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ORIGINAL ARTICLE

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 that is home to workplaces and residences and an exclusively residential suburban area. The paper demonstrates that relative regional social mobility is negatively correlated with segregation and inequality. In the model, segregation, income inequality, and social mobility are driven by differences between urban and residential areas in commuting cost differences between high-skilled and low-skilled workers, and also by the magnitude of taste heterogeneity.

KEYWORDS

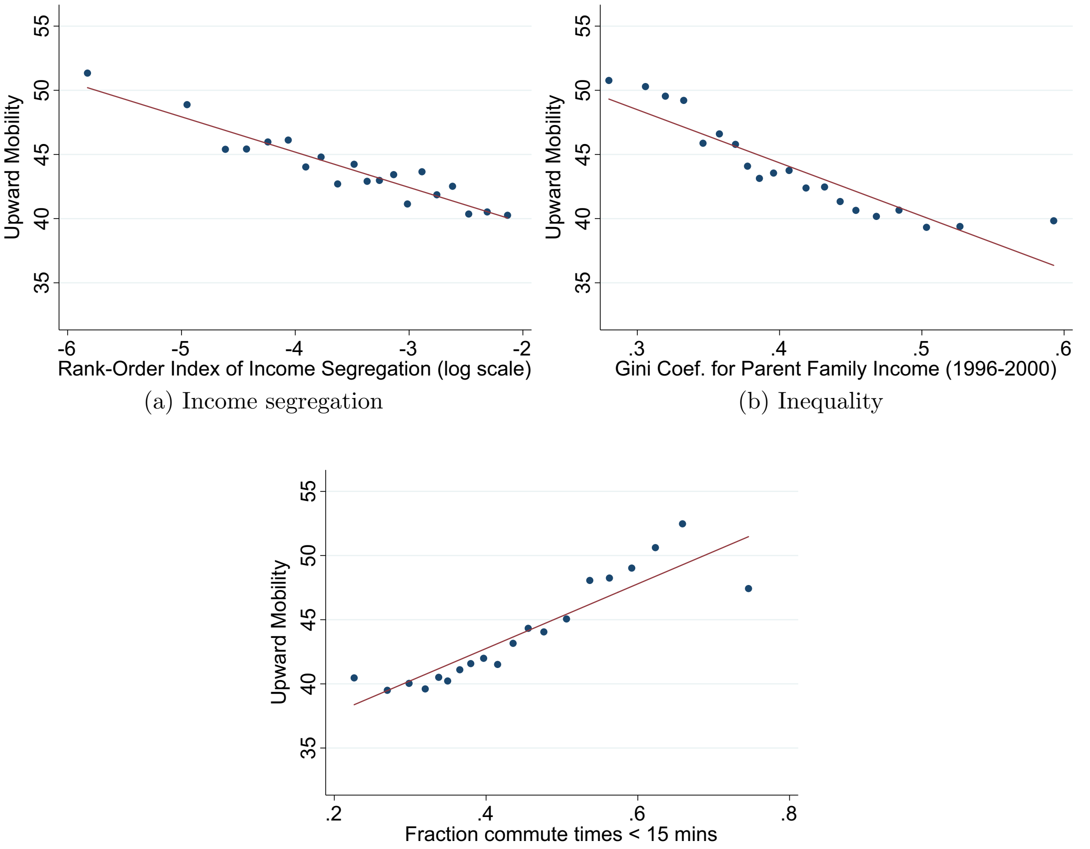
inequality, segregation, social mobility, spatial mobility

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 geographic 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 United States 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 United States. 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. Figure 1a shows the correlation between their measure of upward mobility and income segregation,



(a) Income segregation

(b) Inequality

(c) Fraction commute times < 15 min

FIGURE 1 Correlates of upward mobility [Color figure can be viewed at wileyonlinelibrary.com]
Source: Chetty, Hendren, Kline, and Saez (2014a) and authors' calculations based on data from http://www.equality-of-opportunity.org/

Figure 1b shows the correlation of upward mobility and inequality, and Figure 1c shows the correlation of upward mobility and the fraction of the population with commute times of less than 15 minutes.[1]

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 two regions with two areas each, one with workplaces and residences and the other residential only, so individuals living in residential areas commute to the central area 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 public education as well as parents' private education efforts. This implies that children of high-skilled parents have a higher probability to move to the top than children from low-skilled families. It also implies that there is a positive link between an area's average human capital and social mobility, since average

[1] The figures use a measure called absolute (upward) mobility from Chetty et al. (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 mobility is on the y-axis.

human capital increases the level of public education.[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 suburban area. 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. Third, we demonstrate that weaker place attachment (higher spatial mobility) increases the regional variation of segregation and inequality and—over some range—decreases national inequality and increases social mobility. This resonates well with Long and Ferrie's (2013) argument that high residential mobility in the United States compared to Britain in the 19th century can explain the larger social mobility in the United States 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 Figure 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.

The paper proceeds as follows. The next section describes the related literature. Section 3 presents the basic model. Section 4 presents results from a numerical simulation, and the last section concludes the paper.

2 | RELATED LITERATURE

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., Abbott & Gallipoli, 2017; Björklund & Jäntti, 1997; Corak, 2013). 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 et al. (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 (2017). The focus of this literature, however, 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

[2] Some researchers examine educational investment (see, e.g., Patacchini & 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 transmission of preferences, beliefs, and social norms (see, e.g., Bisin & Verdier, 2011; Bisin, Patacchini, Verdier, & Zenou, 2011a, 2011b).

