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SHORT-TERM AND LONG-TERM EDUCATIONAL MOBILITY OF FAMILIES: A TWO-SEX APPROACH

ABSTRACT

We investigate how families reproduce and pass on their educational advantages to succeeding generations from a multigenerational perspective. Unlike traditional mobility studies that typically focus on one-sex influences from fathers to sons, we rely on a two-sex approach that accounts for the marriage market interaction between males and females, which includes educational assortative mating in both parent and grandparent generations and intergenerational transmission of educational status through both the male and female sides of families over three generations. Using data from the Panel Study of Income Dynamics, we approach this issue from both a short-term and a long-term perspective. For the short term, grandparents' educational attainments have a direct association with grandchildren's education as well as an indirect association that is mediated by parents' education and demographic behaviors. For the long term, initial educational advantages of families may benefit as many as three subsequent generations, but such advantages are later offset by the lower fertility of highly educated persons. Yet all families eventually achieve the same educational distribution of descendants because of intermarriages between high- and low-education origin families.

SHORT-TERM AND LONG-TERM EDUCATIONAL MOBILITY OF FAMILIES: A TWO-SEX APPROACH

INTRODUCTION

Educational attainment is a source of upward social mobility for individuals and families. Higher education changes not only the social circumstances of the present generation but also potentially the educational prospects of children, grandchildren and subsequent generations of a family. This study investigates the educational reproduction of families—that is, how successfully families reproduce their educational advantages in subsequent generations. An examination of this question involves a joint study of demographic reproduction and intergenerational social mobility. Our broad definition of families refers to not only nuclear and extended families, but also lineages that include distant descendants who share the same ancestry.

Unlike traditional mobility studies that focus on parent to offspring mobility, we examine both "short-term" and "long-term" social mobility from a multigenerational perspective. For short-term mobility, which refers to educational mobility across *three* generations, we assess the validity of the Markovian assumption that underpins most mobility research (Mare 2011). Two-generation mobility studies implicitly assume that grandparents' influence on grandchildren occurs only through their influence on parents, who in turn influence their children. This assumption underestimates the degree of multigenerational influence, however, if (1) grandparents' statuses directly affect grandchildren's statuses, net of their intervening effect via parents' statuses, or (2) grandparents influence the grandchild generation through parents' and grandchildren's demographic outcomes, such as their marriage, fertility, and mortality. We examine these two mechanisms for American families using data from the Panel Study of Income Dynamics.

For long-term mobility, we assess differences in the educational composition of progeny from high- and low-education families in an indefinite future. We investigate how individuals who differ in educational attainment may yield different education distributions among their progeny several generations hence. Our analyses shed light on whether an increase in education of families at one generation can permanently change the educational prospects for future descendants. Our approach is to use information on assortative mating, fertility, and intergenerational social mobility based on our short-term analyses to simulate the educational distribution of families in subsequent generations, and to see whether the education distributions of descendants from high- and low-education families converge or remain distinct. In a simple Markov model for educational mobility, the educational distribution of families converges to the same distribution regardless of where a family begins. Yet such a prediction only applies to the mobility process, whereas the interplay between social mobility and reproductive success may further complicate the dynamics of the trend (Lam 1986; Maralani 2013; Mare 1997; Mare and Maralani 2006; Mare and Song 2014; Matras 1961, 1967; Preston 1974).

Building upon the two-sex demographic model of IQ inheritance in Preston and Campbell (1993) and the “birth matrix-mating rule (BMMR) model” in Pollak (1986, 1987, 1990), we develop a two-sex multigenerational demographic model of social mobility. . Compared with the one-sex model, our two-sex approach incorporates two new features: First, it takes account of educational assortative mating from the standpoint of both the male and female populations, in both the parent and the grandparent generations, in creating unequal educational resources across families. Second, it examines roles of both parents and all four grandparents, rather than one sex alone in offspring's educational mobility. Therefore, it provides a more complete account of the formation of multigenerational inequality between families through the interaction of males and females.

Our short-term analyses suggest that grandparents' educational attainments directly influence grandchildren's educational outcomes independent of parents' education. On average, all four grandparents have similar effects on their grandchildren's educational attainment. Grandparents also influence grandchildren's education by influencing parents' marriage and fertility behaviors. Our long-term analyses show different predictions using one-sex and two-sex approaches. The former suggests persistent differences in the educational composition of progeny between families, whereas the latter suggests that the differences eventually disappear. The two-sex model takes account of intermarriages between families with different education levels, which eliminate the ability of highly educated individuals to secure a long run educational advantage for their progeny.

This study also advances our understanding of multigenerational inequality of families (e.g., Chan and Boliver 2013; Mare 2011, 2014; Pfeffer 2014; Zeng and Xie 2014). We show that multigenerational influences are shaped by the combination of families' mobility and demographic behaviors and transmitted through both sexes. Such mechanisms have implications for unequal educational outcomes between families in the short term and the long term. The paper concludes with a taxonomy of approaches to the analysis of mobility, which includes one- and two-sex models, two generation and multi-generation models, and models with and without demographic processes.

SHORT-TERM AND LONG-TERM MULTIGENERATIONAL SOCIAL MOBILITY

Social mobility studies typically rely on a short-term framework, mostly focusing on intergenerational mobility from parents to offspring, (e.g., Blau and Duncan 1967; Erikson and Goldthorpe 1992; Featherman and Hauser 1978; Hout 1983; 1988) and occasionally including grandparents as well (Hodge 1966; Warren and Hauser 1997). The lack of three-generation mobility studies is justified by the Markovian assumption that associations between adjacent generations suffice to explain mobility processes over multiple generations (Mare 2011). Empirical research testing the validity of the Markovian assumption is sparse and inconclusive. For example, using data from the Wisconsin Longitudinal Studies, two studies found that grandparents play a trivial role in directly influencing their grandchildren's educational outcomes (Warren and Hauser 1997; Jæger 2012). Similar findings also appear in a study of Finland (Erola and Moisio 2007). By contrast, several recent studies have challenged the Markovian assumption, showing that grandparents with favorable social characteristics can transmit their advantages to their grandchildren, net of parents' characteristics (e.g., Chan and Boliver 2013; Hertel and Groh-Samberg 2014; Wightman and Danziger 2014; Zeng and Xie 2014).

Regardless of whether the intergenerational transmission of socioeconomic status is Markovian, however, grandparents may also influence grandchildren's socioeconomic status through influencing parents' demographic behaviors (Mare 2011; Mare and Song 2014). Just as the impact of one generation on the next in a two generation model comes about through the joint effects of intergenerational transmission and differential demographic behavior (Mare and Maralani 2006; Maralani 2013), grandparents' socioeconomic characteristics can influence parents' marriage prospects, mate choices, and fertility decisions, all of which make up the "family background" of the grandchildren and subsequently influence their life chances. Even if parents' demographic behaviors are independent of grandparents' social characteristics, parents' decisions on whether, when, and whom to marry and how many children to have children change grandparents' influences on grandchildren. Grandparents with many children and grandchildren will have a much greater capacity to affect subsequent generations, whereas persons cannot pass on their advantages or disadvantages beyond the next generation if their children are childless.

The effects of individuals' characteristics on the characteristics of their progeny include both their direct impacts on their children and grandchildren and also their potential long run impacts across a larger number of generations. Although most demographic effects die out after several generations, it remains possible that some combinations of multigenerational social mobility and demographic patterns may lead to longer run effects. If all families have the same fertility, mortality, and marriage behaviors but unequal mobility opportunities determined by the parent generation's educational attainment, the Markov assumption implies that families eventually lose their influences because descendants from all families converge to the same educational distribution. The mobility process itself removes all initial educational advantages or disadvantages of families (e.g., Bartholomew 1982). Under these conditions, multigenerational influences in the educational reproduction of families are transient, suggesting that short-term inequality between families within three generations does not result in long-term multigenerational inequality.

The interplay between mobility and demography, however, further complicates the trend of long-term educational reproduction of families. In the presence of positive association between fertility and socioeconomic status, the multigenerational influences of social mobility patterns and differential fertility are mutually reinforcing: men in high-status families are more likely to have high-status sons and to have more sons who survive to adulthood (Mare and Song

2014). As a result their descendants account for a disproportionately large share of the high-status population in later generations. In contemporary societies where the association between fertility and socioeconomic status is negative, on the other hand, offspring from high-education families are more likely to attain high education, but the overall advantages of high-education families may be offset by their lower fertility. Therefore, the educational reproduction of high-education families in terms of their total number of high-education descendants in later generations depends on the relative strength of mobility advantages and differential net fertility.

This paper extends the two-generation joint demographic and social mobility approach used in previous studies (e.g., Mare and Maralani 2006; Maralani 2013; Preston 1974) to a multigenerational scenario. Our approach on the multigenerational transmission of educational inequality in the short-term and long-term incorporates a wider array of social and demographic processes, which include educational assortative mating, differential marriage and fertility rates between high-education and low-education couples, and intergenerational transmission of educational status through both sides of families. To integrate these processes into a multigenerational model, we need to modify one-sex intergenerational mobility models to look at both sexes together.

