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Essays on Social Stratification in Multiple Generations

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Sociology

by

Xi Song

2015

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ABSTRACT OF THE DISSERTATION

Essays on Social Stratification in Multiple Generations

by

Xi Song

Doctor of Philosophy in Sociology

University of California, Los Angeles, 2015

Professor Robert Denis Mare, Chair

Transmission of status across generations is a central concern in studies of social stratification and mobility. Most sociological research takes a two-generation approach to understand social mobility from parents to children. Not until recently did mobility researchers acknowledge the role of grandparents, who have become more involved in grandchildren's lives because of increasing human longevity, declining fertility, and the growing number of single-parent families. My approach to multigenerational social mobility in this dissertation looks at the importance of grandparents, but also looks beyond the grandparent generation including great grandparents, relatives in kin networks, and even more remote ancestors. The three empirical chapters take into account long family histories of social status that span from three to more than ten generations. Findings from these chapters show that individuals' social success is not predetermined by their ancestry, but it nevertheless is influenced by ancestry.

In recent years, sociological research investigating grandparent effects in three-generation social mobility has proliferated, mostly focusing on the question of whether grandparents' influence on grandchildren is all mediated by parents. In Chapter 2, I hypothesize that prior research has overlooked an important factor that moderates grandparent effects: family structure. Capitalizing on a counterfactual causal framework and multigenerational data from the Panel Study of Income Dynamics, this study provides a causal interpretation for the direct effect of grandparents on grandchildren's educational attainment. Consistent with findings from several prior studies, the results show that grandparents can directly transmit their educational advantages to their grandchildren, independently of the parent generation. Further, this study reveals that, for both African Americans and whites, grandparent effects are the strongest for grandchildren who grew up in two-parent families, followed by those in single-parent families with divorced parents. The weakest effect was marked in single-parent families with unmarried parents. These findings suggest that the increasing diversity of family forms has led to diverging social mobility trajectories for families across generations.

In Chapter 3, I investigate how families reproduce their social status by passing on educational advantages to succeeding generations. Unlike traditional mobility studies that typically focus on one-sex influences of fathers on sons, I rely on a two-sex approach that accounts for marriage market interactions between males and females. This approach includes educational assortative mating in both parent and grandparent generations and accounts for 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, I approach this issue from both a short-term and a long-term perspective. For the short term, grandparents' educational attainment has a direct influences on grandchildren's education as well as an indirect influence that is mediated by parents' education and demographic behaviors. Over 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.

In Chapter 4, I analyze representation by male descendants in subsequent generations as a new social stratification outcome. Not only was continuity of the patrilineal descent line the central focus of family reproductive strategy in historical China and many other patriarchal societies, but in such societies, networks of patrilineal kin were a key unit of social organization that influenced the life chances of their members. By analyzing two large prospective, multi-generational demographic databases that provide complete pedigrees for males in more than twenty thousand descent lines in eighteenth- and nineteenth-century China, this chapter shows that the high status of a descent line founder increases his representation in later generations not only because he has more sons but because his patrilineal descendants do so as well. The elevated growth rate of high-origin descent lines emerged in the initial generation, then declined slowly over the next 150 years before dissipating completely. Descendants of high-status males therefore account for a disproportionately large share of the male population in later generations. The results show that this advantage was attributable more to high-origin descent lines having a lower probability of extinction at each point in time than to larger numbers of sons per surviving descent member.

The dissertation of Xi Song is approved.

Cameron D. Campbell

Mark S. Handcock

Judith A. Seltzer

Robert Denis Mare, Committee Chair

University of California, Los Angeles

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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VITA

2008	A.B. Sociology Renmin University of China
2010	M.Phil. Social Science Hong Kong University of Science and Technology
2013	M.S. Statistics University of California, Los Angeles
2013	C.Phil. Sociology University of California, Los Angeles

PUBLICATIONS

Song, Xi, Cameron D. Campbell, and James Z. Lee. Forthcoming. ”Ancestry Matters: Patrilineage Growth and Extinction.” *American Sociological Review*.

Song,Xi and Robert D. Mare. Forthcoming. “Retrospective Versus Prospective Approaches to the Study of Intergenerational Social Mobility.” *Sociological Methods and Research*.

Song, Xi and Yu Xie. 2014. “Market Transition Revisited: Changing Regimes of Housing Inequality in China, 1988-2002.” *Sociological Science* 1:277-291.

Wu, Xiaogang and Xi Song. 2014. “Ethnic Stratification in China’s Economic Transition: Evidence from Xinjiang Uyghur Autonomous Region.” *Social Science Research* 44:158-172.

PRESENTATIONS

Song, Xi. 2014. “Educational Mobility in Three Generations: Single-Parent and Grandparent Effect.” Annual Meeting of the Population Association of America, Boston, MA; Research Committee on The Demographic Reproduction of Social Stratification at the XVIII ISA World Congress of Sociology, Yokohama, Japan.

Song, Xi and Robert D. Mare. 2013. “Educational Mobility in Multiple Generations: A Two-Sex Approach.” Research Committee on Social Stratification and Mobility (RC28) of the ISA, Trento, Italy; Annual Meeting of the American Sociological Association, New York, NY; Stanford Workshop in Biodemography.

Bianchi, Suzanne M., Judith A. Seltzer, and Xi Song. 2013. "Money and Time Transfers from Parents to Adult Children in the United States: New Evidence on Between and Within Family Differences from the June 2012 Survey of Consumer." Annual Meeting of the Population Association of America, New Orleans, LA; Research Committee on Social Stratification and Mobility (RC28) of the ISA, Trento, Italy.

Song, Xi and Robert D. Mare. 2012. "Retrospective Versus Prospective Approaches to the Study of Social Mobility." Research Committee on Social Stratification and Mobility (RC28) of the ISA, Hong Kong.

Song, Xi, Cameron D. Campbell, and James Z. Lee. 2012. "Descent Line Growth and Extinction from a Multigenerational Perspective." Annual Meeting of the Population Association of America, San Francisco, CA.

Mare, Robert D. and Xi Song. 2011-2012. "Stratification in Multiple Generations." Research Committee on Social Stratification and Mobility (RC28) of the ISA, Iowa City, IA; Annual Meeting of the Population Association of America, San Francisco, CA; Research Committee on Social Stratification and Mobility (RC28) of the ISA, Hong Kong.

Wu, Xiaogang and Xi Song. 2010. "Ethnic Stratification in China's Labor Market: Evidence from Xinjiang Uyghur Autonomous Region." Research Committee on Social Stratification and Mobility (RC28) of the ISA, Haifa, Israel.

Wu, Xiaogang and Xi Song. 2010. "Gender and Employment in Urban China's Labor Market Transition, 1982-2002." Annual Meeting of the Population Association of America, Dallas, TX.

Song, Xi. 2009. "The Shift of Housing Inequality and Its Regional Variations in Reform Era China." Research Committee on Social Stratification and Mobility (RC28) of the ISA, Beijing, China.

Song, Xi. 2009. "Values and Modes of Conflict Resolution: A Portrait of the Chinese New Middle Class." Annual Meeting of the American Sociological Association, San Francisco, CA.

CHAPTER 1

Introduction

This dissertation focuses on a key question about the rise and fall of families: why do some families successfully preserve their advantages over a long period of time while others fall into oblivion? It is inspired by Robert D. Mare's 2010 PAA presidential address, which called for social and demographic research to go beyond the traditional two-generation paradigm and examine the roles of grandparents, nonresident kin, and remote ancestors in influencing the fortune and fate of families under different circumstances (Mare 2011). Key multigenerational mechanisms include not only the transmission of genetic traits, socioeconomic status, and social and cultural capitals within family lineages, but also demographic processes—such as mating, reproduction and mortality—by which families grow, decline, or even die out. Under this broad framework of multigenerational inequality, the three empirical chapters in this dissertation illustrate patterns of family socioeconomic mobility in multiple generations as well as demographic behaviors of families that determine the socioeconomic status distribution of offspring in a later generation. Based on empirical evidence from several societies and historical periods, the analyses discuss a wide variety of empirical multigenerational processes that vary across socioeconomic groups, institutional contexts, and demographic regimes.

Transmission of social inequality across generations is a central concern in studies of social stratification and mobility. Patterns and degrees of intergenerational status inheritance and mobility reflect the openness of a society as well as the distribution of opportunities for upward mobility. Sociologists have long considered social mobility an important indicator to assess the relative importance of ascribed versus achieved attributes in the process of status attainment for individuals (Blau and Duncan 1967). Traditionally, such studies rely on the association between parents' and offspring's social standing, measured by occupational status, education, income, and wealth. This approach has led to a large body of literature investigating the continuity and disparity of social mobility patterns over time and across places (Diprete and Grusky 1990; Duncan 1966; Erikson and Goldthorpe 1992; Featherman and Hauser 1978; Grusky and Fukumoto 1989; Hauser et al. 1975; Hauser 1982; Hout 1988). Nevertheless, few of these studies go beyond the two-generation paradigm and link short-term intergenerational inequality to the persistence of inequality over multiple generations. This dissertation aims to contribute to discussions on this topic.

The scarcity of research on multigenerational social inequality results from both theoretical considerations and the lack of relevant empirical data. Early theories in social mobility assume that if a stratification system is "Markovian," an investigation of the two-generation pattern suffices to explain mobility processes over multiple generations (Boudon 1973). Markovian, in the context of social mobility, means that each generation only directly influences the immediately following generation and has no direct effect on later generations. This assumption implies that regardless of the amount of influence that parents have on their children's outcomes, they are incapable of influencing the outcomes of their grandchildren independently of the parents. There is no "memory" in the system, so once a family loses its existing advantages, it starts from scratch. Past research has seldom assessed the validity of the "Markovian" assumption and largely neglected the possibility of temporal or institutional variations. If the transmission of social status across multiple generations is non-Markovian, previous studies may have ignored many important social mechanisms that reproduce and reinforce social inequality across time and space. These non-Markovian mechanisms include, but are not limited to, the direct net effect of grandparents, cumulative advantages (or disadvantages) of prior generations, the legacy effect of remote ancestors who experienced extreme hardship or success, and the supplementary effect of available nonresident kin in extended families.

A multigenerational analysis of social inequality requires researchers to develop new methodological approaches that address complexity associated with the diversity of possible multigenerational effects. A simple fact is that individuals have two parents, four grandparents, and an exponentially increasing number of ancestors. The variety of possible multigenerational effects will explode with the number of generations and the dimensions of *influences* that we define, measure, and evaluate. For example, the strength and patterns of multigenerational effects may vary by the types of independent variables that are used as a proxy of social standings. The effect may be stronger if the variable of interest represents “stocks” of social advantages, especially family property such as business, lands, or estates, than if it represents “flows” of advantages such as income, education, and occupational position (Mare 2011). The effect may be conditional on the types of dependent variables of interest, such as whether we measure social attainment by the probability of status inheritance or the distribution of offspring in the social hierarchy. In addition, multigenerational effects may vary across social settings and social strata. Such effects may wane or be interrupted during periods of social transformation, during which elites in a society are replaced. Multigenerational ties may be particularly important for families located at the extreme top of the society, where families rely on their political connections or economic capital rather than human capital to create opportunities for their offspring. The ties may also be strong for families at the bottom of the society, where grandparents and extended kin participate in childcare and help hold families together during hard times. Moreover, the multigenerational effect may vary within families, in that the cultural norms of family division of labor by gender and the gender-specific mobility opportunities in a society may result in stronger effects of some kin relatives to others and different mobility outcomes for sons and daughters.

The scarcity of multigenerational mobility research also results from the paucity of large-scale, longitudinal empirical evidence in the past. Relevant prospective studies are rare because the time required to record the history of several generations typically exceeds the lifespan of most researchers. Most contemporary longitudinal studies only allow for analyses of life events within one generation, since the cost of following multiple generations is extraordinarily large. Fortunately, this data constraint may disappear with time, as more and more large-scale prospective panels are emerging from many countries and populations. Examples of such panel data include the Wisconsin Longitudinal Study (WLS, 1957), the Panel Study of Income Dynamics (PSID, 1968) in the United States and newer panel studies in other countries such as the British Household Panel Survey (BHPS, 1997), Canadian Survey of Labour and Income Dynamics (SLID, 2012), Chinese Family Panel Studies (CFPS, 2010), German Socio-Economic Panel (SOEP, 2000), Household, Income and Labour Dynamics in Australia (HILDA, 2002), Korean Labour and Income Panel Study (KLIPS, 2012), and Swiss Household Panel (SHP, 2012). The second and the third chapters in this dissertation rely on multigenerational linked data from the PSID, and the fourth chapter draws on evidence from historical family genealogies. The approaches taken in these chapters are potentially applicable to other data resources as well, though the duration of some panels is hitherto too short to permit a multigenerational analysis.

The arrangement of the remaining chapters is as follows. The second chapter discusses multigenerational influences of grandparents' education that creates, reproduces, and potentially changes educational inequality among families in the grandchild generation. In particular, this chapter emphasizes the distinct forms and meanings of multigenerational influences between individuals who grew up in two-parent and one-parent families. Relying on a counterfactual causal framework and multigenerational data from the PSID, I find that grandparent effects are the strongest in two-parent families, followed by single-parent families with divorced parents, with the weakest effect occurring in families with unmarried parents. Therefore, families that have maintained intactness in family structure also maintain a high degree of similarity in education across generations. These findings suggest that the increasing diversity of family forms has led to diverging social mobility trajectories of families across generations.

The search for a tool to better describe multigenerational inequality mechanisms leads to the third chapter, in which I discuss the potential limitations of a one-sex multigenerational approach that only applies to men and their male descendants, and propose a two-sex approach that considers male and female populations simultaneously. In demographic models, a two-sex approach takes into account assortative mating between men and women in population growth and change, whereas in mobility studies, a two-sex approach includes effects of both paternal and maternal families in intergenerational mobility. My two-sex multigenerational approach integrates both views. Relying on empirical data from the PSID, I show that grandfathers and grandmothers have an equal influence on the social success of their progeny. Yet a population projection shows that a lineage's social advantages are not permanent. Generations of intermarriages between high-status and low-status families eventually connect social ancestry of all descendants in a population—a well-known phenomenon in population genetics that leads the socioeconomic distributions of descendants of all families to eventually be identical.

The fourth chapter introduces the representation of an individual's descendants in a later population as a new measure of stratification outcome. The key research question is to understand how initial inequality in social status in one generation leads to inequality in later generations. Using data from more than twenty thousand patrilineal descent lines in historical China, I find that patrilineages founded by high status males had higher growth rates for the next 150 years. I also show that the result is due more to families minimizing their probability of extinction, namely by having at least one son at each point in time, than to families maximizing their total number of sons. This paper provides an explanation for family reproductive success from the perspective of social stratification, which is different from previous explanations from anthropology, biology, and economics. Overall, based on abundant empirical evidence and quantitative analyses, these three chapters will reveal some empirical long-term family strategies of status transmission and demographic behaviors. They will fill in important gaps in our understanding of the multigenerational stratification process that results in diverse socioeconomic status trajectories of families.

REFERENCES

BHPS (British Household Panel Survey). 1997. User Manual Codebook. Institute for Social & Economic Research. Retrieved October 7, 2014 (https://www.iser.essex.ac.uk/bhps).

Blau, Peter M., and Otis Dudley Duncan. 1967. *The American Occupational Structure*. New York: Wiley.

Boudon, Raymond. 1973. *Mathematical Structures of Social Mobility*. Jossey-Bass Inc., Publisher.

CFPS (Chinese Family Panel Studies). 2010. ‘‘Chinese Family Panel Studies: A PSC Research Project.’’ Retrieved October 7, 2014 (http://www.psc.isr.umich.edu/research/project-detail/34795).

Diprete, Thomas A., and David Grusky. 1990. “Structure and Trend in the Process of Stratification for American Men and Women.” *American Journal of Sociology* 96: 107-143.

Duncan, Otis Dudley. 1966. “Methodological Issues in the Analysis of Social Mobility." Pp. 51-97 in N. J. Smelser and S. M. Lipset (eds.), *Social Structure and Mobility in Economic Development*. Chicago: Aldine.

Erikson, Robert, and John H. Goldthorpe. 1992. *The Constant Flux: A Study of Class Mobility in Industrial Societies*. Oxford: Clarendon Press.

Featherman, David L. and Robert M. Hauser. 1978. *Opportunity and Change*. New York: Academic Press.

Grusky, David B. and Ivan K. Fukumoto. 1989. “Social History Update: A Sociological Approach to Historical Social Mobility.” *Journal of Social History* 23(1): 221-232.

Hauser, Robert M., John N Koffel, Harry P. Travis, and Peter J. Dickinson. 1975. "Temporal Change in Occupational Mobility: Evidence for Men in the United States." *American Sociological Review* 40:279-97.

Hauser, Robert M. 1982. "Occupational Status in the Nineteenth and Twentieth Centuries." *Historical Methods* 15: 111-126.

HILDA (Household, Income and Labour Dynamics in Australia). 2002. "The Household, Income and Labour Dynamics in Australia Survey: Wave 1." *American Economic Review* 35:339-48.

Hout, Michael. 1988. "More Universalism, Less Structural Mobility: The American Occupational Structure in the 1980s." *American Journal of Sociology* 93:1358-1400.

KLIPS (Korean Labour and Income Panel Study). 2012. "An Overview of the KLIPS." Retrieved October 7, 2014 (http://www.kli.re.kr/klips/en/about/introduce.jsp).

Mare, Robert D. 2011. "A Multigenerational View of Inequality". *Demography* 48: 1-23.

PSID Main Interview User Manual: Release 2012.1. Institute for Social Research, University of Michigan. Retrieved October 7, 2014 (http://psidonline.isr.umich.edu/data/Documentation/UserGuide2011.pdf).

SHP (Swiss Household Panel). 2012. "Swiss Household Panel Documentations." Retrieved October 7, 2014 (http://www.swisspanel.ch/index.php?).

SLID (Canadian Survey of Labour and Income Dynamics). 2012. "A Survey Overview." Retrieved October 7, 2014 (http://www5.statcan.gc.ca/bsolc/olc-cel/olccel?&catno=75F0011X).

SOEP (Socio-Economic Panel Group). 2000. "The German Socio Economic Panel after More than 15-Years Overview." *Vierteljahrshefte zur Wirtschaftsforschung/Quarterly Journal of Economic Research* DIW Berlin: German Institute for Economic Research, 70:7-14.

WLS (Wisconsin Longitudinal Study Handbook). 2006. Wisconsin Longitudinal Study: Tracking the Life Course. Retrieved October 7, 2014 (http://www.ssc.wisc.edu/wlsresearch/documentation/handbook/WLS_Handbook.pdf)

CHAPTER 2

Diverging Mobility Trajectories: Grandparent Effects on Educational Attainment in One- and Two-Parent Families

2.1 INTRODUCTION

In recent years, social scientists in general—and sociologists in particular—have expressed a growing interest in social mobility of families across three or more generations (Mare 2011, 2014; Pfeffer 2014; Sharkey and Elwert 2011; Solon 2014; Wightman and Danziger 2014). An intriguing question that has perplexed multigenerational researchers is whether we underestimate the legacy of family advantages or disadvantages if we focus only on two generations in families. One simple and important way to answer this question is to investigate whether grandparents' social statuses directly contribute to the social success of their grandchildren, independently of parents' influences (Chan and Boliver 2013; Erola and Moisio 2007; Hertel and Groh-Samberg 2014; Jæger 2012; Warren and Hauser 1997; Zeng and Xie 2014). These studies, however, exclusively focus on a comparison of the effects of grandparents to those of parents, rather than heterogeneity in the grandparent effects within a society. By contrast, this study situates the question of social mobility in the context of increasing family instability and complexity (McLanahan and Percheski 2008; Tach 2015), which may have created heterogeneous grandparent effects across various types of single- and two-parent families.

The present study uses educational mobility as an example to examine (1) the direct effect of grandparents' education on grandchildren's education and (2) variations in the direct effect by childhood family structures experienced by both parent and grandchild generations for African American and white families in the United States. Borrowing terms from causal mediation analysis (Baron and Kenny 1986; Pearl 2014), I distinguish between two mechanisms through which family structure shapes the mobility trajectories of families: family structure that *mediates* the effects of grandparents on parents and of parents on grandchildren, operating as a bridge linking social statuses across generations; and family structure that *moderates* the direct effect of grandparents on grandchildren, resulting in an interaction effect between family structure and grandparent effects in social mobility processes. While previous studies have extensively discussed the role of family structure as a mediator in the intergenerational or multigenerational transmission of socioeconomic, psychological, and demographic characteristics (e.g., Amato 2005; Aquilino 1996; Astone and McLanahan 1991; Duncan and Duncan 1969; Furstenberg and Cherlin 1991; Ginther and Pollak 2004; McLanahan and Sandefur 1994; Seltzer 1994), this study investigates the role of family structure as a moderator. More specifically, I evaluate whether the direct effect of grandparents varies between single-parent and two-parent families, such that the multigenerational persistence of educational status is stronger in some family forms than others.

