work and live in the Auckland urban area (n=473,559). Each individual is assigned the diversity of their residential neighbourhood and the diversity of their workplace and these measures are averaged over all employed individuals. The table is restricted to the sample of 'intra-Auckland commuters' because workplace location is not available for other people.

Levels of exposure to diverse residents in residence neighbourhoods and to diverse employed populations in workplace neighbourhoods are similar – 80.7 and 79.1 respectively. There is somewhat greater variation for residence exposure (s.d.=9.2; P90-P10 range of 24.0) than for workplace exposure (s.d.=6.2; P90-P10 range of 14.3). On average, residential exposure to diversity is higher than exposure to workplace diversity. This reflects the fact that the residential measure includes the greater diversity arising from the presence of people who are not employed.

3.3 Commuting

Commuting travel time and road distance is calculated from an open source GIS road network layer made available by Beere (2017). Census places of usual residence and workplaces are in

[11] Using 49 cultural groups, the maximum is $\left(\frac{G-1}{G}\right) = \frac{48}{49}$ = 0.98. Multiplying this term by G/(G-1)=1.02 would create a 'modified fractionalisation index' with a minimum of 0 and a maximum of 1. Our findings are robust to the use of the modified fractionalisation index. We use the unmodified index because of its appealing probabilistic interpretation.

most cases coded to meshblock. The road distance between each pair of meshblocks was calculated as the shortest distance and travel time was based on the fastest route.[12] For some people, workplace location is less accurately coded, linked only to a census area unit. In these cases, time and distance were imputed based on the mean observed values between the residence meshblock and observed workplace meshblocks within the workplace area unit.[13]

Travel distances and time calculated in this way approximate the commuting experience of people who drive to work or are a passenger in a private vehicle. Such commuters account for 82% of all commuters in our data. The average commuting time and distance within Auckland can be compared with estimates from the New Zealand Household Travel Survey.[14] In that survey, 85 percent of home-to-work journeys were completed by drivers or passengers. For such commuters in the Auckland metropolitan area in the 4-year period from 2011 to 2014, the average (single-trip) commuting distance was 11.7km, taking them 23.0 minutes. The comparable measures from our census data on drivers and passengers show a mean commuting distance of 11.9km and mean commuting time of 17.1 minutes. The lower commute times in the census data reflect our use of free-flow road speeds and our exclusion of longer commutes associated with people who work outside the Auckland urban area.

4 Results

4.1 Residential and workplace exposure to difference

Table 3 summarises Aucklanders' exposure to their own group and exposure to difference. Unlike Table 2, which reports means for intra-Auckland commuters, Table 3 reports statistics for the full adult population of Auckland usual residents (n=1,035,150), and for all people employed in Auckland (n=531,117). It is clear that the composition of the employed population differs from that of the resident population. Whereas 49.3 percent of adult residents are New Zealand-born, 56.0 percent of employed adults are New Zealand-born, reflecting relatively high employment rates of New Zealand-born Europeans. People from England, India and Samoa also account for a higher share of employed adults than they do of the resident population.

Segregation, as captured by own-group exposure or isolation (Massey & Denton, 1988) is evident in both residential and workplace composition. Each cultural group is more likely to encounter someone from their own group in their residential or workplace area units than

[12] This processing was done using QGIS: QNEAT3 – QGIS Network Analysis Toolbox 3 v1.0.2, available at https://github.com/root676/QNEAT3. Road speeds were based on estimates that reflect road surface and sinuosity, provided by Beere (2017), following Brabyn & Skelly (2002).

[13] Where people live and work within the same meshblock, travel distance is approximated by the mean radial distance within a circle having the same land area as the meshblock, using the formula $Area^{0.5}128/(45\pi^{1.5})$ (Apsimon, 1958). Travel time is underestimated in these cases, reflecting only the time taken to move from the meshblock centroid to and from the nearest point of the road network.

[14] The measures are not entirely consistent. For census data, mode is reported for a single day, and time and distance are calculated for travel to workplace of main job in the previous 7 days. 2011-2014 Travel Survey measures are based on a two-day travel diary covering all jobs.

would be expected based on their share of the Auckland population. Tongans account for 1.6 percent of the Auckland population but on average live in AUs where 6.3 percent of the population is Tongan – a ratio of almost four. Similarly, South Africans have a 10.4 percent chance of encountering other South Africans in their residential AU, though they make up only 3.1 percent of the Auckland population (a ratio of 3.4). Workplace segregation follows a similar pattern but is much less pronounced than residential segregation. The highest own-group exposure is experienced by New Zealand-born European, reflecting their large population share, as well as their non-random clustering. The modified isolation index described in section 3.2 $\left(II = \frac{col(2)-col(1)}{1-col(1)}\right)$ is presented in the third column, to show the degree of segregation. By this measure, the New Zealand-European group is the most segregated group ($mII_g^{residence}$=10.8; $mII_g^{workplace}$=2.5). South Africans, Fijians, and Chinese also experience relatively high segregation both residentially and at workplaces.