ONE-SEX VERSUS TWO-SEX MOBILITY APPROACHES

A one-sex approach to the study of social mobility is adequate when the socioeconomic position of families and individuals is reproduced through the line of the same-sex parent, whether on the maternal or paternal side of the family, and when the availability of suitable marriage partners is not substantially constrained. In contemporary societies, however, both parents play a role in determining the economic statuses of families and may have independent effects on the life chances of their offspring (e.g., Beller 2009). In addition to the two-generation effects of mothers and fathers, grandmothers and grandfathers on both sides of the family may affect the life chances of their grandchildren (e.g., Cherlin and Furstenberg 1986). A two-sex approach can also incorporate demographic mechanisms into the mobility process that are left out of one-sex models. Several studies have shown the role of interplay between demographic behaviors and social mobility in the evolution of social inequality (Lam 1986; Matras 1961, 1967; Mare 1997; Mare and Maralani 2006; Maralani 2013; Preston 1974; Preston and Campbell 1993). Except for Preston and Campbell's (1993) study, however, these studies rely on a one-sex approach, which does not take account of how numbers of men and women, with varying socioeconomic characteristics, constrain marriage opportunities in a single generation and the distribution of family backgrounds in subsequent generations (Pollak 1990; Schoen 1981; Mare and Schwartz 2006). Overall, the two-sex approach in this paper consists of two components: a mobility component that examines influences of grandparents on grandchildren through both paternal and maternal family lines, and a demographic component that examines educational assortative mating of fathers and mothers in the marriage market in order to form families for the next generation. A comparison of the two-sex results with those from a one-sex approach illustrates the extent to which conclusions about the multigenerational mobility process is an artifact of the approach used in the analysis.

SOCIAL AND DEMOGRAPHIC MOBILITY MODELS

One-Sex Approach

We begin with the one-sex model for the influences of parents' education on the educational outcome of offspring. Following Mare and Maralani (2006), we specify the one-sex model as

$$\boldsymbol{S}_{j|i} = \boldsymbol{F}_i \cdot \boldsymbol{m}_i \cdot \boldsymbol{r}_i \cdot \boldsymbol{p}_{j|i} \tag{1}$$

where $\boldsymbol{S}_{j|i}$ denotes the number of men (woman) in the offspring's generation who are in education group *j* and have fathers (mothers) in education group *i*. $\boldsymbol{F}_i$ denotes the number of men (women) in the paternal (maternal) generation who are in education group *i*. $\boldsymbol{m}_i$ denotes the probability that a man (woman) in education group *i* gets married. $\boldsymbol{r}_i$ denotes the expected number of sons (daughters) who are born to a man (woman) in education group *i* and survive to adulthood. $\boldsymbol{p}_{j|i}$ denotes the probability that a son (daughter) born to a man (woman) in education group *i* enters education group *j*.

A three-generation version of the model further incorporate grandparents' education; therefore, the marriage component $\boldsymbol{m}$, the fertility component $\boldsymbol{f}$ and the mobility component $\boldsymbol{p}$ depend on both fathers' (mothers') and grandfathers' (grandmothers') educational attainments.

$$\boldsymbol{S}_{j|ik} = \boldsymbol{F}_{ik} \cdot \boldsymbol{m}_{ik} \cdot \boldsymbol{r}_{ik} \cdot \boldsymbol{p}_{j|ik} \tag{2}$$

where $\boldsymbol{S}_{j|ik}$ denotes the number of men (woman) in the offspring's generation (G3) who are in education group *j* and have grandfathers (grandmothers) in education group *i* and fathers (mothers) in education group *k*. $\boldsymbol{F}_{ik}$ denotes the number of men (women) in the paternal (maternal) generation (G2) who are in education group *k* and have fathers (G1) in education group *i*. $\boldsymbol{m}_{ik}$ denotes the probability that a man (woman) in education group *k* with a father (mother) in education group *i* gets married. $\boldsymbol{r}_{ik}$ denotes the expected number of sons (daughters) who are born to a father (mother) in education group *k* and a grandfather (grandmother) in education group *i* and survive to adulthood. $\boldsymbol{p}_{j|ik}$ denotes the probability that a son (daughter) born to a father (mother) in education group *k* and a grandfather (grandmother) in education group *i* will enter education group *j*. This model accounts for differentials in marriage behavior by men's (or women's) level of education, but only under very restrictive assumptions such as that the availability of partners of the opposite sex is completely unconstrained or that the matching of men's and women's educational attainments follows complete male dominance or complete female dominance. The one-sex model does not adequately take account of the interdependence of the male and female populations.

Based on the social mobility and demographic model in equation (1), we define the social reproduction effect (*SRE*) as the relative advantages of a college father (or mother) as compared to a high-school father (or mother) to produce college sons (or daughters), that is,

$$Net\ SRE = \frac{S_{k|k}}{F_k} - \frac{S_{k|j}}{F_j} = m_k r_k p_{k|k} - m_j r_j p_{k|j} \tag{3}$$

where education groups *k* and *j* refer to college education and high-school education respectively.

For the social reproduction effect of grandfathers (or grandmothers), we define a net effect as the relative advantages of a high-school father with a college grandfather (or grandmother) as compared to a high-school father with a high-school grandfather (or grandmothers) to produce college sons (or daughters), that is,

$$Net\ SRE = m_{kj} r_{kj} p_{k|kj} - m_{jj} r_{jj} p_{k|jj} \tag{4}$$

where $p_{k|kj}$ (or $p_{k|ji}$) is the conditional probability that a man (or a woman) attains college education if he (or she) has a high-school father (or mother) and a college grandfather (or grandmother).

In addition, we define the total social reproduction effect as the relative advantages of a college grandfather (or grandmother) as compared to a high-school grandfather (or grandmother) to produce college grandsons (or granddaughters), that is,

$$Total\ SRE = \sum_i m_k^{G1} r_k^{G1} p_{i|k}^{G2}\, m_{ki}^{G2} r_{ki}^{G2} p_{k|ki}^{G3} - \sum_i m_j^{G1} r_j^{G1} p_{i|j}^{G2}\, m_{ji}^{G2} r_{ji}^{G2} p_{k|ji}^{G3} \tag{5}$$

Two-Sex Approach

The two-sex model incorporates marriages between pairs of adult males and females specified by their levels of educational attainment; the mean number of surviving children born for each paternal-maternal educational combination; and educational mobility of offspring born into families defined by the education levels of both mothers and fathers.[1] It builds upon two-sex population renewal models (Caswell 2001; Goodman 1953; Keyfitz 1968; Pollak 1986, 1987, 1990). In parallel to the one-sex model, we specify the two-sex model for males and females as

$$\boldsymbol{D}_{k|ij} = \boldsymbol{\mu}^{ij}(\boldsymbol{F},\boldsymbol{M}) \cdot \boldsymbol{r}_{ij}^{d} \cdot \boldsymbol{p}_{k|ij}^{d} \tag{6}$$

$$\boldsymbol{S}_{k|ij} = \boldsymbol{\mu}^{ij}(\boldsymbol{F},\boldsymbol{M}) \cdot \boldsymbol{r}_{ij}^{s} \cdot \boldsymbol{p}_{k|ij}^{s} \tag{7}$$

where $\boldsymbol{D}_{k|ij}$($\boldsymbol{S}_{k|ij}$) denotes the number of females (males) in the offspring's generation who are in education group *k* and have mothers in education group *i* and fathers in education group *j*. $\boldsymbol{\mu}^{ij}(\boldsymbol{F},\boldsymbol{M})$ denotes the number of marriage between females in education group *i* and males in education group *j*. $\boldsymbol{r}_{ij}^{d}$ ($\boldsymbol{r}_{ij}^{s}$) denotes the mean number of surviving daughters (or sons) born for each union of women of education *i* and men of education *j* with completed reproduction history. In general, the difference between $\boldsymbol{r}_{ij}^{d}$ and $\boldsymbol{r}_{ij}^{s}$ are determined by male to female sex ratio at birth in a population and differential survival rates of sons and daughters to adulthood. $\boldsymbol{p}_{k|ij}^{d}$ and $\boldsymbol{p}_{k|ij}^{s}$ refer to the probability of obtaining education group *k* for daughters and sons born to females of education *i* and males of education *j*, respectively.

We adopt Schoen's harmonic mean mating rule (Schoen 1981; 1988), which assumes that the number of marriages between two social groups depends on the relative numbers of single

[1] Note that our model assumes independence of education and age. A refinement of the two-sex model could include age structure of the population, duration of marriages, polygamous mating rules and differential demographic outcomes by age groups (Keyfitz 1972). A model with age structure may reflect effects of timing of marriage and fertility, levels of fertility by age groups, as well as marriage squeeze caused by period fertility fluctuations and sex-ratio imbalance for old age groups on the evolution of population structure.

women and men in these groups in the population and the attractiveness of members in these groups to each other. The harmonic mean mating rule specifies that

$$\boldsymbol{\mu}^{ij}(\boldsymbol{F},\boldsymbol{M}) = \frac{\boldsymbol{\alpha}_{ij}\boldsymbol{F}_i\boldsymbol{M}_j}{\boldsymbol{F}_i+\boldsymbol{M}_j}, \quad \boldsymbol{\alpha}_{ij} > 0, \sum_j \boldsymbol{\alpha}_{ij} \leq 1\ \forall i, \sum_i \boldsymbol{\alpha}_{ij} \leq 1\ \forall j \tag{8}$$

where $\boldsymbol{\alpha}_{ij}$ is the "force of attraction" between women in education group *i* and men in education group *j*, which results from population constraints as well as preferences among all groups (Schoen 1988). $\boldsymbol{F}_i$ is the total number of eligible women in education group *i* and $\boldsymbol{M}_j$ is eligible men in education group *j*. In practice, $\boldsymbol{\alpha}_{ij}$ is estimated from observed numbers of unions between men and women and single persons with those attributes (Qian and Preston 1993). The advantage of this function is that it incorporates constraints from the marriage market though the parameters of $\boldsymbol{F}_i$, $\boldsymbol{M}_j$ and individual preferences through $\boldsymbol{\alpha}_{ij}$. However, one limitation of this function is that it assumes no competition effect among different education groups ("zero spillover mating rule") (Pollak 1990).

