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On the Changing Spatial Distribution of Human Capital and Occupation Groups: An Analysis of Recent Trends in Australia's Main Capital Cities

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On the Changing Spatial Distribution of Human Capital and Occupation Groups: An Analysis of Recent Trends in Australia's Main Capital Cities*

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Abstract

We study changes in the spatial distribution of socioeconomic groups in Australia using a new dataset with harmonised census data for 1991 and 2011. We find a general increase in residential segregation by education and occupation groups across the major capital cities. Importantly, results from our counterfactual analyses show this increase cannot be explained in general by changes in the demographic structure of groups and areas but rather by the rise in the over and underrepresentation of the groups across areas. Our analysis reveals clear diverging trends in the spatial configuration of high and low socioeconomic groups. While high-skilled groups became more concentrated in the inner parts of cities between 1991 and 2011, the low-skilled became increasingly overrepresented in outer areas. This pattern is observed in all five major capital cities but it is especially marked in Sydney, Melbourne, and Brisbane.

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1. Introduction

Social and economic transformations over the past fifty years have had very asymmetric effects on skill groups, especially in Anglo-Saxon countries. The factors contributing to the deterioration of the relative position of low and middle-skilled groups include skilled-biased technical change and the rise in returns to skill (Acemoglu, 2002), offshoring and the polarisation of labour markets (Goos et al., 2014), and the decline of labour market institutions (Fortin and Lemieux, 1997).

Similar to the U.S. and the U.K., Australia's labour markets since the 1980s have been characterised by an increasing polarization and the decline in middle skill and routine jobs leading to growing inequalities between skill groups (Coelli and Borland, 2016). Parallel to the polarisation of labour markets, there was a sharp increase in the number of casual jobs —from 15% in 1983 to 28% in 2002 (Campbell, 2004). These changes in labour markets were also reflected in housing markets, where the strong rise in housing prices negatively impacted the levels of housing stress and affordability of most vulnerable groups (Yates, 2008). We hypothesize these compound inequalities had consequences for the residential sorting of skill groups within Australian cities.

This paper aims to study changes in the spatial distribution of education and occupation groups in Australia's major capital cities between 1991 and 2011 and its effect on residential segregation. We argue Australian cities provide an interesting case study relevant to advanced industrialised countries. As many of those countries, in recent decades Australia has experienced a substantial increase in national and regional incomes. This rise in income standards, however, has disproportionally benefited those at the top (Azpitarte, 2014; Wilkins, 2007). Examining the implications of post-industrial cities for the spatial sorting of skill groups is the primary purpose of this research.

For the analysis we use the measurement framework proposed by Alonso-Villar and Del Río (2010)—which allows to quantify the segregation of a group in a multigroup context—and measures of overall segregation that are consistent with it (Theil and Finizza, 1971; Silber, 1992; Frankel and Volij, 2011). Importantly for our purpose, this framework allows the decomposition of the overall segregation in terms of the segregation experienced by population subgroups, as well as, the segregation of the geographical units that compose the city. This is critical to identify the groups and areas that became more or less segregated and also to quantify the contribution of demographic changes to segregation trends. We apply these measures to a newly created, harmonised dataset based on census data which allows the comparison of the spatial distribution of skill groups across comparable geographies at different levels in 1991 and 2011.

Our research contributes to the literature on residential segregation in Australia, which has mainly focused on segregation by ethnicity, ancestry, or country of origin (Jones et al., 2018; Edgar, 2014), and to the growing literature on the suburbanization of disadvantage in Anglo-Saxon countries (Freeman, 2009; Davidson and Lees, 2005). It differs from earlier works on the suburbanization of disadvantage in Australia's major capital cities (Randolph and Tice, 2017; Randolph and Holloway, 2005; Pawson and Herath, 2015) in several ways. First, whilst those studies focused on the spatial distribution of disadvantage, we focus on the location of both disadvantaged and advantaged groups. We argue this is important to describe changes in the social mix of geographies and evaluate whether the growing inequalities between skill groups also manifests in the location of those groups. Secondly, those studies identified disadvantaged areas using an index based on aggregate socioeconomic information at the area level, which means that all individuals living in areas ranked as socioeconomically disadvantaged are necessarily disadvantaged, whereas we use individual level information.

The paper is organised as follows. Section 2 describes the measurement framework whereas Section 3 describes the new dataset and the harmonisation process. In Section 4, we present the empirical findings including the map evidence for major capital cities. Section 5 concludes.

2. Measurement Framework

We use the framework proposed by Alonso-Villar and Del Río (2010), which allows decomposing the overall segregation of cities in terms of the segregation experienced by the different groups and the segregation of the areas that comprise the city. We study residential segregation from an *evenness* perspective—i.e., the extent to which a group is unequally distributed across locations—as well as a *representativeness* perspective concerned with the extent to which the representation of groups in each location differs from the representation one would expect given the group's weight in the overall population.

To quantify the segregation of any given group, g, we use two indices:

$$D^g = \frac{1}{2}\sum_l \left| \frac{n_l^g}{N^g} - \frac{p_l}{P} \right| \text{ and} \tag{1}$$

$$\Phi^g = \sum_l \frac{n_l^g}{N^g} \ln\left(\frac{n_l^g / N^g}{p_l / P} \right), \tag{2}$$

where N^g is the size of demographic group g; P represents total population; n_l^g is the number of individuals from group g in location l; and p_l is the population size of location l.

These indices are equal to zero if the group is evenly distributed across locations, i.e. when the group's population share in each location matches its share in the whole population. The higher the degree of unevenness of the group, the higher the value of these indices. The measure D^g, proposed by Moir and Shelby-Smith (1979) in the binary case and explored by Alonso-Villar and Del Río (2010) in a multigroup context, has a clear interpretation. It measures the proportion of group g's individuals that would have to move to another location to be evenly distributed across space. Both indices satisfy standard properties in the segregation literature but whereas Φ^g satisfies the Pigou-Dalton transfer principle, D^g does not.[1] We use the two measures to assess the sensibility of our results to the formulation of the index.

The indices D^g and Φ^g of group's segregation are related to the measures of overall segregation IP and M used in multigroup settings:

$$IP = \frac{1}{2}\sum_g \sum_l \left| \frac{n_l^g}{P} - \frac{N^g}{P}\frac{p_l}{P} \right| \text{ and} \tag{3}$$

$$M = \sum_g \frac{N^g}{P}\left(\sum_l \frac{n_l^g}{N^g} \ln\left(\frac{n_l^g / N^g}{p_l / P} \right) \right). \tag{4}$$

The IP index, proposed by Silber (1992), is a generalization of the well-known index of dissimilarity to the multigroup case and corrects some of its shortcomings.[2] Consistent with the index D^g, the measure IP represents the proportion of individuals that would have to change residential location so that all groups are evenly distributed across locations. The mutual information index, M, first proposed by Theil and Finizza (1971), has also been claimed to be a suitable measure to quantify residential segregation (Kramer and Kramer, 2018).

