Understanding the Effects of School Catchment Areas and Households with Children in Ethnic Residential Segregation

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Households with children have been suggested to play a key role in ethnic residential segregation. One possible mechanism is that school district boundaries affect their segregation patterns, but direct evidence on this is scarce. This study investigates the role of school catchment areas for ethnic segregation among different types of households in the city of Helsinki, Finland, using individual-level register-based data covering the complete population of the city annually between 2005 and 2014. The analyses consist of three steps: a description of ethnic segregation among different types of households with segregation indices, an analysis of mobility flows between school catchment areas, and a boundary discontinuity analysis of the causal effects of the boundaries of catchment areas on the mobility of different types of Finnish-origin households. The analyses show that ethnic segregation is stronger among households with children than among childless households and the residential mobility of higher-income Finnish-origin households with children is particularly affected by the school catchment area boundaries.

Keywords: residential segregation; immigrants; schools; residential mobility

Introduction

Ethnic residential segregation is commonly measured among the total population or among the adult population. However, recent studies in the USA have shown that ethnic residential segregation is more pronounced among children (Owens, 2017) and households with children (Iceland *et al.*, 2010), than among the general population. Similarly, Sabater and Catney (2019) found ethnic segregation in England and Wales to be more pronounced among children and among middle-aged and older persons. These findings suggest that families with children are a strong driver of residential segregation and a particularly important group regarding explanations of ethnic segregation.

One explanation for these findings may be that the residential choices of families with children are structured by school district or catchment area boundaries, as especially more affluent families are known to optimize the social and educational environment for their children. As a result, these families move to the school districts with the best schools, driving up property prices, which reinforces patterns of segregation by income and ethnicity. Recent studies have suggested that school district boundaries indeed affect residential segregation by both income and ethnicity in the USA (Owens, 2016; Owens, 2017). Such findings may not be limited to the US context, and European and other international research suggests schools to be a strong factor in the residential decision-making process for urban families (see e.g. Bernelius and Vaattovaara, 2016; Boterman, 2012, 2013; Butler and Hamnett, 2007; Rowe and Lubienski, 2017). However, none of these previous studies have applied strict causal designs.

Especially middle-class families have been demonstrated to be sensitive to perceived socio-economic and ethnic segregation in schools and neighbourhoods, leading to school choices on the basis of student composition rather than academic qualities of the schools (Butler and Hamnett, 2007; Harjunen *et al.*, 2018; Rowe and Lubienski, 2017). If families with children have strong preferences regarding the neighbourhoods they want to live in, this should be visible in their residential mobility patterns. European studies have indicated that the intra-urban mobility of the native-origin population is *generally* an important demographic process increasing ethnic segregation (Bråmå, 2008; Kauppinen and van Ham, 2019; Musterd and de Vos, 2007), but there is not much evidence by type of household. However, a recent Norwegian study found the residential mobility of parents and upcoming parents to be particularly sensitive to concentrations of ethnic minorities (Wessel and Nordvik, 2018).

This study contributes to the literature by assessing differences in segregation and residential mobility by the type of household, and by explicitly investigating the causal role of school catchment areas in understanding ethnic segregation among different types of households. We analyze data from the city of Helsinki in Finland, which provides an interesting context to study segregation in relation to schools, as the school intake is mostly based on the catchment areas of individual schools. In line with findings from other countries, ethnic segregation has been found to be stronger among children than among the working-age population in Helsinki (Saikkonen *et al.*, 2018). School catchment area boundaries have also been found to affect housing prices (Harjunen *et al.*, 2018), and the most disadvantaged catchment areas experience avoidance or loss of native Finnish families (Bernelius and Vilkama, 2019).

Based on the literature we have formulated the following four research questions: (1) How does the residential segregation between Finnish-origin and immigrant-origin households in Helsinki differ by the household type?; (2) Are there differences in levels of ethnic segregation by household type after controlling for income?; (3) Are the migration flows of the Finnish-origin households with children below school-starting age particularly strongly directed towards school catchment areas with lower shares of immigrants?; and (4) Are the moves of Finnish-origin households with children affected by the catchment areas of elementary schools? We use individual-level longitudinal register-based data, covering the complete population of the city of Helsinki annually between 2005 and 2014. Central to our analytical approach, and our main contribution to research, is to isolate causal effects by conducting a boundary discontinuity analysis, taking advantage of detailed information on residential locations of the households.

Ethnic Residential Segregation and the Role of Schools

Residential Segregation by Type of Household

Findings on segregation levels that are based on measuring segregation between individuals may be confounded by different segregation patterns among different types of households, such as among households with children as compared to segregation among single-adult households. Larger households also have more impact on the results, as they contribute more people to the analysis. One way to approach this is to analyze segregation between individuals by age. Owens (2017) argues that in the US context, only few studies have examined racial segregation separately among children and adults, even though there is a large body of research on racial segregation generally. This situation is not limited to the US context, and also Sabater and Catney (2019) see age as an overlooked aspect in most studies of residential segregation. Studies analyzing segregation by age have found pronounced ethnic segregation among children (Owens 2017) or among children and middle-aged and older persons (Sabater and Catney, 2019). According to Sabater and Catney (2019), in England and Wales young adults in their 20s are the age group driving ethnic *mixing*, as in all ethnic groups they move to move diverse areas. However, when age cohorts are followed in time, their ethnic segregation increases afterwards, potentially related to family formation.

Instead of, or in addition to age, it may be fruitful to analyze segregation by type of household, as the residential locations of children are dependent on their parents. Also, in the adult population age is strongly connected with family events and household type. Taking the type of household into account can also provide clearer results concerning the adult population, as childless households may have different preferences and opportunities than families with children. Conducting such analysis at the household level instead of the level of individuals gives equal weight to each household, which may be preferable, as residential mobility outcomes are based on household level decisions. Similarly to age-related studies, Iceland *et al.* (2010) called existing literature on residential segregation by the type of household 'extraordinarily thin.' Findings from the few existing studies suggest that in the USA, families with children are more segregated than either childless households or young adults in age groups typically preceding the establishment of families (Iceland *et al.*, 2010; Owens, 2017).

Why Do Household Types Matter for Understanding Segregation?

Two main reasons have been proposed for why ethnic segregation is stronger among children (Iceland *et al.*, 2010; Owens, 2017). The first relates to *economic resources*. Income is a key characteristic influencing neighbourhood sorting (e.g. Hedman *et al.*, 2011; Clark and Rivers, 2012). If the disparity in economic resources by ethnicity is larger among families with children than among childless households, this can be expected to lead to stronger residential segregation. In that situation, the ability to pay for housing in more expensive neighbourhoods is limited more strongly among *minority* families with children. In the US context, particularly the higher prevalence of single-parent families among black and Hispanic families might be an important driver of segregation. In contexts such as Finland, the low level of employment particularly among non-Western immigrant women could be a similar explanation of segregation patterns.