Despite the observed segregation patterns, most groups have high exposure to non-group members, as shown in the fourth column as 'exposure to difference' Except for New Zealand-born Europeans, all groups have at least an 89 percent chance of encountering a non-group member in their residential AU, and more than a 92 percent chance in their workplace AU. Exposure to difference is lowest for the New Zealand-born group as a whole – capturing exposure to other New Zealand-born, not differentiated by ethnicity (47.8 percent at residence and 43.3 percent at workplace). When we look at the groupings used in the calculation of diversity, which disaggregate New-Zealand-born by 12 ethnicity groups, we find greater exposure to difference for the more disaggregated groups. New Zealand-born Europeans have the lowest exposure to difference (58.2 percent at residence and 55.7 percent at workplace).

The final column of Table 3 compares actual exposure to difference with the exposure that would arise if groups were randomly distributed across areas. These are all negative, reflecting segregation, but are all small, reflecting the limited impact that segregation has on exposure to difference for most groups.

4.2 Exposure to difference – intra-Auckland commuters

In order to focus on the role of commuting, and the different exposure of employed workers at home and at work, we analyse, in Table 4, exposure for intra-Auckland commuters, as described in section 3.1.1. The composition of this population is similar to that of all employed workers as shown in Table 3, differing only in that it excludes people who commute into Auckland, and those whose workplace cannot be coded to a specific AU. Comparing exposure to difference at home (column 2) and at work (column 3), we can see that, apart from New Zealand Europeans, all groups have high exposure to difference both at home (over 89 percent) and at work (over 92 percent). For most groups, their workplace exposure to difference is greater than that which

they experience at their residence. Their combined exposure is an average of these two, as shown in the fourth column of Table 4.

Whether this combined exposure is higher or lower than their residential exposure is shown in the fifth column. For most groups, workplace exposure to difference is greater than exposure in their residence AU. Apart from the New Zealand European group, the groups with the lowest residential exposure to difference, people from China and South Africa, experience an increase in exposure to difference of more than 2.5 percentage points, meaning that for every 100 people that they might bump into either at work or at home, they encounter 2 or 3 more people from a different country of birth than they would at home. New Zealand Europeans are the exception to this pattern. Being the largest group, they have relatively low exposure to difference at home (57.8 percent). However, when they go to work, they commute to areas where New Zealand Europeans are even more prevalent. A large part of this effect is due to the higher employment rates of New Zealand Europeans. The net effect is that this group has greater exposure to difference at home than at work.

4.3 Exposure to diversity

In contrast, New Zealand Europeans' exposure to *diversity* is increased when they go to work, as shown in the second panel of Table 4. Their workplaces are more diverse than their residential neighbourhoods – the opposite of what is experienced by all other groups except those born in England. Among the other groups, the two with the lowest residential exposure to diversity (Samoans, and dual ethnicity New Zealand-born European/ Māori) have relatively small differences between residential and workplace exposure to diversity.

Exposure to diversity and the impact of commuting vary not only across cultural groups but also by other characteristics. Table 5 reports differences by gender, by highest qualification, and for quartiles of residential neighbourhood diversity. Gender differences are small. Male intra-Auckland commuters are exposed to slightly higher levels of diversity at home and at work than are female commuters. They also both experience higher exposure to diversity at home than at workplaces, mirroring the pattern observed for the two largest groups – New Zealand-born European and English-born.

Differences by highest qualification are more pronounced. Degree-qualified commuters have the lowest levels of exposure to diversity at home (79.7) and at work (78.9), and also the smallest decline in exposure as a result of commuting (-0.4). In contrast, the relatively small group of commuters with no qualifications (9 percent of commuters) have the highest residential exposure to diversity (83.1), and also the largest decline in exposure as a result of commuting (-1.6), despite their exposure being greater than that of other qualification groups, both at home and at work.

The final panel of Table 5 reports patterns for commuters living in residential neighbourhoods with different levels of cultural diversity. Commuters are divided into four equal-sized groups based on the diversity of their neighbourhood. As shown in the second column, average residential diversity varies greatly, from 67.5 for people in the least diverse neighbourhoods, to 90.6 for people in the most diverse neighbourhoods. People from neighbourhoods with high residential diversity tend to commute to workplace neighbourhoods that are also more diverse than average. However, because the variation in workplace diversity across these quartiles is smaller than that of residential diversity (reflecting the selection of quartiles based on residential diversity), commuting lowers exposure for those in high-diversity residential areas (-4.3) and raises exposure for people in low-diversity residential neighbourhoods (+4.2).