Although many definitions of family structures appear in the existing literature, I define two-parent families as those in which both parents were married for the entirety of the offspring's childhood. I consider all other types of family structure to be single-parent families in which one biological parent was often absent from the household and the other was widowed, divorced, separated, remarried, or never married. Evidence has shown that by the early 2000s, nearly one in two children lived in a single-parent household at some point before he or she reached age 18 (Ellwood and Jencks 2004). To address heterogeneity within single-parent families, I further differentiate between two subgroups: single-parent families in which parents were married at the time of the birth of their child and single-parent families in which children were born outside of marriage. While the first subgroup constitutes the majority of single-parent families, the second subgroup has grown rapidly in recent years as a result of the "deinstitutionalization of marriage" (Cherlin 2004).

Unlike previous studies that focus only on the effect of childhood family structure on one's educational attainment, I further investigate the effect of one's parents' childhood family structures as well. The reason is that family history of hardship, not only family circumstances during the childhood of the present generation, may have a legacy effect on children's later life outcomes (Sharkey and Elwert 2011; Wightman and Danziger 2014). If parents who grew up in single-parent households raise their children in ways similar to how they were raised themselves, or if grandparents who were single parents while raising their own children are also involved in raising their grandchildren, family structure may have a lagged effect on the social outcomes of subsequent generations. By simultaneously considering the trajectories of family structures and the trajectories of families' socioeconomic statuses, this study provides a fuller picture of the relationship between family structure and the reproduction of social statuses across generations. Overall, the analysis adjudicates among several competing hypotheses—that is, whether the direct effect of grandparents is the same, bigger, or smaller in two-parent families than families that experience single parenthood in any prior generations.

This study attempts to provide a causal interpretation for the varying effects of grandparents across different family structures. Most previous studies of the intergenerational transmission of social standing and the influences of family structure on children have been criticized for their use of methods that fail to distinguish association from causation

(McLanahan, Tach, and Schneider 2013). To address this limitation, the present study builds upon a counterfactual causal graphical modeling framework and specifies assumptions to help identify circumstances under which a statistical estimate linking grandparents' and grandchildren's education can be interpreted as causal (Morgan and Winship 2014; Pearl 2009). I adapt generalized linear mixed effects models with inverse probability weights, a method also known as marginal structural models (MSMs) (Robins and Hernán 2009; Sharkey and Elwert 2011; VanderWeele 2015; Wodtke, Harding, and Elwert 2011), to estimate the direct grandparent effect in a multigenerational model in which family members are nested across generations. The method helps cope with unmeasured confounders and potential endogeneous selection bias (Elwert and Winship 2014) caused by repeated measures of family characteristics over time. This methodological framework is essentially an extension of the path-analysis approach widely used in traditional social mobility studies (e.g., Alwin and Hauser 1975; Blau and Duncan 1967; Duncan 1966a).

Drawing on data from the Panel Study of Income Dynamics, this study shows substantial heterogeneity in grandparent effects on their grandchildren's education associated with family structure. The formation of single-parent families does not only truncate relations between offspring and their noncustodial parents and grandparents (Cherlin and Furstenberg 1986; Furstenberg 1990), but also reduces similarity in educational status across generations. Specifically, grandparent effects are the strongest in two-parent families, followed by single-parent families with divorced parents, with the weakest effect occurring in families with unmarried parents. A further analysis stratified by race shows that these results hold for both African Americans and whites. In addition, despite the legacy effect of the childhood family structure of parents on offspring's educational attainment, the childhood family structure of parents does not moderate the grandparent effect on grandchildren for either racial group. Overall, findings from this study suggest that overlooking the growing complexity of family forms would oversimplify our understanding of multigenerational social mobility processes. The growth of single-parent families has not only led to "diverging destinies" of U.S. children as suggested by McLanahan (2004) but also diverging mobility trajectories of U.S. families across multiple generations.

2.2 GRANDPARENT EFFECT, INTERGENERATIONAL MOBILITY, AND INEQUALITY

Traditional social mobility studies are built upon the two-generation paradigm introduced by Blau and Duncan (1967) in their classic book *The American Occupational Structure*, and subsequently followed by numerous replications and extensions (e.g., Featherman and Hauser 1978; Sewell and Hauser 1975). This two-generation approach focuses attention on parents' effects on their offspring's socioeconomic status, measured by the association between parents' and their offspring's education, income, and occupation. As Mare (2011) points out, the two-generation approach suffices to explain mobility in three or more generations if grandparents do not directly transmit socioeconomic status to their grandchildren, bypassing the parent generation. Rather, the parent generation serves as the intermediary: Grandparents influence their own children, who then guide and rear the grandchildren. Therefore, family influences across three generations amount to the sum of the direct influences over two consecutive generations, without lagged influences from grandparents to grandchildren—a representation of a Markov chain process in social mobility, also known as the Markovian assumption (Bartholomew 1982; Boudon 1973; Duncan 1966b; Hodge 1966; Singer and Spilerman 1976).

Whether three-generation mobility is Markovian or not has important implications for our understanding of the persistence of social inequality along family lines. In two-generation mobility, a strong parent effect suggests that individuals' social outcomes are heavily determined by their family origins; thus children are likely to attain the same social status as their parents and unlikely to fall far below or significantly outperform their parents (Blau and Duncan 1967; Erikson and Goldthorpe 1992; Featherman and Hauser 1978). In three-generation mobility, if we observe an additional effect of grandparents (namely a non-Markovian mobility regime), then families in favorable social positions are likely to pass on their status advantages to their progeny, whereas offspring from historically disadvantaged families face long-term difficulties escaping from their family histories. As success breeds success or poverty breeds poverty, families tend to perpetuate their high or low status across generations. A society with strong non-Markovian grandparent effects thus offers fewer mobility opportunities for families to rise from rags to riches across multiple generations than a society with a Markovian mobility regime.

In recent years, a growing number of empirical studies have tested the Markovian assumption about the grandparent effect using multigenerational data. Increasing human life expectancy has created many families in which grandparents live through a substantial portion of their grandchildren's childhood (Uhlenberg 1996). The concurrent trend of falling fertility has further allowed grandparents to invest their limited time and financial resources in a relatively small set of grandchildren (Bengtson 2001). Do these demographic trends indicate that grandparents play an increasingly important role in their grandchildren's social attainment? Results from prior studies are mixed. Two studies, both using data from the Wisconsin Longitudinal Studies, report that grandparents overall do not directly influence their grandchildren's educational outcomes (Warren and Hauser 1997; Jæger 2012). On the contrary, several studies drawing on evidence from the United Kingdom (Chan and Boliver 2013), China (Zeng and Xie 2014), and nationally representative data from the United States (Hertel and Groh-Samberg 2014; Wightman and Danziger 2014) present a challenge to the Markovian assumption by showing that grandparents' socioeconomic status can directly contribute to the socioeconomic success of their grandchildren, bypassing the parent generation.

The aforementioned studies focus primarily on the *average* effect of grandparents in a population, leaving aside the possibility of varying grandparent effects across social and demographic subpopulations. The present study represents an explicit effort in exploring this possibility by examining heterogeneity in grandparent effects associated with family forms. I choose educational attainment as the outcome variable of interest, because education, as a leading stratification variable in a contemporary society, is a main vehicle by which families transmit their social status across generations (Blau and Duncan 1967), as well as a main social determinant for a host of social outcomes, including occupational status, earnings, political participation, and health (Fischer and Hout 2006). While the substantial expansion of higher education has fostered growth in mobility opportunities (Goldin and Katz 2008), inequality in educational mobility persists: the overall correlation in education between parents and offspring has remained stable at about 0.4 since the 1960s (Hout and Janus 2011). Such stability, however, is misleading because it is an average over various subgroups of family forms, each of which may have different correlations. If the trends differ by family forms, the growth of single-parent families has contributed a *composition* effect to the overall trend in intergenerational inequality by giving more weight to single-parent families in more recent years than in the past (e.g., Bloome 2014; Maralani 2013; Mare 1997; Musick and Mare 2004). In this case, a relatively stable overall correlation over time may have concealed substantial heterogeneity among subgroups with different family structures.

2.3 THEORETICAL FRAMEWORK

The theoretical framework of this paper juxtaposes two mechanisms through which family structure shapes the mobility trajectories of families: one that mediates *indirect* influences from grandparents to grandchildren through the parent generation and the other that modifies the *direct* influence of grandparents. Table 2.1 provides a summary of theoretical definitions, graphic illustrations, and representative work for the two mechanisms. Below, I illustrate these two mechanisms with examples from the previous literature.

Table 2.1

2.3.1 Family Structure: A Mediator in Social Mobility

Sociologists have long recognized the importance of family structure as a mediator in the intergenerational transmission of social status: Family structure serves as both a consequence of parents' educational attainment and a cause of children's educational success. On the one hand, single-parent families are more common among less educated parents than among better educated parents, because low socioeconomic status is positively associated with premarital birth, cohabitation, divorce, and living apart from one's children (Bumpass and Lu 2000; Raley and Bumpass 2003; Thornton, Axinn, and Xie 2008). On the other hand, growing up with a single parent may have adverse effects on children's educational outcomes later in life (Amato 2005; Aquilino 1996; Astone and McLanahan 1991; Biblarz and Raftery 1999; Duncan and Duncan 1969; Ginther and Pollak 2004; Kim 2011; McLanahan and Sandefur 1994; Sandefur and Wells 1999; Seltzer 1994). To further complicate the matter, the intervening role of family structure may further differ according to the timing of family disruption, the number of disruptions and remarriages, and the duration of different types of family forms (Furstenberg, Hoffman, and Shrestha 1995; Krein and Beller 1988; Wojtkiewicz 1993). As a result, family structure mediates the total effect of an individual's social origins on his or her social destinations, creating extra barriers for those who were born into low social status families but hope to achieve upward mobility.

There are several major explanations for the adverse effect of the single-parent family on children's educational outcomes. First, the economic deprivation explanation states that family disruption depletes economic resources available to children, not only because parents no longer pool resources but also because they often experience a job loss or slow income growth following divorce (Brand and Thomas 2014; Thomson, Hanson, and McLanahan 1994). The second major explanation suggests that family disruption often changes intergenerational relationships. Single parents, especially mothers who continue to live with their children after the family disruption, are often exposed to stressful circumstances, thus becoming less effective in terms of parenting styles, which in turn has a negative impact on children's academic performance (Amato 2005). Instead of focusing on the role of mothers, the third explanation stresses the consequences of the absence of fathers (Seltzer 1991) or "pathology of matriarchy" (Duncan and Duncan 1969). According to this view, the absence of fathers as role models in female-headed families affects the functioning of families, especially in children's socialization. Lastly, some research has weighed in with arguments about unobserved selection mechanisms—factors that influence both family disruption and children's educational outcomes, such as parental conflict and antecedent attitudes toward marriage and childrearing—that generate a spurious relationship between single parenthood and children's wellbeing (Fomby and Cherlin

2007; Sandefur and Wells 1999). Taken together, these explanations, however different they seem, deliver a highly consistent conclusion: single parenthood is negatively associated with children's life course outcomes, especially in terms of their educational attainment in adulthood (McLanahan et al. 2013).

The aforementioned mediating role of family structure for two-generation mobility may operate for three-generation mobility as well. On the one hand, family structure in the parent generation may intervene in the educational transmission from grandparents to parents to grandchildren, leading to disadvantages for children growing up in single-parent families to compound with generations. For example, compared to their two-parent counterparts, parents who grew up with a single parent are more likely to receive less education, become single parents themselves, and raise their children in ways similar to how they were raised themselves (McLanahan and Bumpass 1988; Seltzer 1994; Thornton 1991; Wolfinger 1999; Wu and Martinson 1993). Therefore, family structure mediates educational association between every two consecutive generations in a multigenerational process. On the other hand, grandparents' family structure may directly influence grandchildren's educational attainment as a consequence of a lingering effect of parents' adverse childhood circumstances (Sharkey and Elwert 2011; Wightman and Danziger 2014).

2.3.2 Family Structure: A Moderator in Social Mobility

The view of family structure as a mediator in the intergenerational transmission of social status from parents to offspring does not capture heterogeneity in the direct effect of parents on offspring across family forms. This paper examines whether family structure may also moderate the strength of association between the social status of parents and offspring regardless of whether the formation of family structure depends on parents' socioeconomic characteristics or not. From a two-generation perspective, only a handful of studies have documented the role of family structure as a moderator in the intergenerational mobility of occupational status (Biblarz and Raftery 1993, 1999; Biblarz, Raftery, and Bucur 1997), educational achievement (Martin 2012), and income (Björklund and Chadwick 2003). Conclusions from these studies concur that families with two biological parents facilitate the intergenerational transmission of socioeconomic status, resulting in a stronger parent effect in two-parent families than in alternative family forms. However, whether this conclusion can be extended to the case of three-generation mobility remains an open question. Results from the limited amount of research on this question are mixed. Below, I summarize previous empirical findings into three hypotheses based on their prediction about the relative strength of the grandparent effect in one-parent and two-parent families.

Stronger Grandparent Effects in Single-Parent Families. Family research characterizes typical grandparents in single-parent families as "rescuers" or "family stabilizers" who raise their grandchildren during episodes of need, in contrast to grandparents in two-parent families who visit their grandchildren regularly but provide limited services (Bengtson 2001; Hogan, Eggebeen, and Clogg 1993; Hunter and Taylor 1998). For example, less than 15 percent of elderly parents reside with their adult children and grandchildren (Ruggles 2007), but over half of divorced mothers and an even higher proportion of young, teenage mothers live in their parents' households (Bumpass and Raley 1995; Hogan, Hao and Parish 1990; Seltzer, Lau and Bianchi 2012). Family transitions into single parenthood often restructure grandparent-grandchild relationships, thrusting some grandparents into active caregiving roles. Many grandchildren develop a deeper relationship with one or more of their grandparents than they had with either set of grandparents prior to their parents' marital disruption (Cherlin and Furstenberg 1986: 148-164; Swartz 2009).

With respect to educational outcomes, while children exposed to single-parent families fare worse than do their two-parent counterparts (McLanahan and Sandefur 1994), the "latent safety net" provided by grandparents as well as other kin often attenuate the impact of family instability (Bengtson 2001). Many grandparents provide financial, emotional, and practical support to their grandchildren on a regular basis, or even become their custodians (Fuller-Thomson, Minkler, and Driver 1997; King and Elder 1997). Grandchildren may benefit from their grandparents' involvement, which compensates for diminished parental economic resources and helps them cope with stresses caused by parents' divorce or separation (Deleire and Kalil 2002; Denham and Smith 1989; Hayslip and Kaminski 2005). As a result, family crises may activate the grandparent effect, generating a greater resemblance in social status between grandparents and grandchildren in single-parent families than in two-parent families.

Stronger Grandparent Effects in Two-Parent Families. Most studies on grandparents in single-parent families tend to focus on support from maternal grandparents, but fail to emphasize diminished grandparental resources due to attenuated or broken paternal intergenerational ties following parents' divorce (Silverstein and Bengtson 1997). Because of intact kinship ties, grandchildren in two-parent families potentially get exposure to all four of their grandparents, in effect having access to a greater total amount of support. By contrast, grandchildren in single-parent families may drift apart from two of their grandparents, in some cases losing the support of the most helpful grandparents. In addition, the high involvement of maternal grandparents in single-parent families rarely exceeds three years, the average duration between the dissolution of the parental union and the formation of new households (Andersson 2002; Burton and Bengtson

1985), and thus may not have a long-term effect on the educational attainment of the grandchildren.

Even if the quantity of support provided by grandparents does not vary by family structure, the quality of support often does. Grandparents in two-parent families may invest more time and money in grandchildren's learning and education-related activities, whereas grandparents in single-parent families are often more involved in practical support such as helping with household chores, chauffeuring, and babysitting (Kaushal, Magnuson, and Waldfogel 2011; Sarkisian and Gerstel 2004). Intergenerational studies suggest that single parents spend less total and interactive time with their children on activities related to arts, sports, homework, and reading than do parents in two-parent homes (Asmussen and Larson 1991; Kendig and Bianchi 2008). Such observations may also apply to grandparenting styles in single-parent families, especially among younger, low-income grandparents who have to juggle work and childcare for their children and grandchildren (Hayslip and Kaminski 2005).

Furthermore, stronger grandparent effects in two-parent families may result from a selection mechanism: Unobserved family characteristics, such as more traditional cultural values, cohesive kinship relationships, and institutionalized family ties, may reduce the risk of divorce, nonmarital childbearing, or cohabitation, while at the same time facilitating children's educational performance. Hence, the stronger grandparent effect in two-parent families may result not from family structure per se but from these unobserved variables that sort families into different family forms.

No Variations in Grandparent Effects Across Family Structures. Beyond the aforementioned two hypotheses, it is also possible that the grandparent effect does not interact with family structures, such that the multigenerational persistence of educational status is the same across all family forms. Most studies on grandparenthood have suggested that the relationship between American grandparents and their grandchildren is enormously heterogeneous, ranging from extremely aloof to highly influential (Bengtson 1985; Casper and Bianchi 2001). Cherlin and Furstenberg (1986) characterized five grandparenting styles as detached, passive, supportive, authoritative and influential, but they found that none of these styles are dominant in the population. It is possible that grandparenting styles are independent of family structure so that single-parent and two-parent families are equally likely to have very influential or unimportant grandparents. Thus, on average, the grandparent effect on grandchildren within each type of family structure is similar.

2.3.3 The Role of Race

The relationship between family structure and educational mobility may also be intertwined with race (Fomby and Cherlin 2007; Maralani 2013). While the trends in educational attainment between African Americans and whites have converged since the 1960s, their family structures have diverged (Kao and Thompson 2003; Sweeney and Philips 2004). The proportion of children under 18 living with their mother only has increased faster for African American families, from around 20 percent in the 1960s to higher than 50 percent in the 2000s, as compared to an increase from less than 10 percent to 20 percent for whites.[1] The discrepancy is even more striking if single-father families and grandparent-headed families are also taken into account. Single-parent families have become a dominant family form among African Americans, and this partly explains trends in the perpetuation of poverty, lower education, and higher unemployment over generations (Duncan 1968; Wilson 2012).

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[1] Calculations based on data from U.S. Census Bureau, Decennial Census, 1960, and Current Population Survey, Annual Social and Economic Supplements, 1968 to 2013.

Previous social mobility studies have well documented that intergenerational inheritance of social status is stronger for whites than for African Americans (e.g., Blau and Duncan 1967: 207-227; Duncan 1968; Featherman and Hauser 1976; Hout 1984). Put differently, compared to whites, African American children are less likely to obtain the same level of education as their parents. The reasons behind this are multifaceted. The weaker parent effect among African Americans may result from the rapid increase in the upward educational mobility of African American families from the 1950s to the 1980s. It may also be attributed to the effectiveness of parenting skills within families or to social experiences, such as economic inequality, residential segregation, parental unemployment and incarceration, or discrimination in the educational system, that hinder African American parents from transmitting their educational status to offspring (Featherman and Hauser 1978: 329-334; Hout and Janus 2011). To address the potential three-way interactions among grandparent effects, family structure, and race, this study analyzes African Americans and whites separately. Stratifying the analysis by race helps identify the subpopulations in which the underlying heterogeneity of the grandparent effects is particularly significant.

2.4 DATA AND VARIABLES

2.4.1 Data

The analysis draws upon data from the Panel Study of Income Dynamics (PSID, 1968-2011), an ongoing longitudinal survey of roughly 5,000 American families (PSID Main Interview User Manual 2013). The PSID project started with over 18,000 individuals in 1968 and covered more than 70,000 individuals from 1968 to 2011. The project 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 households retain the PSID gene themselves and become permanent PSID respondents. [2] To create a multigenerational sample, I link PSID respondents from non-immigrant families with their parents and grandparents, based on their unique PSID interview ID. For most families, only one set of parents and grandparents (either paternal or maternal) are available, because PSID only follows family members of the original sample in 1968 and their progeny, but not spouses who later marry into a PSID household. To obtain more information about the grandparents, I rely on retrospective questions for the household heads and wives about their parents' educational information. However, if a grandchild was born outside of marriage and his or her parents lived in a PSID household together for less than one year, or if an individual's parents had a very short marriage, information for one parent, often the father, is likely to be missing. Therefore, the analytical sample includes more individuals with complete information for mothers and maternal grandparents than for fathers and paternal grandparents.[3]

The final analytical sample is restricted to grandchildren who are aged 25 to 65 years old in the most recent wave of the survey in 2011 and with nonmissing data on all education and family structure variables. The sample includes 1,409 African American and white families and

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[2] The PSID consists of several samples including the Survey Research Center (SRC) sample, the immigrant sample, the Census sample or Survey of Economic Opportunities (SEO) sample, and the Latino sample. Often, researchers need to adjust for unequal selection probabilities for these subsamples. However, due to missing cases in linking families across three generations, the weighting variable provided to adjust for these subsamples is no longer appropriate. To check the robustness of the results, I restricted my analysis to only families in the SRC sample, and the results are largely consistent with those reported here.