Based on the two-sex model, we can estimate net social reproduction effects of parents analogous to those defined for the one-sex models. The net reproduction effect of parents examines the relative advantages of college parents as compared to high-school parents (both parents have only high-school degrees) to produce college offspring, that is,

$$Net\ SRE_{k|j} = \frac{\mu^{kk}(F,M)\left(r_{kk}^{s}p_{k|kk}^{s} + r_{kk}^{d}p_{k|kk}^{d}\right)}{M_k + F_k} - \frac{\mu^{jj}(F,M)\left(r_{jj}^{s}p_{k|jj}^{s} + r_{jj}^{d}p_{k|jj}^{d}\right)}{M_j + F_j} \tag{9}$$

Similarly, we can derive the net social reproduction effect of grandparents by incorporating grandparents' educational characteristics into μ, r, and p^s (p^d). The net effect examines the relative advantages of a high-school father and a high-school mother with all four college grandparents as compared to a high-school father and a high-school mother with all four high-school grandparents to produce college offspring.

In addition, we define the total social reproduction effect of grandparents as the relative advantages of college grandparents as compared to high-school grandparents to produce college grandchildren. The total social reproduction effect of grandparents sums over the net social reproduction effect of grandparents over all grandchildren, that is,

$$Total\ SRE_{k|j} = \frac{\sum_a \sum_b \mu^{kka,kkb}(F', M')\left(r^s_{kka,kkb}p^s_{k|kka,kkb} + r^d_{kka,kkb}p^d_{k|kka,kkb}\right)}{\sum_a F'_{kka} + \sum_b M'_{kkb}} - \frac{\sum_a \sum_b \mu^{jja,jjb}(F'', M'')\left(r^s_{jja,jjb}p^s_{k|jja,jjb} + r^d_{jja,jjb}p^d_{k|jja,jjb}\right)}{\sum_a F''_{jja} + \sum_b M''_{jjb}} \quad (10)$$

where $F' = \mu^{kk}(F, M)r^d_{kk}p^d_{a|kk}$, $M' = \mu^{kk}(F, M)r^s_{kk}p^s_{a|kk}$, $F'' = \mu^{jj}(F, M)r^d_{jj}p^d_{a|jj}$, and $M'' = \mu^{jj}(F, M)r^s_{jj}p^s_{a|jj}$.

Important special cases of this general unrestricted model include random mating, in which the expected number of marriages results only from the numbers of men and women at risk to various combines of educational attainments, and endogamous mating, in which men and women are constrained to marry only within their own education groups. In random mating the force of attraction is invariant among combinations of women's and men's education groups ($\boldsymbol{\alpha}_{ij}$ = c for all i, j). In endogamous mating, there is no mating between men and women who differ in their educational attainment ($\boldsymbol{\alpha}_{ij}$ = 0 if $i \neq j$). When multigenerational influences exist, we assume the mating, fertility, and mobility rules are determined by both parents and all four grandparents' educational characteristics. Given the short-term rules, it is possible to predict the education distribution in future generations from its distribution in an initial generation.

DATA AND MEASURES

Because of its prospective design and long duration, the Panel Study of Income Dynamics (PSID) is one of the few nationally representative surveys well-suited for the two-sex multigenerational analysis formulated above. Begun in 1968, the PSID was conducted annually until 1997 and biennially thereafter. The study follows targeted respondents according to a genealogical design. All household members recruited into the PSID in 1968 are considered to carry the PSID "gene" and are targeted for collection of detailed socioeconomic information. Members of new households created by the offspring of original targeted household members retain the PSID "gene" themselves and become permanent PSID respondents.

To create our multigenerational sample, we first obtain a FIMS (Family Identification Mapping System)[2] sample that links PSID respondents (G3) with their parents (G2), who are also PSID respondents. Based on the retrospective information from the family interview for household heads and head's wives (G2), we obtain parental information for the grandparent generation (G1), who may not be PSID respondents. Therefore, we have information from all of the four biological grandparents of PSID respondents in G3.[3]

We create two analytical samples: a mobility sample and a marriage/fertility sample. The mobility sample includes education information of PSID sample members and their biological fathers, mothers, and all four grandparents. Individuals who grew up in single-parent families and thus have incomplete education information for one or several parents and grandparents are excluded from the analyses. We recode the educational variable into four categories according to the years of schooling (0-11, 12, 13-15, 16+).

The marriage/fertility sample is generated from the PSID 1985-2011 Marriage History File, which contains details about retrospective marriage history of eligible people living in a PSID family at the time of the interview in any wave between 1985 and 2011 (PSID User

[2] "Family Identification Mapping System" is a tool developed by the PSID to create intergenerational linked samples (http://simba.isr.umich.edu/FIMS/)
[3] This linking method yields a bigger sample size than from a prospective method that links PSID respondents from the first generation to the second and third generations because only a subset of the parents and grandparents of the third generation are themselves PSID respondents.

Manual 2013). We merge the Marriage History File with the 1968-2011 Individual File to find the education information of individuals and their spouses. Some spouses, however, do not have follow-up records on the Individual File if they leave the PSID households, because they do not carry the PSID “gene.” We then rely on household head and wife information from the 1975-2011 Family File to find out the missing information of spouses. To give each individual in the marriage/fertility sample the same weight, we restrict our analyses to the first marriage of all individuals.[4] We measure individuals’ fertility by the number of live births, as recorded in the Individual File, which counts all marital and nonmarital children of an individual through 2011.[5] Since many individuals may have not finished their reproduction by the year of 2011, we control for age groups (25-35, 36-45, 46-55, and 56-65) in our estimation of fertility to account for differential time of exposure to fertility. The total number of children of an individual may come from several spouses, rather than the spouse that we analyze in the marriage file.

We restrict our analytical samples to PSID respondents aged 25 to 65, assuming that all respondents have finished their education by age 25 and childbearing by age 65. Appendix Table A summarizes the education distribution for the offspring, parent and grandparent generations.[6] Our final mobility sample consists of 3,122 sons and 3,145 daughters, and 6,267 parents and

[4] To check the robustness of our analyses on assortative mating, we also examined a sample restricted sample to the most recent marriage of individuals and the results are similar to those presented in this paper.

[5] Because of nonmarital childbearing, the total number of individuals’ offspring may not be equal to the product of the proportion of individuals who were ever married and this fertility measure for married individuals.

[6] Appendix Table A summarizes the education distribution of grandparents, parents and children for the marriage/fertility and mobility samples. These distributions confirm three trends in higher education in recent decades: sizable education differences by gender, increase in educational attainment over generations, and reversed gender gap in college education (Buchmann and DiPrete 2006). About 60 percent of the grandparents in the mobility sample receive education below high school, and less than 8 percent have education beyond college. In contrast, less than one third of fathers and mothers in the mobility sample receive education below high school, whereas more than twice as many parents as grandparents have college education. The children from these families reach much higher levels of educational attainment: very few (< 2 percent) fail to receive more than 9 years of education, whereas more than 20 percent receive college degree. The gender gap in college education diminishes from the grandparent generation to the parent generation, and shows a reversed trend favoring women from the parent generation to the offspring generation.

grandparents with non-missing values. Our marriage sample, which includes respondents who have non-missing educational information on both parents, consists of 9,683 and 9,867 eligible males and females respectively. Among these eligible males and females, 7,586 men and 8,100 women are married or were ever married before the last wave in 2011. We restrict the fertility sample to respondents who have complete educational information of spouse, both parents, and spouse's parents, which yields a sample of 13,090 married couples.[7]

SHORT-TERM MULTIGENERATIONAL INFLUENCES

We begin with analyses based on the one-sex approach, which considers mating, fertility, and mobility patterns for sons, fathers, and grandfathers (Table 1), and daughters, mothers, and grandmothers (Table 2), respectively. For all models, we assume discrete, additive multigenerational effects, meaning that we do not include associations between an individual's educational attainment and interactions between the attainments of their parents and grandparents. For the sake of simplicity, the models presented in the tables only include education variables for grandparents, parents, and offspring generations, but we also experimented with models that include control variables such as race, the number of siblings, and the age group of the offspring generation, as well as interactions of these variables. The control variables do not change the results presented below, and we find little evidence for the effects of these interactions.

The marriage and fertility results in Table 1 and Table 2 suggest that a person's likelihood of getting married and the number of children depends on both his or her own and the

[7] We do not control for race in our analyses because we are unable to examine racial and educational assortative mating jointly given our sample size. We show the racial distribution of our samples in Appendix Table A, which suggests an overrepresentation of African Americans and an underrepresentation of other races due to the sampling design of PSID.

same-sex parent's educational attainment. On average, individuals with higher education or highly educated parents are more likely to get married than their low-education counterparts, but they tend to have a lower level of fertility. The mobility results are consistent with Hertel and Groh-Samberg's (2014) findings that grandfathers' social class is directly associated with their grandsons' socioeconomic attainment.[8] Overall, our marriage, fertility, and mobility models are inconsistent with a simple Markovian assumption, suggesting that grandfathers' and grandmothers' education influences their grandchildren's education not only indirectly through fathers' and mothers' marriage prospects and fertility, but also through a net direct effect.

[Table 1]

[Table 2]

We present parameter estimates for the two-sex mating and fertility models in Table 3 and 4. As discussed earlier, one solution to consider the differential marital rates and mating preferences for males and females simultaneously is to resort to the harmonic mean mating function. The parameter for the "force of attraction" (α_{ij}) represents the likelihood between two education groups of men and women to form unions. The value is a function of the preferences between two education groups and constraints imposed by sizes of the two groups. We present the estimates of α_{ij} for a two-generation model that only takes account of husband's and wife's own characteristics in Table 3. The results suggest that the strongest "attraction" is between males and females with 16 or more years of schooling ($\alpha = 0.091$) and between those with 12 years of schooling ($\alpha = 0.089$). Among all the educational pairs, the attraction force is the smallest for individuals with 16 or more years of schooling to marry those with less than 12 years of schooling ($\alpha = 0.003$). We present three-generation results in Appendix Table B, which

[8] Whereas Hertel and Groh-Samberg also use the PSID, they rely on male patrilineal lineages including grandfathers, fathers, and sons only. We provide a more complete two-sex model below that includes all four grandparents, both parents, and sons and daughters.

reveal further heterogeneity in assortative mating within the same education groups of husbands and wives by their fathers' and mothers' education. In particular, we find that educational matching is most likely to occur between males and females who themselves, as well as their parents, are in the same or adjacent education groups.