To examine the relationship between residential and workplace exposure more fully, we divide both residential neighbourhoods and workplace neighbourhoods into quintiles (five groups with equal numbers of people). The first row of Table 6 shows the average workplace diversity for each of the workplace quintiles, which range from 69.5 for the lowest group, to 86.5 for people in the most diverse workplaces. For residential diversity quintiles, the spread is greater, ranging from 66.1 to 91.1.

The first panel of Table 6 shows the extent to which people from more diverse residential neighbourhoods commute to more diverse workplaces. The statistics reported are row-percentages. From the first row, we see that 38 percent of people in the lowest quintile of residential diversity commute to the least diverse workplace neighbourhoods. This is much greater than the 20 percent that would be observed if diversity in residences and workplaces were unrelated. Similarly, 37 percent of commuters in the most diverse residential neighbourhoods commute to the most diverse workplace neighbourhoods. Although there is clearly a positive correlation, there is also a moderate proportion of people who commute from the least diverse residential areas to the most diverse workplace areas (10%) or from the most diverse residential areas to the least diverse workplaces (8%).

The impact of these commuting patterns on average exposure to diversity is somewhat less symmetric. The second panel of Table 6 shows the difference between average exposure to diversity and residential exposure to diversity for each of the allocation cells. There is a strong increase in exposure to diversity for people commuting from the least diverse neighbourhoods to the most diverse workplaces (+10.0), and a similar-sized reduction in exposure from people commuting from highly diverse residences to the least diverse workplaces (-10.3).

The largest effects of commuting are evident as increases for people who live in the least diverse neighbourhoods, or reductions for those who work in the least diverse neighbourhoods. This is a consequence of the skewness of the exposure distributions, with a relatively large gap

between the lowest and second lowest quintiles in the level of exposure either residentially or at workplaces.

4.4 Spatial patterns of diversity exposure

Both residential and workplace diversity are spatially correlated, and correlated with each other, given that people generally favour short commuting times. Figure 1 maps residential and workplace diversity for the Auckland urban area. The least diverse areas are predominantly those towards the outer limits of the urban area, although there are some low-diversity areas close to Auckland Central – in Devonport, Ponsonby, Remuera, and the Eastern suburbs. Diverse workplaces and diverse residential areas are most concentrated in South Auckland, and in a corridor through the Western suburbs. The map of residential exposure looks less uniformly high in South Auckland but this reflects in part the greater variability of residential diversity rather than marked differences in the level of diversity. The shadings on the maps are chosen so that 20 percent of area units are in each band. Because residential diversity has a higher variance, the top two (darkest) bands of residential diversity are at least as diverse as the most diverse 20 percent of workplace area units.

The lower map in Figure 1 highlights areas where the number of intra-Auckland commuters working in the area is larger than the number living in the area. The mismatch between residences and workplace locations generates commuting flows of varying lengths, with differing impacts on exposure to residential and workplace diversity. The resulting commuting flows are summarised in panel (c) of Table 6. Commuters from low-diversity residential neighbourhoods have longer average travel times, consistent with them being disproportionately located in the outer parts of the urban area. For the two quintiles with the lowest residential diversity, there is a clear positive relationship between commuting times and the increase in exposure to diversity. It would appear that commuters are prepared to incur a greater cost of commuting to reach jobs in areas that yield them higher exposure to diversity.

The relationship between travel times and the effects of commuting on exposure to diversity (from panels (b) and (c) of Table 6) is displayed graphically in Figure 2. For at least the bottom three quintiles of residential diversity, there is a positive relationship between travel times and increased exposure to diversity. Further work is needed to determine whether commuters' preparedness to commute longer distances to reach more diverse workplaces is supported by higher wages at workplaces or lower rents in less diverse residential areas. These possible explanations of the relationships shown in Figure 2 could arise if diversity raised workplace productivity (hence higher wages) or if people were willing to incur higher rents or commuting costs to live in low-diversity neighbourhoods. Research in the Netherlands (Bakens & de Graaff, 2018) suggest that both of these factors operate, but that the latter is found to be a relatively small effect.

5 Summary and discussion

We have examined the well-documented residential segregation that exists in the Auckland urban area, and analysed the impact that this has on different groups' exposure to difference and exposure to diversity, using data from the 2013 Census of Population and Dwellings. As noted at the outset of the paper, the contribution of the paper is built on two novel treatments of the census data – first, using both country of birth and ethnicity to capture diversity among 49 distinct cultural groups; and second, the measurement of diversity at home and at work.

