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Spatial and Social Mobility

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Abstract

This paper analyzes the relationship between spatial mobility and social mobility. It develops a two-skill-type spatial equilibrium model of two regions with location preferences where each region consists of an urban area which is home to workplaces and residences and an exclusively residential suburban area. The paper demonstrates that both segregation and regional income inequality are negatively correlated with relative regional social mobility. In the model, segregation is driven by differences between urban and residential areas in commuting cost differences between high-skilled and low-skilled workers, whereas regional income inequality also depends on the magnitude of the productivity gap of low-skilled relative to high-skilled workers. A larger productivity gap does not affect segregation, but causes higher income inequality and lower relative mobility in the respective region.

JEL-Codes: J620, R130.

Keywords: social mobility, spatial mobility, segregation, inequality.

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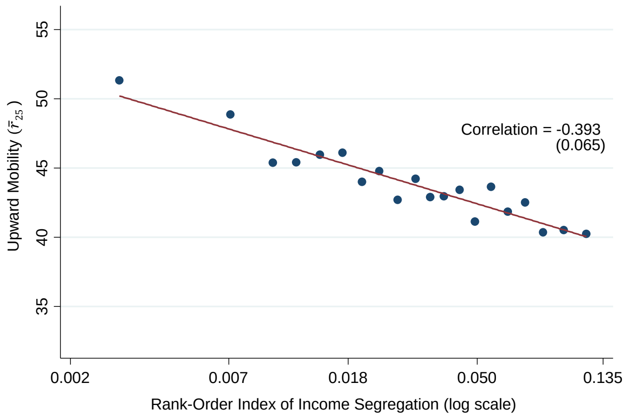
1 Introduction

What determines the geographic variation of social mobility? Clearly, social mobility across generations is an important topic for public policy. The persistence of income, wealth, or social status across generations affects the perceived equality of opportunity and is therefore a prime policy issue. Over the last decades, there has been a large amount of research on the measurement of social mobility and its determinants, but the question we study, namely, the geographical variation of social mobility, has received somewhat less attention. While there has been some interest in cross-country differences in social mobility, the within-country variation has been much less studied.

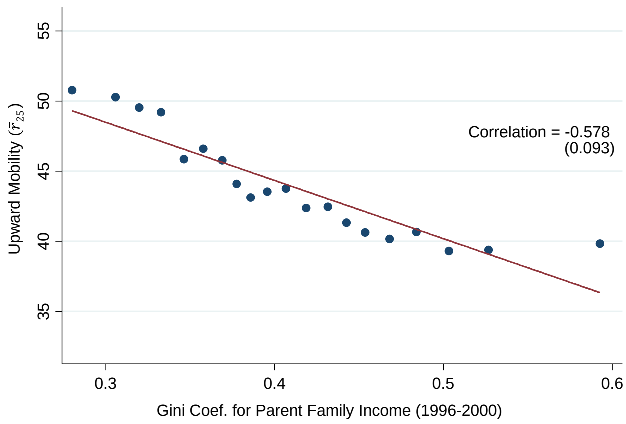
For example, the strong effect of intra-country mobility on social mobility has been noted by Long and Ferrie (2013) who argued that the magnitude and the development of differences in occupational mobility between the US and Britain in the nineteenth and twentieth century can be explained by differing residential mobility patterns. These authors stress that, especially, credit constraints, poor information, and small geographical variation in the returns to migration induce small residential migration flows and, therefore, low intergenerational mobility.

Chetty, Hendren, Kline, and Saez (2014b) have studied the geographical variation of intergenerational mobility in the US. They analyzed the correlation between parent and child income in American commuting zones and found substantial variation in the rank correlation of parent and child incomes. They also studied correlates of their mobility measures. They found that areas with high mobility tend to have less residential segregation by race and income, lower commuting times and lower income inequality, and better education, social capital and greater family stability. Fig. 1a shows the correlation between their measure of upward mobility and income segregation, Fig. 1b shows the correlation of upward mobility and inequality, and Fig. 1c shows the correlation of upward mobility and the fraction of the population with commute times of less than 15 minutes.[1]

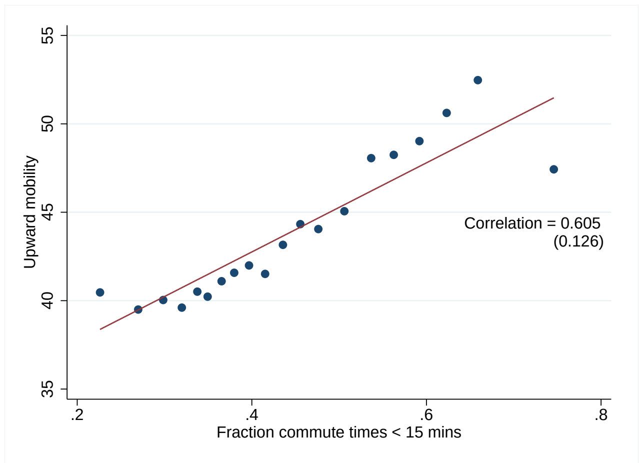
[1] The figures use a measure called absolute (upward) mobility from Chetty, Hendren, Kline, and Saez (2014b), which measures the expected rank in the (national) income distribution of children from families at the 25th percentile of the national parent income distribution. This measure is, however, highly correlated with their measure of relative mobility, which measures the difference in outcomes between children from top versus bottom income families (technically, the coefficient on parent income rank in a regression of child income rank on parent income rank). So the figures look very similar when relative instead of absolute



(a) Income segregation



(b) Inequality



(c) Fraction commute times $<$ 15 min

Figure 1: Correlates of upward mobility
Source: Chetty, Hendren, Kline, and Saez (2014a) and authors' calculations based on data from `http://www.equality-of-opportunity.org/`

Our main goal in this paper is to analyze whether a standard spatial model with regional mobility and intergenerational skill transmission is able to replicate some of these empirical findings. To this end, we set up a theoretical model to study the relationship between social and spatial mobility. There are 2 regions with 2 areas each, one with workplaces and residences and the other residential only, so individuals living there commute to the central region for work. We model mobility between regions using a standard discrete choice approach. Social mobility – that is, the chances of a child of a low-skilled parent to become high-skilled, relative to those of the child of a high-skilled parent – is affected by the fraction of the population who is high-skilled.[2,3] Differences between regions in segregation, income inequality and social mobility emerge from ex ante asymmetries between regions, where we focus on differential commuting costs for the low skilled in one region. These ex ante asymmetries translate into equilibrium (ex post) asymmetries in observed social mobility and its correlates across regions through the location choices of (imperfectly) mobile households.

Our findings can be summarized as follows. First, we show that relative mobility is negatively correlated with skill segregation within regions and regional income inequality. Second, by varying parameters, we show that larger commuting costs for low skilled individuals in one region reduce relative mobility there compared to the other region. The gap in relative social mobility between the regions also widens as the skill premium (i.e. the wage premium of high relative to low skilled) increases. Third, we demonstrate that

mobility is on the y-axis.

[2]Some researchers examine educational ínvestment (see, e.g., Patacchini and Zenou, 2011), human capital of parents and local human capital spillovers (see, e.g., Bénabou, 1993, 1996) as determinants of individual human capital, whereas other researchers focus on the transition of preferences, beliefs, and social norms (see, e.g. Bisin and Verdier, 2011; Bisin, Patacchini, Verdier, and Zenou, 2011a,b).