[Table 3]

[Table 4]

Table 4 shows estimates of binary logistic models for marriage for men and women. The results are largely consistent with one-sex results in Table 1 and 2, suggesting that the likelihood of getting married for men only depends on their own educational characteristics, whereas for women it is determined by both their own and their parents' educational attainments. The two-sex fertility model in Table 4 includes both a couple's and all four of their parents' educational characteristics as determinants of the couple's fertility. Fertility follows a negative educational gradient. The expected number of children is approximately 3.0 (=$e^{(0.304+0.797)}$) for couples both of who have education below high school and belong to the oldest age group, and declines to 1.8 (=$e^{0.609}$) for husbands and wives in the highest education group and the same age group. The education of wives plays a slightly stronger role than that of the husbands in determining the total number of children that a couple has. The three-generation results show some moderate effects from the couple's parents on the couple's total number of children after the couple's education is controlled.

[Table 5]

Finally, we show the two-sex mobility results from ordinal logistic regressions in Table 5. Unlike the one-sex mobility models presented in Table 1 and 2, the two-sex models include both parents' and all four grandparents' educational characteristics. We test differences between the two-generation and three-generation models in Appendix Table C, which shows that grandparents have a jointly strong effect on the educational attainments of their grandsons and granddaughters after parents' education is taken into account. The three-generation models with no constraints in Table 5 show individual effects for each of the four grandparents. We test whether these effects are different from each other by fitting a variety of nested models. Our preferred models, namely model 5, show equal effects for all four grandparents for both grandsons and granddaughters. We present coefficients from the preferred (constrained) model in Table 5, which suggest that overall grandsons and granddaughters with highly educated grandparents are also more likely to achieve higher education themselves even if parental education levels are held constant. Although grandfathers and grandmothers on the paternal and maternal sides of the family may play different roles in the upbringing of their grandchildren (e.g., Cherlin and Furstenberg 1986), we find no systematic support for any of these differentials in the intergenerational associations of grandparents, parents, and grandchildren's educational attainments. This finding parallels Beller's (2009) result that fathers and mothers have approximately equal occupational associations with their offspring even though they may play different roles in a child's development.

Based on coefficients of parents' and grandparents' education in marriage, fertility, and intergenerational mobility models, we estimate net and total social reproduction effects of parents and grandparents in Table 6 by comparing the college group and the high-school group. The mobility probability differences in the last column show that individuals are more likely to obtain a college degree if both of their parents are college graduates (diff = 0.52) relative to having either a college educated father (0.37) or a college educated mother (0.44). In addition, having all four grandparents as college graduates does not give individuals much advantage of graduating from college (0.062) relative to having only the paternal grandfathers as college graduates (0.061), but it does provide a benefit relative to having only college-educated maternal grandmothers (0.031).

The net and the total social reproduction effects of parents are smaller than the mobility probability differences because education is negatively associated with the probability of marriage and the level of fertility, especially when both fathers' and mothers' educational levels are taken into account. The one-sex model suggests that a college father produces 0.3 more sons in college than a high-school father, whereas the two-sex model further suggests that a couple both with college degrees produces 0.2 more college offspring than a couple both with only high-school degrees.

The social reproduction effects of grandparents are much smaller than those of parents. The one-sex models for males suggest that a college grandfather and a high-school father produce 0.06 more college sons than a high-school grandfather and a high-school father. A college grandfather produces 0.13 more college grandsons than a high-school grandfather in total. The effects become negative in two-sex models, suggesting that a high-school couple with all their four parents as college graduates produces 0.026 fewer college offspring than a high-school couple with all their four parents as high-school graduates. The main reason is that the probability of union formation between a high-school man with college parents and a high-school woman with college parents is smaller than that probability between a high-school man with high-school parents and a high-school woman with high-school parents given the two-generation assortative mating patterns shown in Appendix Table B. For the same reason, two college couples produce 0.13 fewer college grandchildren than two high-school couples.

[Table 6]

Taken together, compared to the one-sex models, the two-sex models reveal additional mechanisms that create multigenerational educational inequality across families. Specifically, characteristics of fathers and mothers as well as all four grandparents jointly determine the parents' union formation, fertility, and their offspring's educational mobility. Education of all four grandparents plays an almost equally important role in the educational mobility of their grandsons and granddaughters. To a large extent, multigenerational educational influences from grandparents to grandchildren are "gender-blind"—no systematic differences exist between grandfathers and grandmothers as well as between paternal and maternal grandparents.

LONG-TERM MULTIGENERATIONAL INFLUENCES

The short-term mechanisms in the transmission of educational advantages in three generations may affect the long-term educational reproduction of families. We examine the eventual advantages of high-education families in producing high-education progeny compared to those of low-education families. If a family has at least one parent holding a college degree, compared to another family in which neither of the parents holds a college degree, what are the differences in the number of progeny in subsequent generations who themselves have college degrees? Our long-term multigenerational analysis relies on the marriage, fertility, and mobility rules described above in the method section and the parameters estimated from the short-term analyses presented in Tables 1 to 5. We simulate the educational distribution of families by generations, and explore the evolution of educational reproduction of college- and non-college origin families before the simulation system achieves its equilibrium.

[Figure 1]

Figure 1 presents simulation results based on one-sex and two-sex approaches for both two-generation and three-generation models of short-term effects. We allow for patterns of differential marriage and net fertility in the one-sex simulation, and further incorporate assortative mating in the two-sex simulation. The gray dashed and dotted lines represent the one-sex, two-generation multigenerational effects for males and females respectively. The solid lines represent results from two-sex models. All the black lines represent results that further incorporate grandparent effects in the mating, fertility, and mobility rules. Our interest is the relative educational reproductive success of college over non-college origin families, which is defined as the ratio of college progeny per college family to college progeny per non-college family. A value above 1 means that college-origin families produce more college descendants than non-college families. As discussed earlier, due to the negative relationship between education and fertility, educational advantages for the progeny of college families may be offset by the lower fertility of these families.

Figure 1 reveals several important patterns. First, within the first three generations, families that start with college education produce more college descendants than families that start with non-college education, as the values of the ratio for all the lines are above 1. This implies that for first-generation college families, the achievement of going to college does not only change the educational outcomes of the present generation, but may benefit as many as three generations ahead. Second, the ratio from one-sex models falls below 1.0 and converges to a value between 0.6 and 1.0 over the next 5 to 10 generations, depending on the model, meaning that fertility disadvantages of college-origin families offset their initial educational mobility advantages, and eventually college-origin families produce fewer college-educated descendants than non-college families. Thus the effect of being in the higher education group is *negative* over the longer term because the lower fertility of this group more than offsets the mobility advantages that they can provide their offspring in the short term. Third, comparing the gray lines with the black lines, we find that the long run educational reproduction of families depends upon whether the mating, fertility, and mobility processes are Markovian (only parents' effect) or non-Markovian (parents' and grandparents' effects). Under a three-generation model, the ratio converges to the equilibrium more slowly and reaches a lower value than under a two-generation model. For example, for the one-sex female models, the ratio declines from 0.8 in a two-generation model to 0.7 in a three-generation model. This result suggests that when both parents and grandparents are involved in the educational reproduction of families, educational inequality between college and non-college families is greater than when only parents are involved. Moreover, this inequality is even greater when all four grandparents' effects (the black solid line) rather than only one grandparent effect are considered (the black dashed and dotted lines). Finally, the two-sex results gradually converge to an equilibrium ratio equal of 1, which indicates *no* long run relative educational reproduction advantages among families after roughly 17 generations. The multigenerational influences caused by a family's initial educational status and fertility only persist for a limited number of generations. In contrast, the one-sex approach suggests that the ratio will be stable over time at a level that reflects net fertility differences among education groups.

The above equilibrium results point to very different conclusions about long run effects of socioeconomic differences among families depending on whether one adopts a one-sex or two-sex model. To investigate the differences between the two approaches, we simulate a combination of one-sex and two-sex mating and mobility models (shown in Table 7). For the one-sex mating model, we assume the absence of a marriage market, and thus the number of marriages is determined by the number and preferences of either males or females. For the two-sex mating models, we assume three mating rules as described above: unrestricted, endogamous and random mating. For mobility models, we distinguish between models assuming immobility, in which individuals always inherit their same-sex parent's educational status, and models assuming mobility, in which individuals' education may be different from their parents' education. We further divide the latter into one-sex and two-sex mobility models. The one-sex mobility model assumes that parents only influence offspring of the same sex, whereas the two-sex model assumes that parents influence offspring of both sexes. The one-sex and two-sex models shown in Figure 1 refer to scenarios 10 and 2 respectively, which assume that mating and mobility both follow two-sex or one-sex rules.