The second potential explanation is related to variation in *residential preferences*. Families with children have different preferences than childless households. They are commonly attracted by suburban environments, presence of other children, good access to schools and playgrounds, and availability of dwellings suitable for families (Hedman *et al.*, 2011). A particular difference that may exist is the sensitivity to the ethnic composition of the neighbourhood population. In the majority population, preferences for co-ethnic neighbors, i.e. one aspect of the segregation-reinforcing tendencies in choice and sorting (Clark and Rivers, 2012), could be more prevalent among families with children: concerns for the circumstances of their children may add to their personal preferences. Parents of young children may therefore put more weight on the population composition in their residential choices than other types of households (see e.g. Boterman, 2013). Such preferences might not be directly related to the actual neighbors, but the ethnic composition may act as a signal for other neighbourhood characteristics such as perceived school quality or safety (Iceland *et al.*, 2010). This is called the *racial proxy hypothesis* (e.g. Swaroop and Krysan, 2011). Assumed or observed school characteristics may also directly affect residential decisions when schools have catchment areas. Among childless households, such concerns may be less relevant, leading to lower levels of segregation.

These two potential explanations lead to different expected outcomes. If economic resources are the decisive factor, there should not be stronger ethnic segregation among households with children when the economic resources are controlled for. If households with children are more strongly segregated even after controlling for economic resources, this could be a sign of differential residential preferences (or discrimination). After stratifying the measurement of ethnic segregation by the poverty status of households, Iceland *et al.* (2010) concluded that differences in socioeconomic status do *not* explain why ethnic segregation is stronger among families with children than among non-family households. Neither Owens (2017) nor Sabater and Catney (2019) used information on income in their analyses. Therefore, the significance of economic resources for the differences in ethnic segregation by type of household is not clear, but in the US context, the difference seems to be related to other factors besides poverty status, such as residential preferences.

Studies analyzing residential mobility out from or into ethnic minority concentrations have not typically addressed differences by household type. According to Owens (2017), evidence from existing studies has been mixed on whether households with children are more sensitive to the ethnic composition. Recently, a Norwegian study (Wessel and Nordvik, 2018) found the out-mobility of native-born parents and upcoming parents to be more sensitive to neighbourhood's share of ethnic minorities than the out-mobility of childless native-born adults even after controlling for income and other socio-demographic characteristics. This finding was interpreted from the point of view of the racial proxy hypothesis, as indication of fear of neighbourhood decline.

School Choices and Residential Mobility

Research from several countries demonstrates that especially parents with a higher socio-economic status actively choose schools which they expect will benefit their children most (Ball, 2003; Boterman, 2012; Byrne, 2009; Raveaud and van Zanten, 2007). Therefore, the characteristics of local schools may be an important factor for families with children in neighbourhood selection. On the other hand, the population composition of neighbourhoods affects the socio-economic composition of school populations and school reputations (see e.g. Bernelius, 2013; Boterman, 2012; Boterman, 2013). A growing body of research has highlighted this link between residential and school segregation in urban areas, where the socio-economic structure of the neighbourhood affects the schools' student base and educational attainment, which may affect further school and residential choices made by families with children (Andersson *et al.*, 2010; Boterman, 2012; Boterman, 2013; Cheshire and Sheppard, 2004; Harjunen *et al.*, 2018; Nieuwenhuis and Hooimeijer, 2015; Riedel *et al.*, 2010). Higher-income majority ethnic parents may put particularly strong emphasis on the ethnic composition of schools and neighbourhoods (Owens, 2016; Owens, 2017).

This interaction between schools and urban residential segregation is strong especially when school allocation is regulated through school catchment areas. In these circumstances, residential mobility is an important way of exercising school choice, as it is the central way of ensuring access to the desired schools (Boterman, 2013; Reay *et al.*, 2011). This is reflected in housing prices (e.g. Cheshire and Sheppard, 2004; Gibbons *et al.*, 2013; Harjunen *et al.*, 2018), increasing the importance of economic resources regarding the possibility to choose schools. In many countries, parents can additionally navigate the system by opting out of the public-school system and applying for private education. In Finland, however, private education plays a minor role, and the majority of schools belong to the local network of public school with address-based allocation policies. Parents' selective choice strategies thus focus predominantly on public school alternatives and can be expected to be partly exercised through residential mobility behavior.

School choices are strongly linked to the social and ethnic composition of schools (Boterman, 2013; Byrne, 2006; Karsten *et al.*, 2003; Vowden, 2012). In addition to parents' concerns about the social backgrounds and views on the social aspects of classroom life, parents appear to associate the schools' composition with the quality of education (Bathmaker *et al.*, 2013; Kosunen, 2014; Rowe and Lubienski, 2017; Butler and Hamnett, 2007; Vincent and Ball, 2001). There are thus multiple links between the parents' views on school quality, school composition and neighbourhood qualities, and the choice of neighbourhood may represent a simultaneous choice for a desirable neighbourhood and access to a certain school.

The Finnish Context

The city of Helsinki, the capital of Finland, had 635,000 inhabitants in the end of 2016, and 14 per cent of them had a foreign background (both parents born abroad) (Hiekkavuo, 2017). This proportion has increased rapidly from merely six percent in 2000. Larger-scale immigration to Finland only began in the 1990s, and accordingly, between 1990 and 2016, the population with a foreign background grew from 10,000 to 95,000 in Helsinki. The increasing immigrant population has brought an ethnic dimension to public discussions on segregation. Such a rapid growth of immigration may lead to avoidance of the immigrant population by the native-born population (Hall and Crowder, 2014). Even though ethnic segregation was not found to be particularly strong in the Helsinki region in a Nordic comparison (Skifter Andersen *et al.*, 2016), many immigrants have still settled in socioeconomically deprived neighbourhoods (Kortteinen and Vaattovaara, 2015; Saikkonen *et al.*, 2018; Vilkama, 2011).

Residents with a foreign background are still a minority in all neighbourhoods in Helsinki, but the differences are more marked among children. In the beginning of 2019, 16 per cent of total population and 20 per cent of children aged 0–15 years had a foreign mother tongue. The shares vary between neighbourhoods from a few percent to over a third among the total population and to over 50 percent among children (City of Helsinki, 2019).