[3] Because there are less available grandparent observations in single-parent than in two-parent families, we may have a less accurate measure of the highest years of schooling among all grandparents in single-parent families. Thus, the results may suffer from a bias caused by measurement errors in the grandparent education variable, also known as the attenuation bias. I would like to thank an anonymous reviewer for pointing out this problem.

4,854 respondents in the grandchild generation. Missing data that arise from control variables, such as occupational status, home ownership, and family income in grandparent and parent generations, are replaced based on multiple imputation methods.[4]

2.4.2 Measures

Based on the causal inference literature on mediation, measures in longitudinal settings fall into four categories: exposures (*A*), mediators (*M*), covariates (*V*, *L*, and *C*, also known as confounders), and outcomes (*Y*), all of which can be time-varying or time-invariant. In the multigenerational mobility framework of this study, all measures are considered generation-varying or generation-invariant, while within-generation variation is ignored.[5] For example, the analytical framework illustrated in Figure 2.1 assumes that educational attainment is constant across the lifespan, but may vary across generations. Beyond a simple association of social status across generations, the causal framework in Figure 2.1 provides a dynamic description of processes that produce the association based on relationships among the four sets of variables.

Figure 2.1

The observed outcome variable Y_i is the education of individual i, a grandchild in generation 3, measured by years of schooling. For the sake of simplicity, i is omitted in all the

[4] The model results combine estimates and standard errors from 20 multiple imputed datasets to account for uncertainty associated with missing data. The missing cases account for less than 20% of the whole sample. Model estimates based on complete cases and multiple imputed datasets show similar results regarding the controlled direct effects of grandparents. The results are also robust to different imputation methods. The imputation method adopted in this study relies on multiple imputation chained equations with a predicted mean matching method for continuous variables such as occupational status and family income, and binary logistic model for dichotomous variables, such as home ownership and disability status. Other imputation methods, for example, the multivariate normal model with a truncated regression approach, show results similar to those reported in this paper.

[5] This assumption maximizes the number of cases used in the analysis because missing data occur in multiple measures of variables over time. This framework, however, can be easily extended to a more complex setting to analyze intragenerational and intergenerational mobility jointly.

following notations. Let $\bar{A}(2) = (A(1), A(2))$ denote the exposure variable, that is, individual i's family history of education, which is measured by the highest years of schooling among grandparents in generation 1 and the higher years of schooling between parents in generation 2, respectively.[6] If information for some grandparents or parents is missing, the years of schooling are measured among those whose information is available.

The history of childhood family structure $\bar{M}(2) = (M(1), M(2))$ is treated as a generation-varying mediator. The variable M measures types of family structure based on parents' marital status during a child's childhood at ages 0 to 18. If parents were married throughout a child's entire childhood, then family structure is coded as a two-parent family; otherwise, it would be a single-parent family. The single-parent family group consists of four subgroups: parents were unmarried throughout a child's entire childhood, parents were unmarried at birth but were married at a later point and thereafter during a child's childhood, parents were unmarried at a child's birth but were married and later divorced or separated, and parents were married at birth but subsequently divorced or separated. The analysis combines the first three subgroups of single-parent families, thus yielding three categories of family structure: one-parent families with unmarried parents, one-parent families with divorced parents, and two-parent intact families.

To define family structure across generations, $M(1)$ is treated as a single-parent family in generation 1 if either the father or the mother were raised in a single-parent household before he or she reached age 18. Only when both parents spent their entire childhood in two-parent

[6] For example, if a family has two grandparents whose information is available, then $X_{1,i}$ refers to the education of the grandparent with the higher level of education. I also experimented with using the average education rather than the highest education of parents and grandparents. The results align with those presented below, although the results are slightly less significant.

families, $M(1)$ is coded as a two-parent family. $M(2)$ refers to parents' family structure during the grandchild's childhood. To find out whether grandparents or parents were married during the parents' and grandchildren's childhoods, I resort to the retrospective marriage history file 1985-2011, which contains detailed information on the marriage timing and circumstances of all PSID respondents.[7]

Covariates refer to variables that are not the analytical focus of this study, but the omission of which may lead to biased estimates of exposures and mediators. I categorize these variables into three mutually exclusive groups. First, the baseline or time-invariant covariates V denote covariates that occur before the first exposure or that are transmitted across generations without any mobility, but possibly influence all subsequent exposures, mediators, and covariates. This study treats race as such a family-fixed variable, given the relatively few cases of interracial marriages (64 cases) in the analytical sample. [8]

Second, generation-varying covariates L denote variables that are affected by exposures or by both exposures and mediators and, in turn, confound the mediator-outcome or exposure-mediator relationship. In this study, covariates L include grandparents' and parents' family income, disability status, home ownership, and occupational status. Family income measures average total income from all family members over a child's ages 0 to 18 and is adjusted to 2011 dollars using the Consumer Price Index published by the Bureau of Labor Statistics. The dichotomous measure of disability status indicates the presence of physical disability or nervous

[7] Strictly speaking, the definition of family structure is based on parents' marital status, rather than living arrangements of children, because children in one-parent families may live with only grandparents, one single or divorced parent, or two cohabiting parents.
[8] The PSID only collected race of household heads and heads' wives in its household sample, but not for every individual in a household. For individuals who are neither household heads nor heads' wives, I assume their races are the same as those of the household heads. Given the low percentage of interracial marriages in the PSID, a robustness check shows no differences in results from those presented in the paper if individuals' races are defined by those of the household heads' wives.

disorders reported by the household head in the family. Home ownership is also a dichotomous measure indicating whether the family ever owned their home during an individual's childhood. Occupational status is the average socioeconomic index (SEI) scores of household heads and wives, which are converted from the 1970 and 2000 census 3-digit occupational codes (Frederick 2010).[9]

The third category of covariates is covariates *C*, which only influence the outcome variable *Y* but do not affect nor are affected by exposures and mediators. These variables include gender, age group in 2011, religion, and current residential region[10] of grandchildren. Strictly speaking, the omission of these variables will not affect whether the estimates of exposures and mediators are unbiased if they are only associated with the outcome variable. However, the inclusion of these variables can improve the efficiency of the estimation.

Some covariates that belong to either *V*, *L*, or *C* are omitted from the analysis because measures of these variables are not available in the PSID data or are available only for certain waves. For example, these variables include genetic traits, mental illness, social skills, drinking and drug use behaviors, domestic violence, incarceration, and attitudes toward marriage and nonmarital childbearing in each generation (Sandefur and Wells 1999). These variables are categorized into unobserved confounders *U* or *W*. The variable *U* represents variables that are only associated with covariates *L*, but not with exposures *A* and mediators *M*. For example, status

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[9] The crosswalk from 1970 census occupational codes to SEI is also known as the Duncan SEI index (http://www.ssc.wisc.edu/wlsresearch/documentation/appendices/E/memo122c.asc) (Hauser 1987). The crosswalk from 2000 census occupational codes to SEI is based on Hauser and Warren total SEI reported in Frederick (2010, Table 1).

[10] The PSID defines four regions, the region of Northeast includes Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. The North central includes Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. The South includes Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, Washington, D.C., and West Virginia. The West includes Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

of welfare receipt is related to education (*A*) only through family income (*L*). The variable *W* represents variables that are associated with exposures and mediators regardless of their association with *L*—for example, education-enhancing traits. I discuss assumptions about these unobserved variables in the next section.

2.5 METHODS

2.5.1 Definitions of Controlled Direct Effects

Building upon the path-analysis framework used in traditional mobility studies (e.g., Alwin and Hauser 1975; Duncan 1975; Featherman and Hauser 1976), the current analysis partitions the effect of grandparents' education into indirect effects and a net direct effect. While it is impossible to outline all indirect effects from grandparents to grandchildren, this study accounts for at least several important intervening factors that include grandparents' and parents' family structures, occupational status, income, home ownership, and disability status. The focus of this study, however, is not to assess these indirect effects, but grandparents' direct effect, especially across various types of family forms.

Compared to traditional path analysis, the recent development in causal inference provides a more general, yet rigorous way to define the direct effect based on counterfactual arguments and directed acyclic graphs (Pearl 2001). I first denote $Y_{\overline{am}}$ as the counterfactual outcomes or potential outcomes if a family's educational history $\bar{A}$ were set to $\bar{a}$ and if its family structure history $\bar{M}$ were set to $\bar{m}$. Assume that we increase grandparent's education from $a^*(1)$ to $a(1)$ and allow all future family changes to respond to this change. The direct effect of grandparents refers to the increase in grandchildren's education that is directly affected by this change, instead of being mediated by other associated changes in family structure, socioeconomic status, or other covariates. A formal definition of the controlled direct effect of grandparents is expressed as $CDE_{GP} = E\left[Y_{a(1),a(2),\bar{m}} - Y_{a^*(1),a(2),\bar{m}}\right]$ (see Sobel 2008; Wang and Sobel 2013 for more discussion about the definition).

The controlled direct effect is interpreted as the expected increase in the outcome Y as the exposure changes from $\left(a^*(1), a(2)\right)$ to $\left(a(1), a(2)\right)$, while the mediators are set to the pre-specified level $\bar{M} = \left(m(1), m(2)\right)$ uniformly over the entire population. The controlled direct effect may depend on values of $a(1)$ and $a^*(1)$ that we choose to compare and also on values to which we fix the mediators $\bar{m}$.[11] If the controlled direct effect of grandparents varies across types of family structure, we would observe the following inequality by comparing $\bar{M} = \left(m(1), m(2)\right)$ and $\bar{M}^* = \left(m^*(1), m^*(2)\right)$, in addition to many other possible comparisons.

$$CDE_{GP} - CDE'_{GP}$$
$$= E\left[Y_{a(1),m(1),a(2),m(2)} - Y_{a^*(1),m(1),a(2),m(2)}\right] - E\left[Y_{a(1),m^*(1),a(2),m^*(2)} - Y_{a^*(1),m^*(1),a(2),m^*(2)}\right] \neq 0$$

2.5.2 Assumptions

The causal direct effect of grandparents is identified under two assumptions (Pearl 2001; VanderWeele 2009). I formalize these assumptions in terms of counterfactual independence. These assumptions are encoded into the directed acyclic graph displayed in Figure 2.1.

(i) No unmeasured confounders for the exposure-outcome relationship.

$$Y_{\overline{am}} \coprod A(t) \mid V, \bar{A}(t-1), \bar{L}(t-1), \bar{M}(t-1), C$$

This assumption requires that all confounders of the association between the exposure A and the outcome Y are included in the model. When this assumption is violated, our estimates of

[11] Furthermore, the controlled direct effect may vary across levels of a(2), if grandparents' education A(1) interacts with parent's education A(2). Tests for model results in Table 5 show no evidence for such interactions in this study. Given that education is treated as a continuous variable, such interactions would also be hard to interpret.

$A(t)$ are biased because of potential selection bias caused by unobserved variables that are correlated with both the exposure and the outcome. Based on this assumption, the unobserved variables $W(1), W(3)$ that influence $A(1)$ and $A(2)$ need to be independent of Y.

(ii) No unmeasured confounders for the mediator-outcome relationship.

$$Y_{\overline{am}} \coprod M(t) \,|V, \bar{A}(t), \bar{L}(t), \bar{M}(t-1), C$$

This assumption requires that all confounders of the association between the mediators M and the outcome Y are included in the model. When assumption (ii) is violated, our estimates are subject to a collider bias because controlling for the mediators would lead to a spurious correlation between the exposure and the outcome due to the unobserved variables that are correlated with both the mediator and the outcome (but potentially not with the exposure) (Greenland, Pearl, and Robins 1999; Elwert and Winship 2014). For example, controlling for $M(1)$ would lead to an association between $A(1)$ and $W(2)$. If $W(2)$ is further correlated to Y, then our estimate of $A(1)$ would be biased. Therefore, according to assumption (ii), the unobserved variables W that influence M needs to be independent of Y.

2.5.3 Models

The analysis relies on the generalized linear mixed-effects model with random intercepts (Raudenbush and Bryk 2002), which accounts for clustering of respondents in generation 3 from the same family lineage. Let Y_{ij} be the ith respondent in generation 3 who is from family lineage j. The interactive model written in matrix notation is

Level 1 (Individual level):

$$Y_{ij} = \pi_{0j} + \bar{A}_{ij}\boldsymbol{\pi}_1 + \bar{M}_{ij}\boldsymbol{\pi}_2 + \bar{L}_{ij}\boldsymbol{\pi}_3 + V_{ij}\boldsymbol{\pi}_4 + C_{ij}\boldsymbol{\pi}_5 + \left(\bar{A}_{ij} \times \bar{M}_{ij}\right)\boldsymbol{\pi}_6 + \epsilon_{ij} \quad (1)$$

$$\epsilon_{ij} \sim N(0, \sigma^2) \;\; i.i.d \quad (2)$$

The variable $\bar{A}$ represents a family trajectory of $(A(1), \dots, A(t))$ (the same notation rule also applies to $\bar{M}$ and $\bar{L}$). Each of the coefficients $\boldsymbol{\pi}_p$ $(p = 1,2, \dots, 6)$ represents a set of regression coefficients for the corresponding variable. The errors, ϵ_{ij}, are assumed to be independent and homoscedastic.

Level 2 (Family lineage level):

$$\pi_{0j} \sim N(\pi_0, \sigma_u^2) \;\; i.i.d \text{ and } \epsilon_{ij} \coprod \pi_{0j} \tag{3}$$

To account for heterogeneity in educational attainment associated with families, I assume that each family lineage is independently and normally distributed with the same educational mean π_0 and (between-family) variance σ_u^2.

The interactive model provides estimates for the controlled direct effect of grandparents across types of family structure. To estimate the average controlled direct effect of grandparents, I rely on an additive model without the exposure-mediator interactions between $\bar{A}_{ij}$ and $\bar{M}_{ij}$ in the Level 1 equation. For practical reasons, the model omits all interactions between covariates and exposures or mediators, because they are not the focus of this study. A further model specification test reported in the Online Appendix Table 2G also suggests no mediator-mediator and exposure-exposure interactions.

In this traditional approach to mediation analysis, the control direct effect of grandparents on grandchildren can be expressed as follows (Alwin and Hauser 1975):

$$\begin{aligned} CDE_{gp}(\bar{m}) &= E\left[Y \middle| a(1), a(2), \bar{m}, \bar{l}, v, c\right] - E\left[Y \middle| a^*(1), a(2), \bar{m}, \bar{l}, v, c\right] \\ &= \left(\pi_1^{A(1)} + \pi_6^{A(1)*\bar{M}}\right)(a(1) - a^*(1)) \end{aligned} \tag{4}$$

2.5.4 Inverse Probability Treatment Weighting Estimation

The grandparent effect estimated from the aforementioned regression approach, however, does not necessarily provide a causal interpretation. Recent causal inference literature has formalized assumptions for confounding control and generalized equation (4) to counterfactual-based effects that can be estimated from statistical methods. Yet even if these assumptions, as we discuss in the prior section, are satisfied, standard regression models may not provide unbiased estimates of grandparent effects in a longitudinal setting with complex time-varying confounding. For example, to estimate the effect of $A(1)$ on Y, we have to control for $L(1)$; otherwise, the unobserved variable $U(1)$ would be associated with both $M(1)$ and Y, and assumption (ii) is violated. But controlling for $L(1)$ causes another problem: a spurious association between $A(1)$ and $U(1)$ emerges because $L(1)$ is a collider in the paths $A(1) \rightarrow L(1) \leftarrow U(1)$, and therefore assumption (i) is violated due to this "collider-bias" (Elwert and Winship 2014).

A weighting technique provides an alternative approach to estimate controlled direct effects in longitudinal settings (VanderWeele 2015: 153-168). Instead of regression adjustment, time-varying covariates $\bar{L}$ are controlled for by inverse probability treatment weighting in the final regression model. The overall weight for the grandchild i is

$$w_i = \prod_{t=1}^{T} w_i^A(t) \times \prod_{t=1}^{T} w_i^M(t)$$

where the exposure weight at time t, $w_i^A(t) = \frac{P(A(t)=a_i(t)|\bar{a}_i(t-1),\bar{m}_i(t-1),v)}{P(A(t)=a_i(t)|\bar{a}_i(t-1),\bar{m}_i(t-1),\bar{l}_i(t-1),v)}$, and the mediator weight at time t, $w_i^M(t) = \frac{P(M(t)=m_i(t)|\bar{a}_i(t),\bar{m}_i(t-1),v)}{P(M(t)=m_i(t)|\bar{a}_i(t),\bar{m}_i(t-1),\bar{l}_i(t),v)}$. In particular, $w_i^A(1) = 1$. These probabilities are estimated by multinomial logistic models for the exposures and mediators. This weighting scheme requires that we include the baseline variable V and covariates

C of generation 3 (but not the generation-varying covariates $\bar{L}$) into the final model as specified in equations (1) to (3). The final model is also known as a marginal structural model (MSM) because after the weighting, conditional distributions of the exposures and mediators no longer depend on the time-varying covariates (Robins and Hernán 2009; VanderWeele 2009, 2015). Online Appendix Table 2A shows a summary of these longitudinal stabilized inverse probabilities of treatment weights.

Note that the model assumptions illustrated above and also illustrated in Figure 2.1 include no restrictions on the relationship between parents' and grandparents' unobserved characteristics U—such as mental health, drinking and drug use behaviors—and their socioeconomic characteristics L. These unobserved variables often cause problems in conventional regression analyses, and previous studies have resorted to different analytical strategies—for example, fixed-effect models (Cherlin, Chase-Lansdale, and McRae 1998) and bivariate probit analysis (Astone and McLanahan 1991)—to either eliminate these unobserved variables if they are time-invariant or incorporate correlations among these variables into the model assumptions. In this study, these unobserved variables have no impact on our estimates of the grandparent effects after we reweight the sample by the inverse probability weight and fit the data with marginal structural models.

2.6 RESULTS

2.6.1 Sample Characteristics

Table 2.2 provides a detailed description of distributions of family structure in the analytical sample. The descriptive statistics suggest that most African Americans and whites in the parent generation grew up in traditional two-parent families. However, single-parent families, especially those with unmarried parents have become the prevailing family structure in the grandchild generation for African Americans, but not for whites.[12] Table 2.3 summarizes the full sample characteristics by generation and race for all variables used in the analysis. On average, African American families are disadvantaged in their educational attainments and other socioeconomic indicators compared to those of whites in each generation. While the educational gap between African American and white families from the parent to the grandchild generation indicates a converging trend, their family structures have diverged. The proportion of single-parent families has increased faster for African American families, from around 30 percent of parents growing up in single-parent families to 66 percent in the grandchild generation, compared to an increase from 16 percent to 35 percent for whites.

Table 2.2

Table 2.3

Table 2.4 displays the link between grandchildren's average years of schooling and types of family structure. The results suggest several distinct disparities. First, years of schooling are the highest among grandchildren who are raised in two-parent families, followed by those from divorced families, and the lowest among those from nonmarital birth. Second, family structure cannot explain away all racial disparities in education presented in Table 2.3, in that the educational advantages of whites still prevail, even within the same type of family structure. Third, intact family structures in two consecutive generations engender cumulative advantages to grandchildren's educational attainment, as compared to families that maintain only one

[12] I do not build duration into the definition of family structure because of substantial missing cases in the variables of parents' years of marriage and divorce. Future studies with more complete data may help unpack the role of duration in each kind of family structure.

generation of family intactness. If both grandchildren and their parents grow up in two-parent families, the grandchildren receive, on average, 13.9 years of schooling for whites and 13.1 years for African Americans, the levels of education that are the highest among all types of family structures. The Online Appendix Table 2B provides educational distributions by race and family structures for the parent and grandparent generations.