As shown in Alonso-Villar and Del Rio (2010), the indices IP and M can be decomposed as follows:

[1] This principle is particularly important when evaluating trends in spatial segregation as it requires that segregation increases when some individuals from one group move from a location to another in which the group has a higher representation.

[2] Whilst useful when one is interested in measuring segregation in a binary context (e.g., whites vs. non-whites), the use of the dissimilarity index in a multigroup context becomes cumbersome because it requires calculating it for each pair of groups, which makes it difficult to have a clear picture of overall segregation.

$$IP = \sum_g \frac{N^g}{P} D^g \text{ and} \tag{5}$$

$$M = \sum_g \frac{N^g}{P} \Phi^g . \tag{6}$$

That is, if the total population is divided into several mutually exclusive groups, overall segregation as measured by *IP* and *M* equals the weighted average of the segregation of the groups according to D^g and Φ^g, respectively, with weights equal to the groups' shares in the population.

In addition to its decomposability by population subgroups, the measure *M* can also be decomposed in terms of locations, which makes it particularly suitable for quantifying the contribution of each spatial unit to overall segregation. Following Alonso-Villar and Del Río (2010) and Frankel and Volij (2011), the index *M* can be expressed as

$$M = \sum_l \frac{p_l}{P} \Psi_l , \tag{7}$$

where

$$\Psi_l = \sum_g \frac{n_l^g}{p_l} \ln\left(\frac{n_l^g / p_l}{N^g / P} \right). \tag{8}$$

The index Ψ_l quantifies the level of segregation of any area, *l*, by looking at the level of under and overrepresentation of the different groups in that area. If the share of each demographic group in a location is similar to the one that the group has in the city as a whole, then the value of Ψ_l will be close to zero. In contrast, if the groups' representation in that location differs substantially from the one that would be expected given their shares in the city's population, then the area will be characterised by large values of Ψ_l. Expression (7) implies that overall segregation is equal to the weighted average of the segregation of its areas as measured by the Ψ_l index.

3. Data

We draw on publicly available socioeconomic and geocoded data. Data on education and occupations come from the 1991 and 2011 Basic Community Profiles (BCPs) compiled by the Australian Bureau of Statistics (ABS). These profiles include count data on residents' characteristics at various regional levels. We focus on the population aged 15 and older.

To ensure the comparability of geographies and variables across years we constructed a harmonised data set that allows meaningful comparisons of the spatial distribution of groups in 1991 and 2011. Table 1 below provides descriptive information on the variables and spatial units used in the analysis. In what follows we explain the main features of the harmonisation process; further details are presented in the Appendix included in the supplemental materials.[3]

3.1 Education

Data on education for 1991 were coded using the ABS Classification of Qualifications (ABSCQ) whereas in 2011 they were recorded using the Australian Standard Classification of Education (ASCED). The two classifications differ in the number of categories (eight in ABSCQ and six in ASCED) and to create a classification comparable across years we used the correspondence file provided by the ABS (ABS, 2001), which allows us to create four highly comparable categories—*bachelor's degree and above*, *diploma and advance diploma*, *certificate level*, *and no post-school qualification*.

3.2 Occupations

Occupations for 1991 were classified using the first edition of the Australian Standard Classification of Occupations (ASCO1) whereas data for 2011 were recorded using the Australia and New Zealand Standard Classification of Occupations (ANZSCO). Both classifications divide occupations into eight categories ranging from high-status occupations, such as managers and professionals, to low-status occupations, including labourers and machinery workers. No direct correspondence between the ASCO1 and ANZSCO has been produced to date. Following the recommendation from the ABS, we used the correspondence between the ASCO1 and the second edition of the same classification (ASCO2), and the correspondence between the ANZSCO and ASCO2 classifications produced by the ABS.

We triangulated the available correspondences to create the most comparable albeit imperfect harmonised classification of occupations for 1991 and 2011. Based on results from the triangulation analysis, we decided to create a parsimonious classification with only three categories. The first category, *top*, includes high-skilled occupations and comprises categories (1) and (2) of the ASCO1 and ANZSCO classifications. The second category, *middle,* comprises a range of middle-skilled occupations such as technicians, trades, clerks, sales workers included in categories (3)-(6) of ASCO1 and ANZSCO. The third category, *bottom*, comprises categories (7) and (8) of the two classifications,

[3] The data and Stata codes used in the research are also provided in the online supplemental materials available at https://drive.google.com/open?id=1TUjrSDRRZshBI85epE34ISCAAfLI_c1V .

which include occupations at the bottom of the skill distribution such as drivers, machinery operators, and labourers. The parsimonious classification was motivated by our interest in low and high-skilled groups and also by the large correspondence found between top and bottom categories of the classifications.

3.3 Geographical Units

We used information on three geographical units: Statistical Local Area (SLA), Statistical Subdivision (SSD), and Statistical Division (SD). Data on the first two were used to identify the two spatial levels employed in the analysis, whereas the latter allowed us to delimit Australia's main capital cities. SLAs are general purpose spatial units and constitute the smallest building block of the main structure of the Australian Standard Geographical Classification (ASCG) used in 1991 and 2011 censuses.[4] SLAs aggregate into SSDs, which are socially and economically homogenous regions with identifiable links between their inhabitants (ABS 2011, p. 8). We identified Australia's main capital cities with the Capital City SD of each state. Capital City SDs represent the city in a wider sense and are the most stable spatial units within each state.

The number of SLAs in Australia's major capital cities rose from 390 in 1991 to 456 in 2011, an increase largely caused by the subdivision of SLAs over that period. The boundaries of the SLAs in 2011 in general do not coincide with those in 1991 due to changes to the boundaries of the local government areas, which constitute the building blocks of the SLAs. To create comparable areas we proceeded as follows. Taking 1991 as the reference year, we matched every SLA from that year with the one covering the same area in 2011. For those cases in which a one-to-one match was not possible, we amalgamated the minimum number of contiguous SLAs required to construct a comparable unit. This often required the aggregation of SLAs of 2011 to match a SLA of 1991 whose territory had been partitioned. In some cases, however, creating a harmonised region also required the amalgamation of SLAs from 1991. This resulted in 355 harmonised SLAs covering the same territory in 1991 and 2011. A description of the harmonised units of each capital city is provided in the *Harmonised SLAs* file in the supplemental materials.

[4] The main structure of the ASCG in 1991 included a smaller block—the census collection district—which was excluded in 2011.