We have captured cultural diversity based on detailed country of birth and, for New Zealand-born, by ethnicity as well. We have found that, despite the tendency of all groups to locate disproportionately with members of their own cultural group, people have on average an 82 percent chance of encountering someone from a different group in their residential neighbourhood (Table 3, panel (a)) or a 79 percent chance in the neighbourhood where they work (Table 3, panel (b)). Within this range, groups with relatively low exposure to difference include people from South Africa, China, Fiji and England. The most notable exception to this overall pattern is the largest group – New Zealand-born people of European ethnicity. They account for 35 percent of usually resident adults in Auckland, and have only a 58 percent chance of meeting someone from a different cultural group where they live. Other groups with relatively low exposure to difference include people from South Africa, China, Fiji and England.

The third novel contribution of the paper is our analysis of how commuting affects Aucklanders' exposure to diversity. In order to examine the importance of workplace exposure to diversity, we focus on intra-Auckland commuters. New Zealand-born Europeans account for an even higher proportion of employed residents (55 percent), so when we focus on commuters, we find that this group has only a 45 percent chance of encountering someone from a different group either at home or at work (Table 4 panel (a)). Even with this low exposure to difference, however, New Zealand-born Europeans, like all other groups, have a fairly high exposure to *diversity*, due to potential interactions with people from a diversity of other groups. New Zealand-born Europeans, New Zealand-born European/Māori, South Africans, and English have the lowest overall exposure to diversity, though even for them, diversity is over 77 (Table 4, panel (b)) , meaning that there is at least a 77 percent chance that a random meeting in their home or work neighbourhoods will be between two people from different groups. For two of these groups, New Zealand European and English, exposure at work raises their average exposure.

Commuting raises exposure to diversity particularly strongly for groups for whom residential exposure is relatively low. This includes people with high educational attainment, as well as people with lower than median diversity in their residential neighbourhood. The people whose exposure increases most as a result of commuting incur longer travel times, which is at least suggestive of possible wage advantages associated with diverse workplaces, or people

willing to incur higher commuting costs to live in less diverse neighbourhoods. As noted above, further work is needed to investigate the links between exposure, wages, and rents.

Some caveats are, or course, in order when interpreting the patterns that we report. All of the exposure measures that we consider capture only potential exposure. It is possible that exposure may lead to more positive attitudes to immigrants, at least at relatively low levels of exposure (Ward, Masgoret, & Vauclair, 2011). However, for any of the hypothesised productive advantages of diversity (Page, 2007), there need to be interactions between diverse groups. Our findings therefore need to be interpreted as identifying the *scope* for interactions rather than their occurrence.

Our findings clearly identify the dominant group - New Zealand Europeans, and residents born in England as the groups with the lowest exposure to diversity in the neighbourhoods where they live. These are also the groups for which exposure to diversity at workplaces plays the strongest role in raising their overall exposure to diversity, despite relatively low exposure to diversity there as well. If the potential benefits of diversity are to be realised, the greatest gains may result from increasing the exposure of the largest group to diversity – either in workplaces, or in the neighbourhoods where they live.

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Table 1: Auckland workers and residents

		Place of residence			
	Employed persons	**Live in Auckland urban area**	**Live elsewhere**	**All Auckland UA workers**	**Percentage of Auckland jobs that are held by people living in Auckland**
Place of Work	Auckland urban area • dwelling & income details known	473,559			
	Auckland urban area • missing dwelling or income details	68,184			
	Auckland AU: • Total	501,009	30,108	531,117	[501,009/531,117=] 94%
	elsewhere	40,734	excluded		
	Not codeable to AU	57,612	excluded		
	Employed persons	599,355			
	Not employed	435,795			
	Auckland UA residents	1,035,150			
	Percentage of employed persons living in Auckland who also work in Auckland	$\left[\frac{501,009}{(501,009+40,734)}=\right]$ 92%			

Note: All counts are randomly rounded to base three to maintain confidentiality. Source: 2013 Census of Population and Dwellings.

Table 2: Diversity and commuting (Summary statistics)

	Mean	**s.d.**	**P10**	**P90**
Exposure to diversity - Residence (percent)	80.7	9.2	67.1	91.1
Exposure to diversity - Workplace (percent)	79.1	6.2	71.6	85.9
Commuting travel time (mins)	14.65	9.78	2.05	27.67
Commuting travel distance (km)	10.22	8.76	1.35	21.86

Note: Statistics are based on employed residents who live and work in the Auckland Urban Area. (randomly rounded count = 473,559). Source: 2013 Census of Population and Dwellings.