[3]There is still no consensus whether important neighborhood effects exist (for an overwiew, see e.g., Durlauf, 2004; Cheshire and Nathan, 2014; Topa and Zenou, 2014). In particular, the moving-to-opportunity (MTO) project has shown only small economic effects of moving to favorable neighborhoods. Ludwig, Duncan, Gennetian, Katz, Kessler, Kling, and Sanbonmatsu (2012, 2013) found out that treatment effects on economic outcome variables are only marginal, but effects on health and subjective well-being are substantial. They argue that these effects are mainly driven by income segregation rather than racial segregation. However, their analysis does not fully control for economic, social, and spatial co-variates of segregation (for further critical remarks, see e.g., Cheshire and Nathan, 2014). However, Chetty and Hendren (2015) provide quasi-experimental evidence that neighborhoods affect intergenerational mobility through childhood exposure effects. Chetty, Hendren, and Katz (2015) consider the Moving To Opportunity Experiment and demonstrate that the duration of exposure to a better environment during childhood is a key determinant of an individual's long-term outcomes.

weaker place attachment (higher spatial mobility) increases the geographical variation of segregation, inequality and social mobility. This resonates well with Long and Ferrie's (2013) argument that high residential mobility in the US compared to Britain in the 19th century can explain the larger social mobility in the US during that period.[4]

Hence, our contribution is to show that spatial mobility coupled with commuting within regions can explain some of the observed facts (compare the correlations shown in Fig. 1). In particular, it can explain the negative correlation of social mobility with segregation by income and with intragenerational income inequality. Moreover, since commuting takes time, it also rationalizes the finding that areas with long commute times have lower social mobility. And lastly, social mobility is affected by the spatial mobility of households.

Our paper is related to the literature on geographical variation of intergenerational mobility. The empirical literature has, by and large, focused on international mobility comparisons (e.g. Björklund and Jäntti, 1997, Corak, 2013 and Abbott and Gallipoli, 2014). Since mobility is more limited between nations, this research is less relevant for our purpose. The empirical literature on regional variation of social mobility seems, however, to be small; the study by Chetty, Hendren, Kline, and Saez (2014b) seems to be one of very few papers in this vein.[5]

Some theoretical papers have been concerned with mobility and intergenerational skill transmission, for instance, Bénabou (1996), Fernández and Rogerson (1998), and Bezin and Moizeau (2015). The focus of this literature, however, slightly differs from ours. The papers by Bénabou (1996) and Fernández and Rogerson (1998) are more concerned with how stratification and different school finance systems affect disparities in education spending and consequently intergenerational mobility. By contrast, we want to analyze how segregation and intergenerational mobility are endogenously determined and how they vary together with variations in parameters. Moreover, in these models, segregation usually means communities that are completely stratified, typically by income. Hence, inequality and segregation *within* communities does not occur in these models. In our discrete-

[4]Chetty, Hendren, Kline, and Saez (2014b), however, find no significant correlation between intergenerational mobility and migration rates in US counties.

[5]Kremer (1997) uses a calibrated model to study the effect of sorting on inequality and its intergenerational persistence. He found that, while increased sorting (increased correlation of neighbors' education) has no big effect on inequality, it does affect intergenerational persistence of incomes.

choice framework, we have communities which are not perfectly stratified and within-community inequality and segregation can thus be measured using standard indices such as the dissimilarity index. Bezin and Moizeau (2015) focus on the relationship between preference transmission and endogenously determined segregation. They consider mobility between two otherwise separated areas within one city whereas we model both location choices within metropolitan areas and relocation across metropolitan areas. An important difference between the paper by Bezin and Moizeau (2015) and this paper is that we examine the effect of commuting within cities on segregation and intergenerational mobility.

The paper proceeds as follows. The next section presents the basic model. Section 3 presents results from a numerical simulation, and the last section concludes the paper.

2 The model

2.1 Basics

We consider a model with two regions, indexed $i = 1, 2$ with two areas $k = 1, 2$ each. The population contains of a total of N families, consisting of one parent and one child, where N is exogenous. Families are of two types, high skilled ($j = H$) or low skilled ($j = L$). The mass of low- and high-skilled individuals is given by N_L and N_H.

Parents of skill j living in area k of region i have preferences over consumption, c_{ijk}, housing, s_{ijk} and the region's average human capital, h_{ik}, which is a function of the *regional* share of high-skilled households, $h_{ik} = N_{Hik}/(N_{Hik} + N_{Lik}), i = 1, 2, k = 1, 2$. Parents care for regional human capital for a variety of reasons. For instance, they may care about their children's human capital, average crime in the region, the region's physical appearances etc., all of which depend on average human capital. While some of these neighborhood effects may be very local, others are sure to operate at a larger geographical scale, so it seems plausible that parents care about the regional human capital level.

Utility of a type j individual living in area k of city i is

$$u(c_{jik}, s_{jik}, h_{ik}) = (1 - \gamma) \ln c_{jik} + \gamma \ln s_{jik} + \delta \ln h_{ik}, \quad j = H, L, i = 1, 2, k = 1, 2. \quad (1)$$

All land is owned by absentee landowners and rented to residents at a rental rate of r_{ik} per square meter in area k. We assume that landowners cannot discriminate between skill types. Area k in region i is endowed with M_{ik} units of land available for residences. The opportunity costs of land are normalized to 0. Workers have to commute to work, and commuting is within regions only. In each region, all jobs are located in area 1, but there are residences in both areas. The commuting costs of a type j individual in area k of region i are given by $\rho_{jik} w_{ji}, j = H, L, i = 1, 2, k = 1, 2$, with $\rho_{ji2} > \rho_{ji1} \geq 0$, so we assume that in each region area 2 residents have longer commutes (because jobs are in area 1). Differences in commuting costs within and between regions may reflect distance to jobs (through location differences within areas) or differential provision of infrastructure between regions and areas.

The individual budget constraint is given by

$$c_{jik} = w_{ji}(1 - \rho_{jik}) - r_{ik} s_{jik}, \quad j = H, L, i = 1, 2, k = 1, 2, \tag{2}$$

where w is the wage. We assume wages to be exogenous, but they differ both between skills, because of different productivities, and between regions, because of some unmodeled exogenous productivity difference. In particular, we assume $w_2 = \alpha w_1$, with $\alpha \leq 1$, and $w_{Hi} = w_i$, $w_{Li} = \beta_i w_{Hi}$, for $i = 1, 2$, with $0 < \beta_i < 1$. Hence, region 1 is inherently more productive. The skill gap in wages is given by β_i. Since all individuals in one region work in the same area, we assume their wages, gross of commuting costs, to be identical within the region.

With Cobb-Douglas utility we can solve for land-demand and indirect utility to get:

$$s_{jik} = \gamma \, \frac{w_{ji}(1 - \rho_{jik})}{r_{ik}}, \quad j = H, L, \; i = 1, 2, \; k = 1, 2, \tag{3}$$

$$v_{jik} = \ln \left[\frac{w_{ji}(1 - \rho_{jik})}{r_{ik}^{\gamma}} \, h_{ik}^{\delta} \right], \quad j = H, L, \; i = 1, 2, \; k = 1, 2. \tag{4}$$

Our focus is on regional and social mobility. We assume that mobility within and between regions is imperfect. We consider a standard discrete choice model with random utility (see, e.g., McFadden, 1978; Anas, 1990). Suppose that a type l individual of skill level j living in area k of region i receives utility $u_{jik} + \varepsilon_{ljik}$. Under the assumption that the

ε_{ljik} are independently and identically Gumbel distributed with mean zero and variance $\sigma^2 = \pi^2/6\lambda^2$, where $\lambda > 0$ is the dispersion parameter of the distribution, we can write the probability that a type-j individual lives in area k of region i as a multinomial logit (McFadden, 1973):[6]

$$p_{jik} = \frac{e^{\lambda v(w_{ji}(1-\rho_{jik}), r_{jik}, h_{ik})}}{\sum_{I=1}^{2}\sum_{K=1}^{2} e^{\lambda v(w_{ji}(1-\rho_{jIK}), r_{jIK}, h_{IK})}}, \quad j = H, L,\ i = 1, 2,\ k = 1, 2. \tag{5}$$