Table 1. Key demographic and geographical variables

	Sydney		Melbourne		Brisbane		Adelaide		Perth	
	1991	**2011**	**1991**	**2011**	**1991**	**2011**	**1991**	**2011**	**1991**	**2011**
Population aged 15 and over	2,791,997	3,548,421	2,386,067	3,214,529	1,038,188	1,588,025	817,266	964,061	885,353	1,328,901
Education groups										
Bachelor's degree and above	267,190 (11.2)	856,094 (27.2)	228,246 (10.9)	762,965 (26.5)	80,723 (8.8)	328,014 (22.9)	59,632 (8.2)	177,200 (20.3)	73,453 (9.4)	268,524 (22.6)
Diploma and advance diploma	147,913 (6.2)	318,523 (10.1)	122,219 (5.9)	281,698 (9.8)	54,797 (6.0)	129,020 (9.0)	44,216 (6.1)	74,527 (8.6)	53,549 (6.8)	115,801 (9.8)
Certificate level	394,170 (16.5)	537,612 (17.1)	289,477 (13.9)	477,359 (16.6)	132,962 (14.6)	285,592 (19.9)	111,194 (15.3)	172,809 (19.8)	128,178 (16.4)	243,766 (20.6)
No post-school qualification	1,585,096 (66.2)	1,436,007 (45.6)	1,446,343 (69.3)	1,361,683 (47.2)	645,218 (70.6)	692,724 (48.3)	510,475 (70.4)	446,279 (51.2)	526,768 (67.4)	557,533 (47.0)
Occupation groups										
Top	395,011 (27.0)	800,498 (39.6)	326,149 (26.5)	696,749 (37.6)	127,776 (23.7)	333,196 (34.7)	97,774 (23.8)	179,845 (33.4)	111,363 (24.8)	276,668 (34.0)
Middle	795,052 (54.3)	952,908 (47.1)	661,669 (53.7)	896,606 (48.3)	302,625 (56.2)	477,653 (49.8)	229,573 (55.9)	273,710 (50.8)	253,596 (56.5)	411,482 (50.6)
Bottom	272,903 (18.7)	269,449 (13.3)	243,907 (19.8)	261,715 (14.1)	108,557 (20.1)	148,576 (15.5)	83,429 (20.3)	85,399 (15.8)	83,827 (18.7)	124,404 (15.3)
Geographies										
Statistical Local Areas (SLAs)	45	64	58	79	222	221	32	55	33	37
Statistical Subdivisions (SSDs)	14	14	18	16	9	11	4	4	5	5
SLAs median size	52,048	61,144	39,461	47,743	3,861	5,371	30,206	32,955	21,399	29,392
SLAs (harmonised)	45		53		201		25		31	
SSDs (harmonised)	14		16		9		4		5	

Notes: The numbers in parentheses correspond to the share of the education and occupation groups represented by each category.

4. Residential Segregation by Socioeconomic Status in Australia

4.1 Changes in Overall Segregation Between 1991 and 2011

Table 2 below shows our estimates of overall residential segregation for 1991 and 2011 when using the harmonised statistical local areas (SLAs) as the geographical unit of analysis, the smallest unit for which data are available. Results for the *IP* index reveal a general increase in segregation across the main capital cities. Although observed for both education and occupation, the rise was particularly intense in terms of education, ranging from 36% in Adelaide to 75% in Brisbane. Results for the *M* measure are quantitatively and qualitatively very similar to those of the *IP* index.[5] The increase in segregation is also found when segregation is measured using statistical subdivisions (SSDs) rather than SLAs (see Table B1 in the supplemental materials), which shows the robustness of our findings to the geographical unit of analysis.[6]

Table 2. Overall segregation (indices *IP* and *M*), SLA level

	***IP* index**				
	Sydney	**Melbourne**	**Brisbane**	**Adelaide**	**Perth**
Education					
1991	0.086	0.077	0.068	0.072	0.062
2011	0.129	0.118	0.119	0.097	0.096
Δ (%)	50.0	51.9	75.0	36.1	53.2
Occupation					
1991	0.092	0.090	0.082	0.086	0.074
2011	0.113	0.113	0.103	0.089	0.085
Δ (%)	22.8	24.4	25.6	3.5	14.9

	***M* index**				
	Sydney	**Melbourne**	**Brisbane**	**Adelaide**	**Perth**
Education					
1991	0.033	0.029	0.029	0.029	0.024
2011	0.053	0.045	0.051	0.039	0.035
Δ (%)	60.6	55.2	75.9	34.5	45.8
Occupation					
1991	0.037	0.035	0.033	0.035	0.026
2011	0.044	0.043	0.040	0.033	0.027
Δ (%)	18.9	22.9	21.2	-5.7	3.8

Source: Authors' calculation

[5] The only exception is Adelaide, where the segregation by occupation decreased according to *M*.

[6] As is common in segregation analysis, our indices are affected by the "modifiable areal unit problem", since they do not take into account the spatial distribution inside locations. In the absence of more granular data, we make use of the most disaggregated available data to evaluate segregation at two geographical scales. Given that our measures do not account for distances across locations, they are affected by the "checkerboard problem". We aim to address this issue by complementing our estimates with the graphical analysis of maps in Section 4.4.

In 2011 Sydney and Melbourne were the cities with the highest level of segregation in terms of both education and occupation, followed by Brisbane, which had the largest increase over the period. The *IP* index indicates that, in 2011, 12.9% (resp. 11.3%) of the population in Sydney would have to relocate for the city to eliminate residential segregation by education (resp. occupation). The lowest segregation values are in Perth (requiring moving 9.6% and 8.5% of its population) and Adelaide (9.7% and 8.9%).

4.2 Segregation of Socioeconomic Groups and Locations

We examine the contribution of socioeconomic groups and locations to the rise in segregation exploiting the decomposability properties of the *IP* and *M* measures. These allow us to evaluate whether the increase in segregation stemmed from changes in the residential patterns of disadvantaged or advantaged groups. Table 3 provides estimates of the residential segregation of each group at the SLA level as measured by the D^g and Φ^g indices. As discussed in Section 2, these measures are consistent with the measures of overall segregation *IP* and *M*, which can be expressed as the weighted average of the D^g and Φ^g, respectively.

Figures on Table 3 reveal diverging trends between skill groups. The groups with lower education levels (i.e., those with a certificate or with no post-school qualification) became more segregated as their levels of overrepresentation and underrepresentation across SLAs rose between 1991 and 2011. The rise in the unevenness of the low educated happened across all capital cities. In contrast, the degree of unevenness of the highly educated diminished between 1991 and 2011 in all cities, although that group displayed the highest level of segregation of all groups in both years. For example, the measure D^g for Sydney in 2011 indicates that 20.1% of people with bachelor's degrees would have to change their residential location to have an even distribution across SLAs, whereas the percentage for the other groups ranges between 6.8% and 13.4%. Importantly, these trends for education groups are not sensible to the choice of segregation measure (D^g or Φ^g) or the geographical unit used for the analysis.[7]

[7] Indeed, all these patterns hold for statistical subdivisions as well, although the results for individuals with bachelor's degrees are less robust in the case of Brisbane (see Table B2 in the supplemental materials).