Table 3: Exposure to difference

	Population share	**Exposure to own-group**	**Modified Isolation index**	**Exposure to difference**	**Deviation of exposure to own group from random (ppt)**
	(1)	**(2)**	**(3)**	**(4) = (100%-[2])**	**(5)=(1)-(2)**
		(a) Exposure at place of residence			
		[All adult usual resident of Auckland urban area]			
All groups	100.0%	18.3%		81.7%	
New Zealand-born	49.3%	52.2%	5.9	47.8%	-3.0
• European	34.7%	41.8%	10.8	58.2%	-7.1
• Māori	3.7%	7.9%	4.3	92.1%	-4.2
• Europ/Maori	3.1%	3.7%	0.6	96.3%	-0.6
England	5.9%	8.6%	2.9	91.4%	-2.7
P.R.China	6.1%	11.1%	5.3	88.9%	-5.0
India	3.9%	8.1%	4.4	91.9%	-4.3
Fiji	3.5%	9.4%	6.1	90.6%	-5.9
Samoa	2.5%	5.3%	2.9	94.7%	-2.8
South Africa	3.1%	10.4%	7.6	89.6%	-7.3
Korea	1.7%	5.0%	3.4	95.0%	-3.4
Tonga	1.6%	6.3%	4.8	93.7%	-4.7
		(b) Exposure at place of work			
		[All adults employed in Auckland urban area]			
All groups	100.0%	21.0%		79.0%	
New Zealand-born	56.0%	56.7%	1.5	43.3%	-0.6
• European	42.8%	44.3%	2.5	55.7%	-1.4
• Māori	3.0%	4.4%	1.5	95.6%	-1.4
• Europ/Maori	3.5%	3.7%	0.2	96.3%	-0.2
England	6.9%	7.6%	0.7	92.4%	-0.7
P.R.China	4.6%	5.8%	1.2	94.2%	-1.2
India	4.3%	5.2%	1.0	94.8%	-0.9
Fiji	3.4%	5.0%	1.7	95.0%	-1.6
Samoa	3.3%	4.0%	0.7	96.0%	-0.7
South Africa	2.2%	4.1%	2.0	95.9%	-2.0
Korea	1.3%	2.2%	0.9	97.8%	-0.9
Tonga	1.1%	2.0%	0.9	98.0%	-0.9

Note: For panel (a), statistics are based on all adult usual residents in the Auckland urban area (randomly rounded count =1,035,150); For panel (b), statistics are based on all employed adults in the Auckland urban area (randomly rounded count =531,117). Source: 2013 Census of Population and Dwellings.

Table 4: Exposure to difference and exposure to diversity: Intra-Auckland commuters

	Population share (1)	**Exposure at residence AU (2)**	**Exposure at workplace AU (3)**	**Average exposure (4)**	**Effect of commuting (5) =(4) – (2)**
			(a) Exposure to difference		
All groups	100.0%	79.1%	79.3%	79.2%	0.1%
New Zealand-born	55.2%	47.2%	43.4%	45.3%	-1.9%
• European	42.2%	57.8%	55.7%	56.7%	-1.1%
• Māori	2.8%	93.0%	95.5%	94.3%	1.3%
• Europ/Maori	3.4%	96.4%	96.3%	96.4%	0.0%
England	6.8%	91.4%	92.4%	91.9%	0.5%
P.R.China	4.9%	89.0%	94.2%	91.6%	2.6%
India	4.4%	92.0%	94.8%	93.4%	1.4%
Fiji	3.5%	91.0%	95.0%	93.0%	2.0%
Samoa	3.4%	94.7%	96.0%	95.4%	0.6%
South Africa	2.1%	90.1%	95.8%	93.0%	2.9%
Korea	1.3%	95.1%	97.8%	96.5%	1.3%
Tonga	1.0%	94.0%	98.0%	96.0%	2.0%
			(b) Exposure to diversity		
All groups	100.0%	80.7	79.1	79.9	-0.8
New Zealand-born	55.2%	79.1	78.5	78.8	-0.3
• European	42.2%	77.7	77.9	77.8	0.1
• Māori	2.8%	84.7	81.1	82.9	-1.8
• Europ/Maori	3.4%	80.7	79.2	79.9	-0.7
England	6.8%	76.9	77.8	77.3	0.5
P.R.China	4.9%	84.5	80.1	82.3	-2.2
India	4.4%	86.1	80.9	83.5	-2.6
Fiji	3.5%	87.7	82.1	84.9	-2.8
Samoa	3.4%	80.2	78.9	79.5	-0.6
South Africa	2.1%	88.3	82.7	85.5	-2.8
Korea	1.3%	82.9	78.7	80.8	-2.1
Tonga	1.0%	88.5	82.5	85.5	-3.0

Note: All statistics based on the population of intra-Auckland commuters (randomly rounded count =473,559). For exposure to difference, column (4) is an average of (2) and (3). For exposure to diversity, column (4) captures the diversity of people encountered at either home or at work. Source: 2013 Census of Population and Dwellings.