[3] There is still no consensus whether important neighborhood effects exist (for an overwiew, see, e.g., Cheshire, Nathan, & Overman, 2014; Durlauf, 2004; Topa & Zenou, 2014). In particular, the moving-to-opportunity (MTO) project has shown only small economic effects of moving to favorable neighborhoods. Ludwig et al. (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 covariates of segregation (for further critical remarks, see, e.g., Cheshire et al., 2014). However, Chetty and Hendren (2016) provide quasi-experimental evidence that neighborhoods affect intergenerational mobility through childhood exposure effects. Chetty, Hendren, and Katz (2016) consider the MTO 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.

[4] Chetty et al. (2014b), however, find no significant correlation between intergenerational mobility and migration rates in U.S. 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.

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-choice framework, we have communities that 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 (2017) 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 (2017) and this paper is that we examine the effect of commuting within cities on segregation and intergenerational mobility.

3 | THE MODEL

3.1 | Basics

We consider a model with two regions, indexed $i = 1, 2$ with two areas $k = 1, 2$ each. The population contains 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 ($j = L$) with human capital $h_j, j = H, L$, where $h_H > h_L$. The mass of low- and high-skilled individuals in the economy is given by N_L and N_H. We assume that human capital levels are constant across generations. Hence, social mobility is governed by a skill-specific probability that one's child becomes high-skilled (see below). We let $\Delta \equiv \ln h_H - \ln h_L$ be the skill premium (in human capital levels and also in wages, which are proportional to human capital, see below).

Parents of skill type j living in area k of region i have preferences over consumption, c_{jik}, housing, s_{jik}, and their children's expected human capital, $\mathbb{E}[\ln h_{jik}] = q_{jik} \ln h_H + (1 - q_{jik}) \ln h_L$. Utility of a type j individual living in area k of city i is

$$u(c_{jik}, s_{jik}, h_{ik}) = (1 - \gamma - \delta) \ln c_{jik} + \gamma \ln s_{jik} + \delta \mathbb{E}[\ln h_{jik}], \qquad j = H, L, \qquad i, k = 1, 2, \tag{1}$$

$$\text{where } \gamma, \delta > 0, \gamma + \delta < 1.$$

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 time of a type j individual in area k of region i is given by $\rho_{jik}, j = H, L, i = 1, 2, k = 1, 2$, with $1 > \rho_{ji2} > \rho_{ji1} \geq 0$, 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 for families with different skills. For instance, if the poor tend to use public transport while the rich tend to drive, differential availability of public transport in suburbs of different cities would be analogous to this assumption.

The individual budget constraint is given by

$$c_{jik} = (1 - \tau_{ik})(1 - \rho_{jik}) \alpha_i e_{ji} h_{j0} - r_{ik} s_{jik}, \qquad j = H, L, \qquad i = 1, 2, \qquad k = 1, 2. \tag{2}$$

Here, τ, with $0 \leq \tau < 1$, stands for the income tax rate and $(1 - \rho)\alpha e h_0$ is labor income net of commuting, where $(1 - \rho)e$ denotes working time. The rest of the time endowment after commuting, $(1 - \rho)(1 - e)$, is spent educating one's children (see below). The gross wage of a parent with human capital h_0 is $\alpha e h_0$. We allow regions to differ in their productivity, so wages are proportional to the regional TFP, α_i. We will normalize α_1 to one and set $0 < \alpha_2 = \alpha \leq 1$, so region 1 is inherently more productive. 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.[6]

Social mobility is governed by a skill-type and area-specific transition-to-the-top probability. The probability that a type j household's child in area k of region i will be high-skilled is given by

$$q_{jik} = \ln\left(((1-\rho_{jik})(1-e_{jik})h_{j0})^{\mu} E_{ik}^{1-\mu}\right), \qquad j = H, L, \qquad i = 1, 2, \qquad k = 1, 2. \tag{3}$$

The transition to the top is a function of the area's public education, E, and the parents' private education effort, which is proportional to parents' human capital h_0 and the time they spend educating their children, $(1-\rho)(1-e)$, which is time spent neither commuting nor working. μ is the weight of parents' private education effort, with $0 < \mu < 1$. Equation (3) thus shows on what factors the transition to the top, and hence, social mobility, depends. We discuss this further below, following Equation (8).

Since long commutes mean parents have less time to educate their children, the model implies that commuting affects social mobility.

We assume the following timing. First, individuals choose their place of residence. Then, within each area, spending on public education and the income tax rate are chosen by majority vote. Finally, individuals decide on consumption, housing demand, and the allocation of time between labor supply and private education. We proceed backward and first solve for individual decisions, then the vote on education policy, and finally the residential choice.

With Cobb–Douglas utility, we can solve for land-demand and working time. Using Equations (2) and (3) in Equation (1) and maximizing gives:

$$s_{jik} = \frac{\alpha_i \gamma (1-\tau_{ik})(1-\rho_{jik})h_{j0}}{r_{ik}\Theta_1}, \quad j = H, L, \qquad i = 1, 2, \qquad k = 1, 2, \tag{4}$$

$$e_{jik} = \frac{1-\delta}{\Theta_1} \equiv e, \qquad j = H, L, \qquad i = 1, 2, \qquad k = 1, 2, \tag{5}$$

where $\Theta_1 \equiv 1 - \delta(1 - \Delta\mu)$. Cobb–Douglas utility implies that private education investments are independent of initial human capital.[7] This implies that gross labor income is proportional to parental human capital: $w_{ji} = \alpha_i e h_{j0}$, $j = H, L$, $i = 1, 2$.