Table 3. Segregation of the groups (indices D^g and Φ^g), SLA level

	D^g **Index** (consistent with *IP*)														
	Sydney			**Melbourne**			**Brisbane**			**Adelaide**			**Perth**		
EDUCATION	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**
Bachelor's degree	0.261	0.201	-23.0	0.256	0.2	-21.9	0.276	0.236	-14.5	0.289	0.204	-29.4	0.238	0.193	-18.9
Diploma	0.146	0.068	-53.4	0.149	0.052	-65.1	0.127	0.068	-46.5	0.153	0.072	-52.9	0.115	0.041	-63.5
Certificate	0.079	0.134	69.6	0.09	0.141	56.7	0.074	0.116	55.4	0.063	0.098	55.6	0.067	0.112	67.2
No post-school	0.052	0.097	86.5	0.04	0.077	90.0	0.036	0.075	108.3	0.041	0.059	43.9	0.031	0.053	71.0

	Φ^g **Index** (consistent with *M*)														
	Sydney			**Melbourne**			**Brisbane**			**Adelaide**			**Perth**		
EDUCATION	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**
Bachelor's degree	0.19	0.112	-41.1	0.173	0.103	-39.9	0.227	0.149	-34.4	0.238	0.126	-47.1	0.173	0.102	-41.0
Diploma	0.058	0.013	-77.6	0.062	0.007	-88.7	0.05	0.014	-72.0	0.068	0.017	-75.0	0.041	0.005	-85.4
Certificate	0.019	0.053	178.9	0.025	0.055	120.0	0.019	0.039	105.3	0.013	0.029	123.1	0.017	0.036	111.8
No post-school	0.007	0.026	257.1	0.005	0.017	240.0	0.004	0.017	325.0	0.005	0.012	140.0	0.003	0.009	200.0

	D^g **Index** (consistent with *IP*)														
	Sydney			**Melbourne**			**Brisbane**			**Adelaide**			**Perth**		
OCCUPATION	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**
Top	0.156	0.14	-10.	0.15	0.145	-3.3	0.153	0.142	-7.2	0.167	0.126	-24.6	0.139	0.123	-11.5
Middle	0.032	0.057	78.1	0.032	0.056	78.1	0.029	0.048	65.5	0.03	0.044	50.0	0.03	0.047	60.0
Bottom	0.174	0.233	33.3	0.169	0.218	29.0	0.145	0.193	32.4	0.148	0.156	5.4	0.122	0.126	3.3

	Φ^g **Index** (consistent with *M*)														
	Sydney			**Melbourne**			**Brisbane**			**Adelaide**			**Perth**		
OCCUPATION	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**	**1991**	**2011**	**Δ (%)**
Top	0.072	0.052	-27.8	0.067	0.053	-20.9	0.073	0.057	-21.9	0.081	0.05	-38.3	0.061	0.044	-27.9
Middle	0.003	0.01	233.3	0.003	0.009	200.0	0.003	0.007	133.3	0.003	0.006	133.3	0.003	0.008	133.3
Bottom	0.087	0.143	64.4	0.078	0.13	65.4	0.067	0.108	59.7	0.069	0.082	18.8	0.048	0.055	12.5

Source: Authors' calculation.

Results for occupations tell a similar story to those obtained for education, with clear diverging trends for low- and high-status groups. Thus, while residential segregation rose for individuals working in bottom occupations, it decreased for those in top occupations whatever the index used.[8] Individuals in top and bottom occupations were equally segregated in 1991 but by 2011 those in bottom occupations had become the most segregated group, especially in Sydney and Melbourne. Thus, according to D^g, in 2011, 23.3% and 14 %, respectively, of workers in bottom and top occupations living in Sydney would have to change place of residence to have no segregation, whereas in 1991 these percentages were 17.4 and 15.6. Those working in middle occupations experienced the highest increase in segregation of all groups in all major cities, although their level of segregation was still far below that of the other two groups by 2011.

These results suggest that the rise in overall segregation in Australia's main capital cities was, at least partially, driven by the rise in the residential segregation of low skill groups defined in terms of education and occupation. However, this analysis does not consider changes in the demographic size of the areas and the population shares of the groups. The interplay between demographic changes and the spatial distribution of the groups is something that we explore in Section 4.3.

In addition to the decomposability by groups, trends in cities' overall segregation as measured by M can be linked to the changes in the levels of segregation of the different areas within those cities. As shown in the methods section, the index M can be decomposed in terms of the index Ψ_l that quantifies the segregation of any area looking at the under and overrepresentation of the different groups residing there.

Figure 1 below shows, on the vertical axis, the segregation level of each SLA as measured by index Ψ_l and, on the horizontal axis, the distance of the SLA to the corresponding city centre (in km). The centre is defined as the centroid of the city's inner SLA and distance to the centre is the distance from that point to each SLA's centroid.[9] The graph pools all the SLAs from the main capital cities, with the dark and light grey dots representing, respectively, the SLAs in 1991 and 2011. The chart also includes the average level of

[8] Segregation also increased for those in bottom occupations when using statistical subdivisions. The results for those in the top occupations are less robust to changes in the geographical unit, although this group's segregation also decreased in Adelaide and Perth with the two indices.
[9] For the harmonised SLAs that resulted from the amalgamation of SLAs, the distance was computed as the weighted average of the distances to the city centre from each of the centroids using the size of the SLA as weights.

segregation—computed using a local polynomial estimator of order two with bandwidths determined by a rule-of-thumb optimal bandwidth selector—and the 95% confidence interval around that average.[10]