The school network and allocation in Helsinki reflect the egalitarian Nordic educational policies. The network of schools largely consists of local public schools, where the education is based on a national curriculum. The existing private schools are also publicly controlled, free of tuition fees and tied to the national curriculum. The institutional quality of schools is thus fairly uniform. Each child is assigned a 'local home school' based on their home address, giving the right to attend the nearest school. Since the mid-1990s, families have had the right to express a choice of a school outside their local catchment area, which has led to stronger ethnic segregation between schools than between neighbourhoods (Bernelius, 2013). However, the possibility to attend another school depends on the availability of free places in each school as well as possible admission criteria. The only way to ensure a place in a certain school is to have a home address within the catchment area. Currently 80 percent of the children starting primary school attend the school within their own catchment area.

The direct link between socio-spatial patterns and pupil composition in schools combined with high overall institutional quality makes Helsinki an interesting location to study the links between catchment area based school policies and residential segregation (see also Bernelius and Vilkama, 2019). When the vast majority of pupils attend their nearest school, urban segregation has a direct effect on pupil composition, which is further reflected in the educational attainment of the schools (Bernelius, 2013). The pupil composition and attainment, in turn, affect the school reputation, which further affects school choices (Kosunen, 2014) and potentially also residential segregation. As the institutional qualities of the schools are fairly constant through the city, the parental choices are mostly related to social composition and neighbourhood qualities instead of varying academic qualities in schools.

Study Design

In this study, we aim to demonstrate the differences between household types in ethnic segregation, while taking into account income differences. Additionally, we illustrate differences between household types in residential mobility flows, and we test for one potential mechanism in bringing about these differences: the effect of school catchment areas on residential mobility. Next, we describe the data and the analytical steps and methods of this analysis.

Data

Our dataset is an individual-level register-based dataset covering the complete population of the city of Helsinki annually between 2005 and 2014, created by Statistics Finland (contract number xxxxxxxx). We have aggregated the data on the household level and we measure socio-demographic characteristics of households: ethnic background, income, number and ages of children (those below the age of 25 in a child's position in the family according to Statistics Finland), and age of the youngest adult (either the reference person of the family or his/her spouse or a person not living in a family). Residential locations are known with the precision of 250 m × 250 m grid cells.

Ethnic categorization was based on the "background country" and the mother tongue. Background country refers to parents' countries of birth, prioritizing the foreign-born parent. In the absence of parental information, this is based on own country of birth. By native-origin households, we mean those households in which the background country for all members was Finland and the mother tongue for all members was Finnish. The information on mother tongue was used as a criterion, because there are separate Swedish-language schools with different catchment areas (around six percent of the population of Helsinki belong to the Swedish-speaking minority). By non-Western-origin households we refer to households with all members having a non-Western background country, and by foreign-origin households we refer to households with all members having a foreign origin. The "non-Western" category refers to non-European countries except the USA, Canada, Australia and New Zealand.

Household income was measured as the income decile of the household based on equivalized disposable money income. The deciles were based on the income distribution of the total population of the city of Helsinki. In segregation index calculation, the income is measured from the current year, and in the migration analyses it is measured during the calendar year before the move. As we use income as a stratifying variable, we dichotomize it to have enough observations, with the categories low (deciles 1–4) and high (deciles 5–10) income.

In addition to the grid cells, we used the catchment areas of the municipal Finnish-language elementary schools (N = 85–89, depending on the year). In 2010, the catchment areas had on average 6600 residents (standard deviation = 4100) and 3500 households (standard deviation = 2600). We measured the catchment areas by combining annually the grid cells belonging to the same catchment area. Since the school year 2011–2012, some catchment areas (15 since the school year 2012–2013) were combined into larger districts in the school intake, decreasing the potential importance of catchment areas for moving decisions on average. The catchment areas still remained, so we use them as units in the analysis even when the school intake was not based on them.

In the migration analyses we also used control variables mainly referring to the housing stock characteristics of the areas. These variables are listed in the description of the analyses. They were measured from our individual-level dataset and the information on the housing stock was based on inhabited dwellings.

Analytical Steps and Methods

The analysis consists of three steps, each linked to the research questions (RQs) as formulated in the introduction. In the first step we analyze segregation levels by household types (RQ 1 and 2). In the second step we investigate residential mobility flows (RQ 3) and in step three we use boundary discontinuity analysis to analyze the potential causal effects of catchment area borders on intra-urban residential mobility (RQ 4).

First Step of Analysis: Segregation Levels

The first step is to measure ethnic segregation with segregation indices, comparing the residential distributions of different types of native-origin households to the distributions of similar types of non-Western-origin households (RQ 1). This is done for the year 2010, before the creation of several larger school intake districts. We primarily used the index of systematic dissimilarity (Carrington and Troske, 1997), and we also refer to findings applying the index of dissimilarity (e.g. White, 1983).

The index of systematic dissimilarity takes into account that when the population groups or the spatial units are small, even random allocation can lead to high values of the index of dissimilarity. In its unconditional form, it compares the observed index of dissimilarity to values that could be expected under random allocation (of for example ethnic minorities to areas). The expected value is obtained here similarly to Carrington and Troske (1997) and Åslund and Nordström Skans (2009) by calculating the mean value of the index of dissimilarity in 500 simulations in which the ethnic statuses of households are allocated randomly (only Finnish-origin and non-Western origin households are included).

The index of systematic dissimilarity ranges between -1 and 1 (see Carrington and Troske 1997). Positive values of the index tell the extent of excess segregation as compared to random allocation, as a fraction of the maximum amount that could possibly occur. When the group and unit sizes are sufficiently large, the values are very close to the regular index of dissimilarity. Negative values indicate excess *evenness*.

The index of systematic dissimilarity can be extended by controlling for another dimension of segregation. This is achieved by calculating a *conditional* index of systematic dissimilarity (Åslund and Nordström Skans, 2009). It takes into account one or more systematic sources of segregation in addition to random allocation when calculating the expected values. Here it is used to control for the effects of income, by randomizing the ethnic category of each household *within each income decile* in the 500 simulated residential distributions. Therefore, the index of systematic dissimilarity conditional on income shows how much the observed index of dissimilarity differs from segregation that could be expected if only income differences and random allocation affected the residential patterns. When compared to the unconditional index, we can see what share of ethnic segregation is related to income differences (RQ 2).

Second Step of Analysis: Mobility Flows

The second step continues the analysis of the underlying processes of the segregation levels.

We analyze migration flows between the school catchment areas by the means of count regression. The primary aim is to describe the association between the share of non-Western-origin children in the school-age populations of the catchment areas and the migration of different types of Finnish-origin households with children (RQ 3). Their migration is compared to other household types. We apply ‘gravity’ models of migration at this phase, similarly to Bakens *et al.* (2018).