The public budget constraint in area k of region i is

$$\begin{aligned} E_{ik} &= \tau_{ik} e \bar{h}_{ik}, \\ \text{where } \bar{h}_{ik} &= n_{Hik}h_H + (1-n_{Hik})h_L \quad \text{and} \quad n_{Hik} = \frac{N_{Hik}}{N_{Hik}+N_{Lik}}. \end{aligned} \tag{6}$$

Note that we assume that areas have jurisdiction over education spending. For instance, one may think about areas as being school districts within cities, which would correspond to a decentralized school finance system like in the United States.

Individuals choose the optimal tax rate and spending level to maximize indirect utility, subject to Equation (6). This gives the optimal tax rate in area k of region i

$$\tau_{ik}^{*} = \frac{\delta\Delta(1-\mu)}{\Theta_2} \equiv \tau^{*}, \tag{7}$$

[6] To focus on commuting costs rather than labor market institutions and to keep the model tractable, we model the labor market as entirely passive and assume that all jobs are located in area 1. In the context of our model, the availability of jobs in area 2 would not change the results if workers living and working in area 2 earn area 1's wage minus commuting cost, i.e., if $(1-\rho_{ji2})\alpha_i = (1-\tilde{\rho}_{ji2})\alpha_{ji2}$, where α_{ji2} is the gross wage of type j workers in area 2 of region i and $\tilde{\rho}_{ji2}$ are the commuting cost for this worker when working in area 2. Equalization of wages net of commuting costs across areas can be justified as equilibrium outcome of some wage determination procedure.

[7] As parents' human capital grows, the income effect implies that their demand for a higher human capital level of their children grows. Second, the substitution effect implies that private education gets more expensive for parents with a higher wage. With Cobb–Douglas utility, both effects exactly offset each other.

where $\Theta_2 \equiv 1 - \delta(1 - \Delta(1 - \mu))$. The optimal tax rate is independent of human capital due to Cobb–Douglas utility. Hence, since all agents have the same optimal tax rate, this rate will also be chosen by majority vote.

Using Equations (6) and (7), we can write the transition-to-the-top probability, savings, and consumption as

$$q_{jik} = \ln\left(\left(\frac{(1-\delta)(1-\mu)\delta\Delta\bar{h}_{ik}}{\Theta_1\Theta_2}\right)^{1-\mu}\left(\frac{\mu(1-\rho_{jik})\delta\Delta h_{j0}}{\Theta_1}\right)^{\mu}\right), \tag{8}$$

$$s_{jik} = \frac{\alpha_i\gamma(1-\delta)(1-\rho_{jik})h_{j0}}{r_{ik}\Theta_1\Theta_2}, \tag{9}$$

$$c_{jik} = \frac{\alpha_i(1-\gamma-\delta)(1-\delta)(1-\rho_{jik})h_{j0}}{\Theta_1\Theta_2}. \tag{10}$$

Equation (8) shows the drivers of the skill-specific transition-to-the-top probability. The probability that a child will be high-skilled depends on parents' individual human capital as well as average area human capital as well as the skill and area-specific commuting costs. First, high-skilled parents transmit more human capital to their children (see Equation (3)). Second, an area with larger average human capital spends more on public education, which increases the transition-to-the-top probability. And third, higher commuting costs imply that parents have less time educating their children, which reduces their children's chances to become high-skilled. In sum, children growing up in rich areas with high-skilled parents with low commuting costs have the greatest odds of becoming high-skilled.

The result that the transition to the top depends on the local share of high-skilled is a natural outcome with locally funded public education. Moreover, it is consistent with the large literature on peer effects in education, smoking, drug use, teenage pregnancies, and so on, all of which affect intergenerational mobility.[8] 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 about 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 obtaining an education sufficient to become high-skilled is determined by local peers and therefore varies within the region. The difference of transition to the top probabilities in a certain area only depends on the difference in initial human capital and the difference in commuting costs:

$$q_{Hik} - q_{Lik} = \mu(\ln((1-\rho_{Hik})h_{H0}) - \ln((1-\rho_{Lik})h_{L0})). \tag{11}$$

Hence, commuting costs are the main determinant of social mobility.

Substituting Equations (8)–(10) into Equation (1) gives the indirect utility:

$$v_{jik} = \Theta_1 \ln((1-\rho_{jik})h_{j0}) - \gamma \ln r_{ik} + \delta\Delta(1-\mu)\ln\bar{h}_{ik} + A, \tag{12}$$

where A depends on $\alpha, \delta, \gamma, \mu, h_L, \Theta_1, \Theta_2$, and Δ.

Since location choice is driven by the indirect utility attained in the different areas, Equation (12) ultimately drives residential segregation. Intuitively, regions become relatively more attractive the lower a type's commuting costs there, the lower the housing rent, and the higher its average human capital. This latter effect reflects the better public education in human capital abundant regions, which increases the transition-to-the-top probability for all children. Note, however, that average human capital is itself endogenously determined by households' location choices. Again, by assumption, the only parameter in the model that affects the location choice of different skill types differentially is the skill-type and location-specific commuting cost. Therefore, residential segregation is ultimately driven by differential commuting costs for different types. While we are not aware of any direct evidence on this link, the evidence in

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

Chetty et al. (2014b) shown in Section 1 is clearly compatible with such a link: regressing their segregation index on the fraction of the population with commute times less than 15 min produces a coefficient of −4.14 (t-statistic −19.38). See also the discussion in Section 3.2 below.