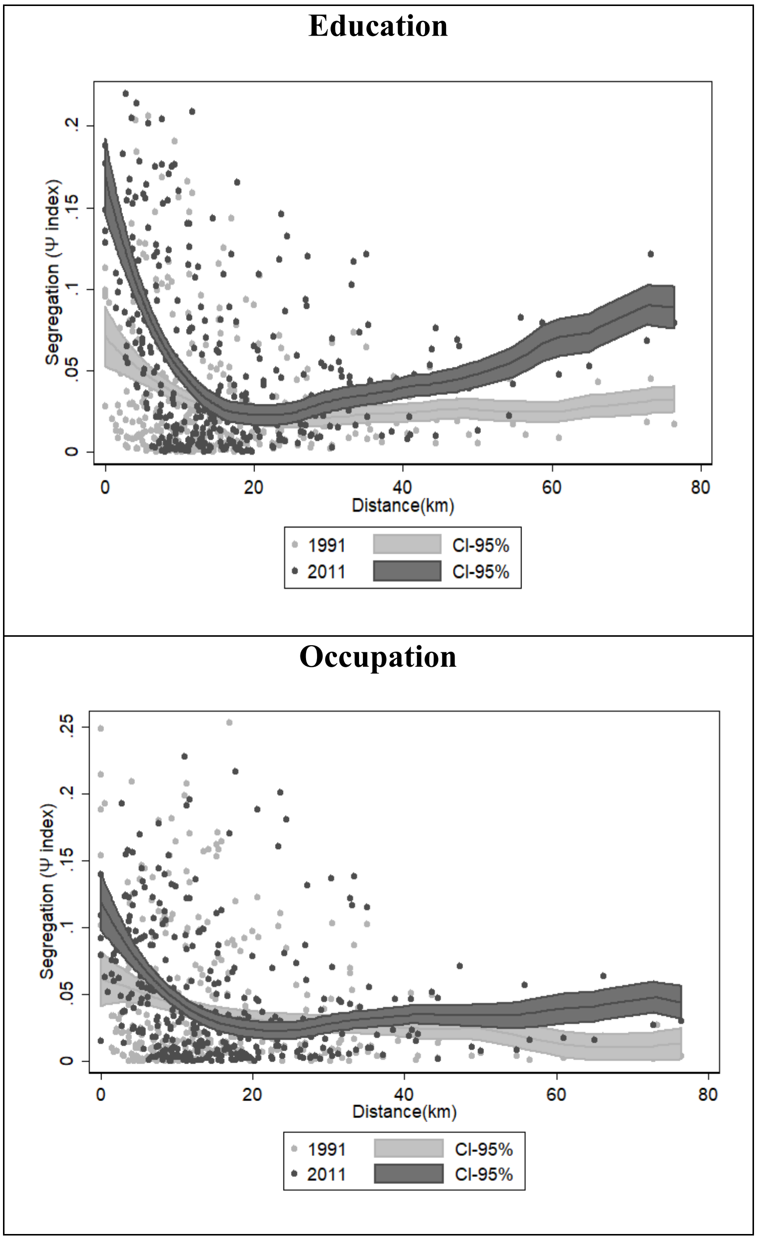


Figure 1. Segregation level of each SLA expressed as a function of distance to city centre

The figure provides insights into the increase in segregation in Australia in recent decades. Levels of segregation increased, on average, across most distance ranges although the increase was far from uniform. Concretely, the largest growth in segregation occurred in central and outer areas of the cities. This is consistent with the U-shaped

[10] For the estimation of the local polynomial we used the *lpoly* Stata command where each SLA was given a weight equal to its population size.

pattern in the graphs where segregation first decreases and then increases with the distance to the center. Although already evident in 1991, the U-shaped pattern of segregation has become more salient in recent decades with central and outer locations becoming more segregated, especially in the case of education. In 2011, SLAs located 20km far from the centre had the lowest levels of segregation (by either education or occupation groups) with segregation increasing when moving to outer areas. The segregation level of areas that are 70 km far from the centre was not very different from that of areas located within a 5-10 km ring.

4.3 Demographic Changes Versus Segregation Changes: A Counterfactual Analysis

When evaluating trends in residential segregation within cities it is important to account for the changes in the demographic structure of those cities. Thus, from an evenness perspective, overall segregation may increase over time because either the relative size of the most segregated groups grows, or the segregation levels of some groups increase, or due to a combination of both factors. Analogously, from a representativeness perspective, an increase in overall segregation may be caused by an increase in the population share of those locations in which some groups are highly over or underrepresented, by an intensification of the over and underrepresentation of groups in some locations, or by a mix of these factors.

The period 1991-2011 was characterised by a growing segregation of low-skilled groups. Parallel to this, there were important changes in the demographic composition of Australian major cities. Cities witnessed a spectacular increase in the number of highly educated individuals, with the proportion of individuals with bachelor's degrees more than doubling in all major capital cities (see Table 1 in Section 3). In contrast, the share of residents with no post-school qualification dropped about 20 percentage points in all cities. Changes in the occupational structure of cities mirror those in education. There was a marked drop in the number (and shares) of workers in middle and bottom occupations and a sharp increase in the number (and weight) of those in top occupations, especially in Sydney and Melbourne.

To evaluate the contribution of demographic changes to segregation trends we turn to counterfactual analysis. We focus on the measure *M*, which has the advantage of being decomposable in terms of both the segregation of groups and regions—equations (6) and

(7). We undertake two counterfactual analyses. First, we calculate *M* using the population shares of the groups in 1991 and their segregation levels in 2011 (labelled M(seg=11; pop=91) in Table 4). In the second counterfactual, we compute *M* assuming the groups' segregation levels in 1991 and their demographic shares of 2011 (M(seg=91; pop=11)). In other words, when moving from 1991 to 2011, we can follow two paths depending on whether we first change the groups' sizes or the groups' segregation levels. These two paths lead to the following decompositions:

$$M_{11} - M_{91} = (M_{11} - \mathrm{M}_{\mathrm{seg=11;\,pop=91}}) + (\mathrm{M}_{\mathrm{seg=11;\,pop=91}} - M_{91}) \qquad (9)$$

$$M_{11} - M_{91} = (M_{11} - \mathrm{M}_{\mathrm{seg=91;\,pop=11}}) + (\mathrm{M}_{\mathrm{seg=91;\,pop=11}} - M_{91}) \qquad (10)$$

Decomposition (9) breaks down the change in overall segregation in two components: one that results from the difference between overall segregation in 2011 and overall segregation in the counterfactual with groups' shares as in 1991 and groups' segregation as in 2011 (labelled *demographic factor*); and a second component given by the difference between overall segregation in that counterfactual and the actual overall segregation in 1991 (labelled *groups' segregation factor*). In the decomposition given by (10), the *demographic factor* arises from the difference between overall segregation in the counterfactual and overall segregation in 1991, whereas the *groups' segregation factor* is the difference between overall segregation in 2011 and overall segregation in the counterfactual. The contribution of *demography* (resp. *groups' segregation*) to the change in overall segregation between 1991 and 2011 is defined as the mean of the two *demographic* (resp. *groups' segregation*) *factors* divided by the total change.

We also explore whether the change in overall segregation between 1991 and 2011 stems from changes in the group composition of the SLAs (*segregation factor*) or in the shares these areas account for (*demographic factor*). To do this, we proceed analogously as in the case of groups by building two counterfactual distributions, one in which we keep unaltered the SLAs' shares and another in which the representation of the groups within each SLA is the factor that remains unchanged.

Table 4 provides the results of the decompositions by groups and regions. Changes in the relative size of education groups unambiguously contributed to the increase in residential segregation by education. If the segregation levels of education groups were as in 1991 and their demographic shares as in 2011, the *M* index would have increased much more than it actually did (compare M(seg=191; pop=91) and M11). The sharp increase in the prevalence of highly educated individuals, who tend to be more unevenly distributed than other groups, certainly lies behind this result. Note that the direction of the segregation factor depends on the pathway followed for the decomposition. Thus, in all cities, M11 is below M(seg=91; pop=11), which indicates that changes in groups' segregation between 1991 and 2011 contributed to prevent the rise in overall segregation. The decline in the unevenness of the most educated is a factor clearly pushing in that direction. In contrast, the value of the counterfactual M(seg=11; pop=91) is greater than M91, suggesting a positive contribution of groups' segregation to the increase in overall segregation, likely reflecting the increase in the segregation of low-educated groups documented above. As mentioned earlier, the contribution of a factor to the change in overall segregation was calculated as the mean contribution of the factor in the two counterfactual analyses. In the case of the segregation factor, this average turns out to be negative, reflecting the larger magnitude of the negative contribution of the segregation factor in one of the decompositions. The analysis thus suggests that although individuals with bachelor's degrees experienced a decrease in segregation, as shown in Section 4.1, this highly segregated group grew so much during this period that it made overall segregation rise. This effect was reinforced by the rise in the unevenness of those with low education.

If we look instead at residential segregation by occupation, we find that in Sydney, Melbourne, and Brisbane, segregation increased mainly because occupation groups became more unevenly distributed across regions (although changes in the groups' sizes played also a role). Thus, for example, in Sydney, 83.4 % of the change came from changes in the groups' segregation levels and 16.6 % from demographic changes.