The migration flow analysis is done separately for each type of household and also separately for the periods 2006–2010 and 2011–2014. In the case of foreign-origin households, we are only able to analyze rather coarse groups (and without detailed ethnic categorization) as there are too few mover households. As a moving household, we define a group of persons who were living together in the previous year in Helsinki and moved together to a new dwelling in another catchment area.

The analysis is done using aggregated data in which there is a cell for each combination of an origin area and a destination area, including those combinations without any movers (total number of combinations: 7308 in 2006–2010 and 6806 in 2011–2014). The outcome is the number of mover households from the origin area to the destination area. The main explanatory variable is the difference in standardized shares of non-Western-origin children in 7–15-years-old population of the catchment area in the end of 2005 or 2010, depending on the period.[1] Other variables central for the gravity model are the (log) distance in kilometers between the catchment area centerpoints, the (log) number of dwellings in the destination area (in 2005 or 2010), the (log) increase of dwellings in the destination area during the period, and to take the population at risk of moving into account, the (log) household-years of the given type in the origin area during the period as an offset term.[2] We also include as control variables the differences between the areas in (log) distance to the city center, the percentage of dwellings in apartment buildings, the percentage of social rental dwellings, and the percentage of dwellings having at least two bedrooms. The control variables are measured in the end of 2005 or 2010. When analyzing households with children, the variables related to the numbers of dwellings and shares of social rental dwellings refer to dwellings with at least two bedrooms.

Our model for the number of movers from area i to area j (λ_{ij}) is

$$\ln \lambda_{ij} = \beta_0 + \beta_1 \Delta s_{ij} + \beta_2 d_{ij} + \beta_3 x_{1j} + \beta_4 x_{2j} + \Delta x'_{ij} \beta_5 + \ln P_i + \varepsilon_{ij} \quad (1)$$

where

Δs_{ij} = difference between the catchment areas in the share of non-Western-origin children in

7–15-years-old population

d_{ij} = log distance between the catchment area centerpoints in kilometers

x_{1j} = log number of dwellings in the destination area

x_{2j} = log increase of dwellings in the destination area (zero in case of no increase)

$\Delta x'_{ij}$ = differences between the catchment areas in housing and distance characteristics

P_i = exposure variable: population at risk of moving (coefficient of the log transformation constrained to 1)

ε_{ij} = unit-specific error allowing for overdispersion (gamma distribution, mean = 1)

We estimate this model with negative binomial regression (Stata command nbreg), as we expect overdispersion due to many zero counts.

Third Step of Analysis: Boundary Discontinuity Analysis

The third step is an attempt to assess the *causality* of the association between catchment area characteristics and residential mobility (RQ 4). We analyze in-migration to vacated dwellings and ask whether it is causally affected by the catchment-area characteristics. For this purpose, we conduct a boundary discontinuity analysis.

In the migration flow analyses described above, the observed associations between catchment area characteristics and residential mobility might have been caused by unobserved factors omitted from the model. The central idea of the boundary discontinuity analysis is that within a small enough area, many of these unobserved locational factors may be expected to be shared within the whole area (Gibbons *et al.*, 2013; Young *et al.*, 2016). Therefore, if outcomes are different on the different sides of a geographical boundary crossing through this area (which we call a boundary region), in absence of other coinciding significant boundaries, the boundary might be the cause for the difference. Study designs employing either fixed effects for the boundary regions or differencing across the boundary allow for controlling for the unobserved locational factors shared by both sides of the boundary.

In this analysis, we look at households moving to dwellings that are vacated in the 250 m × 250 m grid cells along catchment area borders. This includes households moving within the same grid cell or catchment area but not households moving (completely) from other municipalities or countries to Helsinki, as we expect intra-urban migration to be particularly affected by the catchment areas. A vacated dwelling means here a dwelling that has completely different inhabitants in the end of the year as compared to the end of the previous year, or a new dwelling. A mover household includes all persons who live in such a dwelling.

The boundary regions were constructed using information on the catchment area boundaries for the 2014–2015 school year. Detailed information on their construction is given in Appendix 1. We ended up on 41 boundary regions. Several particularly disadvantaged or affluent neighbourhoods were left out due to their clear physical separation from surrounding neighbourhoods.

The available fixed-effects procedures for negative binomial regression do not control for unobserved cluster-level i.e. boundary-region-level characteristics (Allison, 2012; Schunck and Perales, 2017). Therefore, we conduct the boundary discontinuity analysis by applying a hybrid negative binomial regression model (Stata command xthybrid). It can be used to approximate a fixed-effects design as it decomposes the effects of level-one covariates into within-cluster and between-cluster components (Schunck and Perales, 2017).[3]

The unit of analysis is a group of grid cells on one side of a boundary between two catchment areas, which we call a boundary region side. We pool all the years when the boundary existed together, in order to have enough mover households. We do the analysis separately for different types of household.[4] For each type, the outcome is the number of households of this type moving to vacated dwellings. The (log) number of vacated dwellings is in the model as an offset variable. The initial explanatory variable is the standardized share of non-Western-origin children in the 7–15-years-old population of the catchment area, using the annually standardized value from the end of the year preceding the first year when the boundary existed in the dataset. However, we also use a housing-stock related explanatory variable, due to endogeneity concerns (see below).

The other observed predictors measure characteristics of the boundary region side. These include distance measures aiming to capture some spatial trends in amenities: the (log) distance in kilometers to the sea shore and to the nearest metro or railway station. Additionally, differences in housing characteristics are measured: the percentage of dwellings in apartment buildings, the percentage of dwellings in social rental housing and the percentage of vacated dwellings being family-size dwellings (at least two bedrooms).

Our model for the number of movers to the side j of the boundary region i (λ_{ij}) is

$$\ln \lambda_{ij} = \beta_0 + \beta_1 (s_{ij} - \bar{s}_i) + \left((x_{1ij} - \bar{x}_{1i})\beta_2 + \ldots + (x_{5ij} - \bar{x}_{5i})\beta_6 \right) \tag{2}$$

$$+\beta_7 \bar{s}_i + (\beta_8 \bar{x}_{1i} + \ldots + \beta_{12} \bar{x}_{5i}) + \ln V_{ij} + u_i + \varepsilon_{ij}$$

where

s_{ij} = catchment-area characteristic, e.g. % non-Western-origin children in 7–15-years-old population

$x_{1ij} .. x_{5ij}$ = housing and distance characteristics of the side j of the boundary region i

$\bar{s}_i$, $\bar{x}_{1i}$ etc. = boundary-region averages of the variables

V_{ij} = exposure variable: number of vacated dwellings (coefficient of the log transformation constrained to 1)

u_i = random effect of the boundary region

ε_{ij} = unit-specific error allowing for overdispersion (gamma distribution, mean = 1)

The parameter β_1 is intended to capture the causal effect of the catchment area characteristic.