[Table 7]

[Figure 2]

Figure 2 shows that, except for scenarios 6 and 12, all models that take into account a two-sex mating rule indicate a disappearing long run educational disparity between families, whereas all one-sex models without a mating rule indicate a permanent disparity. In all two-sex scenarios except scenario 6, high- and low-education origin families are connected because the mating rule allows marriages formed between progeny from families of different educational origins. Note that in scenario 4 and 5, when only endogamy is allowed, intermarriages between high-education and low-education families can still happen through mobility—for example, progeny born into low-education families achieve upward mobility and marry those from high-education families. In scenario 6 marriages between high- and low-education origin families never occur, as their progeny always marry within their own education groups and intergenerational immobility precludes any intermarriage that occurs as a result of mobility. Therefore, in the presence of intermarriage, whether explicitly permitted by the marriage rule (scenarios 1, 2, 3, 7, 8, 9) or in subsequent generations as a result of intergenerational mobility (scenarios 4, 5), more and more progeny in later generations carry both high-education and low-education origin ancestry in their background. Over generations an increasing proportion of high-education families have low-education descendants who are also descendants of low-education families, and *vice versa*. Such a trend is consistent with Bernheim and Bagwell's (1988) argument that intermarriages make the existence of independent, persistent family dynasties demographically impossible. As a result, the educational distributions of progeny of high- and low-education families become increasingly alike over generations, implying that the educational disparities among families eventually disappear.

The two-sex approach, however, is not always superior to the one-sex approach. The one-sex approach is still useful when the transmission of education and other social characteristics are sex-linked. For example, social positions in a patriarchal society during China's historical dynasties (Lee and Campbell 1997; Lee and Wang 1999; Mare and Song 2014) and the priest status in the ancient Jewish population (Goldstein 2008) were inherited only through male lines. This is analogous to the inheritance of the human Y chromosome, which can only be passed down from paternal grandfathers to fathers then to sons. Although marriages connect genealogies of families and thus make progeny social descendants of both their paternal and maternal families, their sex-linked characteristics are still uniquely linked to their paternal families. When comparing descendants who carry the sex-linked characteristics from families with and without such characteristics, we only need to count male descendants in the male line, not all social descendants in both lines. Therefore, the one-sex model is enough to explain the evolution of inequality in the distribution of the sex-linked characteristics between the two groups of families.

Overall, the two-sex approach is not simply an extension of the one-sex approach. The two models imply different social rules with regard to the inheritance of social status and the definition of “family networks” formed by marriage. The choice of the approach involves not only a methodological concern, but also an accurate representation of the underlying social processes.

CONCLUSION

Our analyses of social and demographic mechanisms and their consequences for families' educational reproduction in the United States yield two main findings. First, in our analysis of short-term multigenerational effects, a two-sex approach provides a more adequate summary of the influences of grandparents' educational attainments on their grandchildren's education. The two-sex approach reveals influences of mothers, grandmothers, and maternal grandparents on grandchildren's educational outcomes, which are ignored in models that exclusively analyze father-son or mother-daughter pairs. These results challenge the Markovian assumption in mobility studies by showing that grandparents' educational attainments have a direct net association with grandchildren's educational attainments, regardless of parents' education. All four grandparents' educational attainments are associated with the attainments of their grandsons and granddaughters to an approximately equal degree. More importantly, the two-sex approach incorporates demographic behaviors of parents, and suggests that grandparents also influence grandchildren's education by influencing whether and whom the parents marry and how many children they have.

Our analysis of long-term effects shows the circumstances under which inequalities in a given generation may have a much more sustained impact than usually recognized in mobility research. Relying on multigenerational simulations, we find that the one-sex and the two-sex approaches show similar trends within the first several generations,[9] suggesting that initial educational advantages of families may benefit as many as three generations ahead, but such advantages are later offset by a negative fertility gradient with educational attainment. Thus, differential fertility and social mobility jointly shape future educational distributions of progeny. In the long run, the one-sex approach suggests that such a trend will become stable, whereas the two-sex approach suggests that all families eventually achieve the same educational distribution of descendants. By simulating various mating, fertility, and mobility regimes, we show that the diverging results are explained by intermarriages between high- and low-education origin families, which are addressed in the two-sex approach, but not the one-sex approach.

This study enriches our understanding of multigenerational inequality in several regards. Along with several other studies (Matras 1961, 1967; Lam 1986; Mare 1997; Mare and Maralani 2006; Maralani 2013; Preston 1974), we illustrate that demography plays an important role in creating and changing intergenerational inequality. By incorporating demographic pathways into social mobility processes, we show that the transmission of intergenerational inequality involves not only the inequality among those who have offspring, but also the inequality between those who have offspring and those who do not. When one considers inequality over generations, to grandchildren, great grandchildren, and other progeny, the role of demography becomes cumulative. The combined analysis of demography and mobility describes the socioeconomic reproduction of families and the social metabolism of a society.

[Figure 3]

Our analyses also link short-term mobility and demographic behaviors with the long-term educational reproductive success of families. Whereas the short-term results suggest

[9] The number of generations that the two-sex model converges to its equilibrium depends on population size. When the population size is large, it takes longer for all families to be connected to each other through marriages.

considerable inequality in mobility opportunities in each generation, the long-term results show an equalizing trend in educational outcomes across families. The opposing implications of the two results suggest that future research needs to explicitly model and analyze long-term stratification processes, rather than assume that short-term inequality necessarily leads to long-term inequality. The demographic behaviors we consider in this study include assortative mating and differential marriage and fertility, but future research may consider more complex demographic strategies of families, including the duration of marriage, ages of parents at childbearing, generation gaps between grandparents, parents, and grandchildren, childhood family structure of each generation, and the time periods of observations (Mare 2014).

The analyses shown in this paper apply to a single country in a single historical epoch. They focus on only a single dimension of socioeconomic achievement, educational attainment, measured dichotomously. They use multivariate models that include a modest list of individual and family level variables, short of the state of the art in studies that focus purely on two-generation relationships with no attention to demographic processes or in studies that focus on a single demographic outcome rather than its interdependence with social mobility. They do not address the difficult problems of causal inference, which efforts to isolate true multigenerational effects (rather than descriptive associations that may be spurious in a rigorous causal analysis). And it is beyond the scope of this paper to specify the circumstances in which analysts should focus exclusively on what we have termed “short-term” effects, when they should go several generations beyond the observation span of their data, when they should examine the implied equilibrium distributions from a short-term model, and when they should consider specific historical effects that may disrupt the intergenerational trajectories implied by ahistorical models alone.

Despite these limitations, our analyses have illustrated a wide variety of possible processes through which educational inequalities among persons in one generation may persist or change in subsequent generations. The full set of possible types of social mobility analyses is shown in Figure 3. The intergenerational transmission of socioeconomic advantage may be exclusively through a direct connection between parents and offspring or, additionally, other more remote kin such as grandparents may also exert their effects across more than one generation. Intergenerational mobility may be essentially a one-sex process through which family advantages are embodied in the standing of just one parent or, alternatively, both parents may have independent effects on their children (and possibly grandchildren as well). Intergenerational social mobility may be considered in isolation from demographic processes, especially fertility and mortality, or we may examine how individuals affect subsequent generations through intergenerational transmission of status combined with differential net fertility. And finally, in considering demographic mechanisms we may regard the male and female populations as reproducing independently via their respective one-sex marriage markets or we may regard them as interacting populations that constrain each other and, through assortative marriage, modify the distributions of family socioeconomic positions in successive generations. The exemplary studies cited in taxonomy in Figure 3 show that much of our research effort has been devoted to relatively simple models and that our empirical investigations of multigenerational and demographic processes that govern social mobility have a long way to go.

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Table 1 One-Sex Multigenerational Marriage, Fertility, and Mobility Models for *Men*

	Marriage		Marital Fertility		Mobility	
	Ever Married (Logit)		Children Ever Born (Negative binomial)		Son's Education (Ordered logit)	
Variable	2 Generation	3 Generation	2 Generation	3 Generation	2 Generation	3 Generation
Men's education (ref: 0-11)						
12	0.414***	0.385***	-0.169***	-0.156***	-	-
	(0.074)	(0.076)	(0.024)	(0.025)		
13-15	0.595***	0.564***	-0.268***	-0.243***	-	-
	(0.083)	(0.087)	(0.027)	(0.029)		
16+	0.837***	0.811***	-0.358***	-0.321***	-	-
	(0.090)	(0.100)	(0.029)	(0.031)		
Father's education (ref: 0-11)						
12	-	0.118	-	-0.037	0.922***	0.874***
		(0.067)		(0.021)	(0.089)	(0.090)
13-15	-	0.073	-	-0.053	1.667***	1.564***
		(0.092)		(0.032)	(0.109)	(0.112)
16+	-	0.050	-	-0.077*	2.681***	2.525***
		(0.093)		(0.031)	(0.108)	(0.113)
Paternal grandfather (ref: 0-11)						
12	-	-	-	-	-	0.163
						(0.088)
13-15	-	-	-	-	-	0.384**
						(0.144)
16+	-	-	-	-	-	0.544***
						(0.141)
Age group (ref: 25-35)						
36-45	1.054***	1.060***	0.137***	0.133***	-	-
	(0.071)	(0.072)	(0.035)	(0.035)		
46-55	1.453***	1.474***	0.200***	0.188***	-	-
	(0.067)	(0.070)	(0.032)	(0.032)		
56-65	2.452***	2.483***	0.378***	0.359***	-	-
	(0.089)	(0.093)	(0.031)	(0.032)		
Intercept	-0.365***	-0.415***	0.658***	0.681***	-	
	(0.079)	(0.085)	(0.035)	(0.036)		
Cut Point 1	-	-	-	-	-1.059***	-1.038***
					(0.073)	(0.073)
Cut Point 2	-	-	-	-	1.222***	1.248***
					(0.074)	(0.075)
Cut Point 3	-	-	-	-	2.576***	2.609***
					(0.084)	(0.085)
N	9,683	9,683	6,869	6,869	3,122	3,122
Log-likelihood	-4540.0	-4538.4	-11480.6	-11476.9	-3741.3	-3731.1

Data source: The Panel Study of Income Dynamics 1968-2011.
Notes: ***p< 0.001; **p< 0.01; *p< 0.05. Preferred models are highlighted.