Table 2.4

2.6.2 Average Direct Effect of Grandparents

Table 2.5 presents model estimates for the direct effect of grandparents on grandchildren, based on both conventional hierarchical linear models and marginal structural models using inverse probability treatment weights. The additive models test the Markovian assumption about the grandparent effect, that is, whether grandparents' education has a direct effect on grandchildren's education. Overall, the regular and the weighted estimates suggest that both parents and grandparents can transmit appreciable educational advantages to their grandchildren among both African Americans and whites. The average parent effect is significantly greater for white families than for African American families (CDE_p = 0.354 versus 0.230). This result aligns with findings from previous studies on racial patterns in two-generation mobility, which suggests that African Americans are less likely to transmit their socioeconomic statuses across generations (Duncan 1968; Featherman and Hauser 1978; Hout 1984; Hauser et al. 2000).

Table 2.5

Compared to the effect of parents' education, the direct effect of grandparents' education is weaker. The amount of the grandparent effect is only one-fifth that of the parent effect. An interpretation of the result is that each one-year difference in grandparents' education translates into only 0.04 year difference in grandchildren's education for African Americans and 0.07 year difference for whites, everything else being equal. Because of the overlap of confidence intervals, racial differences in grandparent effects are not statistically significant. While the results reject a Markovian explanation for the absence of grandparent effects on grandchildren for both races, the direct effect of grandparents is very small compared to the direct effect of parents as well as various indirect effects of grandparents that are mediated by parents' family structure and education.

The coefficients for childhood family structure experienced by parents and grandchildren (M_1 and M_2) reflect that family structure may have a bigger impact on white grandchildren than on African American grandchildren. African American grandchildren's years of education are associated with only their own childhood family structures, but not those of their parents, whereas for whites, family structure experienced by parents during their childhood has a legacy effect on children's educational attainment. Everything else being equal, white grandchildren who themselves or whose parents grew up with divorced or unmarried parents receive roughly 0.5 years less education than their two-parent counterparts. These patterns confirm earlier findings from two-generation studies showing that educational deficits associated with single parenthood are more pronounced for white than for African American children (Amato 2005; McLanahan and Sandefur 1994). As discussed earlier, the coefficients of parents' and grandparents' education and family structure have causal interpretations only when the model assumptions about independence of unobserved variables U remain valid.

2.6.3 Variation in Grandparent Effects Across Types of Family Structure

The interactive models in Table 2.6 show variations in grandparent effects by family structure. Overall, the direct effect of grandparents' education on grandchildren's education varies markedly across types of childhood family structure experienced by grandchildren but not systematically by childhood family structure experienced by their parents. Specifically, grandparents play a much more influential role in grandchildren's education in two-parent families than in families with divorced parents, and especially families with unmarried parents, as suggested by the interaction coefficient between grandparents' education and grandchildren's family structure ($A \times M_2$). The results hold for both racial groups but are especially striking for African Americans.

Table 2.6

Figure 2.2

Figure 2.2 shows a diversity of grandparent effects by the types of family structure and racial group, based on estimates from Table 2.6. Given the small number of single-parent families in the grandparent generation and the insignificant effect of interactions between grandparents' family structure and education, the figure presents grandparent effects by varying only parents' family structure. The graph reveals several sets of findings that are not evident from coefficients in Table 2.6. First, three-generation mobility is non-Markovian among two-parent families but Markovian among families with children born to unmarried parents for both racial groups. The estimated grandparent effect in families with divorced parents is close to that of families with unmarried parents for African Americans, but close to that of two-parent families for whites.

Second, while the average parent and grandparent effects are both weaker among African Americans than among whites, the grandparent effect is particularly strong among African American families that have preserved intactness for two generations: The coefficient of the effect, 0.13, is over half as large as the parent effect, 0.23. Yet such intact families constitute only 23.8 percent of African American families (see Table 2.4). For the majority, namely families that experienced divorced or nonmarital birth in the grandchild generation but were intact in the parent generation, the grandparent effect is negligible. Grandparent effects across the types of family structure exhibit a similar, though less pronounced, trend for whites if we only focus on the point estimates. A further statistical test, however, suggests no significant variations by race.

Third, we observe more variation in grandparent effects by family structure among African Americans than among whites. One possible explanation is that two-parent families are a more selective group among African Americans, resulting in a bigger contrast between two-parent and single-parent families among African Americans than whites. However, that a large proportion of confidence intervals of these estimates overlap indicates statistically insignificant differences among these effects by race. In the online appendix, I further supplement the analyses with a sensitivity analysis that shows the extent to which the causal argument is still valid when some assumptions are violated. Overall, the sensitivity analysis indicates that the magnitude of the intergenerational transmission of the unobserved variables (namely $W_{(t)}$ in Figure 2.1), if there is any, would have to be very large to alter our inferences about the causal effect of grandparents' education on grandchildren's education.

2.7 DISCUSSION

Using multigenerational data from the Panel Study of Income Dynamics, this study tests whether the direct effect of grandparents' education on grandchildren's education varies across types of family structures. The analysis reveals two principal findings. First, consistent with several recent studies, the results suggest a non-Markovian mechanism of grandparent effects—that is, grandparents' education directly influences their grandchildren's educational attainments—for all families as a whole and for both African American and white families respectively. This finding also implies that even if grandparents fail to pass on their social status to the parents, they can extend their influence and contribute to the status attainment of their grandchildren. Consequently, families with both well-educated parents and grandparents create cumulative advantages for the grandchildren to succeed in school, whereas families with undereducated parents and grandparents are likely to be trapped in a vicious cycle.

In contrast to most studies that separate the formation of family structure from social mobility, the second principal finding reveals substantial heterogeneity in the grandparent effect associated with diverse household structures. Specifically, families that have maintained intactness in family structure also maintain a high degree of similarity in education across generations. The disparities of grandparent effects across family forms are especially evident for African Americans. The stronger grandparent effect in two-parent families may be attributed to explanations such as grandparents setting up trust funds for grandchildren's education (Aldous 1995), providing practical or monetary support that fosters a better learning environment, offering advice and discussing grandchildren's academic problems (Cherlin and Furstenberg 1986), serving as role models, monitoring grandchildren's school progress (DeLeire and Kalil 2002), and improving grandchildren's educational prospects through the college admission legacy system (Karabel 2005). Additionally, grandparents' roles can be simply symbolic—the importance of grandparents may not lie in their actions but in "their presence and what they mean for a family" (Bengtson 1985). Some of these mechanisms involve intergenerational contact, interactions, and coresidence and thus are contingent on the survival of grandparents; others may operate through social institutions and thus transcend individual lives. However, the focus of this paper is not to delineate and evaluate these mechanisms but to quantify the grandparent effect; therefore, I consider the aforementioned explanations for my results as merely speculative.

Several limitations of the present study are worth noting. First, my results regarding the non-Markovian mobility pattern may arise from grandparents' and parents' uncontrolled characteristics. In dealing with these uncontrolled characteristics, this paper assumes that they are independent, albeit not very likely, of variables that are included in the analysis based on the two assumptions laid out in the paper. For example, parents' personal characteristics, such as commitment to marriage and family, may simultaneously influence family structure during grandchildren's childhoods and grandchildren's educational attainment. Some previous research based on two-generation studies has provided discussions on how to revise these assumptions (e.g., Manski et al. 1992; McLanahan et al. 2013). A true causal effect of grandparents always depends on our assumptions or beliefs about social processes that generate associations across generations. Future research may help test the validity of the results presented in this paper by directly measuring the intergenerational transmission of these unobserved variables.

Furthermore, the definition of grandparent effects does not take into account many factors that may complicate the estimates of grandparent effects, such as grandparents' ages (Silverstein and Marenco 2001), number of living grandparents, family tradition of grandparent-grandchild relationships (King and Elder 1997), living arrangements (Dunifon and Kowaleski-Jones 2007), rural residence (King and Elder 1995), and geographic proximity of grandparents and grandchildren (Cherlin and Furstenberg 1986), as well as the ages of grandchildren when their parents separated or divorced. Likewise, our estimates of grandparent effects may further depend on our definition of families' social advantages. For example, the strength and patterns of grandparent effects may vary by dimensions of social status, ranging from "stocks" of social advantages such as businesses, lands, or estates, to "flows" of advantages such as income, education and occupational position (Mare 2011; Pfeffer 2014). Grandparent effects may vary within families as well, in that the cultural norms of family division of labor by gender and the gender-specific mobility opportunities in a society may be conducive to stronger effects of some grandparents relative to others and unequal mobility outcomes for grandsons and granddaughters (Coall and Hertwig 2010; Uhlenberg and Hammill 1998).

Given the relatively small sample size and its related statistical power, this paper cannot investigate temporal trends in grandparent effects. The analysis only provides a snapshot of grandparent effects by pooling all respondents and their parents and grandparents in the PSID. Therefore, strictly speaking, we cannot establish a causal relationship between demographic changes in declining mortality and growing family complexity and the increasing importance of grandparents over time. The substantial heterogeneity in grandparent effects associated with family structure may result from increasing grandparent effects in two-parent families, or from a composition change. Several studies have illustrated the later point: As the number of single-parent families grows in a population (Bloome 2014; Musick and Mare 2004), the association between grandparent effects and family structure eventually becomes detectable. Future multigenerational data that permit an analysis of the temporal trend in grandparent effects will help adjudicate between these two possible explanations.

Finally, the results may suffer from bias caused by missing data on grandparents' information. Due to the structure of the PSID sampling design, we were unable to observe all four grandparents for all families; for most families only data on paternal or maternal grandparents are available because only one parent carries the PSID sample "gene." Based on the assumption that observations of grandfathers and grandmothers, as well as paternal and maternal grandparents, are completely missing at random, results presented in the supplemental file parcel out influences of different sets of grandparents. Overall, we observe little difference between the average effects of paternal and maternal grandparents or between grandfathers and grandmothers in Table 2C. The results confirm Cherlin and Furstenberg's (1986: 123-127) findings that grandfathers and grandmothers are almost equally likely to visit their grandchildren, act like parents, and exchange services, *ceteris paribus*, although grandfathers may specialize in "task-oriented, instrumental family roles," whereas grandmothers' roles are more expressive, nurturant, and related to "kin-keeping." However, variations in the effects across family structures presented in Table 2D are mostly associated with maternal grandparents and grandmothers, especially among African Americans. This finding indicates that some sets of grandparents may behave differently in one- and two-parent families. Given that the missing at random assumption may be violated, I consider these supplementary results to be tentative. A refined analysis would require data that follow both paternal and maternal sides of all families over generations.

American families are in transition, as are grandparents' roles in grandchildren's lives. Results from this study suggest that the formation of single-parent families due to recent trends in divorce, remarriage, and premarital and multipartner fertility has altered socioeconomic similarities between biological grandparents and grandchildren. Yet another parallel trend is the growth in the percentage of grandparents who are step-grandparents (Yahirun and Seltzer 2014). So far, we know little about the roles of step-grandparents—whether they supplement or replace the roles of biological kindred. The collective role of kin networks, rather than parents and grandparents alone, may contribute to persistent inequalities among families across generations.

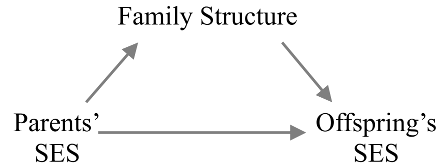
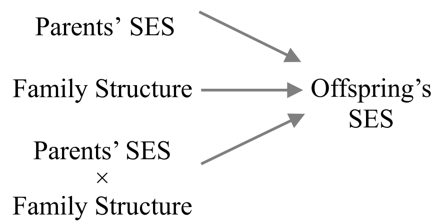
2.8 CONCLUSION

In a population, major changes in family organization may beget changes in social stratification (Bengtson 2001). For example, changes in the increasing life expectancy of grandparents and the declining prevalence of two-parent families may have far-reaching consequences for how families create, reproduce, and potentially change their social standing over generations. Along with several recent studies (e.g., Chan and Boliver 2013; Hertel and Groh-Samberg 2014; Zeng and Xie 2014), this study shows the importance of grandparents' roles in grandchildren's social attainment—an opposing view to the Markovian assumption in social mobility. Nonetheless, this study further points out that the decline in two-parent families also has generated more American children who now live in families where the grandparent effect in the transmission of social status is weak. In short, these two competing demographic forces jointly drive the evolution of multigenerational social mobility patterns.

Within families, generations are connected not only by social status but also by demographic behaviors (Lam 1986; Maralani 2013; Mare 1997; Mare and Maralani 2006; Matras 1961, 1967; Preston 1974; Preston and Campbell 1993). As illustrated in this paper, the formation of family structures mediates the association between the socioeconomic statuses of parents and offspring, serving as a mechanism to reproduce class disparities. But more importantly, family disruption and reconstitution also modify status connections across generations, placing children born into different types of family structures on different mobility trajectories. Clearly, the family structures investigated in the present study represent only one form of parents' and grandparents' demographic behaviors; other factors such as living arrangements, assortative mating, family size, longevity, adoption, migration, and the timing of these events may all influence the strength of intergenerational resemblance in social status across multiple generations. Additionally, socioeconomic standing and demographic behaviors of individuals within the same nuclear family as well as within a wider network of kin may be intertwined (Mare 2015), leading to a spillover effect or a social contagion phenomena that is often treated as a nuisance in traditional studies of social mobility but may pose a threat to our mobility estimates when a causal interpretation is desired (Hong 2015; Manski 2013). All these demographic complications bear implications for the ramification of social mobility trajectories of families and present challenges for future research.

At the individual level, sociologists have long been intrigued by the question of who gets ahead in social mobility (Jencks et al. 1979). As Hout (2015) points out, however, what we should really be concerned about is "how the conditions and circumstances of early life constrain adult success" rather than "who is moving up." In the face of demographic changes, this appeal requires us to expand the set of factors by which traditional social mobility studies define individuals' social origins. Family structure and grandparents' socioeconomic characteristics are two of these factors that have not been included in most social mobility studies because of their marginal significance in the stratification process until recently. Building on these prior studies, this paper takes a further step in showing that the interaction of these two factors also matters. Still, many other factors that were once considered to be making limited or redundant contributions to individuals' social origins may now independently or interactively determine individuals' social destinations. Investigating such factors as the roles of nonresident parents, stepparents and grandparents, other biological or nonbiological kin, great-grandparents and beyond, will further reveal how demography restructures social mobility processes.

Table 2.1. Summary of the Two Mechanisms Through Which Family Structure Shapes the Mobility Trajectories of Families

The Role of Family Structure	Conceptual Interpretation [a]	A Graphic Illustration	Exemplary Work based on Two-Generation Mobility	Focus of the Present Study?
Mediator	In the classic causal mediation theory, a mediator is a third variables that accounts for the relation between an independent variable and a dependent variable.		e.g., Duncan and Duncan (1969); McLanahan and Sandefur (1994)	No
Moderator	A moderator is a third variable that "affects the direction and/or strength of the relation" between an independent variable and a dependent variable.		e.g., Biblarz and Raftery (1993), Martin (2012)	Yes

Notes: [a] Definitions provided by Baron and Kenny (1986).

Table 2.2. Definitions of Family Structures by Parents' Marital Status (Unmarried, Married, Divorced/Separated/Widowed) Throughout Offspring's Childhood at Ages 0-18

Types of family structure		Parents' marital status when a child is at		Percent in G2			Percent in G3		
		Birth	Age 1-18	All	African Americans	Whites	All	African Americans	Whites
(1a)	One-parent, unmarried	Unmarried	Unmarried	2.5	4.8	0.4	11.2	22.0	1.3
(1b)	One-parent, unmarried	Unmarried	Married	1.1	1.6	0.8	5.6	9.1	2.5
(1c)	One-parent, unmarried	Unmarried	Divorced/separated/ widowed/remarried	1.1	1.6	0.8	7.0	11.6	2.8
(2)	One-parent, divorced	Married	Divorced/separated/ widowed/remarried	18.2	22.0	14.6	26.3	23.7	28.7
(3)	Two-parent, intact	Married	Married	77.1	70.1	83.5	49.9	33.7	64.6
Total (Observations)				100 (4,854)	100 (2,317)	100 (2,537)	100 (4,854)	100 (2,317)	100 (2,537)

Data sources: Multigenerational linked data from Panel Study of Income Dynamics (PSID), 1968-2011.
Notes: G2 and G3 refers to parents in generation 2 and grandchildren in generation 3 in the multigenerational sample, respectively. The sample is restricted to grandchildren in G3 who are aged between 25 and 54. As the subsample of other racial and ethnic groups, such as Native Americans and Asians, are underrepresented in the PSID data (< 3 percent), they are combined with whites into a single group. Parents' marital status can be more complicated than as it is presented above. For example, we can further differentiate between unmarried parents by their cohabitating status. Parents who are divorced, separated, or widowed may remarry, cohabit with a partner, or stay single, and among those parents with new partners, they may have children with their new partner, they may live with children from previous relationships, or their new partners may bring children from their previous relationships to the household. Moreover, we can define marital statuses for fathers and mothers separately. Overall, the definition of family structure is based on parents' marital statuses during the childhood of a specific child, whereas parents' marital histories before the birth of the child are ignored. Results from such a "child-based" classification scheme may be inconsistent with those from a "family-based" classification, in which family structures experienced by all children are considered (Ginther and Pollak 2004). Strictly speaking, children growing up with two biological parents who have no other children from previous relationships may experience different grandparent effects from children growing up in blended families in which one or both biological parents have children from previous relationships

Table 2.3. Sample Characteristics by Generation and Race

Variables	Mean (S.D)		
	All	African Americans	Whites
Grandparents, generation 1			
Grandparents' highest years of schooling	10.6 (3.3)	9.5 (3.1)	11.6 (3.2)
Family structure during G2's childhood			
% One-parent families, unmarried parents	4.8	7.9	1.9
% One-parent families, divorced parents	18.2	22.0	14.6
% Two-parent families	77.1	70.1	83.5
Disability	30.4	36.8	24.4
Occupational status (socioeconomic index)	28.4 (20.6)	18.0 (11.6)	37.8 (22.4)
Own home	67.8	52.6	81.7
Average family income during G2's childhood	53,383 (36,407)	35,047 (18,867)	70,128 (40,296)
Parents, generation 2			
Parents' highest years of schooling	13.1 (2.3)	12.5 (2.1)	13.7 (2.4)
Family structure during G3's childhood			
% One-parent families, unmarried parents	23.8	42.6	6.6
% One-parent families, divorced parents	26.3	23.7	28.7
% Two-parent families	49.9	33.7	64.6
Disability	48.0	54.0	42.5
Occupational status (socioeconomic index)	34.3 (19.1)	27.3 (14.9)	40.7 (20.3)
Own home	81.5	70.7	91.5
Average family income during G3's childhood	61,778 (145,325)	40,071 (25,240)	81,601 (197,508)
Grandchild, generation 3			
Years of schooling	13.0 (2.2)	12.5 (2.1)	13.4 (2.2)
% Male	50.7	51.3	50.2
Age in 2011			
% 25-34	54.6	49.5	59.2
% 35-44	36.5	38.2	34.9
% 45-54	6.4	8.9	4.1
% 55-65	2.5	3.4	1.7
Region			
% Northeast	13.1	5.7	19.8
% North central	23.4	16.4	29.8
% South	50.3	71.6	30.8
% West	13.3	6.4	19.6
Religion			
% Catholic	17.3	6.1	27.4
% Jewish	1.4	0.3	2.4
% Protestant	75.4	89.5	62.6

% Others	5.9	4.1	7.6
Number of family lineages	1,409	571	838
Number of observations	4,854	2,317	2,537

Data sources: Multigenerational linked data from Panel Study of Income Dynamics (PSID), 1968-2011.
Notes: Figures in parentheses are standard deviations for continuous variables. The income data have been adjusted to the level of year 2011 based on consumer price index (CPI) to account for the inflation that occurs over time. The analytical sample is restricted to data with complete cases in variables of grandparents' and parents' education, family structure, and grandchildren's education. Multiple imputation replaces missing data in variables of disability, occupational status, family income, and homeownership in grandparent and parent generations. None of the other variables in the model have missing data. The model results combine estimates and standard errors from 20 multiple imputed datasets to account for uncertainty associated with missing data. The missing cases account for around 20% of the whole sample. The descriptive statistics are calculated based on data from the first imputed dataset. Given the small number of families with mixed race, $n = 64$, they are included into the African American sample.