This implies that the distribution of population is given by

$$N_{jik} = p_{jik} N_j, \quad j = H, L,\ i = 1, 2,\ k = 1, 2. \tag{6}$$

Social mobility is governed by a skill-type and area specific transition-to-the-top probability, which we assume to be a concave function of the area's share of high-skilled: $f_{jik}(h_{ik}), j = H, L, i = 1, 2, k = 1, 2$, with $f''_{jik}(h_{ik}) < 0 < f'_{jik}(h_{ik})$ and $0 < f_{Lik}(h_{ik}) < f_{Hik}(h_{ik}) < 1$. Thus, we assume that, for every area's share of high-skilled, the likelihood to move upward is lower than the likelihood to stay at the top. In the numerical simulation, we use the specific transition function

$$f_{jik}(h_{ik}) = A_j(1-\rho_{jik})^{\eta} h_{ik}^{\mu}, \quad \text{with } A_L < A_H < 1, \quad j = H, L,\ i = 1, 2,\ k = 1, 2, \tag{7}$$

with $1 > \mu > 0, \eta \geq 0$. This function allows for a direct negative effect of commuting time on upward mobility. The assumption that the transition to the top depends on the regional share of high-skilled is consistent with the large literature on peer effects in education, smoking, drug use, teenage pregnancies and so, all of which affect intergenerational mobility.[7] Note also that while gross wages are constant for given skill within the region, the transition to the top probability is assumed to vary within region. We think of gross wages and earnings to be determined solely by the skill level, which depends on an individual's education and does not vary with the local peer group. However, the probability of

[6] If $\lambda \to 0$, individuals choose their residence randomly; if $\lambda \to \infty$, individuals select the location where they achieve the maximum possible value of (deterministic) utility.

[7] Among others, this literature includes contributions by Bisin, Patacchini, Verdier, and Zenou (2011a) and Constant, Schüller, and Zimmermann (2013) on ethnicity, by Gaviria and Raphael (2001) on drug use, by Crane (1991) on dropping out and teenage childbearing.

obtaining an education sufficient to become high-skilled is determined by local peers and therefore varies within areas.

While we do not know of studies analyzing the direct link between commuting and social mobility, we think that such an effect might be plausible, for instance, because long commute times for parents mean they have less time to care for their children. In any case, however, our qualitative results are not affected if $\eta = 0$ so that this effect is absent.

2.2 Short-run equilibrium

We now proceed to describe the equilibrium of the model. First, we characterize the short-run equilibrium. Here, we take total population N, as well as the mass of high- and low-skilled, N_H and N_L, as given. The stochastic short-run equilibrium has the following properties: (i) the land markets clear: within each area, aggregate land demand equals the exogenous land supply (equations (8)), (ii) individuals (stochastically) maximize utility by choice of location, that is, equations (9) hold, and (iii) the population constraints (10) hold:

$$\sum_{j=H,L} p_{jik} s_{jik} N_j = M_{ik}, \quad i = 1, 2,\ k = 1, 2, \tag{8}$$

$$p_{jik} = \frac{e^{\lambda v(w_{ji}(1-\rho_{jik}), r_{ik}, h_{ik})}}{\sum_{I=1}^{2} \sum_{K=1}^{2} e^{\lambda v(w_{jI}(1-\rho_{jIK}), r_{jIK}, h_{IK})}}, \quad j = H, L,\ i = 1, 2,\ k = 1, 2, \tag{9}$$

$$p_{jik} N_j = N_{jik}, \quad j = H, L,\ i = 1, 2,\ k = 1, 2. \tag{10}$$

Equations (9) provide the stochastic version of the usual spatial equilibrium conditions. Using (10), (9) can be written

$$\frac{e^{\lambda v(w_{ji}(1-\rho_{jik}), r_{ik}, h_{ik})}}{N_{jik}} = \frac{\sum_{I=1}^{2} \sum_{K=1}^{2} e^{\lambda v(w_{jI}(1-\rho_{jIK}), r_{IK}, h_{IK})}}{N_j}, \quad j = H, L,\ i = 1, 2,\ k = 1, 2, \tag{11}$$

which shows that $e^{\lambda v(w_{ji}(1-\rho_{jik}), r_{ik}, h_{ik})}/N_{jik}$ is independent of i and k. Hence, if the regional wage level is low or commuting costs are high, there will be few individuals of the respective type in that region. In the usual manner of compensating differentials, a low wage level can be compensated by low land rents or a high high-skilled ratio.

Using (3), and (10), and $w_{Li} = \beta_i w_{Hi}$, (8) can be solved for the land rent:

$$r_{ik} = \frac{\gamma w_{Hi}\left[(1-\rho_{Hik})N_{Hik} + \beta_i(1-\rho_{Lik})N_{Lik}\right]}{M_{ik}}. \tag{12}$$

This shows that an area's land rent is decreasing in the area's commuting costs and land supply, and increasing in the regional wage level and the area's population of high and low skilled.

Given (12) and the probabilities in (10), equations (9) provide a system of 8 equations in 8 unknowns, which can be solved for the endogenous variables, $N_{Hik}, N_{Lik}, i = 1,2, k = 1,2$.

Combining equations (11), yields for two areas k in region i and m in region l, $i = 1,2$, $k = 1,2$, $l = 1,2$, $m = 1,2$,

$$\frac{N_{Hik}}{N_{Lik}}\left(\beta_i\,\frac{1-\rho_{Lik}}{1-\rho_{Hik}}\right)^{\lambda} = \frac{N_{Hlm}}{N_{Llm}}\left(\beta_l\,\frac{1-\rho_{Llm}}{1-\rho_{Hlm}}\right)^{\lambda}. \tag{13}$$

The ratio of two area's high-skilled-low-skilled ratios, $[h_{ik}/(1-h_{ik})]/[h_{lm}/(1-h_{lm})] = (N_{Hik}/N_{Lik})/(N_{Hlm}N_{Llm})$, is positively correlated with the two area's ratio of commuting-cost factors of the high-skilled, $(1-\rho_{Hik})/(1-\rho_{Hlm})$, and is negatively correlated with the two area's ratio of commuting-cost factors of the low-skilled, $(1-\rho_{Lik})/(1-\rho_{Llm})$, and the two regions' ratio of productivity gaps, β_i/β_l. Neither wages nor land supply directly affect the quotient of high-skilled-low-skilled ratios.

Furthermore, using the fact that $e^{v_{jik}}/N_{jik}$ is independent of i and k, we can compare areas which are identical except for one dimension regarding their population size. Totally differentiating $e^{v_{jik}}/N_{jik}$ for $j = H, L$, leads to

$$\begin{aligned}
\frac{dN_{Hik}}{dw_{Hi}} + \frac{dN_{Lik}}{dw_{Hi}} &= \frac{(1-\gamma)\lambda(N_{Hik}+N_{Lik})}{(1+\gamma\lambda)w_{Hi}},\\
\frac{dN_{Hik}}{dM_{ik}} + \frac{dN_{Lik}}{dM_{ik}} &= \frac{\gamma\lambda(N_{Hik}+N_{Lik})}{(1+\gamma\lambda)M_{ik}}.
\end{aligned}$$

Despite the compensating effect of the land rent both a high wage and large land supply imply a large population relative to any other area where either the wage is lower or less land is available.

In general, how the mass of high- and low-skilled in all areas depends on the exogenous variables depends on the parameters which govern the underlying function. Since the model cannot be solved analytically, we leave any further description of these comparative static effects to the numerical simulation.