Table 2 One-Sex Multigenerational Marriage, Fertility, and Mobility Models for *Women*

	Marriage		Marital Fertility		Mobility	
	Ever Married (Logit)		Children Ever Born (Negative binomial)		daughter's Education (Ordered logit)	
Variable	2 Generation	3 Generation	2 Generation	3 Generation	2 Generation	3 Generation
Women's education (ref: 0-11)						
12	0.515***	0.423***	-0.240***	-0.224***	-	-
	(0.081)	(0.083)	(0.024)	(0.025)		
13-15	0.708***	0.579***	-0.330***	-0.309***	-	-
	(0.089)	(0.094)	(0.027)	(0.029)		
16+	0.792***	0.650***	-0.490***	-0.461***	-	-
	(0.094)	(0.103)	(0.029)	(0.032)		
Mother's education (ref: 0-11)						
12	-	0.351***	-	-0.050*	1.265***	1.111***
		(0.072)		(0.020)	(0.091)	(0.094)
13-15	-	0.308***	-	-0.011	2.021***	1.787***
		(0.091)		(0.028)	(0.107)	(0.112)
16+	-	0.258**	-	-0.069*	3.225***	2.901***
		(0.105)		(0.034)	(0.127)	(0.134)
Maternal grandmother						
(ref: 0-11)	-	-	-	-	-	-
12	-	-	-	-	-	0.544***
						(0.081)
13-15	-	-	-	-	-	0.528***
						(0.126)
16+	-	-	-	-	-	0.701***
						(0.171)
Age group (ref: 25-35)						
36-45	1.108***	1.127**	0.157***	0.155***	-	-
	(0.075)	(0.076)	(0.033)	(0.033)		
46-55	1.607***	1.678***	0.199***	0.192***	-	-
	(0.072)	(0.075)	(0.030)	(0.031)		
56-65	2.270***	2.369***	0.255***	0.245***	-	-
	(0.091)	(0.094)	(0.031)	(0.032)		
Intercept	-0.214***	-0.375***	0.818***	0.836***	-	-
	(0.085)	(0.092)	(0.034)	(0.036)		
Cut Point 1	-	-	-	-	-1.264***	-1.210***
					(0.079)	(0.079)
Cut Point 2	-	-	-	-	1.239***	1.313
					(0.078)	(0.080)
Cut Point 3	-	-	-	-	2.597***	2.693***
					(0.088)	(0.089)
N	9,867	9,867	6,802	6,802	3,145	3,145
Log-likelihood	-4202.6	-4190.2	-11073.8	-11069.8	-3651.6	-3622.9

Data source: The Panel Study of Income Dynamics 1968-2011.
Notes: ***p< 0.001; **p< 0.01; *p< 0.05. Preferred models based on likelihood ratio tests are highlighted.

Table 3 Two-Sex Assortative Mating and Force of Attraction

Panel A		Observed Assortative Mating					
Schooling Men	Women	# of eligible males (age 25-65)	# of eligible females (age 25-65)	# of eligible male person-year (age 25-65)	# of eligible female person-year (age 25-65)	# of marriages	Force of attraction (α_{ij})
0-11	0-11	1,534	1,466	17,314	12,781	451	0.061
	12	1,534	3,846	17,314	28,872	493	0.046
	13-15	1,534	2,484	17,314	20,108	119	0.013
	16+	1,534	2,017	17,314	19,329	28	0.003
12	0-11	3,872	1,466	38,730	12,781	379	0.039
	12	3,872	3,846	38,730	28,872	1,478	0.089
	13-15	3,872	2,484	38,730	20,108	658	0.050
	16+	3,872	2,017	38,730	19,329	239	0.019
13-15	0-11	2,317	1,466	23,609	12,781	96	0.012
	12	2,317	3,846	23,609	28,872	568	0.044
	13-15	2,317	2,484	23,609	20,108	671	0.062
	16+	2,317	2,017	23,609	19,329	349	0.033
16+	0-11	1,860	1,466	19,585	12,781	20	0.003
	12	1,860	3,846	19,585	28,872	210	0.018
	13-15	1,860	2,484	19,585	20,108	355	0.036
	16+	1,860	2,017	19,585	19,329	883	0.091
Total	Total	9,583	9,813	99,238	81,090	6,992	-

Data source: The Panel Study of Income Dynamics 1968-2011.
Notes: The expected number of eligible person years = average age at marriage (for the married) * the number of married + (60-18) * # of unmarried.

Table 4 Two-Sex Multigenerational Marriage and Fertility Models for *Men* and *Women*

	Marriage		Marriage		Marital Fertility	
	Men Ever Married (Logit)		Women Ever Married (Logit)		Couples (Negative binomial)	
Variable	2 Generation	3 Generation	2 Generation	3 Generation	2 Generation	3 Generation
Men's education (ref: 0-11)						
12	0.414***	0.378***	-	-	-0.111***	-0.096***
	(0.074)	(0.077)			(0.018)	(0.018)
13-15	0.595***	0.572***	-	-	-0.155***	-0.132***
	(0.083)	(0.089)			(0.021)	(0.022)
16+	0.837***	0.827***	-	-	-0.207***	-0.172***
	(0.090)	(0.103)			(0.024)	(0.026)
Women's education (ref: 0-11)						
12	-	-	0.515***	0.396***	-0.152***	-0.139***
			(0.081)	(0.084)	(0.018)	(0.019)
13-15	-	-	0.708***	0.535***	-0.196***	-0.180***
			(0.089)	(0.095)	(0.021)	(0.022)
16+	-	-	0.792***	0.553***	-0.285***	-0.264***
			(0.094)	(0.106)	(0.025)	(0.026)
Men's father (ref: 0-11)						
12	-	0.090	-	-	-	0.017
		(0.073)				(0.017)
13-15	-	0.106	-	-	-	0.007
		(0.099)				(0.024)
16+	-	0.090	-	-	-	-0.014
		(0.103)				(0.025)
Men's mother (ref: 0-11)						
12	-	0.105	-	-	-	-0.053**
		(0.075)				(0.017)
13-15	-	-0.140	-	-	-	-0.056*
		(0.095)				(0.024)
16+	-	-0.070	-	-	-	-0.051
		(0.110)				(0.027)
Women's father (ref: 0-11)						
12	-	-	-	0.181*	-	-0.031
				(0.076)		(0.017)
13-15	-	-	-	0.182	-	-0.048*
				(0.099)		(0.023)
16+	-	-	-	0.465***	-	-0.031
				(0.111)		(0.024)
Women's mother (ref: 0-11)						
12		-	-	0.269***	-	-0.010
	-			(0.078)		(0.017)
13-15		-	-	0.189	-	0.056*
	-			(0.098)		(0.022)
16+	-	-	-	0.040	-	-0.016
				(0.117)		(0.027)

Table 4 (continued)

	Marriage		Marriage		Marital Fertility	
	Men Ever Married (Logit)		Women Ever Married (Logit)		Couples (Negative binomial)	
	2 Generation	3 Generation	2 Generation	3 Generation	2 Generation	3 Generation
Age group (ref: 25-35)						
36-45	1.054***	1.050***	1.108***	1.127***	0.153***	0.148***
	(0.071)	(0.072)	(0.075)	(0.076)	(0.024)	(0.024)
46-55	1.453***	1.457***	1.607***	1.708***	0.193***	0.181***
	(0.067)	(0.070)	(0.072)	(0.076)	(0.022)	(0.023)
56-65	2.452***	2.468***	2.270***	2.407***	0.304***	0.285***
	(0.089)	(0.094)	(0.091)	(0.096)	(0.022)	(0.023)
Intercept	-0.365***	-0.417***	-0.214*	-0.424***	0.797***	0.824***
	(0.079)	(0.089)	(0.085)	(0.094)	(0.026)	(0.028)
N	9,683	9,683	9,867	9,867	13,311	13,311
Log-likelihood	-4540.0	-4533.1	-4202.6	-4181.2	-21944.9	-21927.1

Data source: The Panel Study of Income Dynamics 1968-2011.
Notes: ***p< 0.001; **p< 0.01; *p< 0.05.

Table 5 Two-Sex Multigenerational Mobility Models for *Men* and *Women* aged 25-65

	MEN			WOMEN		
Variable	Two-Generation	Three-Generation	Three-Generation (constraints)	Two-Generation	Three-Generation	Three-Generation (constraints)
Father's education (ref: 0-11)						
12	0.504***	0.461***	0.455***	0.469***	0.367***	0.360***
	(0.096)	(0.098)	(0.098)	(0.094)	(0.096)	(0.096)
13-15	1.045***	0.962***	0.952***	0.861***	0.701***	0.700***
	(0.119)	(0.123)	(0.122)	(0.116)	(0.119)	(0.119)
16+	1.695***	1.575***	1.560***	1.559***	1.361***	1.353***
	(0.126)	(0.131)	(0.131)	(0.127)	(0.133)	(0.132)
Mother's education (ref: 0-11)						
12	0.877***	0.842***	0.836***	0.936***	0.835***	0.846***
	(0.103)	(0.104)	(0.104)	(0.099)	(0.101)	(0.101)
13-15	1.277***	1.215***	1.204***	1.395***	1.230***	1.243***
	(0.126)	(0.129)	(0.128)	(0.121)	(0.124)	(0.124)
16+	2.022***	1.851***	1.861***	2.309***	2.077***	2.098***
	(0.142)	(0.149)	(0.148)	(0.146)	(0.152)	(0.151)
Paternal grandfather (ref: 0-11)						
12	-	-0.041	0.076*	-	-0.006	0.139**
		(0.100)	(0.032)		(0.099)	(0.032)
13-15	-	0.153	0.055	-	0.322	0.231***
		(0.151)	(0.058)		(0.172)	(0.062)
16+	-	0.219	0.210***	-	0.241	0.184**
		(0.158)	(0.061)		(0.167)	(0.063)
Paternal grandmother (ref: 0-11)						
12	-	0.012	0.076*	-	0.151	0.139**
		(0.090)	(0.032)		(0.091)	(0.032)
13-15	-	-0.059	0.055	-	0.362*	0.231***
		(0.150)	(0.058)		(0.159)	(0.062)
16+	-	0.219	0.210***	-	0.070	0.184**
		(0.184)	(0.061)		(0.180)	(0.063)
Maternal grandfather (ref: 0-11)						
12	-	0.080	0.076*	-	0.076	0.139**
		(0.094)	(0.032)		(0.097)	(0.032)
13-15	-	0.240	0.055	-	-0.053	0.231***
		(0.145)	(0.058)		(0.146)	(0.062)
16+	-	0.375*	0.210***	-	0.101	0.184**
		(0.164)	(0.061)		(0.172)	(0.063)
Maternal grandmother (ref: 0-11)						
12	-	0.220*	0.076*	-	0.326***	0.139**
		(0.092)	(0.032)		(0.094)	(0.032)
13-15	-	-0.096	0.055	-	0.380**	0.231***
		(0.133)	(0.058)		(0.137)	(0.062)
16+	-	0.010	0.210***	-	0.301	0.184**
		(0.184)	(0.061)		(0.194)	(0.063)