Table 5: Exposure to diversity – by gender, qualifications, and quartiles of residential exposure

	Population share (1)	Exposure at residence AU (2)	Exposure at workplace AU (3)	Average exposure (4)	Effect of commuting (5) =(4) – (2)
2013	100%	80.7	79.1	79.9	-0.8
			(a) By gender		
Men	50%	80.8	79.2	80.0	-0.8
Women	50%	80.6	78.9	79.7	-0.8
			(b) By highest qualification		
Degree Qualification	34%	79.7	78.9	79.3	-0.4
Sub-degree post-school	22%	80.5	78.9	79.7	-0.8
School qual	33%	80.9	79.1	80.0	-0.9
No qual	9%	83.1	80.0	81.5	-1.6
			(c) By quartiles of FR_{res}		
1. Low FR_{res}	25%	67.5	75.8	71.6	4.2
2.	25%	78.9	78.8	78.8	0.0
3.	25%	85.8	79.7	82.8	-3.0
4. High FR_{res}	25%	90.6	82.0	86.3	-4.3

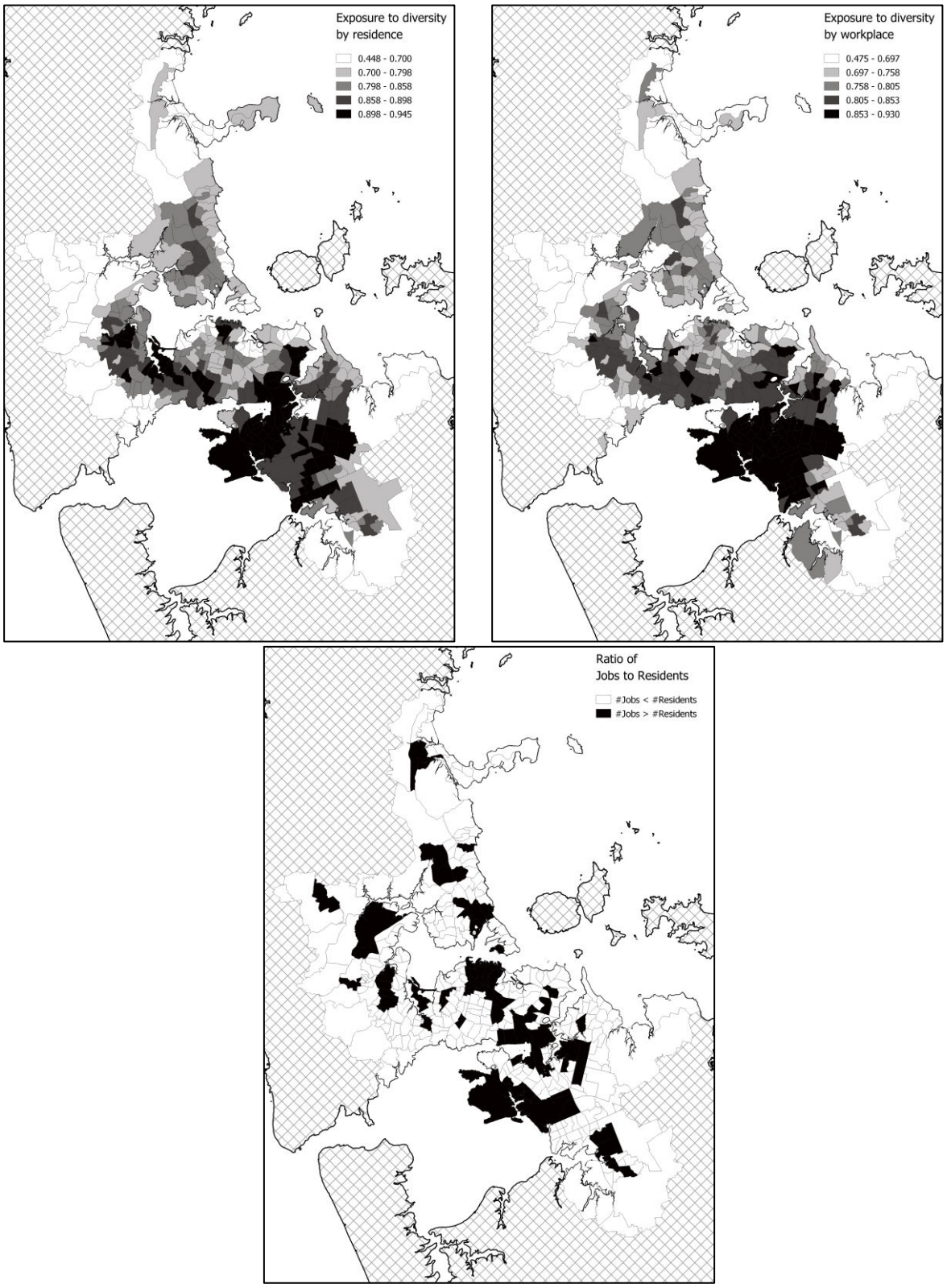
Note: All statistics based on the population of intra-Auckland commuters (randomly rounded count =473,559). Source: 2013 Census of Population and Dwellings.