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., Anas, 1990; McFadden, 1978). This modeling strategy has the advantage that it naturally generates equilibria without perfect sorting. Models with deterministic utility and one-dimensional heterogeneity, by contrast, typically generate equilibria with perfect sorting of skill types and are therefore not well suited to study segregation within regions.

Suppose that an individual of skill level j living in area k of region i receives utility $v_{jik} + \varepsilon_{jik}$. Under the assumption that the ε_{jik} 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):[9]

$$p_{jik} = \frac{\exp(\lambda v_{jik})}{\sum_{I=1}^{2}\sum_{K=1}^{2}\exp(\lambda v_{jIK})}, \qquad j = H, L, \qquad i = 1, 2, \qquad k = 1, 2. \tag{13}$$

This implies that the distribution of population is given by

$$N_{jik} = p_{jik}N_j, \qquad j = H, L, \qquad i = 1, 2, \qquad k = 1, 2. \tag{14}$$

3.2 | 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 (15)), (ii) individuals (stochastically) maximize utility by choice of location, that is, Equations (16) hold, and (iii) the population constraints (17) hold:

$$\sum_{j=H,L} p_{jik}s_{jik}N_j = M_{ik}, \qquad i = 1, 2, \qquad k = 1, 2, \tag{15}$$

$$p_{jik} = \frac{\exp(\lambda v_{jik})}{\sum_{I=1}^{2}\sum_{K=1}^{2}\exp(\lambda v_{jIK})}, \qquad j = H, L, \qquad i = 1, 2, \qquad k = 1, 2, \tag{16}$$

$$p_{jik}N_j = N_{jik}, \qquad j = H, L, \qquad i = 1, 2, \qquad k = 1, 2. \tag{17}$$

Equations (16) provide the stochastic version of the usual spatial equilibrium conditions. Equations (16) and (17) imply that only few individuals of a certain type will live in a particular region if the regional wage level is low or commuting costs are high. 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 Equations (4) and (17), Equation (15) can be solved for the land rent:

$$r_{ik} = \frac{\alpha_i\gamma(1-\delta)(N_{Hik}(1-\rho_{Hik})h_H + N_{Lik}(1-\rho_{Lik})h_L)}{\Theta_1\Theta_2 M_{ik}}. \tag{18}$$

[9] 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.

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

Given Equation (18) and the probabilities in Equation (17), Equations (16) provide a system of eight equations in eight unknowns, which can be solved for the endogenous variables, $N_{Hik}, N_{Lik}, i = 1, 2, k = 1, 2$.

Combining Equations (16) and (17) for two areas k in region i and m in region l, $i = 1, 2, k = 1, 2, l = 1, 2, m = 1, 2$, yields

$$\frac{N_{Hik}/N_{Hlm}}{N_{Lik}/N_{Llm}} = \left(\frac{(1-\rho_{Hik})/(1-\rho_{Hlm})}{(1-\rho_{Lik})/(1-\rho_{Llm})}\right)^{\lambda\Theta_1}. \tag{19}$$

Equation (19) shows the determinants of the equilibrium high-skilled to low-skilled ratios of an area relative to another, and hence, the drivers of segregation. In particular, segregation in the model results exclusively from factors that affect high- and low-skilled differentially in the different areas. For instance, we have assumed that land supply differs between areas—in particular, the suburban areas have a larger land supply. This will make suburban land cheaper and the suburbs more attractive for both skill types. However, other things equal, land supply in our model does not drive segregation, since it affects both groups symmetrically.[10]

By assumption, the only exogenous factor affecting high- and low-skilled differentially in the different areas is commuting cost. As Equation (19) shows, area ik's high-skilled-to-low-skilled ratio will be high, relative to area lm, the larger the ratio of low-skilled commuting costs in area ik relative to area lm and the lower the ratio of high-skilled commuting costs in ik relative to lm.[11] In the numerical example in the next section, we assume that commuting costs are identical for high- and low-skilled in all areas except one (area 2,2), where the low-skilled have higher commuting costs. This will lead to segregation in this region, as the low-skilled flock to the areas with lower commuting costs.[12]

Furthermore, using the fact that Equations (16) and (17) imply that $\exp(v_{jik})/N_{jik}$ is independent of i and k, we can easily compare areas that are identical except for one dimension regarding their population size. Totally differentiating $\exp(v_{jik})/N_{jik}$ for $j = H, L$, it can be shown that both a high productivity and large land supply imply a large population relative to any other area where either the productivity is lower or less land is available (despite the compensating effect on land rent). However, since these parameters affect both skill types symmetrically, they will affect area's population shares, but not their skill composition and hence the segregation pattern.

In general, how the mass of high- and low-skilled in all areas depends on the exogenous variables depends on the parameters that 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.

3.3 | Long-run equilibrium

We now characterize the long-run steady-state equilibrium. Total population N is still exogenous. But, starting from the short-run equilibrium, the mass of high- and low-skilled individuals evolve according to the (short-run) transition probabilities described above until a steady state is reached.[13] In this long-run steady state, the mass of high-skilled must equal the sum of high- and low-skilled, weighted by their transition probabilities. Further, the population

[10] Analogously to the "spatial mismatch" literature (see, e.g., Gobillon, Selod, & Zenou, 2007), we could argue that discrimination in housing markets against a certain group (say, low-skilled) leads to segregation.