Table 2.4. Educational Attainment of Grandchildren by Multigenerational Types of Family Structure

	Grandchildren's Years of Schooling: Mean (S.D)								
	Family structure in G1			Family structure in G2			Family structure in both G1 and G2		
	Unmarried	Divorced	2-parent	Unmarried	Divorced	2-parent	Unmarried	Divorced	2-parent
Full Sample	12.7	12.6	13.1	12.1	12.7	13.6	12.6	12.5	13.7
	(2.1)	(2.1)	(2.2)	(1.9)	(2.1)	(2.2)	(1.8)	(1.9)	(2.2)
N	231	881	3,742	1,156	1,278	2,420	113	218	1,951
Percent, %	4.8	18.1	77.1	23.8	26.3	49.9	2.3	4.5	40.2
African Americans	12.6	12.4	12.5	12.1	12.4	13.0	12.5	12.4	13.1
	(2.0)	(2.1)	(2.1)	(1.9)	(2.0)	(2.2)	(1.8)	(1.9)	(2.2)
N	183	510	1,624	988	549	780	102	102	552
Percent, %	7.9	22.0	70.1	42.6	23.7	33.7	4.4	4.4	23.8
Whites	13.0	12.9	13.5	12.0	12.9	13.8	12.6	12.6	13.9
	(2.1)	(2.1)	(2.3)	(2.1)	(2.1)	(2.2)	(1.9)	(2.0)	(2.2)
N	48	371	2,118	168	729	1,640	11	116	1,399
Percent, %	18.9	14.6	83.5	6.6	28.7	64.6	0.4	4.6	55.1

Data sources: Multigenerational linked data from Panel Study of Income Dynamics (PSID), 1968-2011.
Notes: For the sake of simplicity, the figures are calculated based on data from the first imputed dataset. The statistics are similar for the other 19 imputed samples. When presenting the joint distribution of family structure in both G1 and G2, the table omits all categories except for those that have the same structure in G1 and G2, namely both unmarried, divorced, and 2-parent.

Table 2.5. Additive Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education based on Generalized Linear Mixed-Effects Models with Random Intercepts (Regular) and Marginal Structural Models (MSM)

	Full Sample		African Americans		Whites	
	Regular	MSM	Regular	MSM	Regular	MSM
Grandparents, generation 1						
Years of schooling (A_1)	0.026†	0.063***	0.028	0.043*	0.025	0.069***
	(0.013)	(0.012)	(0.018)	(0.017)	(0.019)	(0.017)
Family structure (M_1) (reference: two-parent)						
One-parent, divorced	-0.222**	-0.358***	-0.098	-0.188	-0.330**	-0.493***
	(0.085)	(0.094)	(0.113)	(0.135)	(0.125)	(0.127)
One-parent, unmarried	0.250†	0.116	0.289	0.213	0.303	0.059
	(0.149)	(0.167)	(0.170)	(0.191)	(0.297)	(0.325)
Parents, generation 2						
Years of schooling (A_2)	0.247***	0.296***	0.178***	0.230***	0.294***	0.354***
	(0.017)	(0.018)	(0.025)	(0.027)	(0.024)	(0.024)
Family structure (M_2) (reference: two-parent)						
One-parent, divorced	-0.502***	-0.520***	-0.411***	-0.575***	-0.418***	-0.427***
	(0.070)	(0.076)	(0.116)	(0.116)	(0.090)	(0.103)
One-parent, unmarried	-0.519***	-0.569***	-0.406***	-0.605***	-0.539***	-0.612***
	(0.083)	(0.091)	(0.107)	(0.109)	(0.162)	(0.171)
Number of family lineages	1,409	1,409	571	571	838	838
Number of observations	4,854	4,854	2,317	2,317	2,537	2,537

Data sources: Multigenerational linked data from Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in parentheses are robust standard errors from 20 imputed samples. $p† < .1$, $p^* < .05$, $p^{**} < .01$, $p^{***} < .001$ (two-tailed tests). Coefficients of control variables including grandparents' and parents' disability status, occupational status, family income, and homeownership as well as grandchildren's age groups, sex, region, and religion are not presented in the table. Full model results are presented in the Online Appendix Table 2E.

Table 2.6. Interactive Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education by Family Structures across Generations based on Generalized Linear Mixed-Effects Models with Random Intercepts (Regular) and Marginal Structural Models (MSM)

	Full Sample		African Americans		Whites	
	Regular	MSM	Regular	MSM	Regular	MSM
Grandparents, generation 1						
Years of schooling (A_1)	0.063***	0.098***	0.112***	0.134***	0.040†	0.082***
	(0.018)	(0.019)	(0.030)	(0.033)	(0.024)	(0.025)
A_1 × Family structure in G1 (M_1) (reference: two-parent)						
One-parent, divorced	-0.020	-0.038	-0.041	-0.063	0.012	0.009
	(0.029)	(0.030)	(0.037)	(0.042)	(0.046)	(0.053)
One-parent, unmarried	0.026	0.014	0.031	0.028	-0.015	-0.031
	(0.044)	(0.048)	(0.055)	(0.062)	(0.070)	(0.073)
A_1 × Family structure in G2 (M_2) (reference: two-parent)						
One-parent, divorced	-0.042†	-0.040	-0.100**	-0.102*	-0.020	-0.019
	(0.022)	(0.025)	(0.036)	(0.041)	(0.030)	(0.036)
One-parent, unmarried	-0.089***	-0.096***	-0.118***	-0.123***	-0.099*	-0.107*
	(0.025)	(0.029)	(0.033)	(0.038)	(0.050)	(0.054)
Number of family lineages	1,409	1,409	571	571	838	838
Number of observations	4,854	4,854	2,317	2,317	2,537	2,537

Data sources: Multigenerational linked data from Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in parentheses are robust standard errors. *p*† < .1, *p** < .05, *p*** < .01, *p**** < .001 (two-tailed tests). Coefficients of main effects of parents' family structure and education as well as interactions between parents' education and family structure in G1 and G2 are omitted from the table. Coefficients of control variables including grandparents' and parents' disability status, occupational status, family income, and homeownership as well as grandchildren's age groups, sex, region, and religion are not presented in the table. Full model results are presented in the Online Appendix Table 2F.

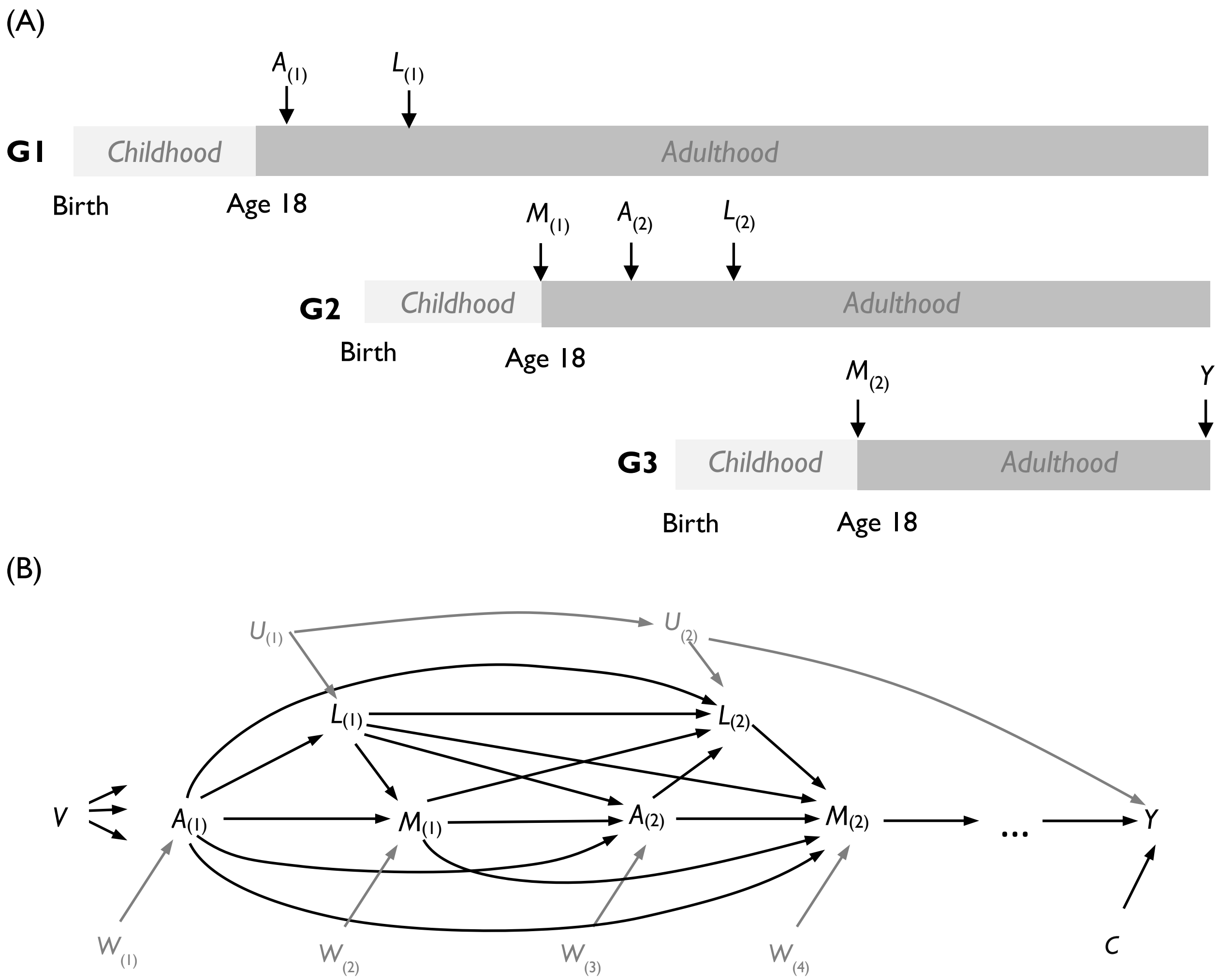


Figure 2.1. Temporal Ordering of Measures and a Hypothetical Causal Framework of Multigenerational Social Mobility

Notes: $A_{(1)}$ = G1's educational attainment, $M_{(1)}$ = family structure in G1 during G2' childhood, $L_{(1)}$ = socioeconomic characteristics, such as family income, occupational status, home ownership, and disability status in G1 during G2' childhood, $A_{(2)}$ = G2' education, $M_{(2)}$ = family structure in G2 during G3's childhood, U, W = unmeasured variables, Y = G3's educational attainment. C = exogenous variables that influence Y, such as gender and age group. V = family invariant variables, such as race. Part (A) shows time points at which each variable is measured during a person's lifetime in a multigenerational framework. Part (B) shows the hypothetical causal relationship among variables. The order of these variable measurements in the timeline indicates the direction of causal effect. Relationships among variables are encoded in the directed acyclic graph (DAG) above. For the sake of simplicity, the graph omits all the arrows pointing from $A_{(t)}$, $L_{(t)}$, $M_{(t)}$ to Y. According to the causal assumptions, the errors of $W_{(t)}$ can be associated with each other, but have to be independent of Y. The causal framework omits all intermediate variables between family structure and offspring's education, such as parenting behaviors, parent-child relationship, and parental investment in their children's education, so that effects of all these variables are absorbed into the effect of family structure. While not explicitly shown in the graph, the strength of grandparent's direct effect, i.e., the arrow pointing from $A_{(1)}$ to Y, may vary by the values of $M_{(1)}$ and $M_{(2)}$ according to the research hypothesis of this study.

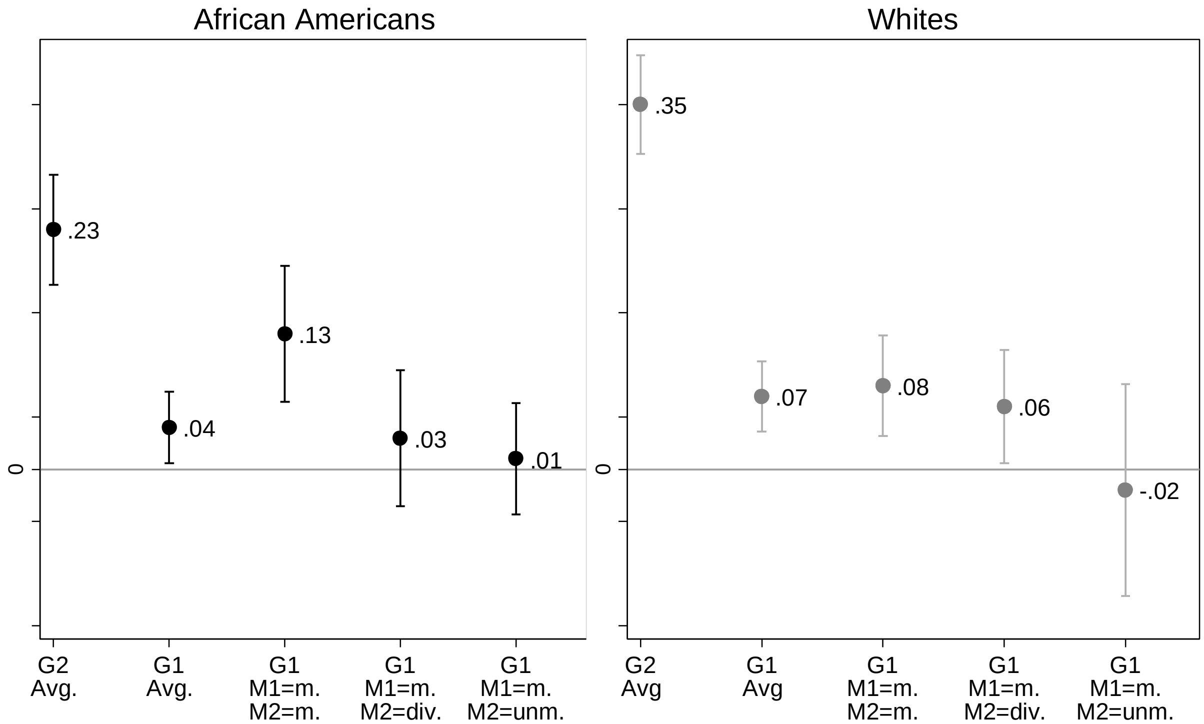


Figure 2.2. Heterogeneous Direct Effects of Parents' and Grandparents' Education on Grandchildren's Education by Family Structure and Race

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: The first two points in each subgraph refer to estimates of average parent and grandparent effects from the additive models in Table 2.5. The other points refer to estimates of grandparent effects in each family form from the interactive models in Table 2.6. Capped spikes refer to 95 percent confidence intervals of the estimates. Variables M1 and M2 refer to family structure in the grandparent generation and parent generation respectively. All the other variables are fixed at their means. Abbreviations refer to married parents (m.), divorced parents (div.), and unmarried parents (unm.).

2.9 ONLINE SUPPLEMENT

SUPPLEMENTARY TABLES

Appendix Table 2A Longitudinal Stabilized Inverse Probability of Treatment Weights

			Percentile			
Stabilized treatment weights (SW)	Mean	S.D	1st	25th	75th	99th
Parents' education, A_2	.98	.39	.45	.85	1.04	1.96
Grandparents' family structure, M_1	1.00	.39	.58	.92	1.04	1.79
Parents' family structure, M_2	1.00	.31	.53	.83	1.08	2.28
Total weights $SW_{A_2} \times SW_{M_1} \times SW_{M_2}$	.98	.57	.30	.71	1.09	2.89

Data sources: Multigenerational linked data from Panel Study of Income Dynamics (PSID), 1968-2011.
Notes: For the sake of simplicity, the figures are calculated based on data from the first imputed dataset. The statistics are similar for the other 19 imputed samples. The stabilized treatment weights for all A_1 is 1.

Appendix Table 2B Educational Attainment of Each Generation by Multigenerational Types of Family Structure

	Years of Schooling: Mean (S.D)								
	Family structure in G1			Family structure in G2			Family structure in both G1 and G2		
	Unmarried	Divorced	2-parent	Unmarried	Divorced	2-parent	Unmarried	Divorced	2-parent
Full Sample									
Grandparent, G1	9.0	10.3	10.8	9.6	10.6	11.1	9.2	10.7	11.3
	(3.6)	(3.0)	(3.3)	(3.0)	(3.5)	(3.2)	(3.1)	(2.9)	(3.2)
Parent, G2	12.7	12.9	13.2	12.1	12.9	13.8	12.0	13.1	13.9
	(2.4)	(2.3)	(2.3)	(2.0)	(2.4)	(2.2)	(2.1)	(2.2)	(2.2)
Grandchild, G3	12.7	12.6	13.1	12.1	12.7	13.6	12.6	12.5	13.7
	(2.1)	(2.1)	(2.2)	(1.9)	(2.1)	(2.2)	(1.8)	(1.9)	(2.2)
N	231	881	3,742	1,156	1,278	2,420	113	218	1,951
African Americans									
Grandparent, G1	9.1	9.9	9.5	9.6	9.6	9.4	9.3	10.8	9.6
	(3.3)	(3.2)	(3.0)	(2.9)	(3.3)	(3.0)	(3.0)	(3.2)	(2.9)
Parent, G2	12.7	12.5	12.5	12.1	12.7	13.0	12.1	13.4	13.1
	(2.4)	(2.3)	(2.1)	(1.9)	(2.2)	(2.2)	(2.1)	(1.8)	(2.1)
Grandchild, G3	12.6	12.4	12.5	12.1	12.4	13.0	12.5	12.4	13.1
	(2.0)	(2.1)	(2.1)	(1.9)	(2.0)	(2.2)	(1.8)	(1.9)	(2.2)
N	183	510	1,624	988	549	780	102	102	552
Whites									
Grandparent, G1	8.8	10.9	11.7	9.7	11.3	11.9	8.2	10.6	12.0
	(4.5)	(2.6)	(3.2)	(3.6)	(3.4)	(3.0)	(4.0)	(2.6)	(3.0)
Parent, G2	12.4	13.5	13.7	12.0	13.0	14.1	11.2	12.9	14.2
	(2.5)	(2.2)	(2.4)	(2.4)	(2.5)	(2.1)	(2.2)	(2.4)	(2.2)
Grandchild, G3	13.0	12.9	13.5	12.0	12.9	13.8	12.6	12.6	13.9
	(2.1)	(2.1)	(2.3)	(2.1)	(2.1)	(2.2)	(1.9)	(2.0)	(2.2)
N	48	371	2,118	168	729	1,640	11	116	1,399

Data sources: Multigenerational linked data from Panel Study of Income Dynamics (PSID), 1968-2011.
Notes: For the sake of simplicity, the figures are calculated based on data from the first imputed dataset. The statistics are similar for the other 19 imputed samples.

Appendix Table 2C Additive Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education based on Marginal Structural Models (MSM) of Generalized Linear Mixed-Effects Models with Random Intercepts

	African Americans				Whites			
	Paternal grandparent	Maternal grandparent	Grandfather	Grandmother	Paternal grandparent	Maternal grandparent	Grandfather	Grandmother
Grandparents, generation 1								
Years of schooling (A_1)	0.045	0.038*	0.044*	0.049*	0.076**	0.067**	0.080***	0.060***
	(0.033)	(0.019)	(0.019)	(0.019)	(0.025)	(0.023)	(0.018)	(0.019)
Family structure (M_1) (ref: two-parent)								
One-parent, divorced	-0.033	-0.161	-0.341	-0.196	-0.472*	-0.496***	-0.579**	-0.473***
	(0.222)	(0.145)	(0.224)	(0.138)	(0.221)	(0.155)	(0.183)	(0.129)
One-parent, unmarried	0.072	0.381†	0.658*	0.195	-0.177	-0.010	-0.077	-0.052
	(0.323)	(0.203)	(0.313)	(0.199)	(0.390)	(0.399)	(0.476)	(0.337)
Parents, generation 2								
Years of schooling (A_2)	0.245***	0.251***	0.274***	0.230***	0.381***	0.382***	0.368***	0.373***
	(0.046)	(0.032)	(0.041)	(0.029)	(0.036)	(0.032)	(0.029)	(0.025)
Family structure (M_2) (ref: two-parent)								
One-parent, divorced	-0.574**	-0.572***	-0.598***	-0.576***	-0.650***	-0.230†	-0.517***	-0.430***
	(0.209)	(0.140)	(0.147)	(0.120)	(0.170)	(0.127)	(0.115)	(0.106)
One-parent, unmarried	-0.983***	-0.525***	-0.640***	-0.578***	-0.756*	-0.494*	-0.549*	-0.721***
	(0.231)	(0.134)	(0.142)	(0.111)	(0.386)	(0.195)	(0.218)	(0.170)
Number of family lineages	215	516	341	553	449	605	675	816
Number of observations	569	1,803	1,287	2,220	1,112	1,499	2,021	2,461

Data sources: Multigenerational linked data from Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in parentheses are standard errors from 20 imputed samples. $p† < .1$, $p* < .05$, $p** < .01$, $p*** < .001$ (two-tailed tests). Coefficients of control variables including grandparents' and parents' disability status, occupational status, family income, and homeownership as well as parents' age groups, sex, region, and religion, are not presented in the table.