Even if we apply the boundary discontinuity design and clear temporal ordering of the variables to get closer to observing causal effects, there is still a risk of an endogenous relationship between the population characteristics of the catchment areas and the moves we explain: the migration flows shaping the population characteristics might earlier have been influenced similarly as the present moves. Therefore, the catchment area characteristics are calculated from those grid cells in each catchment area that did not belong to any of the boundary regions under analysis. Still, the same process influencing migration to the boundary regions might have influenced the population characteristics of these other parts of the catchment areas. In order to take this into account, we use the percentage of state-subsidized rental dwellings in the housing stock of the catchment area (excluding the boundary region cells) as an alternative explanatory variable. It cannot be easily (or quickly) affected by the phenomenon studied, especially given the municipal planning monopoly.

As we analyze the total population instead of a random sample, we mostly base our interpretations on the point estimates. However, we still show information on the statistical significance of the estimates, because the individual life histories can be seen as realizations of stochastic processes that are subject to random variation (Hoem, 2008).

Findings

Segregation Levels

We begin by investigating how ethnic segregation differs for different household types (RQ 1). Table 1 shows the level of segregation between the Finnish-origin and non-Western-origin households at the catchment-area level in 2010. We compare similar types of households in the two ethnic groups.[5]

The index of dissimilarity was higher among households with children than among childless households, as expected. For more detailed comparisons, it is preferable to look at the results obtained with the index of systematic dissimilarity, due to the rather small sizes of some of the groups. The unconditional estimates show that ethnic segregation is stronger among households with children than in any of the categories among the childless households. Two-adult households with at least one member below 40 years of age are the most strongly segregated among the childless households.

The index values conditional on income show how much segregation remains after controlling for income differences between the ethnic groups (RQ 2). This decreases the estimates especially among households with children. Most — but not all — of the excess segregation among households with children seems to be related to income differences between Finnish-origin and non-Western-origin households. In contrast, income does not explain much of the low segregation among childless households. However, except for two-adult households below 40 years of age, the segregation level is still higher among households with children.

<Table 1 here>

Residential Mobility Flows

Selective intra-urban residential mobility can be expected to be the main mechanism producing the segregation outcomes observed in Table 1. Based on the segregation levels, particularly the mobility of households with children is expected to be related to the ethnic composition of the areas. Therefore we analyze the patterns of residential mobility flows between all pairs of catchment areas by type of household, focusing on households with children (RQ 3). We stratify the analysis by the age of the oldest child, as we expect schools to have the greatest impact on residential mobility decisions in those households in which all children are below the school-starting age of seven. After that phase, the residential flows to other areas decrease, as families seek to stabilize their children's educational paths (Bernelius and Vilkama, 2019).

Table 2 shows the results from the gravity model of migration. The results indicate how the share of the 7–15-years-old non-Western origin population predicts the migration flows of different types of households, when several other characteristics of the catchment areas are controlled for. Among Finnish-origin households with children, the migration flows are smaller when the destination area has a higher proportion of non-Western-origin school-age children. The association is clearest in the case of households in which the oldest child is 4–7 years old, i.e. just below the school-starting age. In the 2006–2010 analysis, the predicted migration rate of these households — adjusted for the other measured differences between the areas — was 11.5 per cent lower (IRR = 0.885) when the destination area had one standard deviation higher proportion of non-Western-origin school-age children than the origin area, as compared to migration rates between areas with identical proportions. In contrast, migration flows of households without children are only weakly related to the shares of non-Western-origin children. Among foreign-origin households, a higher share of non-Western-origin children in the catchment area predicts a higher rate of migration to the catchment area. This is clearest in the case of households with children.

When we stratify the analysis by the income of the household, we see that among the Finnish-origin households with the oldest child between 1–7 years, particularly the migration of higher-income households is related to the ethnic composition of the destination area. A one standard deviation higher share of non-Western-origin school-age children predicts an 11.4 per cent lower rate of residential mobility, whereas among the low-income households a similar difference predicts only a 5.9 per cent lower rate. Similar difference by income is observed when the oldest child is 8–15 years old. Among foreign-origin households, the small number of cases does not allow precise analyses by income.

The results for the 2011–2014 period indicate mostly weaker associations than in the 2006–2010 analysis. This was expected, as some schools based their pupil intake on larger school districts since 2011. The point estimates also suggest that differences by the age of the oldest child became smaller. Otherwise the results are similar to those for 2006–2010.

<Table 2 here>

When the difference between the catchment areas in the percentage of the 7–15-years-old children living in low-income households was used as an alternative explanatory variable, the results were similar to those presented above. Therefore, we cannot determine, whether the ethnic composition — instead of something else correlating with it — is the characteristic that matters. Additionally, although we have shown the predictive power of the ethnic composition, the analyses above have not shown any clear evidence of causal effects. In the next section we will use boundary discontinuity analysis to get more insight into these causal relationships.

Causal Effects of Catchment Area Boundaries on Intra-Urban Residential Mobility

In the last step of the analysis, we analyzed the potential causal effects of catchment area borders on intra-urban residential mobility (RQ 4). We used data on intra-urban moves to vacated dwellings in the boundary regions along the boundaries of catchment areas (Fig. 1).

<Figure 1 here>

Figure 2 shows how the share of non-Western-origin children among the school-age population of the catchment area predicts migration of Finnish-origin households to vacated dwellings when the unobserved boundary-region effects and observed boundary-region-side characteristics are controlled for (see Appendix 2 for the exact values). A higher share of non-Western-origin children predicts lower rate of in-migration especially among higher-income households with children and higher-income households of two over-40-years-old persons. As a stricter test for causal effects, we obtained results with the share of state-subsidized rental dwellings as the catchment-area-level explanatory variable (see *Analytical steps and methods*). These results suggest that the catchment-area effect is the strongest among higher-income households with children at or below the school-starting age of seven: a one standard deviation higher share of state-subsidized rental dwellings predicts a 14.8 per cent lower rate of in-migration. If confidence intervals are used as a criterion (although we analyze the complete population), a statistically significant effect is observed only among these households. Effects of all variables in this model are shown in Appendix 3.

<Figure 2 here>

Apparent effects among childless high-income households could reflect the ”social multiplier” effect of high demand for housing increasing the housing prices, and therefore making it more difficult for lower-income households to move to the area. Other reasons for catchment-area effects, such as preferences regarding the pupil composition in the school, could be expected to show as effects already at lower income levels. Therefore, we checked, whether the catchment-area effect persists when income is measured in a more detailed way, by dividing the higher-income group to deciles 5–7 and deciles 8–10. These groups have rather small numbers of movers, which is why we did not include such detail in the above analysis. We found that based on the point estimates, in both of the more detailed higher-income groups the strongest negative effect is observed among the households with seven-years-old or younger children (-10% in deciles 5–7 and -21% in deciles 8–10), whereas among older singles or two-adult households a negative effect was only observed in income deciles 8–10. These findings could be an indication of preference-related catchment area effects especially among middle-to-high-income households with young children. The confidence intervals are wide, however, suggesting caution with making generalizations.