[11] Log utility ensures that the relationship between the relative commuting cost ratio and the high-skilled-to-low-skilled ratio is strictly monotonic and not confounded in complex ways by land-supply differences, area productivity differences, human capital differences, and various preference parameters.

[12] Note that this leads to a "U.S.-type" residential pattern in region 2, with the low-skilled predominantly in the city center and the high-skilled predominantly in the suburb. (By contrast, region 2 in the example has identical commuting cost ratios for high- and low-skilled and therefore the high-skilled share in both areas in this region is the same.) This kind of pattern could be reversed, for instance, by assuming higher relative commuting costs for the high-skilled in the suburbs, or some other exogenous factor that makes suburbs relatively less attractive for the high-skilled, such as a cultural amenity (Brueckner, Thisse, & Zenou, 1999).

[13] In the numerical example, we check that the steady state is stable.

constraint (21) must hold. In addition to Equations (15)–(17), the stochastic long-run equilibrium must satisfy:

$$\sum_{j=H,L} \sum_{i=1}^{2} \sum_{k=1}^{2} q_{jik} N_{jik} - N_j = 0, \tag{20}$$

$$\sum_{j=H,L} N_j - N = 0. \tag{21}$$

In addition to the endogenous variables pinned down by the short-run equilibrium, Equations (20) and (21) determine N_H and N_L as a function of the model's parameters. The equilibrium conditions ensure that the total mass of high-skilled, N_H, stays constant over time, but 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.

3.4 | 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 et al., 2014b), H_i, defined as

$$H_i = \sum_{k=1}^{2} \left(\frac{N_{Hik} + N_{Lik}}{\sum_{j=1}^{2} \left(N_{Hij} + N_{Lij} \right)} \right) \left(\frac{S_i - S_{ik}}{S_i} \right), \tag{22}$$

where

$$\begin{aligned} S_i &= n_{Hi} \ln_2 \frac{1}{n_{Hi}} + (1 - n_{Hi}) \ln_2 \frac{1}{(1 - n_{Hi})}, \qquad \text{with } n_{Hi} = \frac{\sum_{k=1}^{2} N_{Hik}}{\sum_{k=1}^{2} (N_{Hik} + N_{Lik})}, \\ S_{ik} &= n_{Hik} \ln_2 \frac{1}{n_{Hik}} + (1 - n_{Hik}) \ln_2 \frac{1}{(1 - n_{Hik})}. \end{aligned}$$

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 $S_{ik} = 0$ in all areas. It is minimized at $H_i = 0$ when within-area diversity is the same across all areas in a region.

Note that we measure segregation at the region level, which, given our two region-2 area setup, seems to be the only meaningful definition. It also matches the segregation measure used by Chetty et al. (2014b).[14]

Since the entropy-based index, H_i, is additively decomposable (Reardon & Firebaugh, 2002), the segregation index at the country level

$$H = \sum_{i=1}^{2} \sum_{k=1}^{2} \left[\left(\frac{N_{Hik} + N_{Lik}}{N} \right) \left(\frac{S - S_{ik}}{S} \right) \right] \tag{23}$$

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

$$H = H_{between} + \sum_{i=1}^{2} \left[\left(\frac{\sum_{j=H,L} \sum_{k=1}^{2} N_{jik}}{N} \right) \left(\frac{S_i}{S} \right) H_i \right], \tag{24}$$

[14] See also Cutler and Glaeser (1997).

where

$$H_{between} = \sum_{i=1}^{2} \left[\left(\frac{\sum_{j=H,L} \sum_{k=1}^{2} N_{jik}}{N} \right) \left(\frac{S - S_i}{S} \right) \right],$$

$$S = \frac{N_H}{N} \ln_2 \frac{N}{N_H} + \frac{N_L}{N} \ln_2 \frac{N}{N_L}.$$

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., $H_i = H = H_{between} = 0$.

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):

$$T_i = \frac{1}{\sum_{j=H,L} \sum_{k=1}^{2} N_{jik}} \sum_{j=H,L} \sum_{k=1}^{2} \frac{w_{ji}}{\bar{w}_i} \ln \left(\frac{w_{ji}}{\bar{w}_i} \right) N_{jik}, \tag{25}$$

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 Equation (25) shows that

$$\frac{dT_i}{dh_i} > 0 \Leftrightarrow w_{Hi} w_{Li} \ln \left(\frac{w_{Hi}}{w_{Li}} \right) > (w_{Hi} - w_{Li}) \bar{w}_i$$

$$\Leftrightarrow \frac{h_H h_L \Delta}{h_H - h_L} > \bar{h}_i, \tag{26}$$

where $\bar{h}_i = (\sum_{k=1}^{2} n_{Hik}) h_H + (1 - \sum_{k=1}^{2} n_{Hik}) h_L$. The Theil index is thus more likely to rise with the share of high-skilled in a region, the lower the average human capital there is originally.