Appendix Table 2D Interactive Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education based on Marginal Structural Models (MSM) of Generalized Linear Mixed-Effects Models with Random Intercepts

	African Americans				Whites			
	Paternal grandparent	Maternal grandparent	Grandfather	Grandmother	Paternal grandparent	Maternal grandparent	Grandfather	Grandmother
Grandparents, generation 1								
Years of schooling (A_1)	0.105*	0.143***	0.078*	0.125***	0.069*	0.098**	0.080***	0.077**
	(0.052)	(0.041)	(0.031)	(0.035)	(0.032)	(0.032)	(0.021)	(0.026)
A_1 × Family structure in G1 (M_1) (reference: two-parent)								
One-parent, divorced	-0.114***	-0.058	-0.115†	-0.040	0.077	-0.062	0.022	0.005
	(0.071)	(0.045)	(0.066)	(0.045)	(0.085)	(0.064)	(0.060)	(0.053)
One-parent, unmarried	0.065	-0.002	-0.068	0.084	-0.090	0.049	-0.003	-0.028
	(0.068)	(0.075)	(0.069)	(0.073)	(0.058)	(0.091)	(0.148)	(0.069)
A_1 × Family structure in G2 (M_2) (reference: two-parent)								
One-parent, divorced	-0.047	-0.112*	-0.040	-0.104*	0.021	-0.034	0.026	-0.038
	(0.084)	(0.046)	(0.040)	(0.044)	(0.050)	(0.044)	(0.034)	(0.039)
One-parent, unmarried	-0.056	-0.129**	-0.018	-0.124***	-0.236†	-0.120*	-0.103†	-0.093†
	(0.066)	(0.046)	(0.042)	(0.039)	(0.126)	(0.060)	(0.062)	(0.055)
Number of families	215	516	341	553	449	605	675	816
Number of observations	569	1,803	1,287	2,220	1,112	1,499	2,021	2,461

Data sources: Multigenerational linked data from Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in parentheses are standard errors from 20 imputed samples. $p† < .1$, $p* < .05$, $p** < .01$, $p*** < .001$ (two-tailed tests). Coefficients of control variables including grandparents' and parents' disability status, occupational status, family income, and homeownership as well as parents' age groups, sex, region, and religion, are not presented in the table.

Appendix Table 2E Additive Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education based on Generalized Linear Mixed-Effects Models with Random Intercepts (Regular) and Marginal Structural Models (MSM)

	Full Sample		African Americans		Whites	
	Regular	MSM	Regular	MSM	Regular	MSM
Grandparents, generation 1						
Years of schooling (A_1)	0.026†	0.063***	0.028	0.043*	0.025	0.069***
	(0.013)	(0.012)	(0.018)	(0.017)	(0.019)	(0.017)
Family structure (M_1) (ref: two-parent)						
One-parent, divorced	-0.222**	-0.358***	-0.098	-0.188	-0.330**	-0.493***
	(0.085)	(0.094)	(0.113)	(0.135)	(0.125)	(0.127)
One-parent, unmarried	0.250	0.116	0.289†	0.213	0.303	0.059
	(0.149)	(0.167)	(0.170)	(0.191)	(0.297)	(0.325)
Disability	-0.187*	-	-0.034	-	-0.326**	-
	(0.083)		(0.107)		(0.123)	
Occupational status (socioeconomic index)	0.001	-	-0.000	-	-0.000	-
	(0.002)		(0.005)		(0.003)	
Own home	0.033	-	0.120	-	-0.020	-
	(0.090)		(0.113)		(0.149)	
Average family income during G2's childhood	$5.80*10^{-6}$	-	$3.11*10^{-6}$	-	$5.15*10^{-6}$	-
	$(1.37*10^{-6})$		$(3.05*10^{-6})$		$(1.52*10^{-6})$	
Parents, generation 2						
Years of schooling (A_2)	0.247***	0.296***	0.178***	0.230***	0.294***	0.354***
	(0.017)	(0.018)	(0.025)	(0.027)	(0.024)	(0.024)
Family structure (M_2) (ref: two-parent)						
One-parent, divorced	-0.505***	-0.520***	-0.411***	-0.575***	-0.418***	-0.427***
	(0.070)	(0.076)	(0.116)	(0.116)	(0.090)	(0.103)
One-parent, unmarried	-0.522***	-0.569***	-0.406***	-0.605***	-0.539***	-0.612***
	(0.083)	(0.091)	(0.107)	(0.109)	(0.162)	(0.171)
Disability	-0.181**	-	-0.099	-	-0.222**	-
	(0.060)		(0.086)		(0.083)	
Occupational status (socioeconomic index)	0.010***	-	0.005	-	0.009***	-
	(0.002)		(0.004)		(0.003)	
Own home	0.269***	-	0.158	-	0.300*	-
	(0.082)		(0.102)		(0.147)	
Average family income during G2's childhood	$-3.98*10^{-7}$	-	$8.87*10^{-6}$	-	$-4.63*10^{-7}$	-
	$(1.99*10^{-7})$		$(2.24*10^{-6})$		$(2.00*10^{-7})$	
Grandchildren, generation 3						
African Americans	0.035	-0.201*	-	-	-	-
	(0.088)	(0.089)				
Female	0.675***	0.671***	0.844***	0.834***	0.534***	0.535***
	(0.053)	(0.054)	(0.077)	(0.077)	(0.072)	(0.074)

Appendix Table 2E (Cont.)

Age group (ref: 25-34)						
35-44	0.120*	0.106	0.168†	0.144	0.091	0.085
	(0.061)	(0.066)	(0.089)	(0.092)	(0.083)	(0.096)
45-54	0.122	0.177	0.005	0.043	0.297	0.425*
	(0.127)	(0.137)	(0.160)	(0.177)	(0.208)	(0.189)
55-65	0.719***	0.748***	0.756**	0.706*	0.598†	0.717**
	(0.191)	(0.214)	(0.246)	(0.285)	(0.308)	(0.261)
Religion (ref: Catholic)						
Jewish	0.318	0.725*	-0.543	-0.290	0.335	0.670*
	(0.293)	(0.307)	(0.872)	(0.418)	(0.313)	(0.324)
Protestant	0.005	-0.070	0.117	-0.005	-0.017	-0.099
	(0.099)	(0.103)	(0.204)	(0.227)	(0.114)	(0.114)
Others	-0.122	-0.243	0.178	0.003	-0.176	-0.307
	(0.159)	(0.173)	(0.300)	(0.326)	(0.187)	(0.198)
Region (ref: Northeast)						
North central	0.106	0.089	-0.144	-0.210	0.209	0.201
	(0.116)	(0.123)	(0.226)	(0.233)	(0.137)	(0.142)
South	-0.054	-0.105	0.051	-0.057	-0.146	-0.165
	(0.111)	(0.118)	(0.204)	(0.213)	(0.136)	(0.143)
West	-0.142	-0.149	-0.121	-0.205	-0.170	-0.138
	(0.130)	(0.135)	(0.265)	(0.262)	(0.149)	(0.155)
Intercept	8.585***	8.530	8.949***	9.254***	8.213***	7.736***
	(0.275)	(0.297)	(0.456)	(0.523)	(0.375)	(0.367)
Number of family lineages	1,409	1,409	571	571	838	838
Number of observations	4,854	4,854	2,317	2,317	2,537	2,537

Data sources: Multigenerational linked data from Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in the parentheses are robust standard errors from 20 imputed samples. $p† < .1$, $p^* < .05$, $p^{**} < .01$, $p^{***} < .001$ (two-tailed tests). The final marginal structural models do not include covariates grandparents' and parents' disability status, occupational status, family income, and homeownership because they are used to construct the inverse probability weights and do not bias our estimates of exposure variables, namely grandparents' education, after the weighting.

Appendix Table 2F. Interactive Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education by Family Structures across Generations based on Generalized Linear Mixed-Effects Models with Random Intercepts (Regular) and Marginal Structural Models (MSM)

	Full Sample		African Americans		Whites	
	Regular	MSM	Regular	MSM	Regular	MSM
Grandparents, generation 1						
Years of schooling (A_1)	0.063***	0.098***	0.112***	0.134***	0.040†	0.082***
	(0.018)	(0.019)	(0.030)	(0.033)	(0.024)	(0.025)
Family structure in G1 (M_1) (ref: two-parent)						
One-parent, divorced	0.921*	1.328*	0.029	0.484	1.364†	1.593†
	(0.469)	(0.523)	(0.627)	(0.769)	(0.773)	(0.855)
One-parent, unmarried	0.711	0.846	-0.192	-0.139	1.024	1.166
	(0.802)	(1.100)	(0.973)	(1.341)	(1.447)	(1.233)
A_1 × Family structure in G1 (M_1) (ref: two-parent)						
One-parent, divorced	-0.020	-0.038	-0.041	-0.063	0.012	0.007
	(0.029)	(0.030)	(0.037)	(0.042)	(0.046)	(0.052)
One-parent, unmarried	0.026	0.014	0.031	0.028	-0.015	-0.026
	(0.044)	(0.048)	(0.055)	(0.062)	(0.071)	(0.072)
A_1 × Family structure in G2 (M_2) (ref: two-parent)						
One-parent, divorced	-0.042†	-0.040	-0.100**	-0.102*	-0.020	-0.019
	(0.022)	(0.025)	(0.036)	(0.041)	(0.030)	(0.036)
One-parent, unmarried	-0.089***	-0.096***	-0.118***	-0.123***	-0.099*	-0.107*
	(0.025)	(0.029)	(0.033)	(0.038)	(0.050)	(0.054)
Disability	-0.178*	-	-0.053	-	-0.316*	-
	(0.083)		(0.107)		(0.123)	
Occupational status (socioeconomic index)	0.001	-	0.001	-	0.001	-
	(0.002)		(0.005)		(0.003)	
Own home	0.036	-	0.124	-	-0.012	-
	(0.090)		(0.113)		(0.147)	
Average family income during G2's childhood	$5.25*10^{-6}$***	-	$2.52*10^{-6}$	-	$-4.95*10^{-6}$**	-
	($1.37*10^{-6}$)		($3.03*10^{-6}$)		($1.53*10^{-6}$)	
Parents, generation 2						
Years of schooling (A_2)	0.283***	0.353***	0.157***	0.246***	0.325***	0.401***
	(0.024)	(0.027)	(0.041)	(0.043)	(0.031)	(0.033)
Family structure in G2 (M_2) (ref: two-parent)						
One-parent, divorced	0.049	0.419	-0.167	0.357	0.112	0.412
	(0.411)	(0.484)	(0.682)	(0.867)	(0.532)	(0.613)
One-parent, unmarried	1.138*	1.563*	0.729	1.029*	0.491	0.996
	(0.464)	(0.550)	(0.612)	(0.736)	(0.875)	(1.004)
A_2 × Family structure in G1 (M_1) (ref: two-parent)						
One-parent, divorced	-0.071†	-0.096*	0.024	-0.000	-0.135*	-0.157**
	(0.037)	(0.043)	(0.050)	(0.065)	(0.056)	(0.058)

Appendix Table 2F (Cont.)

One-parent, unmarried	-0.053	-0.063	0.017	0.009	-0.047	-0.069
	(0.059)	(0.080)	(0.069)	(0.095)	(0.112)	(0.086)
A_2 × Family structure in G2 (M_2) (ref: two-parent)						
One-parent, divorced	-0.007	-0.037	0.055	0.003	-0.022	-0.046
	(0.033)	(0.038)	(0.052)	(0.064)	(0.043)	(0.046)
One-parent, unmarried	-0.062†	-0.094*	-0.003	-0.039	0.001	-0.037
	(0.037)	(0.045)	(0.048)	(0.057)	(0.075)	(0.088)
Disability	-0.181**	-	-0.100	-	-0.210*	-
	(0.060)		(0.086)		(0.083)	
Occupational status (socioeconomic index)	0.009***	-	0.005	-	0.009***	-
	(0.002)		(0.004)		(0.003)	
Own home	0.295***	-	0.172†	-	0.320*	-
	(0.082)		(0.103)		(0.147)	
Average family income during G2's childhood	-3.58*10^{-7}†	-	8.67*10^{-6}***	-	-4.49*10^{-7}*	-
	(1.99*10^{-7})		(2.25*10^{-6})		(2.04*10^{-7})	
Grandchildren, generation 3						
African Americans	0.058	-0.159†	-	-	-	-
	(0.088)	(0.090)				
Female	0.671***	0.660***	0.840***	0.833***	0.536***	0.529***
	(0.053)	(0.054)	(0.077)	(0.078)	(0.072)	(0.074)
Age group (ref: 25-34)						
35-44	0.123*	0.102	0.159†	0.135	0.097	0.088
	(0.061)	(0.067)	(0.089)	(0.092)	(0.083)	(0.095)
45-54	0.100	0.133	-0.011	0.019	0.281	0.384*
	(0.126)	(0.136)	(0.161)	(0.176)	(0.209)	(0.190)
55-65	0.717***	0.691***	0.743**	0.655*	0.613*	0.710**
	(0.191)	(0.204)	(0.246)	(0.278)	(0.309)	(0.255)
Religion (ref: Catholic)						
Jewish	0.286	0.628*	-0.568	-0.361	0.349	0.649*
	(0.293)	(0.299)	(0.870)	(0.388)	(0.315)	(0.316)
Protestant	0.006	-0.047	0.115	0.045	-0.009	-0.082
	(0.098)	(0.100)	(0.204)	(0.225)	(0.114)	(0.113)
Others	-0.132	-0.229	0.167	0.067	-0.221	-0.345†
	(0.158)	(0.174)	(0.300)	(0.344)	(0.188)	(0.196)
Region (ref: Northeast)						
North central	0.009	0.079	-0.175	-0.230	0.203	0.190
	(0.116)	(0.119)	(0.226)	(0.230)	(0.137)	(0.140)
South	-0.055	-0.096	0.035	-0.050	-0.145	-0.167
	(0.110)	(0.115)	(0.203)	(0.211)	(0.136)	(0.141)
West	-0.113	-0.123	-0.116	-0.169	-0.124	-0.099
	(0.129)	(0.132)	(0.265)	(0.260)	(0.149)	(0.152)
Intercept	7.746***	7.331***	8.461***	8.098***	7.613***	6.931***
	(0.356)	(0.384)	(0.628)	(0.717)	(0.462)	(0.477)
Number of families	1,409	1,409	571	571	838	838
Number of observations	4,854	4,854	2,317	2,317	2,537	2,537

Data sources: Multigenerational linked data from Panel Study of Income Dynamics, 1968-2011.

Notes: Figures in parentheses are robust standard errors. $p† < .1$, $p^{*} < .05$, $p^{**} < .01$, $p^{***} < .001$ (two-tailed tests). The final marginal structural models do not include the covariates, including grandparents' and parents' disability status, occupational status, family income, and homeownership, because they are used to construct the inverse probability weights and have an impact on our estimates of exposure variables, namely grandparents' education, through the weighting.

MODEL SPECIFICATION

The marginal structural model with inverse probability weighting estimates may be sensitive to different model specifications of the final marginal structural model. Table 2G summarizes key coefficients related to grandparent effects based on a variety of model specifications based on the final causal model. Model 1 reports the original model estimates (presented in Table 2.6). Models 2 to 4 add interactions between grandparents' and parents' education, between the childhood family structures of parents and grandchildren, and between grandchildren's covariates and parents' and grandparents' education, respectively. The models do not include any three-way interactions, given the insignificance of the two-way interactions. Because none of these extra interactions are highly significant, the results suggest that fitting more complicated models would not change our conclusion about heterogeneous grandparent effects across types of family structure (i.e., the interaction between A_1 and M_2). The original models are preferred for the sake of parsimony.

Appendix Table 2G Marginal Structural Model Estimates for Direct Effects of Grandparents by Family Structures across Generations under Various Model Specifications

	African Americans				Whites			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
	Original in Equation (1)	Model 1+ interactions $M_1 * M_2$	Model 1 + interactions $A_1 * A_2$	Model 1 + interactions between A_1, A_2 and covariates	Original in Equation (1)	Model 1+ interactions $M_1 * M_2$	Model 1 + interactions $A_1 * A_2$	Model 1 + interactions between A_1, A_2 and covariates
Grandparents, G1								
Years of schooling (A_1)	0.134***	0.130***	-0.051	0.051	0.082***	0.082***	-0.002	0.085†
	(0.033)	(0.034)	(0.104)	(0.088)	(0.025)	(0.025)	(0.092)	(0.047)
Family structure in G1 (M_1) (ref: two-parent)								
One-parent, divorced	0.484	0.645	0.487	0.524	1.593†	1.069	1.663†	1.561†
	(0.769)	(0.818)	(0.813)	(0.766)	(0.855)	(0.879)	(0.853)	(0.853)
One-parent, unmarried	-0.139	-0.894	-0.170	-0.099	1.166	1.728	0.826	1.261
	(1.341)	(1.676)	(1.338)	(1.385)	(1.233)	(2.098)	(1.180)	(1.164)
$A_1 \times$ Family structure in G1 (M_1) (ref: two-parent)								
One-parent, divorced	-0.063	-0.058	-0.057	-0.063	0.007	0.010	0.003	-0.006
	(0.042)	(0.043)	(0.044)	(0.043)	(0.052)	(0.051)	(0.052)	(0.051)
One-parent, unmarried	0.028	0.014	0.019	0.056	-0.026	-0.027	-0.026	-0.012
	(0.062)	(0.063)	(0.063)	(0.057)	(0.072)	(0.071)	(0.071)	(0.073)
$A_1 \times$ Family structure in G2 (M_2) (ref: two-parent)								
One-parent, divorced	-0.102*	-0.097*	-0.098*	-0.105*	-0.019	-0.022	-0.012	-0.014
	(0.041)	(0.041)	(0.041)	(0.044)	(0.036)	(0.036)	(0.036)	(0.034)
One-parent, unmarried	-0.123***	-0.117**	-0.110**	-0.123***	-0.107*	-0.100†	-0.096†	-0.126*
	(0.038)	(0.037)	(0.038)	(0.037)	(0.054)	(0.054)	(0.055)	(0.055)
Parents, G2								
Years of schooling (A_2)	0.246***	0.252***	0.121	0.376**	0.401***	0.398***	0.330***	0.427***
	(0.043)	(0.045)	(0.076)	(0.130)	(0.033)	(0.033)	(0.086)	(0.058)

Appendix Table 2G (Cont.)

	African Americans				Whites			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
	Original in Equation (1)	Model 1+ interactions $M_1 * M_2$	Model 1 + interactions $A_1 * A_2$	Model 1 + interactions between A_1, A_2 and covariates	Original in Equation (1)	Model 1+ interactions $M_1 * M_2$	Model 1 + interactions $A_1 * A_2$	Model 1 + interactions between A_1, A_2 and covariates
Family structure in G2 (M_2) (ref: two-parent)								
One-parent, divorced	0.357	0.409	0.428	0.225	0.412	0.365	0.210	0.235
	(0.867)	(0.864)	(0.869)	(0.857)	(0.613)	(0.624)	(0.657)	(0.669)
One-parent, unmarried	1.029	1.095	0.958	1.041	0.996	0.975	0.720	1.012
	(0.736)	(0.764)	(0.750)	(0.753)	(1.005)	(0.996)	(1.058)	(1.051)
A_2 × Family structure in G1 (M_1) (ref: two-parent)								
One-parent, divorced	-0.000	-0.006	-0.007	-0.005	-0.157**	-0.134*	-0.159**	-0.145*
	(0.065)	(0.068)	(0.066)	(0.065)	(0.058)	(0.059)	(0.058)	(0.059)
One-parent, unmarried	0.009	0.042	0.019	-0.017	-0.069	-0.087	-0.040	-0.085
	(0.095)	(0.119)	(0.096)	(0.100)	(0.086)	(0.114)	(0.086)	(0.094)
A_2 × Family structure in G2 (M_2) (ref: two-parent)								
One-parent, divorced	0.003	-0.003	-0.004	0.018	-0.046	-0.044	-0.038	-0.038
	(0.064)	(0.064)	(0.064)	(0.064)	(0.046)	(0.046)	(0.047)	(0.049)
One-parent, unmarried	-0.039	-0.048	-0.043	-0.039	-0.037	-0.049	-0.026	-0.022
	(0.057)	(0.058)	(0.057)	(0.058)	(0.088)	(0.088)	(0.089)	(0.091)
Interactions G1 * G2								
Years of schooling in G1 (A_1) × in G2 (A_2)	-	-	0.014†	-	-	-	0.006	-
			(0.008)				(0.006)	
Family structure in G1 (M_1) × in G2 (M_2)								
One-parent, divorced × One-parent, unmarried	-	-0.222	-	-	-	0.418	-	-
		(0.286)				(0.281)		
One-parent, divorced × One-parent, divorced	-	0.457	-	-	-	-1.197*	-	-
		(0.553)				(0.564)		
One-parent, unmarried × One-parent, divorced	-	-0.211	-	-	-	0.378	-	-
		(0.243)				(0.409)		

Appendix Table 2G (Cont.)