2.3 Long-run equilibrium

We now characterize the long-run steady-state equilibrium. Total population N is still exogenous, but now the mass of high and low skilled are determined by the steady-state solution, which is governed by the (short-run) transition probabilities described above. This implies that the mass of high skilled must equal the sum of high and low skilled, weighted by their transition probabilities. Further, the population constraint (15) must hold. In addition to equations (8)–(10), the stochastic long-run equilibrium must satisfy:

$$\sum_{j=H,L} \sum_{i=1}^{2} \sum_{k=1}^{2} f_{jik}(h_{ik}) N_{jik} - N_H = 0, \tag{14}$$

$$\sum_{j=H,L} N_j - N = 0. \tag{15}$$

In addition to the endogenous variables pinned down by the short-run equilibrium, (14) and (15) determine N_H and N_L as a function of the model's parameters. The equilibrium conditions do not imply that the mass of high-skilled offsprings in a particular region let alone in a particular area matches the mass of high-skilled residents living in the respective unit. Even in a long-run equilibrium, net-migration of high skilled across areas and regions most likely occurs.

Since the equilibrium cannot be solved analytically, in the next section we present results from numerical simulations.

2.4 Segregation, inequality, and mobility measures

Our main interest is in studying the relation between segregation, inequality, and social mobility. We now present different measures for each of these that we compute in our example. Although our focus is on the geographical variation, we also calculate these measures at the country level and examine within-region and between-region differences.

To measure segregation, we use the entropy-based (Theil) index of segregation (Chetty, Hendren, Kline, and Saez, 2014b), H_i, defined as

$$H_i = \sum_{k=1}^{2} \left(\frac{N_{Hik} + N_{Lik}}{\sum_{j=1}^{2} N_{Hij} + N_{Lij}} \right) \left(\frac{E_i - E_{ik}}{E_i} \right), \tag{16}$$

where

$$\begin{aligned} E_i &= h_i \log_2 \frac{1}{h_i} + (1 - h_i) \log_2 \frac{1}{(1 - h_i)}, \\ E_{ik} &= h_{ik} \log_2 \frac{1}{h_{ik}} + (1 - h_{ik}) \log_2 \frac{1}{(1 - h_{ik})}. \end{aligned}$$

The segregation index H_i measures the extent to which the skill distribution in each area deviates from the overall skill distribution in the region. The index is maximized at $H_i = 1$ when the population is homogeneous within areas, in which case $E_{ik} = 0$ in all areas. It is minimized at $H_i = 0$ when within-area diversity is the same across all areas in a region. Since the entropy-based index, H_i, is additively decomposable (Reardon and Firebaugh, 2002), the segregation index at the country level

$$H = \sum_{i=1}^{2} \sum_{k=1}^{2} \left[\left(\frac{N_{Hik} + N_{Lik}}{N} \right) \left(\frac{E - E_{ik}}{E} \right) \right] \tag{17}$$

can be written as sum of two terms indicating between-region segregation and within-region segregation, respectively,

$$H = H_{between} + \sum_{i=1}^{2} \left[\left(\frac{\sum_{j=H,L} \sum_{k=1}^{2} N_{jik}}{N} \right) \left(\frac{E_i}{E} \right) H_i \right], \tag{18}$$

where

$$H_{between} = \sum_{i=1}^{2} \left[\left(\frac{\sum_{j=H,L} \sum_{k=1}^{2} N_{jik}}{N} \right) \left(\frac{E - E_i}{E} \right) \right],$$
$$E = \frac{N_H}{N} \log_2 \frac{N}{N_H} + \frac{N_L}{N} \log_2 \frac{N}{N_L}.$$

If $(1-\rho_{Li2})/(1-\rho_{Hi2}) = (1-\rho_{Li1})/(1-\rho_{Hi1})$, high-skilled shares in the suburban area, the city center, and the region would be identical eliminating segregation, i.e., yielding $H_i = H = H_{between} = 0$.

Since inequality is a potential correlate of social mobility, we also examine regional income inequality using the additively decomposable Theil index of inequality, T_i (Cowell, 2000):

$$T_i = \frac{1}{\sum_{j=H,L} \sum_{k=1}^{2} N_{jik}} \sum_{j=H,L} \sum_{k=1}^{2} \frac{w_{ji}}{\bar{w}_i} \ln \left(\frac{w_{ji}}{\bar{w}_i} \right) N_{jik}, \tag{19}$$

where

$$\bar{w}_i = \frac{\sum_{j=H,L} \sum_{k=1}^{2} w_{ji} N_{jik}}{\sum_{j=H,L} \sum_{k=1}^{2} N_{jik}}$$

is the average regional wage. Since we have assumed that the region's residents work in the city area, income inequality (as measured by gross wages) is not directly affected by the distribution of residents within the region. In other words, segregation has no direct effect on income inequality. The Theil index is 0 if $w_{ji} = \bar{w}$ for all j, i. Although, for any given population, regional income inequality increases if the productivity disadvantage of the low skilled increases, in the mobility equilibrium this effect might be dominated by a move to a more homogeneous population.

Differentiating (19) shows that

$$\frac{dT_i}{dh_i} > 0 \Leftrightarrow w_H w_L \log \left(\frac{w_H}{w_L} \right) > (w_H - w_L)\bar{w} \tag{20}$$
$$\Leftrightarrow (\beta - 1)(h_i + (1-h_i)\beta) > \beta \log \beta,$$

where $h_i = \sum_{k=1}^{2} N_{Hik} / \sum_{j=H,L} \sum_{k=1}^{2} N_{jik}$. For given β, the Theil index is thus more likely to rise with the share of high-skilled in a region, the less high-skilled there are originally.

At the country level, the Theil index is defined as

$$\begin{aligned} T &= \frac{1}{N} \sum_{j=H,L} \sum_{i=1}^{2} \sum_{k=1}^{2} \frac{w_{ji}}{\bar{w}} \ln\left(\frac{w_{ji}}{\bar{w}}\right) N_{jik} \\ &= T_{between} + \sum_{i=1}^{2} \theta_i T_i, \end{aligned} \tag{21}$$

where

$$T_{between} = \sum_{i=1}^{2} \theta_i \ln \frac{\bar{w}_i}{\bar{w}}$$

measures the between-region inequality and

$$\bar{w} = \frac{\sum_{j=H,L} \sum_{i=1}^{2} \sum_{k=1}^{2} w_{ji} N_{jik}}{N} \text{ and } \theta_i = \frac{\sum_{j=H,L} \sum_{k=1}^{2} w_{ji} N_{jik}}{\sum_{j=H,L} \sum_{i=1}^{2} \sum_{k=1}^{2} w_{ji} N_{jik}}.$$

Because of the small number of types in our model, we employ measures of social mobility common in sociology to analyze "class" mobility (Goldthorpe, Llewellyn, and Payne, 1987) and occupational mobility (see, e.g., Xie and Killewald, 2013). Our measure, the odds ratio, OR_i, measures relative mobility (Xie and Killewald, 2013):

$$OR_i = \frac{\left\{\sum_{k=1}^{2} f_{Lik}(h_{ik}) N_{Lik}\right\} / \left\{\sum_{k=1}^{2} [1 - f_{Lik}(h_{ik})] N_{Lik}\right\}}{\left\{\sum_{k=1}^{2} f_{Hik}(h_{ik}) N_{Hik}\right\} / \left\{\sum_{k=1}^{2} [1 - f_{Hik}(h_{ik})] N_{Hik}\right\}}. \tag{22}$$

The odds ratio measures the ratio of the odds of low skilled moving to the high-skill level and the odds of the high skilled staying at the high-skill level. With complete mobility, the odds ratio would be 1, and the lower the odds ratio, the less mobility there is in a region.[8] The odds ratio at the country level, OR, is defined analogously with the regional measures.

[8] Xie and Killewald (2013) also present a measure called absolute mobility rate, which measures the fraction of the population which moves either up or down the skill ladder. However, they note that this measure is affected by the marginal distributions of class within generations. Note also that the term relative mobility is used differently by Chetty, Hendren, Kline, and Saez (2014b).

3 Numerical simulation

To demonstrate the effect of model parameters on the distribution of the population, on segregation, income inequality, and social mobility in the short run and in the long run, we now describe the results of numerical simulations.