Both in the case of education and occupation, the decomposition by regions shows that the increase in overall segregation in Sydney, Melbourne, Brisbane, and Perth can only be explained by an intensification in the over and underrepresentation of the groups within SLAs. The demographic factor is either negative or slightly positive, which indicates that the driver of the segregation rise in these cities was not the growth of SLAs with segregation issues. The situation in Adelaide is similar to that in the other cities when exploring segregation by education. However, this city has a different evolution than the others when socioeconomic status is proxied by occupation. The decomposition by regions suggests that the overall segregation reduction in Adelaide arose mainly from changes in the relative size of the regions (68.3%), although changes in the over and underrepresentation of the groups within regions also played a role (31.7%).

Table 4. Actual and counterfactual *M* values and decompositions by groups and regions

Segregation by Education				Counterfactuals-Groups		Decomposition by Groups		Counterfactuals-Regions		Decomposition by Regions	
	M91	M11	Δ (%)	M(seg=11; pop=91)	M(seg=91; pop=11)	Segregation (%)	Demography (%)	M(seg=11; pop=91)	M(seg=91; pop=11)	Segregation (%)	Demography (%)
Sydney	0.033	0.053	60.30	0.039	0.064	-13.27	113.27	0.053	0.032	100.84	-0.84
Melbourne	0.029	0.045	53.61	0.031	0.058	-35.42	135.42	0.044	0.030	94.93	5.07
Brisbane	0.029	0.051	77.57	0.032	0.062	-18.00	118.00	0.053	0.027	107.93	-7.93
Adelaide	0.029	0.039	32.86	0.024	0.059	-133.45	233.45	0.039	0.029	104.13	-4.13
Perth	0.024	0.035	46.98	0.022	0.048	-65.35	165.35	0.038	0.023	115.55	-15.55

Segregation by Occupation				Counterfactuals-Groups		Decomposition by Groups		Counterfactuals-Regions		Decomposition by Regions	
	M91	M11	Δ (%)	M(seg=11; pop=91)	M(seg=91; pop=11)	Segregation (%)	Demography (%)	M(seg=11; pop=91)	M(seg=91; pop=11)	Segregation (%)	Demography (%)
Sydney	0.037	0.044	18.28	0.046	0.042	83.44	16.56	0.045	0.037	113.34	-13.34
Melbourne	0.035	0.043	21.84	0.045	0.038	94.50	5.50	0.043	0.034	103.77	-3.77
Brisbane	0.033	0.040	22.23	0.039	0.037	61.91	38.09	0.042	0.030	134.47	-34.47
Adelaide	0.035	0.033	-5.24	0.032	0.039	247.43	-147.43	0.035	0.034	31.67	68.33
Perth	0.026	0.027	4.63	0.026	0.030	-131.39	231.39	0.030	0.025	243.37	-143.37

Source: Authors' calculation.

4.4 Who is Moving Where?

To further shed light on the changes in the spatial distribution of low and high skill groups we examine the degree of over and underrepresentation of the groups across SLAs. The level of representation of any group g in location l, denoted by $r_{g,l}$, is equal to the ratio $\frac{n_l^g / N^g}{p_l / P}$, which compares the size of the group in location l with that in the overall population and constitutes the main building block of the index Φ^g (see Section 2). We distinguish 5 levels of representation based on the quintiles of the distribution of $r_{g,l}$ in 1991 computed at city level pooling information on all groups (education or occupation) and SLAs.[11] A group is very underrepresented in a given SLA if $r_{g,l} \leq P_{20}$, underrepresented if $P_{20} < r_{g,l} \leq P_{40}$, represented at the expected level if $P_{40} < r_{g,l} \leq P_{60}$, overrepresented if $P_{60} < r_{g,l} \leq P_{80}$, and very overrepresented if $r_{g,l} > P_{80}$.

Figures 2-4 show the level of representation of occupation groups across SLAs, for both 1991 and 2011, in the cities in which segregation by occupation increased the most over the period: Sidney, Melbourne, and Brisbane (the charts for Perth and Adelaide are shown in the supplemental materials).[12] The charts reveal important changes in the spatial distribution of skill groups. Interestingly, we find evidence of a growing concentration of high-skilled occupations in inner city locations across all five cities, as suggested by the increase in the number of inner SLAs coloured in dark red on the maps. In 1991, those working in top occupations had a representation larger than the expected in 71 % of the 132 SLAs within a 10km ring of the centre. By 2011, this percentage had risen to 92 % (121 out of 132 SLAs). In contrast, the charts provide clear evidence of the outward displacement of people working in middle and bottom occupations consistent with a growing underrepresentation of those groups in central locations. The percentage of SLAs within a 10km ring where bottom occupations are under or very underrepresented rose from 67% to 92%, with similar trends found for those in middle occupations (from 55% to 83%).

The reconfiguration of the inner cities came accompanied by substantial changes in the social and economic mix of middle and outer regions. Most salient among them is the large increase in the overrepresentation of people working in bottom and middle occupations in suburban and peri-urban areas. In 1991, those working in bottom (middle) occupations were very

[11] The percentiles P_{20}, P_{40}, P_{60}, and P_{80} are shown in the supplemental materials (Table B3). In the five cities, the median (P_{50}) is very close to 1(expected representation).

[12] The results for education are very similar and are available upon request.

overrepresented in 42 (46) of the 100 capital cities' SLAs located more than 20km far from the centre, and by 2011 that number had grown to 59 (78).

These findings are consistent with the suburbanization of disadvantage in Australia's major capital cities documented in Randolph and Tice (2017) and Pawson and Herath (2015). Using an aggregate measure of disadvantage, Randolph and Tice (2017) report an increasing concentration of disadvantage in areas 20km far from the centre, which is consistent with our micro evidence. In contrast with other occupations, those working in top occupations became more underrepresented in middle and outer areas as evidenced by the increase in the number of light-coloured outer SLAs.

The diverging pattern of skill groups is observed in the five cities although is particularly evident in Sydney, Melbourne, and Brisbane. In Sydney, the concentration of high-status occupations occurred in the north-west and inner ring parts, expanding the area where those occupations were already overrepresented in 1991. These areas coincide with the highly advantaged areas identified in Baum et al. (2006) using data for 2001. The rise in the overrepresentation of top occupations was particularly evident in the southern parts of the inner city. Bottom and middle occupations became increasingly overrepresented in south-west suburbs and outer areas. Similar to Sydney, top occupations in Melbourne and Brisbane became increasingly overrepresented in the inner cities. By 2011, bottom and middle occupations in Melbourne were clearly overrepresented in the north-west and south-east suburban and peri-urban areas of the city. In Brisbane middle occupations became more overrepresented in the northern and southern parts of the city.