	African Americans				Whites			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
	Original in Equation (1)	Model 1+ interactions $M_1 * M_2$	Model 1 + interactions $M_1 * M_2$ and $A_1 * A_2$	Model 1 + interactions between A_1, A_2 and covariates	Original in Equation (1)	Model 1+ interactions $M_1 * M_2$	Model 1 + interactions $M_1 * M_2$ and $A_1 * A_2$	Model 1 + interactions between A_1, A_2 and covariates
One-parent, unmarried	-	0.676	-	-	-	0.175	-	-
× One-parent, unmarried		(0.549)				(0.717)		
Interactions G1 * G3								
A_1 × Sex	-	-	-	Controlled	-	-	-	Controlled
A_1 × Age groups	-	-	-	Controlled	-	-	-	Controlled
A_1 × Religion	-	-	-	Controlled	-	-	-	Controlled
A_1 × Region	-	-	-	Controlled	-	-	-	Controlled
Interactions G2 * G3								
A_2 × Sex	-	-	-	Controlled	-	-	-	Controlled
A_2 × Age groups	-	-	-	Controlled	-	-	-	Controlled
A_2 × Religion	-	-	-	Controlled	-	-	-	Controlled
A_2 × Region	-	-	-	Controlled	-	-	-	Controlled
Intercept	8.098***	8.052***	9.745***	7.170***	6.931***	6.997***	7.893***	6.523***
	(0.717)	(0.737)	(1.119)	(1.943)	(0.477)	(0.483)	(1.169)	(0.766)
Number of families	571	571	571	571	838	838	838	838
Number of observations	2,317	2,317	2,317	2,317	2,537	2,537	2,537	2,537

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in parentheses are standard errors. $p† < .1$, $p* < .05$, $p** < .01$, $p*** < .001$ (two-tailed tests). Main effects of control variables including age groups, sex, religion, and current region, are not presented in the table. None of the interactions between A_1, A_2 and the covariates in Model 4 are highly statistically significant. Full results of all models are available upon request.

MISSING DATA AND THE ANALYSES OF COMPLETE CASES

The model results combine estimates and standard errors from 20 multiple imputed datasets to account for uncertainty associated with missing data. The missing cases account for less than 20% of the whole sample. The imputation method adopted in this study relies on multiple imputation chained equations with a predicted mean matching method for continuous variables such as occupational status and family income, and a binary logistic model for dichotomous variables, such as home ownership and disability status. Model estimates based on complete cases and multiple imputed datasets show similar results regarding the controlled direct effects of grandparents except that the imputed datasets with a larger sample size give us more statistical power to test the research hypotheses. Tables 2H and 2I present model estimates based on complete cases.

Appendix Table 2H Additive Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education based on the Complete Case Analysis

	Full Sample		African Americans		Whites	
	Regular	MSM	Regular	MSM	Regular	MSM
Grandparents, generation 1						
Years of schooling (A_1)	0.030†	0.069***	0.028	0.042†	0.032	0.083***
	(0.017)	(0.015)	(0.018)	(0.022)	(0.023)	(0.020)
Family structure (M_1) (reference: two-parent)						
One-parent, divorced	-0.156	-0.265**	-0.098	-0.093	-0.236†	-0.389**
	(0.096)	(0.100)	(0.113)	(0.143)	(0.137)	(0.137)
One-parent, unmarried	0.441*	0.306	0.289	0.428†	0.380	0.075
	(0.177)	(0.206)	(0.170)	(0.234)	(0.365)	(0.389)
Parents, generation 2						
Years of schooling (A_2)	0.269***	0.341***	0.178***	0.284***	0.298***	0.378***
	(0.022)	(0.022)	(0.025)	(0.036)	(0.029)	(0.028)
Family structure (M_2) (reference: two-parent)						
One-parent, divorced	-0.587***	-0.628***	-0.411***	-0.685***	-0.542***	-0.556***
	(0.083)	(0.089)	(0.116)	(0.143)	(0.103)	(0.115)
One-parent, unmarried	-0.599***	-0.672***	-0.406***	-0.695***	-0.561**	-0.654***
	(0.095)	(0.104)	(0.107)	(0.127)	(0.188)	(0.205)
Number of family lineages	1,159	1,159	474	474	685	685
Number of observations	3,577	3,577	1,652	1,652	1,925	1,925

Data sources: Multigenerational linked data from Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in parentheses are robust standard errors from 20 imputed samples. $p† < .1$, $p* < .05$, $p** < .01$, $p*** < .001$ (two-tailed tests). Coefficients of control variables, including grandparents' and parents' disability status, occupational status, family income, and homeownership as well as grandchildren's age groups, sex, region, and religion, are not presented in the table. The regular method refers to generalized linear mixed-effects models with random intercepts. The MSM method refers to marginal structural models. The analysis is based on complete cases. Missing data are handled by the listwise deletion method.

Appendix Table 2I Interactive Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education by Family Structures across Generations based on the Complete Case Analysis

	Full Sample		African Americans		Whites	
	Regular	MSM	Regular	MSM	Regular	MSM
Grandparents, generation 1						
Years of schooling (A_1)	0.073***	0.111***	0.144***	0.150***	0.040	0.093***
	(0.022)	(0.021)	(0.030)	(0.039)	(0.028)	(0.027)
A_1 × Family structure in G1 (M_1) (reference: two-parent)						
One-parent, divorced	-0.032	-0.042	-0.041	-0.078	0.020	0.015
	(0.033)	(0.034)	(0.037)	(0.050)	(0.052)	(0.050)
One-parent, unmarried	-0.025	-0.034	0.031	-0.067	-0.014	-0.044
	(0.058)	(0.057)	(0.055)	(0.083)	(0.104)	(0.075)
A_1 × Family structure in G2 (M_2) (reference: two-parent)						
One-parent, divorced	-0.043	-0.047	-0.130**	-0.137**	-0.001	-0.008
	(0.028)	(0.029)	(0.049)	(0.050)	(0.036)	(0.042)
One-parent, unmarried	-0.097***	-0.107***	-0.135***	-0.129***	-0.110	-0.115
	(0.030)	(0.032)	(0.040)	(0.044)	(0.068)	(0.076)
Number of family lineages	1,159	1,159	474	474	685	685
Number of observations	3,577	3,577	1,652	1,652	1,925	1,925

Data sources: Multigenerational linked data from Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in parentheses are robust standard errors. $p† < .1$, $p^* < .05$, $p^{**} < .01$, $p^{***} < .001$ (two-tailed tests). Coefficients of main effects of parents' family structure and education as well as interactions between parents' education and family structure in G1 and G2 are omitted from the table. Coefficients of control variables, including grandparents' and parents' disability status, occupational status, family income, and homeownership as well as grandchildren's age groups, sex, region, and religion, are not presented in the table. The regular method refers to generalized linear mixed-effects models with random intercepts. The MSM method refers to marginal structural models. The analysis is based on complete cases. Missing data are handled by the listwise deletion method.

MORE MOBILITY: UPWARD OR DOWNWARD?

Results in Table 2.5 show that the multigenerational transmission of educational status is weaker in single-parent families than in two-parent families and among African Americans than among whites. In other words, grandchildren growing up in families with weaker grandparent and parent effects are more likely to eventually reach an educational level different from that of their parents and grandparents. However, it is unclear whether more educational mobility in these families results from upward or downward mobility. Implications of these two kinds of mobility for social inequality among families are distinct. If weaker grandparent effects indicate more upward mobility, grandchildren in single-parent and African American families actually benefit from being loosely tied to their disadvantaged family origins. In contrast, if weaker grandparent effects indicate more downward mobility, grandchildren in these families are further handicapped in their educational attainment processes as compared to their white and two-parent counterparts because their families are less capable of maintaining their multigenerational advantages and gaining opportunities for achieving higher education.

Table 2J presents relative educational mobility from grandparents to grandchildren by family structure and race. A general trend shown in the table suggests that African American families have experienced more upward mobility from the grandparent to the parent and further to the grandchild generations, as compared to white families. Thus, multigenerational correlation in education between grandparents and grandchildren is less for African Americans (r = 0.11, not reported in the table) than for whites (r = 0.30, not reported in the table). In addition, upward mobility was more prevalent from the grandparent to the parent generation, than from the parent to the grandchild generation among African American families. Given the time frame of the PSID data (1968-2011), the result confirms Hout and Janus's (2011) conclusion that "what we do have is evidence that African Americans closed the gap between themselves and whites between the 1950s and 1980s but have subsequently lost most of the ground they gained."

Table 2K further shows that the occurrence of upward mobility is higher among two-parent households than single-parent households, especially for African Africans. Given the small sample of single-parent families with unmarried parents, I combine individuals who grow up in divorced families and families with unmarried parents into one group. More than 80 percent of African American two-parent families have experienced upward mobility from the grandparent to the grandchild generation. The results substantiate my earlier conclusion that a weaker grandparent effect in single-parent families means that these families are less likely to preserve their family privilege rather than more likely to escape from their family histories of hardship.

Appendix Table 2J Multigenerational Educational Mobility

	African Americans (N = 2,317)		
	Grandparent-Parent	Parent-Grandchild	Grandparent-Grandchild
Upward mobility	76.1	34.0	73.6
Immobility	14.7	27.1	13.0
Downward mobility	9.3	38.9	13.5
Total, %	100	100	100
	Whites (N = 2,537)		
	Grandparent-Parent	Parent-Grandchild	Grandparent-Grandchild
Upward mobility	64.4	31.0	61.4
Immobility	22.3	27.7	17.4
Downward mobility	13.3	41.4	21.3
Total, %	100	100	100

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: Upward mobility means that grandchildren's years of schooling are greater than parents' or grandparents' years of schooling. I combine single-parent families with divorced parents and unmarried parents.

Appendix Table 2K Educational Mobility from Grandparent to Grandchild by Family Structure

	Parents' and grandchildren's childhood family structures			
African Americans	Single, Single	Single, Two	Two, Single	Two, Two
Grandparent-Grandchild				
Upward mobility, %	65.8	80.2	70.3	83.1
Immobility	12.7	12.6	14.6	10.5
Downward mobility	21.5	7.2	15.1	6.4
N	456	222	1,051	562
Chi-square	22.5***		35.6**	

	Parents' and grandchildren's childhood family structures			
Whites	Single, Single	Single, Two	Two, Single	Two, Two
Grandparent-Grandchild				
Upward mobility, %	67.8	66.0	56.1	62.4
Immobility	10.7	16.6	17.5	18.2
Downward mobility	21.5	17.5	26.4	19.4
N	176	236	719	1,403
Chi-square	3.4		14.1***	

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: $p^* < .05$, $p^{**} < .01$, $p^{***} < .001$ (Chi-square tests). I combine single-parent families with divorced parents and unmarried parents.

SENSITIVITY ANALYSIS

The causal interpretation for results presented in Tables 2.5 and 2.6 rests on the assumption that unobserved confounding variables that affect education and family structure across generations (namely $W_{(t)}$ in Figure 2.1) do not correlate. This assumption may be invalid because unmeasured factors such as a genetic component of education-enhancing traits of grandparents and parents may sort individuals into different educational groups. Such a selection mechanism may lead to spurious or overestimated effects of grandparents' education on grandchildren's education. By simulating a range of correlations between the unobserved variables ($W_{(t)}$) and education ($A_{(t)}$) across generations (shown in Figure 2A), the sensitivity analysis assesses the extent to which the causal effect of grandparents' education is robust to the selection bias caused by the intergenerational transmission of unobserved variables. Figure 2A shows the new hypothetical causal diagram with the revised assumptions about unobserved variables. Note that the sensitivity analysis shows only one among many possible scenarios of relationships among the unobserved variables.

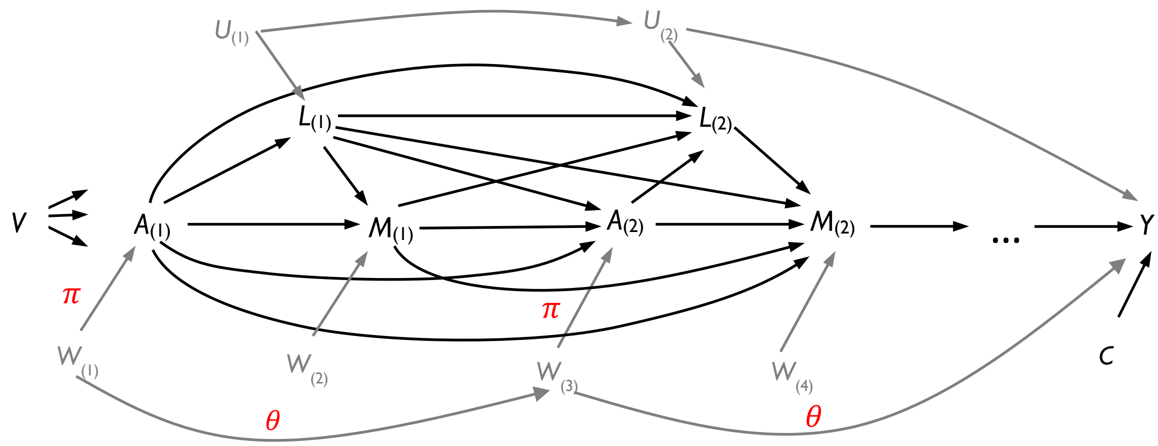
The sensitivity analysis follows two steps. In the first step, I assume a single variable $W_{(t)}$ that is a combination of all the omitted variables and thus captures selection bias from any source. I simulate plausible values for the association between $W_{(t)}$ and $A_{(t)}$ (namely θ) and between $W_{(t)}$ and $W_{(t-1)}$ (namely π), both of which range from 0 (no correlation) to 1 (perfect correlation). Given that all variables are standardized, the parameter θ can be roughly interpreted as the intergenerational correlation in the unobserved variables. The parameter π refers to the correlation between education (or family structure) and the unobserved variables in each generation, which reflects the magnitude of the selection bias. According to the causal mediation principles (Pearl 2014), we do not need to assume the effect of unobserved variables

$U_{(t)}$ on covariates $L_{(t)}$ because these variables are not directly associated with the exposure variables $A_{(t)}$, mediators $M_{(t)}$, or the outcome variable Y, and biases caused by these variables are already addressed in the marginal structural models based on inverse probability weights. In the second step, I estimate grandparent effects by treating the simulated unobserved variables as time-varying covariates and include them into the weighted generalized linear mixed-effect models. Lastly, I compare the bias-corrected estimates of grandparent effects with the original ones.

Figure 2B displays adjusted average grandparent effects, based on a range of selected values of θ and π in the sensitivity analysis. When the parameter π is equal to 0, namely no intergenerational transmission of the unobserved variables, the estimated grandparent effects simply replicate previous estimates shown in Table 2H. To speed up the simulation, I rely on data with complete cases rather than data with missing-data imputation. Despite a wide range of possible combinations between values of θ and π , Figure 2B only presents results from scenarios when $\theta = \pi$. Results from the sensitivity analysis based on other possible values of θ and π are available upon request.

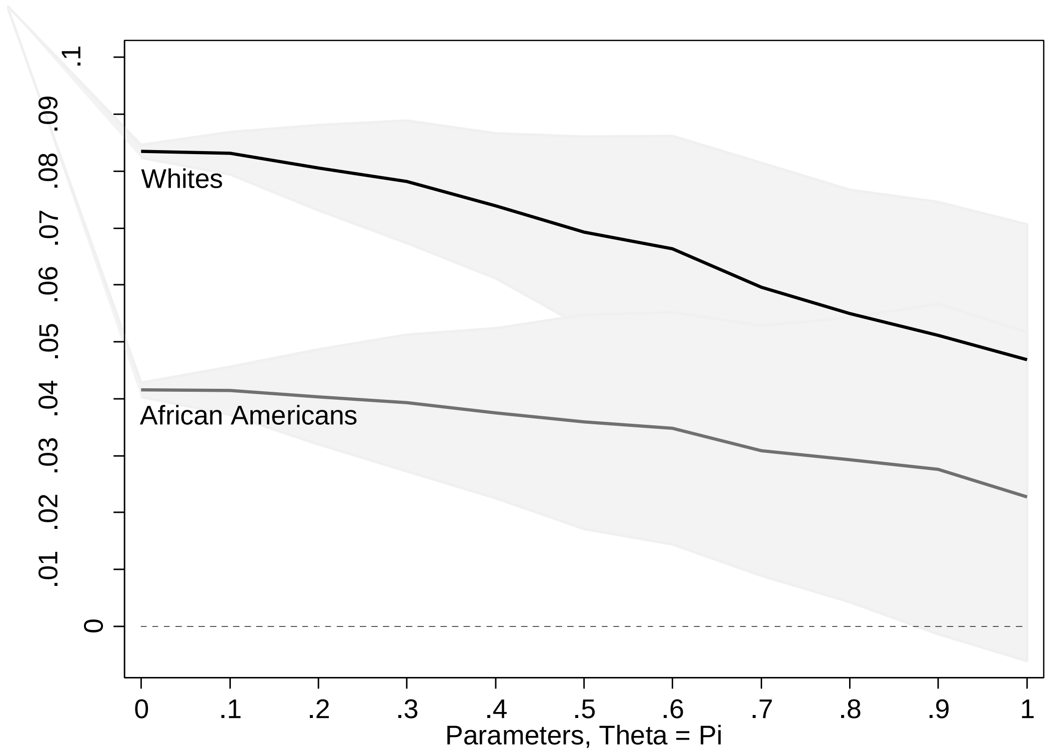
In general, the estimated grandparent effects decline with the increase of θ or π. The horizontal line refer to the scenario under which the average grandparent effect are zero. The shaded areas refer to 95% confidence intervals of the estimates. Estimates that fall below this line indicate that we need to reconsider the causal interpretation for influences of grandparents' education on grandchildren's education because of potential selection mechanisms caused by the unobserved variables.

The results suggest that for African Americans, we would expect to see a positive causal effect of grandparents' education on grandchildren's education as long as the intergenerational correlation of the unobserved variables and the correlation between education and the unobserved variables are both below roughly 0.85. For whites, the causal effect of grandparents persists even if the unobserved variable W_1 and grandparents' education A_1 are perfectly correlated. Therefore, the sensitivity analysis indicates that if there is any intergenerational transmission of the unobserved variables, the magnitude would have to be unreasonably large to alter our inferences about the causal effects of grandparents' education on grandchildren's education. The interpretation of the grandparent effect is subject to revision if future research reveals a stronger intergenerational transmission of the unobserved variables.



Appendix Figure 2A A Hypothetical Causal Framework of Multigenerational Social Mobility with Unmeasured Time-Varying Variables

Notes: $A_{(1)}$ = G1's educational attainment, $M_{(1)}$ = family structure in G1 during G2' childhood, $L_{(1)}$ = socioeconomic characteristics, such as family income, occupational status, home ownership, and disability status in G1 during G2' childhood, $A_{(2)}$ = G2' education, $M_{(2)}$ = family structure in G2 during G3's childhood, U, W = unmeasured variables, Y = G3's educational attainment. C = exogenous variables that influence Y, such as gender and age group. V = family invariant variables, such as race. Relationships among variables are encoded in the directed acyclic graph (DAG) above. For the sake of simplicity, the graph omits all the arrows pointing from $A_{(t)}$, $L_{(t)}$, $M_{(t)}$, and $W_{(t)}$ to Y. While not explicitly shown in the graph, the strength of grandparent's direct effect, i.e., the arrow pointing from $A_{(1)}$ to Y, may vary by the values of $M_{(1)}$ and $M_{(2)}$ according to the research hypothesis of this study. Unlike Figure 2.1, this graph assumes that the errors of $W_{(t)}$ are correlated with each other as well as with Y. The correlations of these standarized variables are represented by π and θ.



Appendix Figure 2B Sensitivity Analyses for Effects of Grandparents' Education on Grandchildren's Education under Various Assumptions about the Strengths of Unobserved Variables

Notes: The parameter π can be roughly interpreted as the selection bias, or the correlation between *W* and *A*. The parameter θ refers to the intergenerational correlation between $W_{(t)}$ and $W_{(t+1)}$. Specifically, I assume that the unobserved variable $W_1 = \pi * A_1^* + \epsilon_1$ and $W_3 = \theta * W_1^* + \pi * A_2^* + \pi * Y^* + \epsilon_2$, where W^*, A^*, and Y^* are standardized variables of $W, A,$ and Y. The values of $\theta, \pi \in [0,1]$. For the sake of simplicity, this figure shows only results from the sensitivity analysis when $\theta = \pi$. The bias-corrected estimates for each value of the parameters are based on point estimates from 200 simulated samples. The horizontal line refers to the scenario under which the average grandparent effect is zero. The shaded areas refer to 95% confidence intervals. To speed up the computation, the sensitivity results are based on data with complete cases rather than data with missing-data imputation.