At the country level, the Theil index is defined as

$$T = \frac{1}{N} \sum_{j=H,L} \sum_{i=1}^{2} \sum_{k=1}^{2} \frac{w_{ji}}{\bar{w}} \ln \left(\frac{w_{ji}}{\bar{w}} \right) N_{jik}$$

$$= T_{between} + \sum_{i=1}^{2} \theta_i T_i, \tag{27}$$

where

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

measures the between-region inequality and

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

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, & Payne, 1987) and occupational mobility (see, e.g., Xie & Killewald, 2013). Our measure, the odds ratio, OR_i, measures relative mobility (Xie & Killewald, 2013):

$$OR_i = \frac{\left\{\sum_{k=1}^{2} q_{Lik}N_{Lik}\right\} / \left\{\sum_{k=1}^{2}[1-q_{Lik}]N_{Lik}\right\}}{\left\{\sum_{k=1}^{2} q_{Hik}N_{Hik}\right\} / \left\{\sum_{k=1}^{2}[1-q_{Hik}]N_{Hik}\right\}}. \tag{28}$$

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.[15] The odds ratio at the country level, OR, is defined analogously with the regional measures.

4 | 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.

4.1 | Benchmark results

We use the following benchmark parameters. For simplicity, we set the dispersion parameter λ equal to 2. We set the budget share of housing to $\gamma = 0.3$ and δ to 0.4. The weight of parent's education effort is $\mu = 0.3$. The human capital levels of high- and low-skilled individuals are given by $h_L = 10, h_H = 15$, so the skill gap between high- and low-skilled is 33 percent. Both regions are equally productive, $\alpha_i = 1, i = 1, 2$. 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 of 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.

The short-run equilibrium values are shown in Table 1. The more accessible area 1 has fewer inhabitants in both regions due to its smaller 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 than area 2 in region 1. 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 variation of transition probabilities across skill types is particularly large in area 2 of region 2 where the high-skilled share is large. The Theil index indicates larger inequality in region 2 than in region 1.[16] 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.[17]

[15] Xie and Killewald (2013) also present a measure called absolute mobility rate, which measures the fraction of the population that 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 et al. (2014b).

[16] For income net of commuting costs, $(1 - \rho_{jik})w_{ji}$, the respective Theil index indicates more pronounced differences of inequality between regions.

[17] The transition probability to stay at the top for high-skilled increases in region 2 relative to region 1 and the probability of transition to the top for the low-skilled decreases, so the odds ratio is lower in region 2.

TABLE 1 Short-run equilibrium (benchmark)

	Region 1		Region 2	
	Area 1	Area 2	Area 1	Area 2
High-skilled share (n_{Hik})	0.389485	0.389485	0.389485	0.431374
Population ($N_{Hik} + N_{Lik}$)	24.3157	26.266	24.3157	25.1026
Land rent (r_{ik})	1.34165	0.813622	1.34165	0.744956
Trans. prob. high-skilled (q_{Hik})	0.415059	0.363504	0.415059	0.375669
Trans. prob. low-skilled (q_{Lik})	0.293419	0.241864	0.293419	0.21397
Segregation index (H_i)	0		0.00133867	
Inequality (Theil) index (T_i)	0.0203412		0.020462	
Odds ratio (OR_i)	0.572822		0.524895	
Country level				
Segregation index (H)	0.00101595			
Between-region index ($H_{between}$)	0.000350347			
Inequality (Theil) index (T)	0.020411			
Between-region index ($T_{between}$)	0.00000982396			
Odds ratio (O)	0.548867			

TABLE 2 Long-run equilibrium (benchmark)

	Region 1		Region 2	
	Area 1	Area 2	Area 1	Area 2
High skilled (N_H)	24.6449			
High-skilled share (n_{Hik})	0.23825	0.23825	0.23825	0.2710967
Population ($N_{Hik} + N_{Lik}$)	24.3611	26.315	24.3611	24.9628
Land rent (r_{ik})	1.25908	0.763549	1.25908	0.675974
Trans. prob. high-skilled (q_{Hik})	0.369291	0.317735	0.369291	0.327933
Trans. prob. low-skilled (q_{Lik})	0.247651	0.196096	0.247651	0.166234
Segregation index (H_i)	0		0.00125196	
Theil index (T_i)	0.0169318		0.017545	
Odds ratio (OR_i)	0.544188		0.492193	
Country level				
Segregation index (H)	0.000960742			
Between-region index ($H_{between}$)	0.000333022			
Inequality (Theil) index (T)	0.0172423			
Between-region index ($T_{between}$)	0.00000684348			
Odds ratio (O)	0.518177			

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 24.64 percent of 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.