Table 6: Exposure to diversity and commuting - by work and residence

Quintiles of residential exposure		Quintiles of workplace exposure				
		1. Low	2	3	4	5. High
Mean FR_{Work}		69.5	76.8	80.2	82.8	86.5
	Mean FR_{Res}			(a) Allocation shares		
1. Low	66.1	38%	19%	21%	12%	10%
2	76.1	25%	24%	23%	15%	12%
3	83.1	17%	25%	25%	17%	14%
4	87.3	12%	19%	22%	22%	23%
5. High	91.1	8%	12%	19%	22%	37%
	Mean Effect			(b) Effect of commuting (Average minus residential exposure)		
1. Low	4.8	0.9	5.1	7.0	8.3	10.0
2	1.0	-2.6	0.4	2.1	3.2	4.9
3	-2.0	-6.0	-3.1	-1.5	-0.1	1.7
4	-3.4	-8.3	-5.1	-3.6	-2.3	-0.5
5. High	-4.4	-10.3	-7.1	-5.5	-4.1	-2.1
	Mean travel time			(c) Commuting travel time (minutes, single trip)		
1. Low	15.8	9.8	17.2	17.1	21.6	25.8
2	14.4	11.0	13.1	14.3	16.8	20.8
3	14.4	14.2	12.0	13.5	15.8	18.9
4	14.7	17.1	13.9	14.5	13.8	15.1
5. High	14.0	19.5	17.0	13.7	14.5	11.9

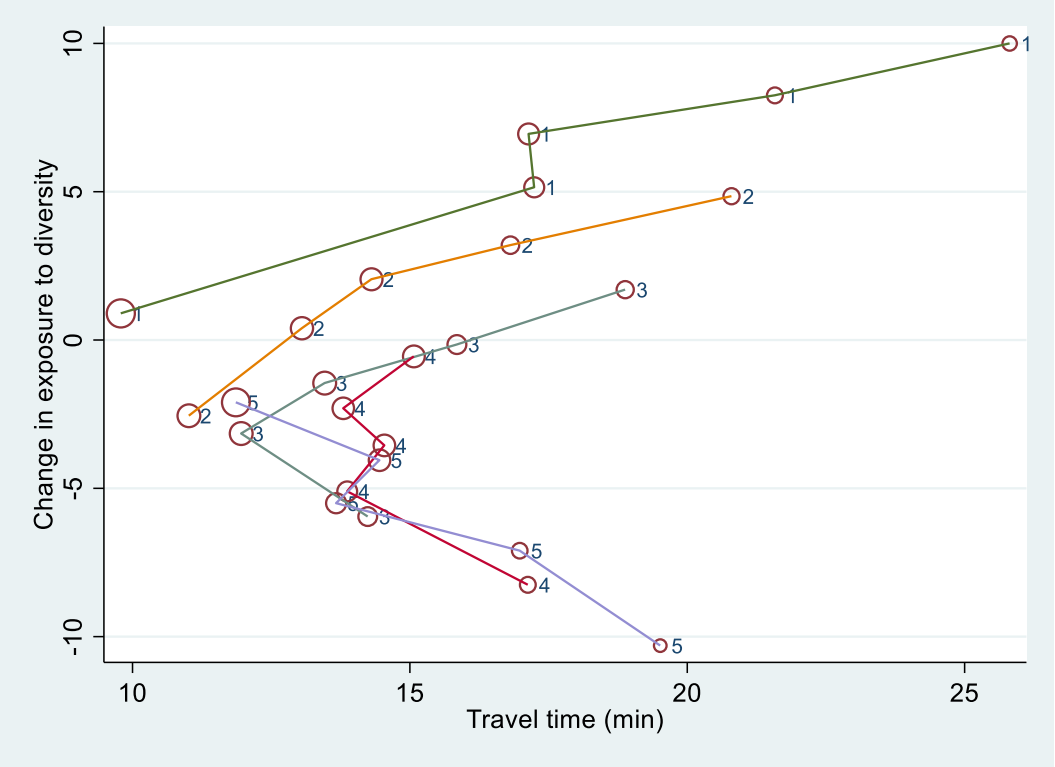
Note: All statistics based on the population of intra-Auckland commuters (randomly rounded count =473,559). Source: 2013 Census of Population and Dwellings.

Figure 1: Exposure to diversity at home and at work (Auckland Urban Area)



Note: Scales differ across maps. Each scale is chosen to split area units into five equally sized groups. Cross-hatched areas represent areas not included in the study. The lower map highlights area units where the number of jobs exceeds the number of residents. Source: 2013 Census of Population and Dwellings.

Figure 2: Commuting and changes in exposure to diversity



Note: Numbered labels refer to quintiles of residential diversity, with 1 as lowest diversity and 5 as highest. Each line shows, for a particular residential quintile, the combinations of commuting time and diversity change for commuters travelling to each quintile of the workplace diversity distribution. The underlying numbers are included in panels (b) and (c) of Table 6.