3.1 Benchmark results

We use the following benchmark parameters. For simplicity, we set the dispersion parameter λ equal to 5. We set the budget share of housing to $\gamma = 0.25$ and the spillover parameter δ also to 0.25. The high-skilled wage in region 1 is $w_{H1} = 100$, both regions are equally productive, $\alpha = 1$, and the low-skilled wage gap in both regions is $\beta_i = 0.7$. The commuting cost parameters are $\rho_{jk1} = 0.05$, $j = H, L$, $k = 1, 2$, $\rho_{H12} = \rho_{L12} = \rho_{H22} = 0.2$, and $\rho_{L22} = 0.3$. Thus, low-skilled workers face comparatively high commuting costs in area 2 in region 2. This assumption may be thought of as representing some form of spatial mismatch due to either the spatial structure of cities combined with housing market discrimination and/or differential provision of infrastructure between cities and/or areas.

The set of commuting cost parameters implies that in equilibrium, high-skilled shares vary across regions. Total population is $N = 100$ with initially $N_H = 40$ high skilled and $N_L = 60$ low-skilled. The land areas are $M_{11} = M_{21} = 80, M_{12} = M_{22} = 120$ which reflects the fact that land is scarcer in the city centers than in the suburbs. Finally, the productivity parameters in the transition functions are given by $A_H = 0.9, A_L = 0.7$ with $\eta = 0.125$ and $\mu = 0.75$.

The short-run equilibrium values are shown in Table 1. The more accessible area 1 has more inhabitants in both regions despite its lower land area and commands a higher housing price. Due to the high commuting costs of the low-skilled in area 2 in region 2, this area exhibits a larger high-skilled share than all the other areas and smaller total population. Because the ratio of commuting costs does not vary across areas in region 1, this region is not segregated, whereas region 2 is somewhat segregated. The Theil index indicates larger inequality in region 2 than in region 1. Relative mobility is higher in region 1.

This is our first finding: stronger segregation and higher inequality are associated with lower relative mobility. The reason is that differential access to central city jobs for the low skilled creates segregation within the city. This segregation causes larger inequality than in the other region, and also reduces relative mobility.[9]

Table 1: Short-run equilibrium (benchmark)

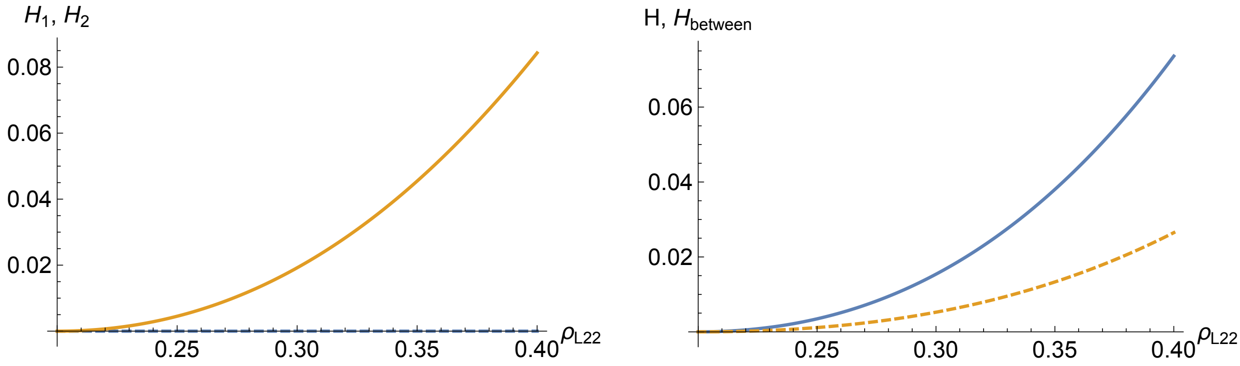
	Region 1		Region 2	
	Area 1	Area 2	Area 1	Area 2
High-skilled share (h_{ik})	0.229405	0.215795	0.229405	0.325395
Population ($N_{Hik} + N_{Lik}$)	25.533	24.0182	25.533	24.9158
Land rent (r_{ik})	6.12333	3.23372	6.12333	3.38409
Segregation index (H_i)	0		0.019738	
Inequality (Theil) index (T_i)	0.015426		0.0158741	
Odds ratio (OR_i)	0.673437		0.592705	
Country level				
Segregation index (H)	0.0151714			
Between-region index ($H_{between}$)	0.0050229			
Inequality (Theil) index (T)	0.0157638			
Between-region index ($T_{between}$)	0.000108442			
Odds ratio (O)	0.618006			

The long-run equilibrium values are shown in Table 2. Due to the human capital spillovers, in the steady-state equilibrium, the population converges to a share of 30.8% high-skilled individuals. Qualitatively, the patterns of population, land rents, segregation, inequality, and mobility do not differ from the corresponding patterns in the short-run equilibrium.

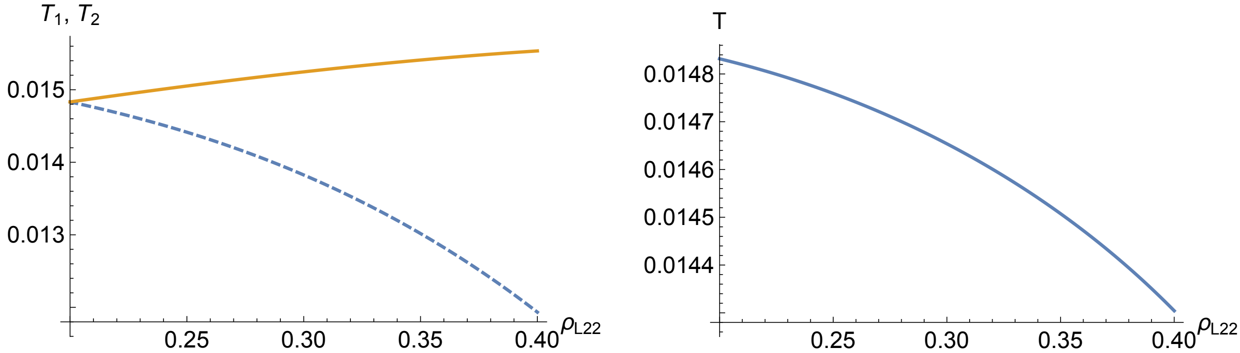
3.2 Sensitivity analysis

The sensitivity analysis focusses on the impact of commuting costs, regional and skill specific productivity gaps, and preference heterogeneity on the spatial equilibrium. Since the effects in the short run are qualitatively similar to the long-run effects, we show only long-run effects. One at a time, we vary ρ_{L22} from 0.2 to 0.4, α from .5 to 1, β_2 from 0.5 to 1, and λ from .1 to 10.

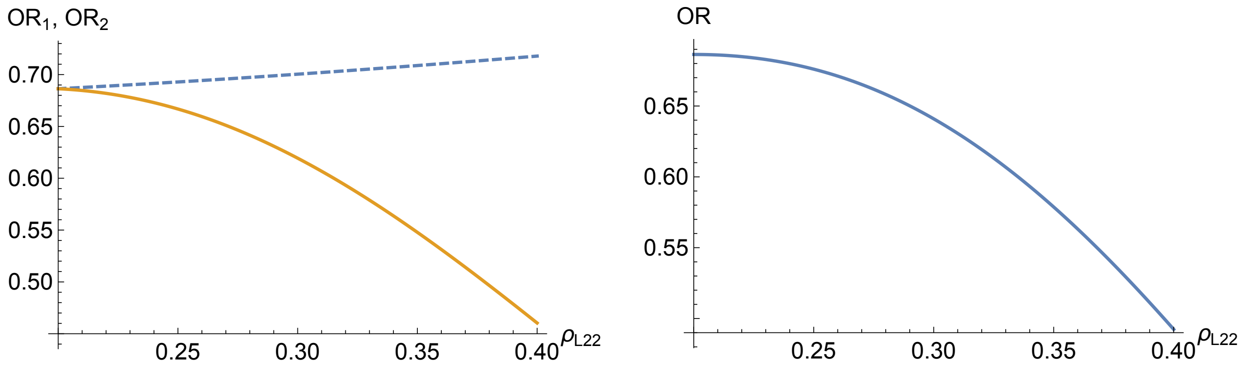
[9]While the probability of transition to the top for the low-skilled increases in region 2 relative to region 1 (because of the larger high-skilled share), the transition probability to the stay at the top for high-skilled increases even more, so the odds ratio is lower in region 2.