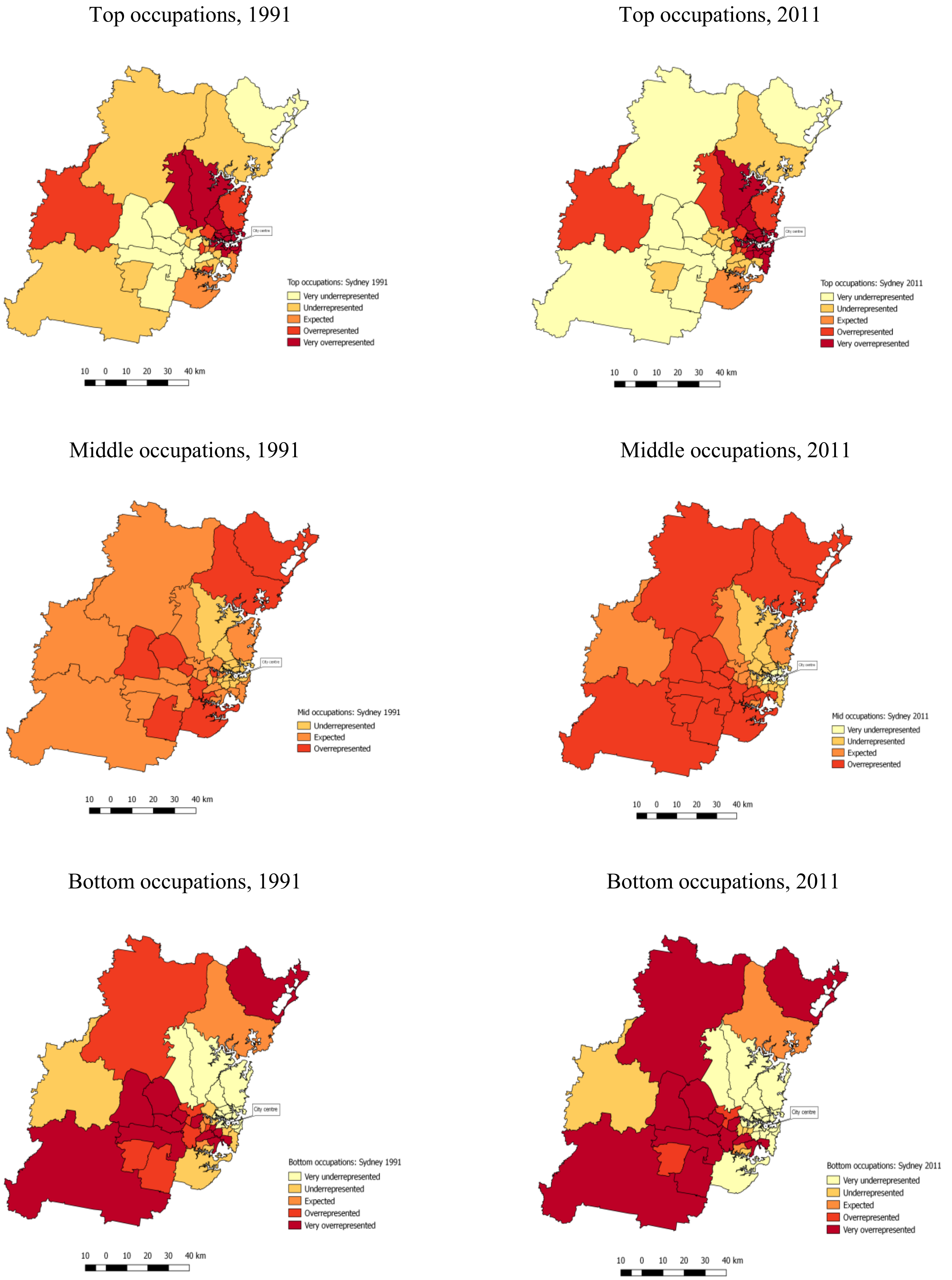


Figure 2. Representation of occupation groups in each SLA, Sydney

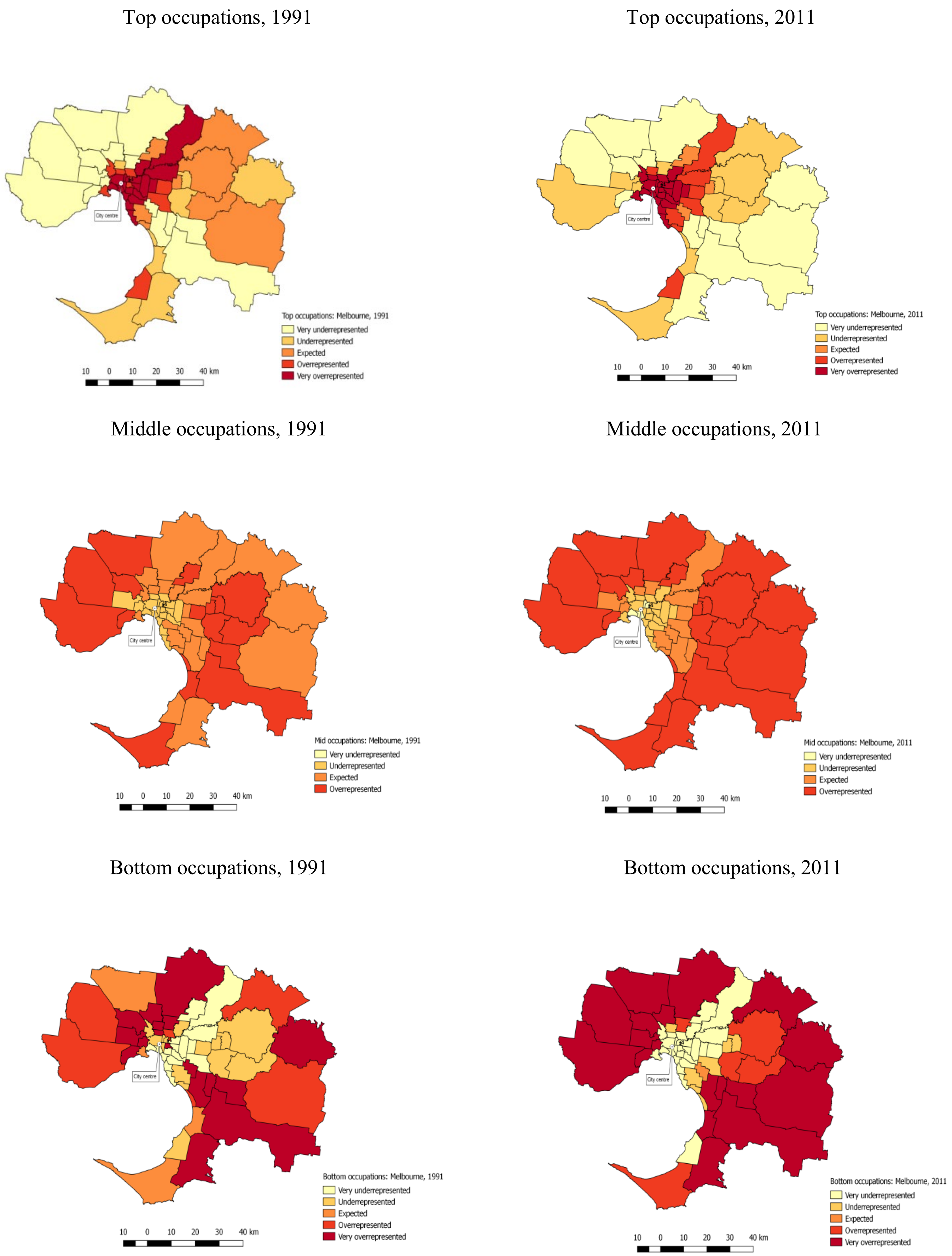
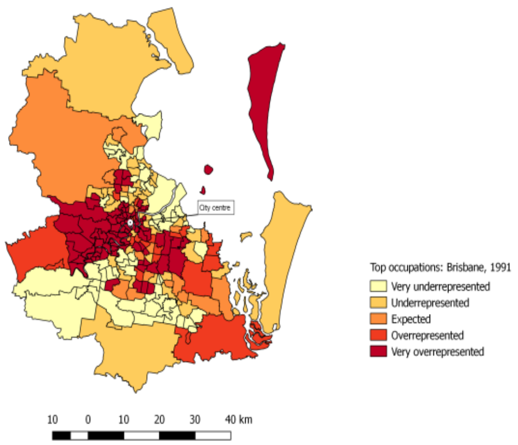
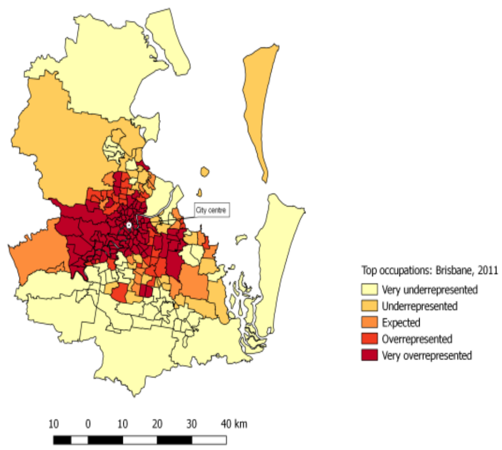