Appendix

Appendix Table 1: Groupings used for diversity measurement

Birthplace	Number of people (2013)	Main ethnicities (15% or 10,000)
New Zealand	509,988	
• *Ethnicity: NZ European*	*359,229*	*NZEUR (70.4% of NZ-born)*
• *Ethnicity: Māori*	*38,505*	*MAO (7.6% of NZ-born)*
• *Ethnicity: NZ European-Māori*	*32,070*	*NZEUR_MAO (6.3% of NZ-born)*
• *Ethnicity: Other single ethnicity*	*30,852*	*Other1 (6.0% of NZ-born)*
• *Ethnicity: Samoan*	*14,937*	*Samoan (2.9% of NZ-born)*
• *Ethnicity: Cook Islands Māori*	*6,432*	*Cook Islands Māori (1.3% of NZ-born)*
• *Ethnicity: Chinese*	*6,060*	*Chinese (1.2% of NZ-born)*
• *Ethnicity: Tongan*	*5,721*	*Tongan (1.1% of NZ-born)*
• *Ethnicity: Indian*	*4,920*	*Indian (1.0% of NZ-born)*
• *Ethnicity: NZ European-Samoan*	*3,621*	*NZ European-Samoan (0.7% of NZ-born)*
• *Ethnicity: Niuean*	*2,613*	*Niuean (0.5% of NZ-born)*
• *Ethnicity: All other combinations*	*5,025*	*All other combinations (1.0% of NZ-born)*
China People's Republic of	62,769	Chinese (99.1%)
England	60,798	NZEUR (70.6%)
India	39,861	Indian (96.6%)
Fiji	35,919	FijianIndian (15.4%); Indian (65.5%); Other1 (15.6%)
Samoa	32,148	Samoan (94.5%)
South Africa	25,692	NZEUR (38.8%); SouthAfricannec (43.1%);
Korea Republic of	17,469	Korean (98.1%)
Tonga	16,368	Tongan (97.1%)
Philippines	15,525	Filipino (90.4%)
Australia	14,154	Australian (30.0%); NZEUR (51.7%)
Middle East (nfd)	9,249	MiddleEastern (85.2%)
Malaysia	8,772	Chinese (65.3%)
Mainland South-East Asia (nfd)	8,739	Chinese (16.3%); SoutheastAsian (59.8%)
Cook Islands	8,550	CookIslandsMAO (94.2%)
Scotland	6,804	NZEUR (58.0%); Scottish (25.8%)
Taiwan	6,090	Chinese (96.1%)
Eastern Europe (nfd)	5,847	NZEUR (25.6%); OtherEuropean (68.4%)
Polynesia (excludes Hawaii) (nfd)	5,385	Niuean (61.2%); Other1 (25.1%)
United States of America	5,373	American (39.9%); NZEUR (34.7%)
South Eastern Europe (nfd)	5,361	NZEUR (37.5%); OtherEuropean (53.8%)
Sri Lanka	5,322	SriLankan (76.9%); nec (18.3%)
Maritime South-East Asia (nfd)	5,127	Chinese (36.5%); Other SE Asian (30.5%)
North-East Asia (nfd)	5,037	Chinese (89.7%)
Southern and Central Asia (nfd)	4,986	OtherAsian (78.8%)
Japan	4,311	Japanese (92.3%)
South America (nfd)	4,194	LatinAmerican (83.0%)
Netherlands	4,182	Dutch (71.9%); NZEUR (17.3%)
United Kingdom (nfd)	3,786	British (16.9%); NZEUR (55.0%)
Germany	3,519	German (58.4%); NZEUR (29.3%)
Thailand	3,450	OtherSoutheastAsian (85.5%)
Zimbabwe	3,252	African (25.5%); NZEUR (39.0%); Other Eur (19.1%)
Southern and East Africa (nfd)	3,207	African (43.5%); NZEUR (22.9%);

Birthplace	Number of people (2013)	Main ethnicities (15% or 10,000)
Canada	2,811	NZEUR (43.9%); OtherEuropean (42.0%)
Ireland	2,673	Irish (63.5%); NZEUR (30.8%)
Western Europe (nfd)	2,625	NZEUR (35.3%); OtherEuropean (53.1%)
Not Stated	67,482	NotStated (85.8%)
Other	8,325	NZEUR (20.8%); Other1 (16.6%); Other Eur (22.7%)
Total Population	1,035,150	

Note: All counts are randomly rounded to base 3 to maintain confidentiality. Groupings of countries of birth and ethnic identifications are based on all adult residents of the Auckland Urban Area. Listed ethnic groupings are those that account for more than 15% of the country of birth population, or that account for more than 10,000 people. Nfd: not further defined. Source: 2013 Census of Population and Dwellings.

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