Table 5 (continued)

	MEN			WOMEN		
Variable	Two-Generation	Three-Generation	Three-Generation (constraints)	Two-Generation	Three-Generation	Three-Generation (constraints)
Cut point 1	-0.658***	-0.632***	-0.636***	-1.129***	-1.094***	-1.097***
	(0.084)	(0.084)	(0.084)	(0.082)	(0.083)	(0.083)
Cut point 2	1.730***	1.763***	1.754***	1.428***	1.476***	1.470***
	(0.092)	(0.092)	(0.092)	(0.085)	(0.085)	(0.085)
Cut point 3	3.149***	3.193***	3.180***	2.846***	2.913***	2.903***
	(0.102)	(0.102)	(0.102)	(0.095)	(0.096)	(0.095)
N	3,122	3,122	3,145	3,145	3,145	3,145
Log-likelihood	-3633.5	-3619.4	-3571.1	-3547.5	-3625.6	-3619.4

Data source: The Panel Study of Income Dynamics 1968-2011.
Notes: ***p< 0.001; **p< 0.01; *p< 0.05.

Table 6 Short-Term Net and Total Social Reproduction Effects

	Social Reproduction Effect		Mobility probability differences
	Net effect	Total effect	
Parents			
One-sex (father)	0.315	0.315	0.366
One-sex (mother)	0.329	0.329	0.443
Two-sex	0.224	0.224	0.518
Grandparents			
One-sex (grandfather)	0.055	0.131	0.061
One-sex (grandmother)	0.026	0.046	0.031
Two-sex	-0.026	-0.132	0.062

Data source: The Panel Study of Income Dynamics 1968-2011.
Notes: For the net social reproduction effect, we compare parents (or grandparents) who are college graduates to those who are high-school graduates in producing college offspring. For the total net effect of grandparents, we compare grandparents who are college graduates to those who are high-school graduates in producing college grandchildren. For the mobility probability differences, we calculate the difference between the probability of attaining college by having college parents rather than high-school parents (or college grandparents and high school parents vs. high-school grandparents and parents). These figures are calculated based on equations (4), (5), (9), and (10).

Table 7 Hypothetical Long-Term Mating and Mobility Rules (with differential fertility)

		Mobility		
		Yes		No
	Mating Rule	One-sex same-sex parent	Two-sex	One-sex same-sex parent
Two-sex	Unrestricted	1	2	3
	Endogamous	4	5	6
	Random	7	8	9
One-sex	No mating	10	11	12

Notes: we also experiment with mobility patterns in which both sons and daughters are influenced by their fathers. The results are the same as those from the one-sex mobility, in which sons and daughters are only influenced by the same-sex parent.

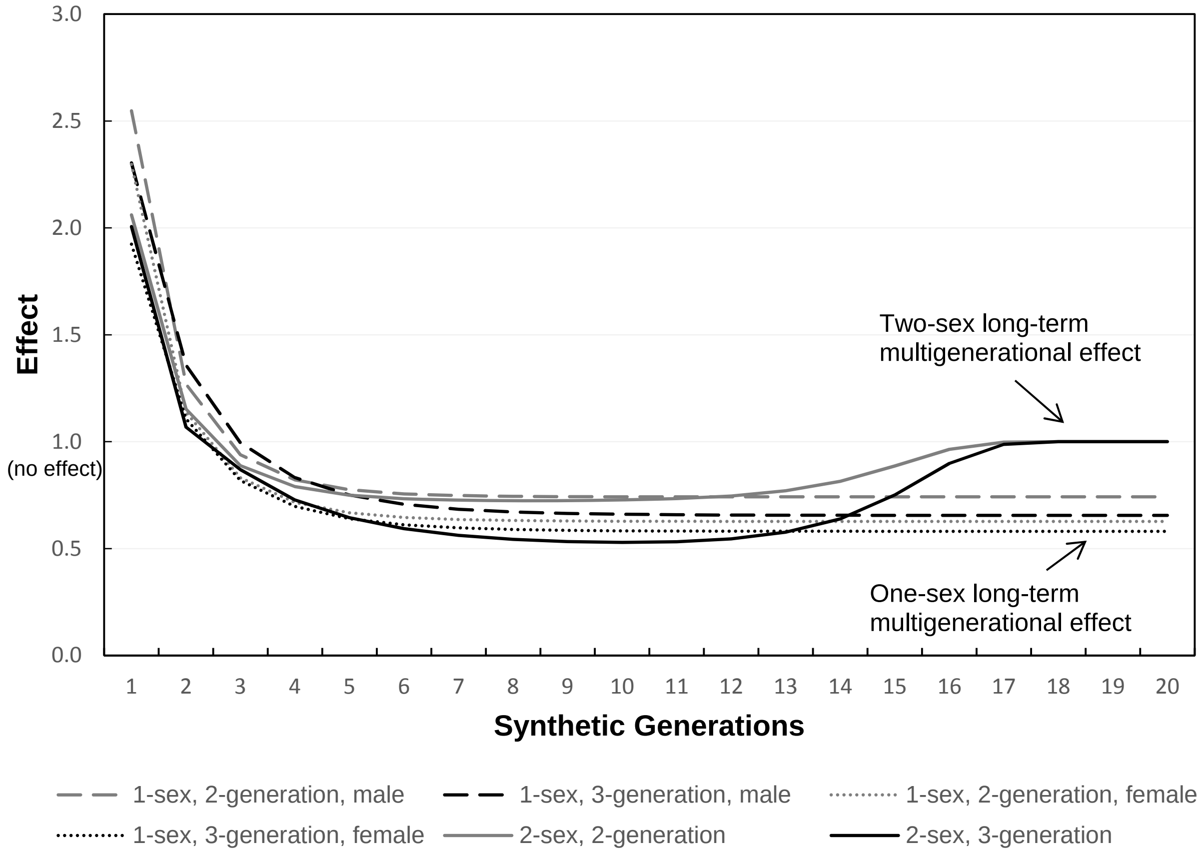

Fig 1. Multigenerational Reproduction of College Education

Notes: We define the effect as the ratio of college progeny per college family over college progeny per non-college family. The ratio = 1 means no multigenerational effect.