Discussion

The main aim of this study was to contribute to segregation literature by explicitly investigating the role of school catchment areas in understanding ethnic segregation among different types of households. Using data from Helsinki, we found that segregation between Finnish-origin and non-Western origin households is stronger among households with children than among childless households. We also found that the stronger segregation within households with children seems to be related to a large extent to the higher incomes of Finnish-origin households as compared to non-Western-origin households.

Next we explored the association between ethnic composition of school catchment areas and the migration flows of different types of households. The main finding was that the intra-urban mobility flows between the catchment areas contribute to reproducing ethnic segregation. This concerns particularly households with children, especially higher-income households with children in the case of Finnish-origin households. The net effect of intra-urban residential mobility on ethnic segregation depends also on the stock of different types of households in different kinds of neighbourhoods (Kauppinen and van Ham, 2019) and on the extent of within-neighbourhood mobility, but we have shown that those moves of higher-income Finnish-origin households with children that occur between the catchment areas tend to increase ethnic segregation.

In our final analysis, we conducted a boundary discontinuity analysis of intra-urban residential mobility, which suggested that the catchment-area boundaries have causal effects on the mobility. This was clearest in the case of higher-income Finnish-origin households with children below the school-starting age. Therefore, we have demonstrated a process that may have brought about the previous finding of catchment areas affecting housing prices in Helsinki (Harjunen *et al.*, 2018). Our findings suggest that there are both resource- and preference-based explanations for the stronger segregation among households with children (cf. Iceland *et al.*, 2010).

Even though we were mainly interested in the effects of the ethnic composition of the catchment area population, we had to rely on a housing-stock related variable to get stricter causal estimates. Our design could not determine the actual catchment area characteristic affecting residential mobility. However, we expect the share of social rental housing to matter by influencing and signaling the social and ethnic composition of the population. Harjunen et al. (2018) suggest that concerning school characteristics, the composition of the pupil body is more important than the assumed quality of teaching (see also Bernelius and Vilkama, 2019). Still, parents could treat the assumed pupil composition as a signal of the desirability of the school more generally. Similarly, Wessel and Nordvik (2018) suggest that assumptions concerning potential neighbourhood decline explain the increased sensitivity to the ethnic composition among parents and parents-to-be in Norway.

Families with children — particularly families with high resources belonging to the ethnic majority — are in the focal point of the processes leading to growing ethnic segregation. Their apparent sensitivity to social compositions and perceived qualities of neighbourhoods has the potential to shape the social and educational landscapes in urban areas. The stronger ethnic segregation among households with children can be seen as an emergent consequence of such sensitivity and the ensuing patterns of residential mobility (cf. Sampson and Sharkey, 2008). Schools are not the only factor that parents consider when choosing a residential location, but school catchment area boundaries appear to influence the development of residential segregation through mediating access to certain schools and influencing the residential decisions of families. The link between residential segregation and school segregation can lead to vicious circles (van Ham *et al.*, 2018), where the existing segregation, working partly through school, acts as a driver of further segregation. Schools' role in the residential patterns in the city underlie the need for integrated educational and urban policies.

Our results offer insight into linkages between residential segregation and schools' pupil intake policies. Compared to many other countries, the institutional or academic qualities of schools are fairly constant in the Finnish context. This highlights the significance of socio-spatial segregation for school choice, as the school quality does not play a major role in the decision making (see also Harjunen *et al.*, 2018). This suggests that ensuring high institutional quality in education across the board is not enough to level the playing field between neighbourhoods. The existing socio-economic and ethnic divisions appear to act as drivers for residential mobility, and thus the neighbourhood policies and educational measures need to be considered together. The need for finding ways to avoid self-perpetuating cycles of segregation through "native avoidance" or "native flight" is heightened by the observation that socio-economic segregation has been increasing across a large number of urban areas in many European countries (Tammaru *et al.*, 2016). Growing socio-spatial segregation may increase the pressure to look for environments perceived as safe or seek access to particular types of schools and neighbourhoods, fueling further differentiation. Besides the observed effects on the school system and residential segregation, this development has potential to fuel marginalization of non-Western origin children, who grow up disproportionately in disadvantaged neighbourhoods (cf. Rosenbaum and Friedman, 2001).

Notes

1. In this variable, we count also those children who have both a Finnish-born and a non-Western-born parent as having a non-Western origin.
2. The risk population was not easy to define for the childless households, as persons could split from all types of households and form new childless households. Therefore we focus more on households with children and use the total number of households of the given ethnicity as the risk population for childless movers. Essentially the same results were obtained when using only the same household type as the risk population.
3. Fixed-effects Poisson regression analysis with the Stata command xtpoisson produces very similar point estimates with some differences in statistical significance.
4. Here we use a more coarse age classification for children to get enough cases.
5. The age limits refer to the adults in the household. See *Data* for our definition of an adult.

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Appendix 1. Details of the boundary discontinuity design.

A boundary region means here a group of grid cells on both sides of a particular boundary between two school catchment areas. We first identified grid cells with at least a part of the cell within 250 meters from a catchment area boundary. Only those boundaries between catchment areas were selected which did not coincide with another major border such as a railroad, highway, water body, forest, field, or an industrial area. For each boundary region, only those consecutive years were used in the analysis during which the boundary existed (unchanged) and the catchment areas were used as the basis for pupil intake. If there were major changes in the boundaries elsewhere in either catchment area, the boundary region was not used any more after those changes. Grid cells clearly separated from the other cells of the boundary region by borders listed above (railroads etc.) were not included. In the case of the catchment area boundary crossing across a grid cell, we used auxiliary information on the locations of residential buildings and their numbers of residents and included only those grid cells in which at least 75% of the residents lived on one side of the boundary. When a grid cell would otherwise have belonged to two or more boundary regions, it was allocated to the region to which its residential area most clearly belonged to as a continuation of the region's residential area, or removed if this was not clear.

Appendix 2. Effects of the catchment-area variables in the boundary discontinuity analyses.