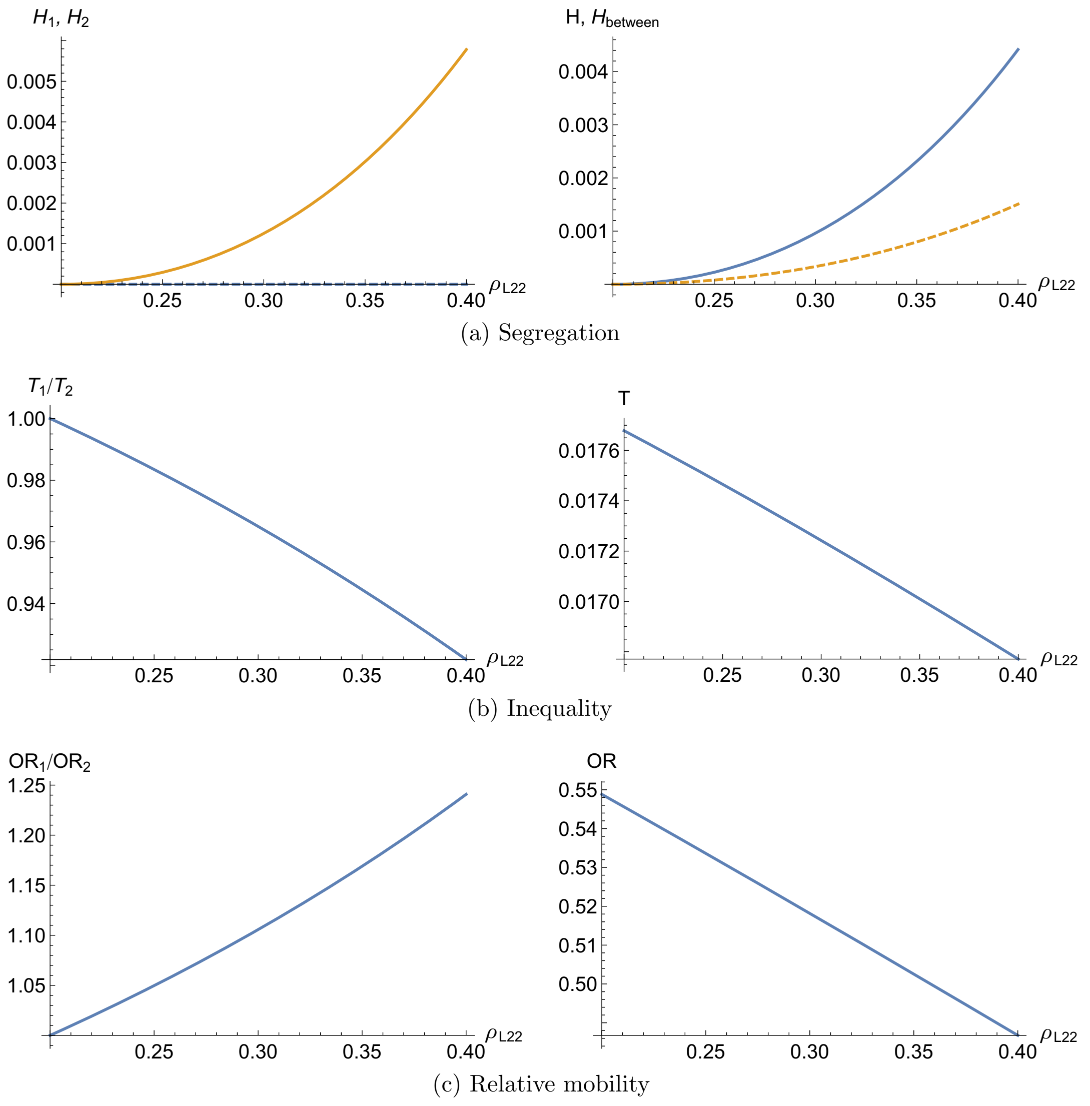


FIGURE 2 Impact of ρ_{L22} on segregation, inequality, and mobility (H_1: dashed, H_2: solid; H: solid, $H_{between}$: dashed) [Color figure can be viewed at wileyonlinelibrary.com]

4.2 | Sensitivity analysis

The sensitivity analysis focusses on the impact of commuting costs, regional productivity gap, 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 0.7 to 1, and λ from 0.1 to 10.

4.2.1 | 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} naturally reduces population size in the affected area 2. In the short run, low-skilled households relocate from area 2 in region 2 to the other areas. Consequently, the high-skilled share in area 2,2 rises, whereas it falls in the other areas. The transition-to-the-top probabilities fall for both high- and low-skilled in all areas with the exception of the transition-to-the-top probability of the high-skilled in area 2,2. While in area 2,2, the decline of the transition-to-the-top probability for the low-skilled is brought about by the rise in commuting costs, which dominates the influence of the increase in the high-skilled share, in the other areas, it is a consequence of the fall in high-skilled shares. Since the high-skilled share in area 2,2 rises, the transition-to-the-top probability for the high-skilled also rises. As a result, the odds-ratios fall in both regions. Then, the long-run high-skilled share falls. In the long run, an increase in ρ_{L22} reduces the increase of the high-skilled share in area 2,2 and decreases the high-skilled shares in all other areas. As a result, transition-to-the-top probabilities fall in both regions except for the high-skilled individuals in area 2,2. The high-skilled share effect in area 2,2 is a general equilibrium effect that is of second order: the negative impact of the rise in low-skilled worker's commuting costs in area 2,2 outweighs the positive impact of the rise in the share of high-skilled.[18] The odds-ratio clearly falls in both regions, but more so in region 2, where the high-skilled share effect is compounded by the rise in commuting costs. Segregation in region 1 is not affected, but segregation in region 2 rises. This is a consequence of the relocation of poor households away from area 2,2. Inequality falls in both regions, but more so in region 1. It does so because the high-skilled share, and therefore, average human capital is lower in region 1.

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.[19] Since social mobility in region 2 reacts more strongly to the change in commuting costs in region 2 than social mobility in region 1, relative mobility at the country level falls.

4.2.2 | Varying regional productivity gap

In contrast to commuting costs, the regional productivity gap parameter, α, has only minor effects on regional segregation, income inequality, and mobility (results are therefore not shown).