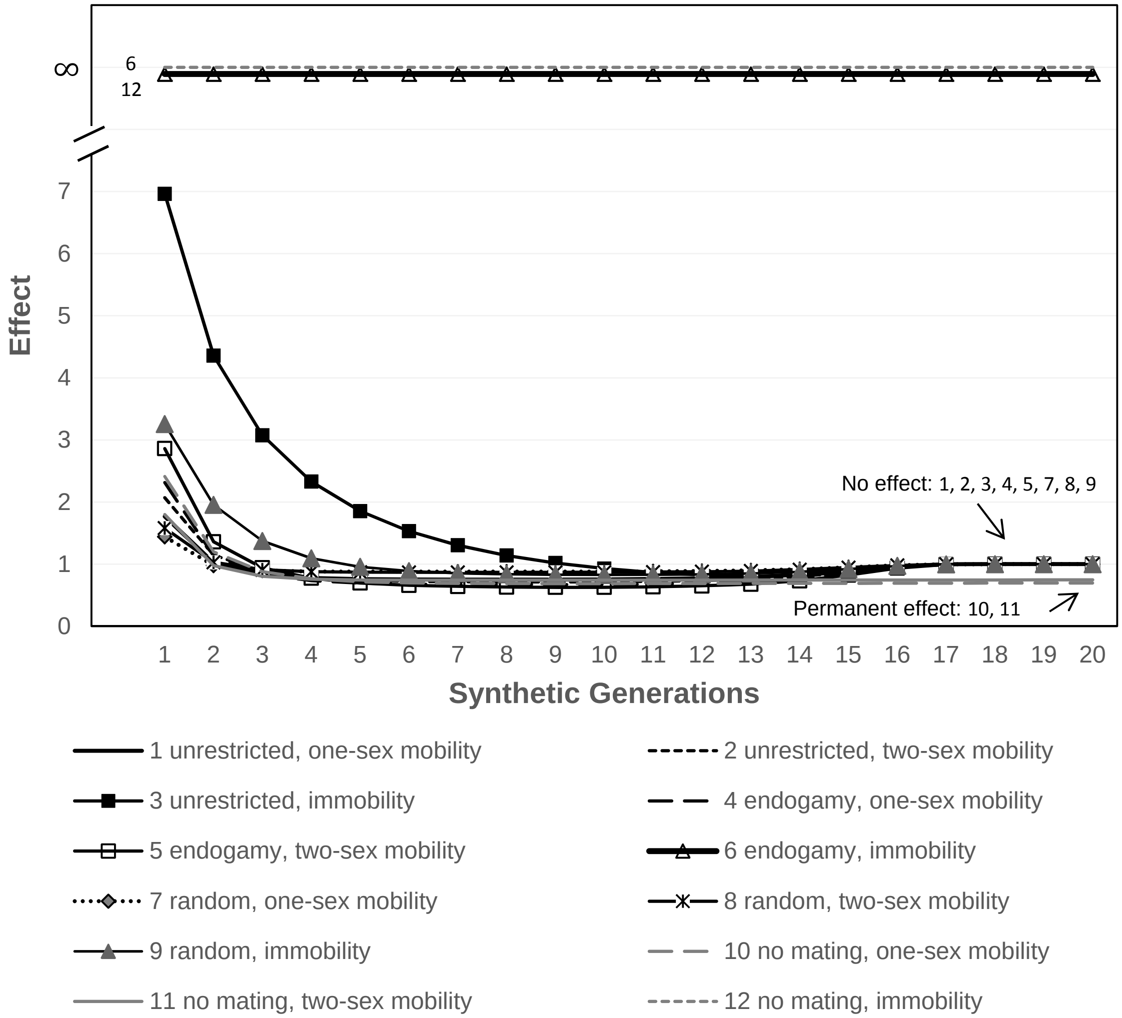

Fig 2. Multigenerational Reproduction of College Education based on Various Scenarios of Mating and Mobility Rules

Notes: We define the effect as the ratio of college progeny per college family over college progeny per non-college family.

Marriage Market

Marriage Market: One-sex; Mobility: One-sex

	Generations	Mobility: Father	Mobility: Grandfather	Mobility: Great Grandfather+
Net Fertility	None (Assumed)	Standard 2-Generation Mobility Studies	Chan-Boliver (2013), Zeng-Xie (2014)	
	Ego	Maralani (2013), Mare (1997), Mare-Maralani (2006), Matras (1961), Preston (1974)		
	Father			
	Grandfather+			Mare and Song (2014)

Marriage Market: Two-sex; Mobility: One-sex

	Generations	Mobility: Father	Mobility: Grandfather	Mobility: Great Grandfather+
Net Fertility	None (Assumed)			
	Ego			
	Father			
	Grandfather+			

Marriage Market: One-sex; Mobility: Two-sex

	Generations	Mobility: Parents	Mobility: Grandparents	Mobility: Great Grandparents+
Net Fertility	None (Assumed)	Sewell-Hauser (1975), Beller (2009)	Warren-Hauser (1997)	
	Ego	.		
	Parents			
	Grandparents+			

Marriage Market: Two-sex; Mobility: Two-sex

	Generations	Mobility: Parents	Mobility: Grandparents	Mobility: Great Grandparents+
Net Fertility	None (Assumed)			
	Ego	Preston-Campbell (1993)		
	Parents			
	Grandparents+			

Fig 3. Taxonomy of Multigenerational Effects and Exemplary Studies

Appendix A Summary Statistics of Demographic and Educational Characteristics by Generations

	Marriage/Fertility Sample				Mobility Sample							
Variable	Male	Female	Father	Mother	Son	Daughter	Father	Mother	Paternal grandfather	Paternal grandmother	Maternal grandfather	Maternal grandmother
Schooling (%)												
0-8*	3.8	3.8	26.5	19.5	1.3	1.3	16.4	10.7	57.4	44.0	49.7	41.8
9-11	12.3	11.2	11.5	13.1	11.3	7.8	11.5	11.5	9.6	14.0	12.5	15.4
12	40.5	39.2	34.5	39.9	38.7	37.6	35.3	42.4	20.7	30.6	22.9	28.2
13-15	24.0	25.3	12.5	15.5	25.2	26.0	16.6	19.1	5.4	6.3	7.5	9.3
16+	19.3	20.5	15.0	12.1	23.6	27.4	20.3	16.3	6.9	5.1	7.6	5.4
Age group (%)												
25-35	18.9	19.1			29.2	30.1						
36-45	20.5	20.1			24.0	22.1						
46-55	33.3	34.0			28.9	30.7						
56-65	27.2	26.7			17.9	17.1						
Race (%)												
Whites	55.9	51.9			68.6	64.6						
African Americans	30.2	33.2			25.7	30.6						
Others	14.0	14.9			5.8	4.8						
#Siblings	3.3	3.4			3.1	3.2						
	(2.6)	(2.7)			(2.6)	(2.6)						
N	9,683	9,867	19,550	19,550	3,122	3,145	6,267	6,267	6,267	6,267	6,267	6,267

Data source: The Panel Study of Income Dynamics 1968-2011.
Notes: Given the small sample size of sons and daughters in the educational category 0-8, we combine 0-8 and 9-11 into one category in the analyses. We restrict males and females in the marriage/fertility sample and sons and daughters in the mobility sample to individuals aged 25-65. Figures in parentheses are standard deviations.

Appendix B Multigenerational Assortative Mating and Force of Attraction (the top 30 of α_{ij} out of 4,096)

Panel A Schooling Male	Male's father	Male's mother	Female	Female's father	Female's mother	Observed Assortative Mating: # of eligible males (age 25-65)	# of eligible females (age 25-65)	# of eligible male person-year (age 25-65)	# of eligible female person-year (age 25-65)	# of marriages	Force of attraction (α_{ij})
12	12	16+	0-11	0-11	16+	93	5	866	11	1	0.0921
12	12	0-11	0-11	0-11	16+	277	5	2,675	11	1	0.0913
0-11	0-11	0-11	0-11	0-11	0-11	862	903	9,614	7746	282	0.0657
12	0-11	0-11	12	0-11	0-11	957	1,152	9,064	9135	210	0.0462
13-15	16+	12	0-11	0-11	16+	108	5	1,248	11	1	0.0459
13-15	12	12	0-11	0-11	16+	596	5	5,925	11	1	0.0455
0-11	0-11	16+	0-11	0-11	0-11	8	903	47	7746	2	0.0428
16+	16+	16+	16+	16+	16+	444	452	4,482	4504	91	0.0403
13-15	16+	12	0-11	16+	13-15	108	2	1,248	26	1	0.0393
12	12	12	12	12	12	1,117	929	11,371	6525	159	0.0384
0-11	0-11	0-11	12	0-11	0-11	862	1,152	9,614	9135	168	0.0359
12	12	12	12	16+	12	1,117	90	11,371	484	17	0.0355
0-11	16+	16+	12	0-11	0-11	7	1,152	74	9135	3	0.0341
16+	16+	16+	16+	16+	13-15	444	173	4,482	1529	35	0.0303
0-11	0-11	0-11	0-11	16+	0-11	862	9	9,614	67	2	0.0301
12	0-11	0-11	0-11	12	0-11	957	105	9,064	739	20	0.0293
12	0-11	0-11	0-11	0-11	0-11	957	903	9,064	7746	117	0.0279
0-11	0-11	0-11	0-11	16+	12	862	6	9,614	58	2	0.0260
0-11	13-15	16+	0-11	12	0-11	6	105	41	739	1	0.0257
0-11	13-15	16+	13-15	13-15	13-15	6	208	41	1571	1	0.0250
0-11	16+	0-11	13-15	0-11	12	7	223	41	1879	1	0.0249
0-11	16+	0-11	12	0-11	12	7	492	41	3447	1	0.0247
0-11	16+	0-11	0-11	0-11	0-11	7	903	41	7746	1	0.0245
12	12	0-11	0-11	12	16+	277	4	2,675	42	1	0.0242
12	0-11	0-11	12	0-11	12	957	492	9,064	3447	60	0.0240
16+	12	12	16+	12	12	340	341	3214	3139	37	0.0230
0-11	12	16+	12	12	12	5	929	44	6525	1	0.0229
13-15	0-11	0-11	13-15	0-11	0-11	329	380	3,340	3196	37	0.0227
0-11	0-11	16+	12	13-15	13-15	8	124	47	1038	1	0.0222
12	0-11	0-11	12	16+	0-11	957	22	9,064	137	3	0.0222

Notes: We find that 2,266 of the total 4,096 α_{ij} equals 0. A full list is available upon request.

Appendix C Goodness-of-Fit Statistics for Two-Sex Multigenerational Mobility Models

Model Description	Comparisons between 2-generation and 3-generation models			Comparisons between 3-generation models		
	LR X^2 vs. 1	df vs. 1	p-value vs. 1	LR X^2 vs. 2	df vs. 2	p-value vs. 2
Men						
1 FF = MF = MF = MM = 0 (2 generation model)	-	-	-	-	-	-
2 FF ≠ MF ≠ MF ≠ MM ≠ 0 (full 3 generation model)	28.2	12	0.005	-	-	-
3 FF = MF = MF = MM ≠ 0 (restricted 3 generation model)	15.7	3	0.001	12.5	9	0.186
4 FF = FM and MF = MM	20.0	6	0.003	8.2	6	0.221
5 FF = MF and FM = MM	22.2	6	0.001	6.0	6	0.428
Women						
1 FF = MF = MF = MM = 0 (2 generation model)	-	-	-	-	-	-
2 FF ≠ MF ≠ MF ≠ MM ≠ 0 (full 3 generation model)	47.2	12	0.000	-	-	-
3 FF = MF = MF = MM ≠ 0 (restricted 3 generation model)	36.1	3	0.000	11.1	9	0.268
4 FF = FM and MF = MM	40.6	6	0.000	6.6	6	0.358
5 FF = MF and FM = MM	40.5	6	0.000	6.7	6	0.351

Notes: FF- father's father, MF- father's mother, MF- mother's father, MM- mother's mother.