(a) Segregation



(b) Inequality



(c) Relative mobility

Figure 2: Impact of ρ_{L22} on segregation, inequality, and mobility ($i = 1$: dashed, $i = 2$: solid; H: solid, $H_{between}$: dashed)

Table 2: Long-run equilibrium (benchmark)

	Region 1		Region 2	
	Area 1	Area 2	Area 1	Area 2
High skilled (N_H)	30.8151			
High-skilled share (h_{ik})	0.223246	0.210002	0.223246	0.343505
Population ($N_{Hik} + N_{Lik}$)	25.4282	23.9196	25.4282	25.224
Land rent (r_{ik})	5.89699	3.11419	5.89699	3.25857
Entropy based segregation index (H_i)	0		0.019205	
Theil index (T_i)	0.0138251		0.0152464	
Odds ratio (OR_i)	0.70042		0.61937	
Country level				
Segregation index (H)	0.0153918			
Between-region index ($H_{between}$)	0.00524584			
Inequality (Theil) index (T)	0.0146538			
Between-region index ($T_{between}$)	0.0000987708			
Odds ratio (O)	0.64093			

Varying commuting costs. We first vary ρ_{L22}, the commuting cost parameter for the low skilled in area 2 of region 2. Since for $\rho_{L22} = 0.2$ parameters do not differ across regions, measures of segregation, inequality, and mobility also do not vary between regions. Commuting cost changes have strong effects on the size and the composition of the population, and, thus, also on segregation, inequality, and social mobility (see Figure 2). Due to spatial mobility across regions, these effects are not limited to the region where commuting costs change, but there are spillovers regarding inequality and relative mobility, but not regarding segregation. Increasing ρ_{L22} reduces population size and increases the high-skilled share in this area; since the high-skilled share in area 1 falls less sharply than that in area 2 rises, segregation in region 2 rises. In region 1, segregation is not affected, since the ratio of commuting cost factors does not change. Income inequality increases in region 2 and decreases in region 1. The Theil index in a region increases with the number of low skilled if their population share in this region increases faster than their share of income. In our benchmark case, we then find that Region 2's Theil index increases with a rising share of high skilled while conversely, region 1's Theil decreases with a falling high skilled share.

As the high skilled share increases in region 1, the transition-to-the-top probability there increases. While this increases mobility to the top of the low skilled, this effect is dominated by the fact that the probability of high skilled to stay at the top increases. Conversely, in region 2 the transition-to-the-top probability decreases. For low ρ_{L22}, the resulting increased downward mobility of the high skilled dominates the reduced upward mobility of the low skilled; however, this is reversed when ρ_{L22} becomes large enough. The odds ratio in region 2 falls: the odds of the low skilled moving to the top decrease faster than the odds of the high skilled staying at the top. Conversely, in region 1, the odds of the low skilled moving to the top increase faster than the odds of the high skilled staying at the top, so the odds ratio rises.

Increasing ρ_{L22} increases both within-region segregation in region 2 and between region segregation, and, therefore, segregation at the country level. It reduces inequality at the country level since inequality in region 1 sharply declines although between-region inequality increases.[10] Since mobility in region 2 reacts more strongly to the change in commuting costs in region 2 than mobility in region 1, relative mobility at the country level falls.

In contrast to commuting costs, the regional productivity gap parameter, α, has only minor effects on income inequality and mobility, and no effects on segregation (results are therefore not shown).

Varying the skill gap. Next, we vary the skill-specific productivity gap in region 2, β_2. Again, this has no effect on segregation in region 1, while segregation in region 2 slightly falls. But changing this parameter substantially changes income inequality and mobility (see Figure 3). Decreasing the skill gap in region 2 (raising β_2) draws more low skilled to this region. As a consequence of the lowered skill gap, inequality, as measured by the Theil index, decreases in this region. The Theil index in region 1 increases moderately. We find an increase in region 2's odds ratio and a decrease in region 1's odds ratio. In region 2, the probability of transition to the top for the low skilled decreases less than the probability to stay at the top for the high skilled so the odds ratio increases. Similarly, in region 1, the probability to stay at the top rises faster than the probability of transition to the top so the odds ratio decreases.

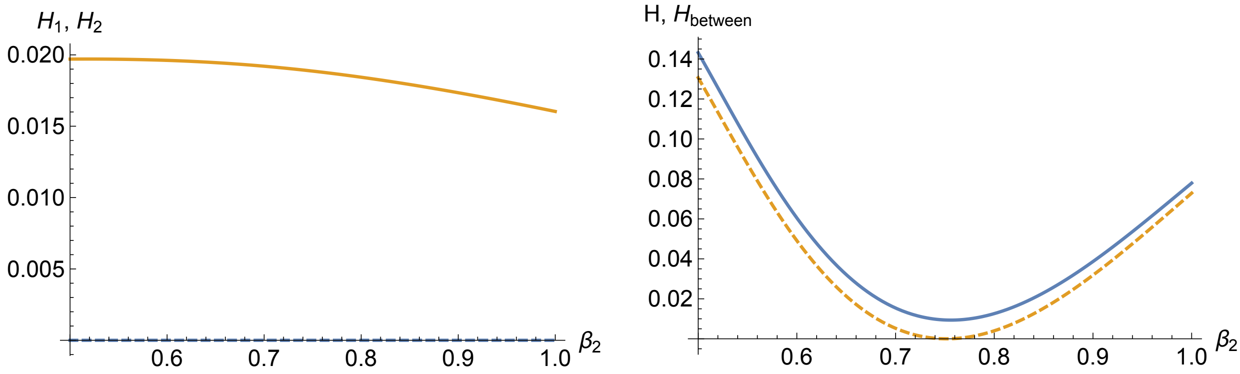
At the country level, the relationship between β_2 and both segregation and inequality is

[10] $T_{between}$ increases from 0 to approximately 0.0005.

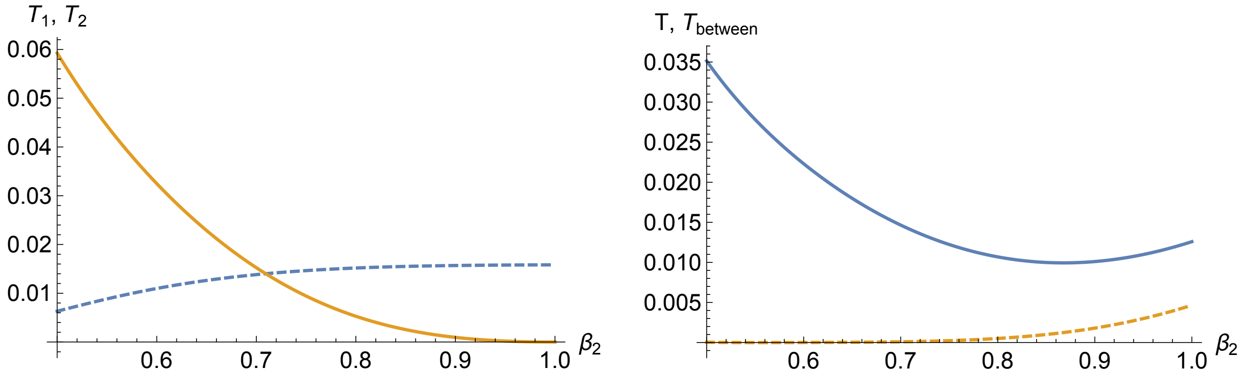
U-shaped, while the relationship between β_2 and relative mobility is inversely U-shaped (see Figure 3). Because of the commuting cost disadvantage of region 2, minimum segregation and maximum social mobility do not obtain exactly at the uniform productivity level, $\beta_2 = \beta_1 = 0.7$. The U-shaped pattern of segregation is mainly driven by interregional differences (between-variation) rather than intraregional differences, see Fig. 3a. If β_2 is low, region 2 is much more densely populated and has a substantially higher share of the high-skilled. Increasing β_2 makes region 2 a much more favorable place for both the low-skilled and the high-skilled and, therefore, first reduces interregional differences and, eventually, reverses these differences. Increasing β_2 first reduces inequality at the country level since inequality sharply declines in region 2, but increases only moderately in region 1. Eventually inequality at the country level increases because between-region inequality increases sufficiently strongly.