	Effect of one standard deviation higher value of the catchment area variable on the relative rate of moving to the boundary-region side				
	% Non-Western (7–15 years old)		% State-subsidized rental dwellings		
Household type	IRR	95% C.I.	IRR	95% C.I.	Number of mover households
Single person, <40, low income	0.963	(0.840 – 1.104)	0.956	(0.858 – 1.064)	10938
Single person, <40, high income	0.959	(0.846 – 1.087)	0.934	(0.850 – 1.026)	7394
Single person, ≥40, low income	1.092	(0.906 – 1.314)	1.100	(0.952 – 1.272)	2970
Single person, ≥40, high income	0.998	(0.903 – 1.103)	0.968	(0.902 – 1.040)	3512
Two adults, <40, low income	1.141	(0.967 – 1.347)	1.098	(0.964 – 1.251)	3733
Two adults, <40, high income	0.932	(0.807 – 1.077)	0.939	(0.840 – 1.049)	6143
Two adults, ≥40, low income	1.044	(0.680 – 1.604)	0.867	(0.615 – 1.224)	324
Two adults, ≥40, high income	0.803	(0.715 – 0.902)	0.922	(0.835 – 1.019)	1530
Household with children, oldest child ≤7, low income	1.112	(0.919 – 1.346)	1.010	(0.873 – 1.168)	1311
Household with children, oldest child ≤7, high income	0.857	(0.721 – 1.019)	0.852	(0.753 – 0.963)	1838
Household with children, oldest child 8+, low income	0.970	(0.798 – 1.180)	0.968	(0.832 – 1.127)	1415
Household with children, oldest child 8+, high income	0.860	(0.744 – 0.995)	0.911	(0.820 – 1.012)	1684

Note: Separate model for each combination of a household type and catchment area variable, housing and distance characteristics of the boundary-region side controlled for.

Appendix 3. Effects of all explanatory variables in the boundary discontinuity model explaining moves of higher-income households with seven years old or younger children, incidence rate ratios (IRR).

	IRR	95% C.I.			p
Within-boundary-region effects					
Standardized share of social rental dwellings in the catchment area	0.852	(0.753	–	0.963)	0.011
Ln (distance to the nearest railway or metro station, m)	1.024	(0.799	–	1.312)	0.850
Ln (distance to the sea in, m)	0.819	(0.698	–	0.961)	0.014
% of dwellings in the boundary-region side in apartment buildings	1.003	(0.993	–	1.013)	0.582
% social rental dwellings in the boundary-region side	0.991	(0.985	–	0.997)	0.003
% of dwellings with at least 2 bedrooms among vacated dwellings	1.023	(1.009	–	1.036)	0.001
Between-boundary-region effects					
Standardized share of social rental dwellings in the catchment area	0.952	(0.750	–	1.209)	0.687
Ln (distance to the nearest railway or metro station, m)	1.184	(1.014	–	1.383)	0.033
Ln (distance to the sea in, m)	0.960	(0.861	–	1.070)	0.458
% of dwellings in the boundary-region side in apartment buildings	0.988	(0.976	–	1.001)	0.063
% social rental dwellings in the boundary-region side	1.001	(0.989	–	1.013)	0.825
% of dwellings with at least 2 bedrooms among vacated dwellings	1.016	(0.998	–	1.033)	0.083

Table 1. Catchment-area level segregation between Finnish-origin and non-Western-origin households, by the type of household, 2010.

		Index of systematic dissimilarity		Number of households	
	Index of dissimilarity	Unconditional	Conditional on income	Finnish origin	Non-Western origin
All households	25.5	22.4	18.8	240983	7448
Households with children, all	35.4	31.0	21.6	44255	3303
Households with children, <40	35.1	29.4	20.8	17690	2123
Households with children, >=40	37.5	30.1	23.1	26565	1180
Households without children, all	18.2	13.6	11.5	196728	4145
Single-person households	13.6	7.8	7.0	129039	2853
Single-person households <40	21.0	14.6	14.3	45305	1825
Single-person households >=40	16.3	6.4	5.2	83734	1028
Two adults' households	29.4	20.2	16.8	63457	926
Two adults' households <40	34.3	25.0	23.6	25408	739

Table 2. Incidence rate ratios (IRR) of residential mobility between catchment areas, by period and the type of household.

	Effect of one standard deviation higher % of non-Western origin in the 7–15-years-old population in the destination area as compared to the origin area				Number of mover households	
	2006–2010		2011–2014			
Household type	IRR	95% C.I.	IRR	95% C.I.	2006–2010	2011–2014
All movers	0.995	(0.957 – 1.033)	1.001	(0.967 – 1.036)	150264	132021
All Finnish-origin movers	0.981	(0.949 – 1.014)	0.990	(0.959 – 1.022)	121281	102216
Finnish-origin households without children	0.987	(0.954 – 1.020)	0.991	(0.961 – 1.022)	107211	90226
Finnish-origin households with children	0.888	(0.851 – 0.927)	0.921	(0.880 – 0.965)	14070	11990
Finnish origin, oldest child 1-3 years	0.928	(0.877 – 0.981)	0.949	(0.888 – 1.013)	3384	2874
Finnish origin, oldest child 4-7 years	0.885	(0.834 – 0.939)	0.914	(0.858 – 0.974)	2483	2408
Finnish origin, oldest child 8-11 years	0.913	(0.845 – 0.986)	0.903	(0.850 – 0.960)	1556	1372
Finnish origin, oldest child 12-15 years	0.940	(0.872 – 1.012)	0.934	(0.873 – 0.999)	2158	1540
Finnish origin, oldest child 1-7 years, low income	0.941	(0.884 – 1.003)	0.987	(0.930 – 1.049)	2608	2234
Finnish origin, oldest child 1-7 years, high income	0.886	(0.837 – 0.938)	0.901	(0.846 – 0.959)	3259	3048
Finnish origin, oldest child 8-15 years, low income	0.928	(0.872 – 0.987)	0.924	(0.841 – 1.015)	3007	2380
Finnish origin, oldest child 8-15 years, high income	0.867	(0.809 – 0.930)	0.865	(0.814 – 0.919)	2431	1962
All foreign-origin movers	1.128	(1.064 – 1.196)	1.105	(1.055 – 1.157)	16053	17433
Foreign-origin households with children	1.148	(1.083 – 1.218)	1.120	(1.055 – 1.189)	2770	3132
Foreign-origin households without children	1.115	(1.053 – 1.180)	1.089	(1.041 – 1.139)	13283	14301
Foreign origin, oldest child 1-7 years	1.139	(1.049 – 1.237)	1.065	(0.971 – 1.168)	1094	1339

Note: Separate model for each household type, control variables of the gravity model controlled for.