Figure 3. Representation of occupation groups in each SLA, Melbourne

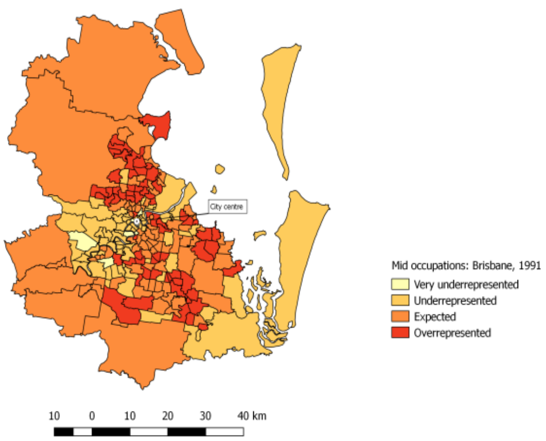
Top occupations, 1991



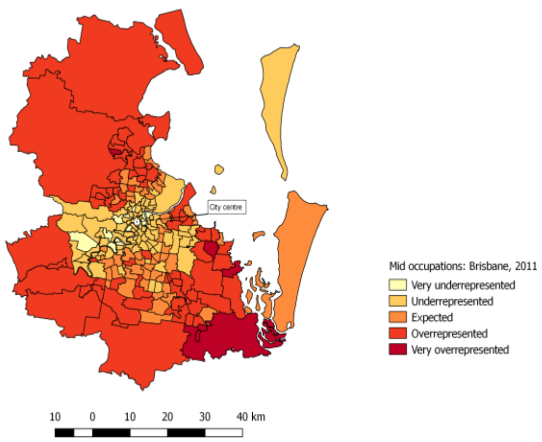
Top occupations, 2011



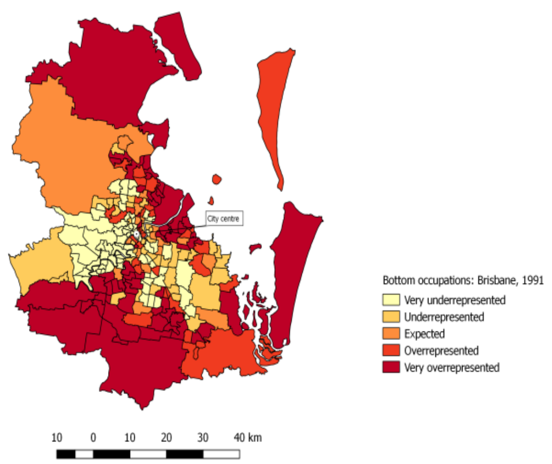
Middle occupations, 1991



Middle occupations, 2011



Bottom occupations, 1991



Bottom occupations, 2011

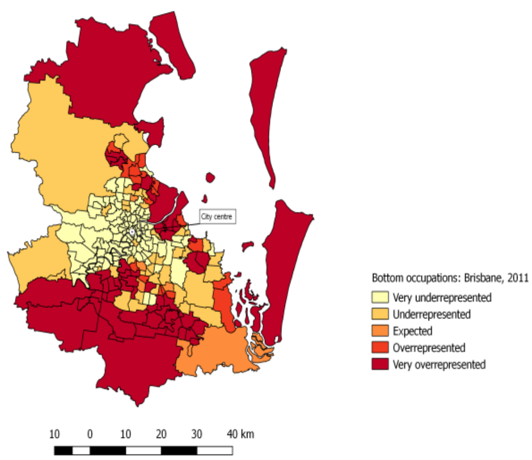


Figure 4. Representation of occupation groups in each SLA, Brisbane

5. Final Comments

This paper has explored changes in the spatial distribution of skill groups in Australia's main capital cities. We find a marked increase in residential segregation across all major cities between 1991 and 2011. The rise in segregation by occupation groups cannot be explained by demographic changes but rather by an intensification of the over and underrepresentation of groups across locations. Regarding education, while highly educated groups are in general the most segregated, the rise in segregation was mostly driven by the increasing segregation of the low educated and the growth of highly educated groups. Our analysis reveals a striking divergence in the residential patterns of the low and high skill groups: while least skilled groups became increasingly overrepresented in middle and outer areas of the cities, the most qualified and those in top occupations became more concentrated in the inner parts. These results are consistent with the suburbanization of disadvantaged in Australian cities documented by Randolph and Tice (2017) and Pawson and Herath (2015).

The welfare implications of skill sorting are still unclear. Using evidence from a spatial equilibrium model, Diamond (2016) concludes that spatial segregation increases *welfare* inequality between skill groups because human capital externalities and access to desirable amenities occur in places where there is a concentration of highly educated individuals. On the other hand, many observational studies document negative effects of concentrated disadvantage for individuals' opportunities and development (e.g., Rothwell and Massey, 2015). Despite this evidence, whether mixed communities are superior to segregated ones remains a contentious academic and policy issue (Lees, 2008). Understanding why high and low skill groups are pulling away from each other in modern cities and the welfare consequences of this are highly relevant questions that merit further research.

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