Varying taste heterogeneity. As a last exercise, we increase λ, which decreases the variance of the distribution of taste heterogeneity; hence, households become less attached to their region of residence. As $\lambda \to 0$, households choose their residence basically at random so the regions (and areas) converge. However, as the variance of the distribution decreases, differences between the regions are magnified. As λ increases, the commuting cost disadvantage of region 2 naturally translates into a higher high-skilled share and population in this region. As a consequence, segregation and inequality in this region increase, while inequality decreases in the other region (see Figure 4). The increased high-skilled share in region 2 increases the probabilities of transition to the top and stay at the top in this region, but the probability to stay at the top rises faster so the odds ratio falls. In region 1 the high skilled share falls, which decreases both the probability to rise to the top and the probability to stay at the top. As a consequence, the odds ratio rises slightly.

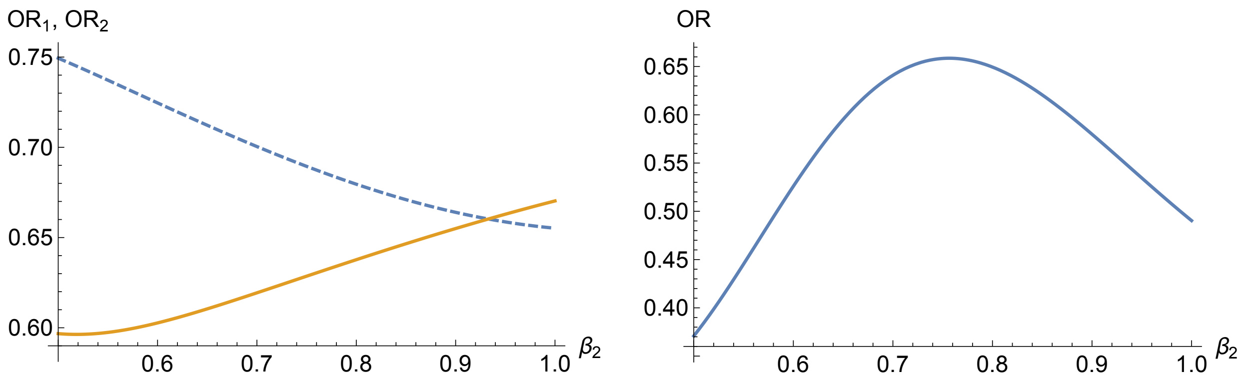
At the country level, increasing λ increases segregation and reduces both inequality and relative mobility. The increase in country-level segregation is due both to increasing segregation in region 2 and the increase in between-region segregation (Fig. 4a). Increasing λ consistently increases the share of high-skilled in region 2 and reduces their share in region 1, but first decreases region 2's population share and then increases its share.



(a) Segregation

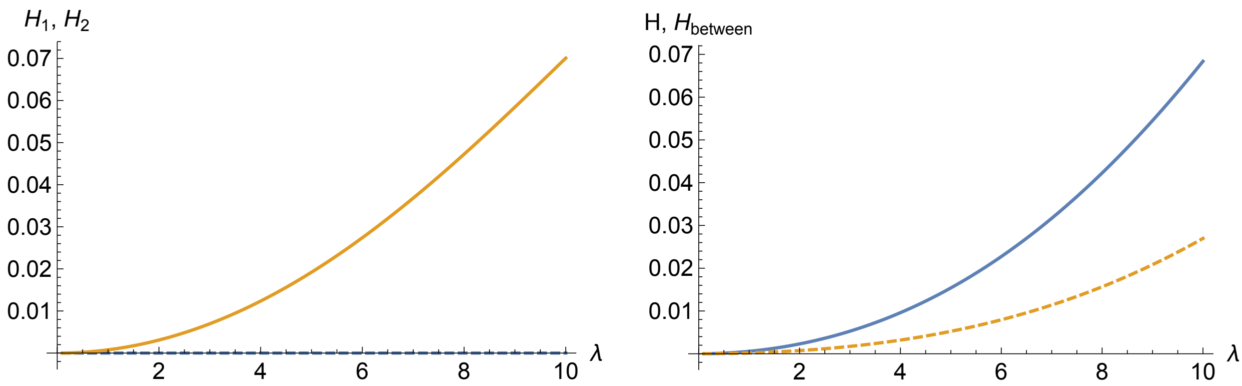


(b) Inequality

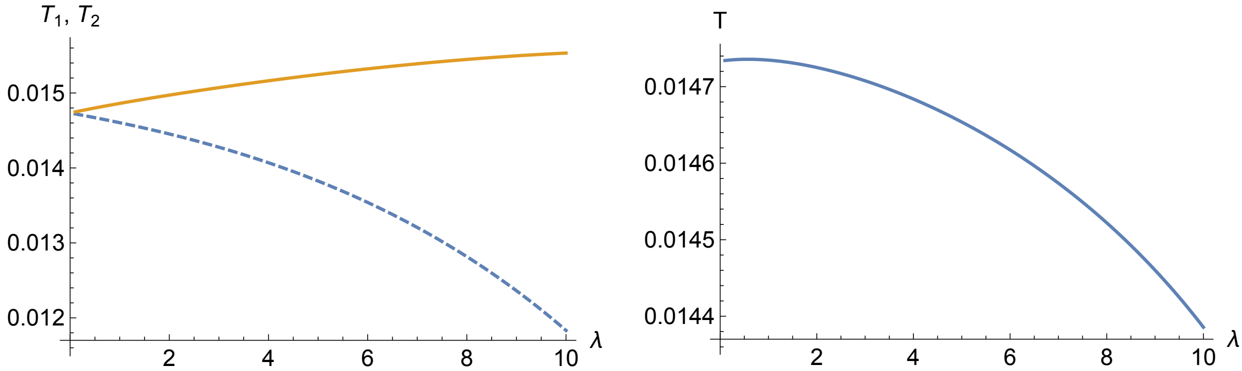


(c) Relative mobility

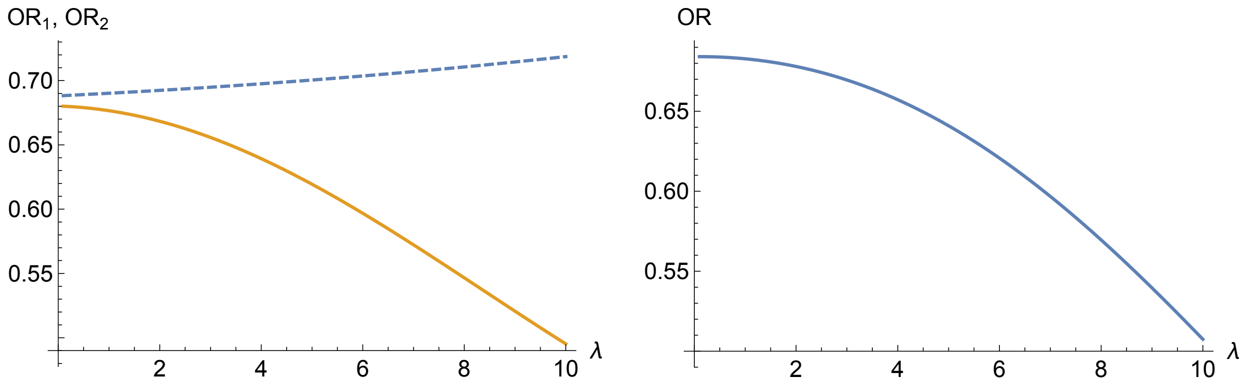
Figure 3: Impact of β_2 on segregation, inequality, and mobility ($i = 1$: dashed, $i = 2$: solid; H: solid, $H_{between}$: dashed; T: solid, $T_{between}$: dashed)



(a) Segregation



(b) Inequality



(c) Relative mobility

Figure 4: Impact of λ on segregation, inequality, and mobility ($i = 1$: dashed, $i = 2$: solid; H: solid, $H_{between}$: dashed)

4 Conclusion

Our paper has examined how social and spatial mobility are related. We thus contribute to the analysis of spatial variations of intergenerational mobility. In our model, these variations are caused by sorting of different skills into geographic areas, which affects the intergenerational transmission of skills.