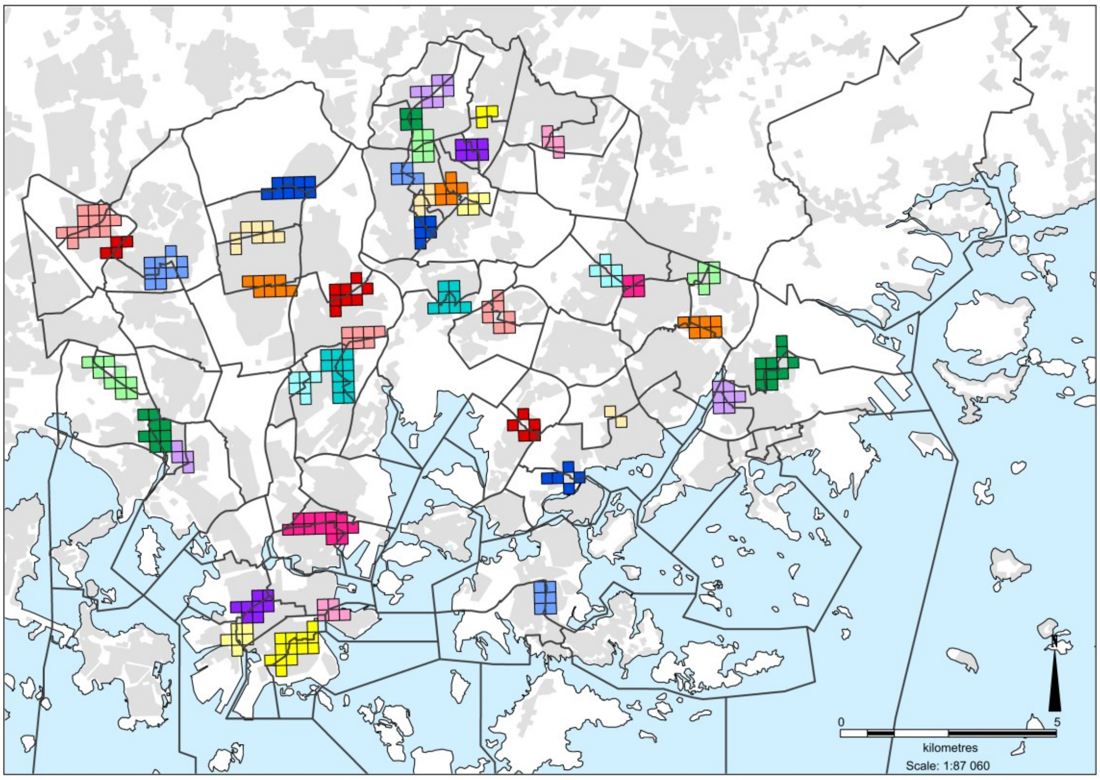

Figure 1. The catchment areas of the schools in 2014 and the boundary regions used in the boundary discontinuity analysis.

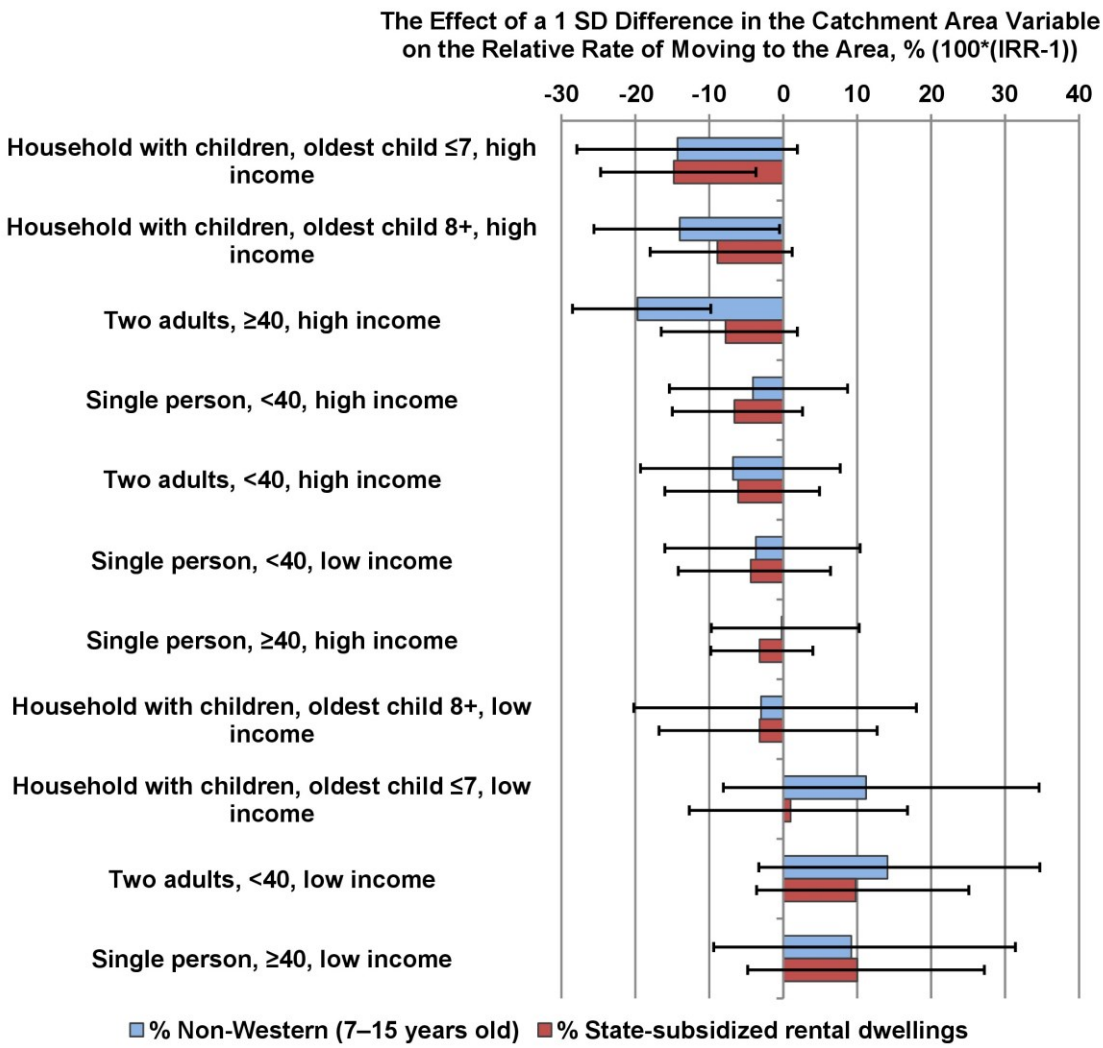

Figure 2. The effects of catchment area characteristics on intra-urban mobility of different types of Finnish-origin households to vacated dwellings in the boundary regions of selected catchment areas, results from hybrid negative binomial regression analyses.