4.2.3 | 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 (see Figure 3). As $\lambda \to 0$, households choose their residence basically at random so that the regions (and areas) converge. However, as the variance of the distribution decreases, differences between the regions are magnified. As λ increases, in the short run, the high-skilled share increases in area 2 of region 2 and decreases in the other areas. Consequently, the transition-to-the-top probability for the low-skilled rises in area 2,2 and falls in the other areas; similar changes occur for the high-skilled. In the long run, this translates into a rising odds ratio in region 2 and falling odds ratio in region 1. As the low-skilled move away from area 2,2, region 2 becomes more unequal and remains less socially mobile albeit less so. Finally, the segregation index in region 2 rises.

At the country level, due both to increasing segregation in region 2 and the increase in between-region segregation, increasing λ raises segregation (Figure 3a). Interestingly, the national Theil index is U-shaped and the national odds ratio inversely U-shaped in λ. Inequality declines in region 1 and increases in region 2 and between regions, but the relative size of these opposing effects changes with rising λ. Similarly for social mobility: social mobility decreases in regions 1 and increases in region 2, but the former effect dominates the latter if λ is sufficiently large.

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[18] Various simulations consistently confirm the negative net effect.

[19] $T_{between}$ increases from 0 to approximately 0.00003.

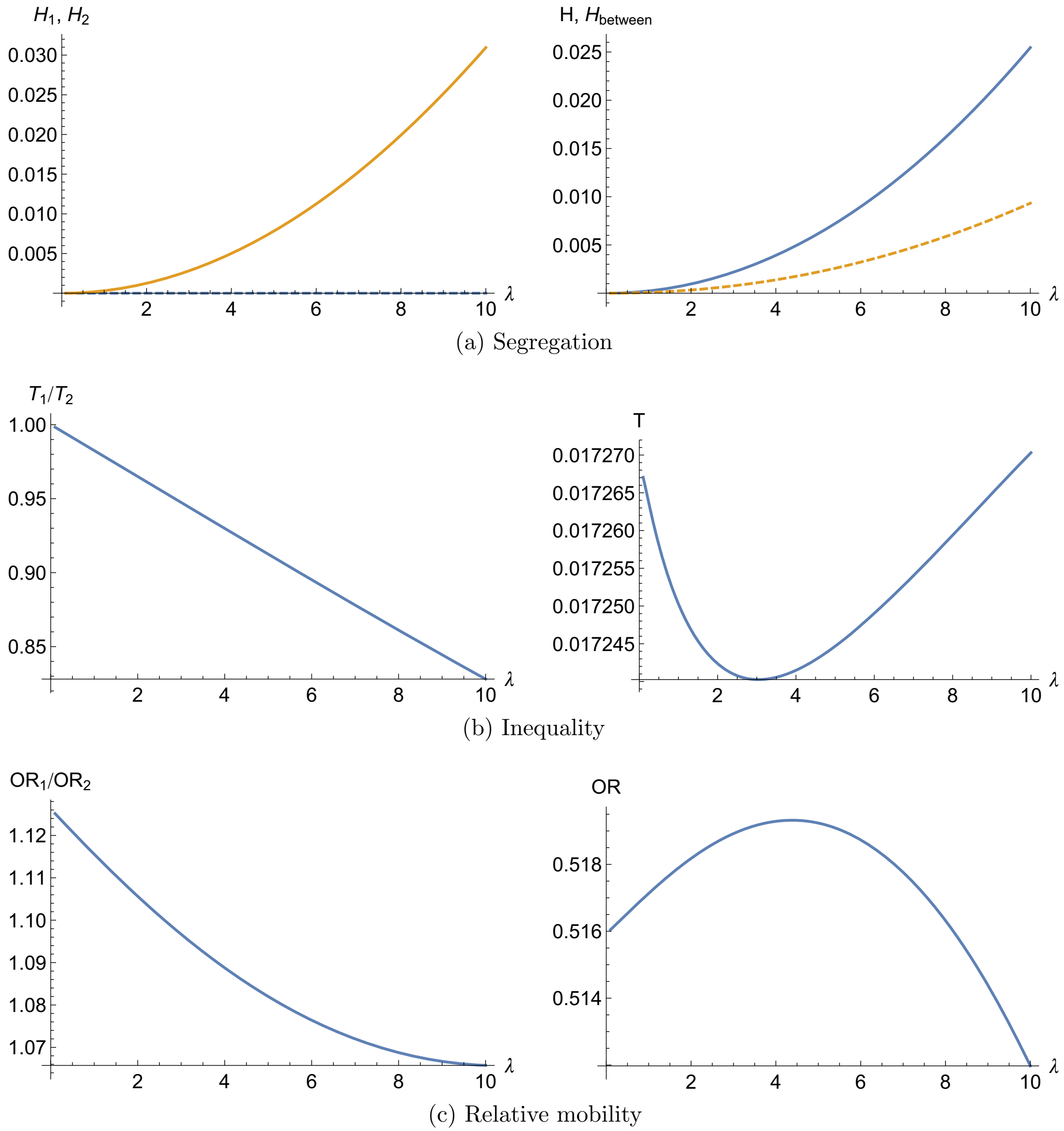

FIGURE 3 Impact of λ on segregation, inequality, and mobility (H_1: dashed, H_2: solid; H: solid, $H_{between}$: dashed) [Color figure can be viewed at wileyonlinelibrary.com]

5 | 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, and, up to some point, positively correlated with regional mobility. Thus, this type of model is able to explain some of the empirical facts uncovered by Chetty et al. (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 relative commuting costs of the low-skilled in disadvantaged areas by direct fiscal measures or better infrastructure. These policies could be addressed in future research on this topic.

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