We have found that social mobility is negatively correlated with segregation by income, intragenerational inequality, long commute times for the poor in one region, high-skilled wage premiums and with regional mobility. Thus this type of model is able to explain some of the empirical facts uncovered by Chetty, Hendren, Kline, and Saez (2014b).

Our model also shows some ways for policies to affect social mobility. In particular, if regional mobility is important in shaping interregional differences in segregation, inequality and social mobility, then policies aimed at reducing the persistence of inequality might increase incentives for interregional migration. Another policy would be to subsidize commuting costs of the low skilled by direct fiscal measures or better infrastructure. These policies could be addressed in future research on this topic.

Acknowledgments

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References

Abbott, B., and G. Gallipoli (2014): "Skill Complementarity and the Geography of Intergenerational Mobility," Unpublished manuscript.

Anas, A. (1990): "Taste Heterogeneity and Urban Spatial Structure: The Logit Model and Monocentric Theory Reconciled," *Journal of Urban Economics*, 28, 318–335.

Bénabou, R. (1993): "Workings of a City: Location, Education, and Production," *Quarterly Journal of Economics*, 108, 619–652.

Bénabou, R. (1996): "Equity and Efficiency in Human Capital Investment: The Local Connection," *Review of Economic Studies*, 63, 237–264.

Bezin, E., and F. Moizeau (2015): "Cultural Dynamics, Social Mobility and Urban Segregation," Working Paper WP 2015-13, University of Caen, University of Rennes 1.

Bisin, A., E. Patacchini, T. Verdier, and Y. Zenou (2011a): "Ethnic Identity and Labor-Market Outcomes of Immigrants in Europe," *Economic Policy*, 65, 57–92.

Bisin, A., E. Patacchini, T. Verdier, and Y. Zenou (2011b): "Formation and Persistence of Oppositional Identities," *European Economic Review*, 55, 1046–1071.

Bisin, A., and T. Verdier (2011): "The Economics of Cultural Transmission and the Evolution of Preferences," *Journal of Economic Theory*, 97, 298–319.

Björklund, A., and M. Jäntti (1997): "Intergenerational Income Mobility in Sweden Compared to the United States," *American Economic Review*, 87, 1009–1018.

Cheshire, P. C., and M. Nathan (2014): *Urban Economics and Urban Policy: Challenging Conventional Policy Wisdom*. Edward Elgar Publishing Ltd.

Chetty, R., and N. Hendren (2015): "The Impact of Neighborhoods on Intergenerational Mobility: Childhood Exposure Effects and County-Level Estimates," Mimeo.

Chetty, R., N. Hendren, and L. Katz (2015): "The Effects of Exposure to Better Neighborhoods on Children: New Evidence from the Moving to Opportunity Experiment," *American Economic Review*, forthcoming.

Chetty, R., N. Hendren, P. Kline, and E. Saez (2014a): "Online Appendics for Where is the Land of Opportunity? The Geography of Intergenerational Mobility in the United States," available online at `http://qje.oxfordjournals.org/content/suppl/2014/09/14/qju022.DC1/QJEC12904_CHETTY_ONLINE_appendix.pdf`.

——— (2014b): "Where is the Land of Opportunity? The Geography of Intergenerational Mobility in the United States," *Quarterly Journal of Economics*, (forthcoming).

Constant, A. F., S. Schüller, and K. F. Zimmermann (2013): "Ethnic Spatial Dispersion and Immigrant Identity," Discussion Paper 7868, IZA.

Corak, M. (2013): "Income Inequality, Equality of Opportunity, and Intergenerational Mobility," *Journal of Economic Perspectives*, 27, 79–102.

Cowell, F. A. (2000): "Measurement of Inequality," in *Handbook of Income Distribution*, ed. by A. B. Atkinson, and F. Bourguignon, vol. 1, pp. 87–166. Elsevier.

Crane, J. (1991): "The Epidemic Theory of Ghettos and Neighborhood Effects on Dropping Out and Teenage Childbearing," *American Journal of Sociology*, 96, 1226–1259.

Durlauf, S. N. (2004): "Neighborhood Effects," in *Handbook of Regional and Urban Economics*, ed. by J. V. Henderson, and J. F. Thisse, vol. 4, pp. 2173–2242. Elsevier Publisher, Amsterdam.

Fernández, R., and R. Rogerson (1998): "Public Education and Income Distribution: A Dynamic Quantitative Evaluation of Education-Finance Reform," *American Economic Review*, 88, 813–833.

Gaviria, A., and S. Raphael (2001): "School-Based Peer Effects and Juvenile Behavior," *Review of Economics and Statistics*, 83, 257–268.

Goldthorpe, J. H., C. Llewellyn, and C. Payne (1987): *Social Mobility and Class Structure in Modern Britain*. Clarendon Press, Oxford, 2nd edn.

Kremer, M. (1997): "How Much Does Sorting Increase Inequality?," *The Quarterly Journal of Economics*, 112(1), pp. 115–139.

Long, J., and J. Ferrie (2013): "Intergenerational Occupational Mobility in Great Britain and the United States since 1850," *American Economic Review*, 103, 1109–1137.

Ludwig, J., G. J. Duncan, L. A. Gennetian, L. F. Katz, R. C. Kessler, J. R. Kling, and L. Sanbonmatsu (2012): "Neighborhood Effects on the Long-Term Well-Being of Low-Income Adults," *Science*, 337, 1505–1510.

——— (2013): "Long-Term Neighborhood Effects on Low-Income Families: Evidence from Moving to Opportunity," *American Economic Review Papers and Proceedings*, 103(3), 226–231.

McFadden, D. (1973): "Conditional Logit Analysis of Qualitative Choice Behavior," in *Frontiers in Econometrics*, ed. by P. Zaremmbka. Academic Press, New York.

——— (1978): "Modeling the Choice of Residential Location," in *Spatial Interaction Theory and Planning Models*, ed. by A. Karlquist, L. Lundquist, F. Snickbars, and J. Weibull, pp. 75–96. North-Holland, Amsterdam.

Patacchini, E., and Y. Zenou (2011): "Neighborhood Effects and Parental Involvement in the Intergenerational Transmission of Education," *Journal of Regional Science*, 51, 987–1013.

Reardon, S. F., and G. Firebaugh (2002): "Measures of Multigroup Segregation," *Sociological Methodology*, 32, 33–67.

Topa, G., and Y. Zenou (2014): "Neighborhood versus Network Effects," in *Handbook of Regional and Urban Economics*, ed. by V. H. G. Duranton, and W. Strange, vol. 5. Elsevier Publisher, Amsterdam.

Xie, Y., and A. Killewald (2013): "Intergenerational Occupational Mobility in Great Britain and the United States Since 1850: Comment," *American Economic Review*, 103, 2003–2020.