REFERENCES

Aldous, Joan. 1995. "New Views of Grandparents in Intergenerational Context." *Journal of Family Issues* 16(1): 104-22.

Alwin, Duane F., and Robert M. Hauser. 1975. "The Decomposition of Effects in Path Analysis." *American Sociological Review* 40(1): 37-47.

Amato, Paul R. 2005. "The Impact of Family Formation Change on the Cognitive, Social, and Emotional Well-Being of the Next Generation." *The Future of Children* 15(2): 75-96.

Andersson, Gunnar. 2002. "Children's Experience of Family Disruption and Family Formation: Evidence from 16 FFS Countries." *Demographic Research* 7(7): 343-64.

Aquilino, William S. 1996. "The Life Course of Children Born to Unmarried Mothers: Childhood Living Arrangements and Young Adult Outcomes." *Journal of Marriage and Family* 58(2): 293-310.

Asmussen, Linda, and Reed Larson. 1991. "The Quality of Family Time Among Young Adolescents in Single-Parent and Married-Parent Families." *Journal of Marriage and Family* 53(4): 1021-30.

Astone, Nan Marie, and Sara S. McLanahan. 1991. "Family Structure, Parental Practices, and High School Completion." *American Sociological Review* 56(3): 309-20.

Baron, Reuben M., and David A. Kenny. 1986. "The Moderator—Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations." *Journal of Personality and Social Psychology* 51(6): 1173-82.

Bartholomew, David J. 1982. *Stochastic Models for Social Processes*. Third Edition. New York: Wiley.

Bengtson, Vern L. 1985. “Diversity and Symbolism in Grandparent Roles.” Pp. 11-25 in *Grandparenthood* edited by Vern L. Bengtson and Joan F. Robertson. Beverly Hill: Sage.

Bengtson, Vern L. 2001. “Beyond the Nuclear Family: The Increasing Importance of Multigenerational Bonds.” *Journal of Marriage and Family* 63(February): 1-16.

Biblarz, Timothy J., and Adrian E. Raftery. 1993. “The Effects of Family Disruption on Social Mobility.” *American Sociological Review* 58(1): 97-109.

Biblarz, Timothy J., and Adrian E. Raftery. 1999. “Family Structure, Educational Attainment, and Socioeconomic Success: Rethinking the ‘Pathology of Matriarchy’.” *American Journal of Sociology* 105(2): 321-65.

Biblarz, Timothy J., Adrian E. Raftery, and Alexander Bucur. 1997. “Family Structure and Social Mobility” *Social Forces* 75(4): 1319-341.

Björklund, Anders, and Laura Chadwick. 2003. “Intergenerational Income Mobility in Permanent and Separated Families.” *Economics Letters* 80(2): 239-46.

Blau, Peter M., and Otis Dudley Duncan. 1967. *The American Occupational Structure*. New York: Wiley.

Bloome, Deirdre. 2014. “Racial Inequality Trends and the Intergenerational Persistence of Income and Family Structure.” *American Sociological Review* 79(6): 1196-225.

Boudon, Raymond. 1973. *Mathematical Structures of Social Mobility*. Jossey-Bass Inc., Publisher.

Brand, Jennie E., and Juli Simon Thomas. 2014. “Job Displacement among Single Mothers: Effects on Children’s Outcomes in Young Adulthood.” *American Journal of Sociology* 119 (4): 955-1001.

Bumpass, Larry L., and Hsien-Hen Lu. 2000. “Trends in Cohabitation and Implications for Children’s Family Contexts in the United States.” *Population Studies* 54(1): 29-41.

Bumpass, Larry L., and R. Kelly Raley. 1995. “Redefining Single-Parent Families: Cohabitation and Changing Family Reality.” *Demography* 32(1): 97-109.

Burton, Linda M., and Vern. L. Bengtson. 1985 “Black Grandmothers: Issues of Timing and Continuity of Roles.” Pp. 61-77 in *Grandparenthood*, edited by Vern L. Bengtson and Joan F. Robertson. Beverly Hills: Sage.

Casper, Lynne M., and Suzanne M. Bianchi. 2001. *Continuity and Change in the American Family*. Thousand Oaks, CA: Sage.

Chan, Tak Wing, and Vikki Boliver. 2013. “The Grandparents Effect in Social Mobility: Evidence from British Birth Cohort Studies.” *American Sociological Review* 78(4): 662-78.

Cherlin, Andrew J. 2004. “The Deinstitutionalization of American Marriage.” *Journal of Marriage and Family* 66(4): 848-61.

Cherlin, Andrew J., P. Lindsay Chase-Lansdale, and Christine McRae. 1998. “Effects of Parental Divorce on Mental Health throughout the Life Course.” *American Sociological Review* 63(2): 239-49.

Cherlin, Andrew J., and Frank F. Furstenberg, Jr. 1986. *The New American Grandparent: A Place in the Family, A Life Apart*. New York: Basic Books, Inc., Publishers.

Coall, David A., and Ralph Hertwig. 2010. “Grandparental Investment: Past, Present, and Future.” *Behavioral and Brain Sciences* 33: 1-59.

DeLeire, Thomas, and Ariel Kalil. 2002. “Good Things Come in Threes: Single-Parent Multigenerational Family Structure and Adolescent Adjustment.” *Demography* 39(2): 393-413.

Denham, Thomas E., and Craig W. Smith. 1989. "The Influence of Grandparents on Grandchildren: A Review of the Literature and Resources." *Family Relations* 38(3): 345-50.

Duncan, Beverly, and Otis Dudley Duncan. 1969. "Family Stability and Occupational Success." *Social Problems* 16(3): 273-285.

Duncan, Otis Dudley. 1966a. "Path Analysis: Sociological Examples." *American Journal of Sociology* 72(1): 1-16.

Duncan, Otis Dudley. 1966b. "Methodological Issues in the Analysis of Social Mobility." Pp. 51-97 in *Social Structure and Mobility in Economic Development*, edited by Neil J. Smelser and Seymour Martin Lipset. Chicago: Aldine.

Duncan, Otis Dudley. 1968. "Inheritance of Poverty of Inheritance of Race?" in *On Understanding Poverty* edited by D. P. Moynihan. New York: Basic Books.

Duncan, Otis Dudley. 1975. *Introduction to Structural Equation Models*. New York: Academic Press.

Dunifon, Rachel, and Lori Kowaleski-Jones. 2007. "The Influence of Grandparents in Single-Mother Families." *Journal of Marriage and Family* 69(2): 465-81.

Ellwood, David T., and Christopher Jencks. 2004. "The Uneven Spread of Single-Parent Families: What Do We Know? Where Do We Look for Answers?" Pp. 3-77 in *Social Inequality*, edited by Kathryn Neckerman. New York: Russell Sage Foundation.

Elwert, Felix, and Christopher Winship. 2014. "Endogenous Selection Bias: The Problem of Conditioning on a Collider Variable." *Annual Review of Sociology* 40: 31-53.

Erikson, Robert, and John H. Goldthorpe. 1992. *The Constant Flux: A Study of Class Mobility in Industrial Societies.* Oxford University Press.

Erola, Jani, and Pasi Moisio. 2007. "Social Mobility over Three Generations in Finland, 1950-2000." *European Sociological Review* 23(2): 169-83.

Featherman, David L., and Robert M. Hauser. 1976. "Changes in the Socioeconomic Stratification of the Races, 1962-1973." *American Journal of Sociology* 82(November): 621-651.

Featherman, David L., and Robert M. Hauser. 1978. *Opportunity and Change*. New York: Academic Press.

Fischer, Claude S., and Michael Hout. 2006. *Century of Difference: How America Changed in the Last One Hundred Years*. Russell Sage Foundation.

Fomby, Paula, and Andrew J. Cherlin. 2007. "Family Instability and Child Well-Being." *American Sociological Review* 72(2): 181-204.

Frederick, Carl. 2010. "A Crosswalk for Using Pre-2000 Occupational Status and Prestige Codes with Post-2000 Occupation Codes" Working Paper No. 2010-03, Center for Demography and Ecology, University of Wisconsin, Madison, WI.

Fuller-Thomson, Esme, Meredith Minkler, and Diane Driver. 1997. "A Profile of Grandparents Raising Grandchildren in the United States." *The Gerontologist* 37(3): 406-11.

Furstenberg, Frank F. 1990. "Divorce and the American Family." *Annual Review of Sociology* 16: 379-403.

Furstenberg, Frank F., and Andrew J. Cherlin. 1991. *Divided Families: What Happens to Children When Parents Part*. Cambridge, MA: Harvard University Press.

Furstenberg, Frank F., Saul D. Hoffman, and Laura Shrestha. 1995. "The Effect of Divorce on Intergenerational Transfers: New Evidence" *Demography* 32(3): 319-33.

Ginther, Donna K., and Robert A. Pollak. 2004. “Family Structure and Children’s Educational Outcomes: Blended Families, Stylized Facts, and Descriptive Regressions.” *Demography* 41(4): 671-96.

Goldin, Claudia, and Lawrence Katz. 2008. *The Race Between Education and Technology*. Cambridge, MA: Harvard University Press.

Greenland, Sander, Judea Pearl, and James M. Robins. 1999. “Causal Diagrams for Epidemiologic Research” *Epidemiology* 10:37-48.

Hauser, Robert M. 1987. “The 1962 and 1973 Occupational Changes in a Generation Surveys: An Overview and List of Selected Data Files and Publications.” Working Paper No. 87-5, Center for Demography and Ecology, University of Wisconsin, Madison, WI.

Hauser, Robert M., John Robert Warren, Min-Hsiung Huang, and Wendy Y. Carter. 2000. “Occupational Status, Education, and Social Mobility in the Meritocracy.” Pp. 179-229 in *Meritocracy and Economic Inequality*, edited by Kenneth Joseph Arrow, Samuel Bowles, and Steven N. Durlauf. Princeton: Princeton University Press.

Hayslip, Bert Jr., and Patricia L. Kaminski. 2005. “Grandparents Raising Their Grandchildren: A Review of the Literature and Suggestions for Practice.” *The Gerontologist* 45(2): 262-69.

Hertel, Florian R., and Olaf Groh-Samberg. 2014. “Class Mobility Across Three Generations in the U.S. and Germany.” *Research in Social Stratification and Mobility* 35: 35-52.

Hodge, Robert W. 1966. “Occupational Mobility as a Probability Process.” *Demography* 3: 19-34.

Hogan, Dennis P., David J. Eggebeen, and Clifford C. Clogg. 1993. “The Structure of Intergenerational Exchanges in American Families.” *American Journal of Sociology* 98 (6):1428-58.

Hogan, Dennis P., Ling-Xin Hao and William Parish. 1990. "Race, Kin Networks, and Assistance to Mother-Headed Families." *Social Forces* 68(3): 797-812.

Hong, Guanglei. 2015. *Causality in a Social World: Moderation, Mediation, and Spillover.* West Sussex, UK: Wiley-Blackwell.

Hout, Michael. 1984. "Status, Autonomy, and Training in Occupational Mobility." *American Journal of Sociology* 89(6): 1379-409.

Hout, Michael. 2015. "A Summary of What We Know about Social Mobility." *The ANNALS of the American Academy of Political and Social Science* 1: 27-36.

Hout, Michael, and Alexander Janus. 2011. "Educational Mobility in the United States since the 1930s." Pp. 165-86 in *Whither Opportunity? Rising Inequality, Schools, and Children's Life Chances* edited by Greg J. Duncan and Richard J. Murnane. New York: Russell Sage Foundation.

Hunter, Andrea G., and Robert J. Taylor. 1998. "Grandparenthood in African American Families." Pp. 70-86 in *Handbook on Grandparenthood* edited by Maximiliane E. Szinovacz. CT: Greenwood Press.

Jæger, Mads Meier. 2012. "The Extended Family and Children's Educational Success." *American Sociological Review* 77(6): 903-22.

Jencks, Christopher, Susan Bartlett, Mary Corcoran, James Crouse, David Eaglesfield, Gregory Jackson, Kent McClelland, Peter Mueser, Michael Olneck, Joseph Schwartz, Sherry Ward, and Jill Williams. 1979. *Who Gets Ahead? The Determinants of Economic Success in America*. New York: Basic Books.

Kao, Grace, and Jennifer S. Thompson. 2003. "Racial and Ethnic Stratification in Educational Achievement and Attainment" *Annual Review of Sociology* 29: 417-42.

Karabel, Jerome. 2005. *The Chosen: The Hidden History of Admission and Exclusion at Harvard, Yale, and Princeton*. Boston: Houghton Mifflin Harcourt.

Kaushal, Neeraj, Katherine Magnuson, and Jane Waldfogel. 2011. *How Is Family Income Related to Investments in Children's Learning?* New York: Russell Sage Foundation.

Kendig, Sarah M., and Suzanne M. Bianchi. 2008. "Single, Cohabitating, and Married Mothers' Time Use with Children." *Journal of Marriage and Family* 70(5): 1228-40.

Kim, Hyun Sik. 2011. "Consequences of Parental Divorce for Child Development." *American Sociological Review* 76(3): 487-511.

King, Valarie, and Glen H. Elder, Jr. 1995. "American Children View Their Grandparents: Linked Lives Across Three Rural Generations." *Journal of Marriage and Family* 57(1): 165-78.

King, Valarie, and Glen H. Elder, Jr. 1997. "The Legacy of Grandparenting: Childhood Experiences with Grandparents and Current Involvement with Grandchildren." *Journal of Marriage and Family* 59(4): 848-59.

Krein, Sheila Fitzgerald, and Andrea H. Beller. 1988. "Educational Attainment of Children from Single-Parent Families: Differences by Exposure, Gender, and Race." *Demography* 25: 221-34.

Lam, David. 1986. "The Dynamics of Population Growth, Differential Fertility, and Inequality." *The American Economic Review* 76(5): 1103-16.

Manski, Charles F. 2013. *Identification of Treatment Response with Social Interactions*. *The Econometrics Journal* 1(16): S1-S23.

Manski, Charles F., Gary D. Sandefur, Sara McLanahan, and Daniel Powers. 1992. “Alternative Estimates of the Effect of Family Structure during Adolescence on High School Graduation.” *Journal of the American Statistical Association* 87(417): 25-37.

Maralani, Vida. 2013. “The Demography of Social Mobility: Black-White Differences in the Process of Educational Reproduction.” *American Journal of Sociology* 118(6): 1509-58.

Mare, Robert D. 1997. “Differential Fertility, Intergenerational Educational Mobility, and Racial Inequality.” *Social Science Research* 26(3): 263-91.

Mare, Robert D. 2011. “A Multigenerational View of Inequality.” *Demography* 48(1): 1-23.

Mare, Robert D. 2014. “Multigenerational Aspects of Social Stratification: Issues for Future Research.” *Research in Social Stratification and Mobility* 35: 121-28.

Mare, Robert D. 2015. “Measuring Networks beyond the Origin Family.” *The ANNALS of the American Academy of Political and Social Science*. 1: 97-107.

Mare, Robert D., and Vida Maralani. 2006. “The Intergenerational Effects of Changes in Women’s Educational Attainments.” *American Sociological Review* 71(4): 542-64.

Martin, Molly A. 2012. “Family Structure and the Intergenerational Transmission of Educational Advantage.” *Social Science Research* 41(1): 33-47.

Matras, Judah. 1961. “Differential Fertility, Intergenerational Occupational Mobility and Change in the Occupational Distribution: Some Elementary Interrelationships.” *Population Studies* 15(2): 187-97.

Matras, Judah. 1967. “Social Mobility and Social Structure: Some Insights from the Linear Model.” *American Sociological Review* 32(4): 608-14.

McLanahan, Sara. 2004. “Diverging Destinies: How Children Are Faring under the Second Demographic Transition.” *Demography* 41(4): 607-27.

McLanahan, Sara, and Larry L. Bumpass. 1988. "Intergenerational Consequences of Family Disruption." *American Journal of Sociology* 94(1): 130-52.

McLanahan, Sara, and Christine Percheski. 2008. "Family Structure and the Reproduction of Inequalities." *Annual Review of Sociology* 34(1): 256-76.

McLanahan, Sara, and Gary Sandefur. 1994. *Growing Up with a Single Parent: What Hurts, What Helps*. Cambridge, Mass.: Harvard University Press.

McLanahan, Sara, Laura Tach, and Daniel Schneider. 2013. "The Causal Effects of Father Absence." *Annual Review of Sociology* 399: 399-427.

Morgan, Stephen L., and Christopher Winship. 2014. *Counterfactuals and Causal Inference: Methods and Principles for Social Research*. Second Edition. Cambridge: Cambridge University Press.

Musick, Kelly A., and Robert D. Mare. 2004. "Family Structure, Intergenerational Mobility, and the Reproduction of Poverty: Evidence for Increasing Polarization?" *Demography* 41(4): 629-48.

Pearl, Judea. 2001. "Direct and Indirect Effects." *Proceedings of the Seventeenth Conference on Uncertainty and Artificial Intelligence* (UAI2001): 411-20.

Pearl, Judea. 2009. *Causality*. 2nd ed. New York: Cambridge University Press.

Pearl, Judea. 2014. "Interpretation and Identification of Causal Mediation." *Psychological Methods* 19(4): 459-81.

Pfeffer, Fabian. 2014. "Multigenerational Approaches to Social Mobility: A Multifaceted Research Agenda." *Research in Social Stratification and Mobility* 35: 1-12.

Preston, Samuel H. 1974. "Differential Fertility, Unwanted Fertility, and Racial Trends in Occupational Achievement." *American Sociological Review* 39(4): 492-506.

Preston, Samuel H., and Cameron Campbell. 1993. “Differential Fertility and the Distribution of Traits: The Case of IQ.” *American Journal of Sociology* 98(5): 997-1019.

PSID Main Interview User Manual: Release 2013. Institute for Social Research, University of Michigan, Ann Arbor, MI.

Raley, R. Kelly, and Larry Bumpass. 2003. “The Topography of the Divorce Plateau: Levels and Trends in Union Stability in the United States after 1980.” *Demographic Research* 8(8): 245-260.

Raudenbush, StephenW., and Anthony S. Bryk. 2002. *Hierarchical Linear Models: Applications and Data Analysis Methods.* 2nd ed. Newbury Park, CA: Sage Publications.

Robins, James M., and Miguel A. Hernán. 2009. “Estimation of the Causal Effects of Time-Varying Exposures.” Pp. 553-99 in *Longitudinal Data Analysis* edited by Garrett Fitzmaurice, Marie Davidian, Geert Verbeke, Geert Molenberghs. New York: Chapman and Hall/CRC Press.

Ruggles, Steven. 2007. “The Decline of Intergenerational Coresidence in the United States, 1850 to 2000.” *American Sociological Review* 72: 964-89.

Sandefur, Gary D., and Thomas Wells. 1999. “Does Family Structure Really Influence Educational Attainment?” *Social Science Research* 28: 331-57.

Sarkisian, Natalia, and Naomi Gerstel. 2004. “Kin Support among Blacks and Whites: Race and Family Organization.” *American Sociological Review* 69(6): 812-37.

Seltzer, Judith A. 1991. “Relationship between Fathers and Children Who Live Apart: The Father’s Role after Separation.” *Journal of Marriage and Family* 53(1): 79-101.

Seltzer, Judith A. 1994. “Consequences of Marital Dissolution for Children.” *Annual Review of Sociology* 20: 235-66.

Seltzer, Judith A., Charles Q. Lau, and Suzanne M. Bianchi. 2012. "Doubling Up When Times Are Tough: A Study of Obligations to Share a Home in Response to Economic Hardship." *Social Science Research* 41(5): 1307-1319.

Sewell, William H., and Robert M. Hauser. 1975. *Education, Occupation, and Earnings. Achievement in the Early Career*. New York: Academic Press Inc.

Sharkey, Patrick, and Felix Elwert. 2011. "The Legacy of Disadvantage: Multigenerational Neighborhood Effects on Cognitive Ability." *American Journal of Sociology* 116(6): 1934-81.

Silverstein, Merril, and Vern L. Bengtson. 1997. "Intergenerational Solidarity and the Structure of Adult Child—Parent Relationships in American Families." *American Journal of Sociology* 103(2): 429-60.

Silverstein, Merril, and Anne Marenco. 2001. "How Americans Enact the Grandparent Role Across the Family Life." *Journal of Family Issues* 22(4): 493-522.

Singer, Burton, and Seymour Spilerman. 1976. "The Representation of Social Processes by Markov Models." *American Journal of Sociology* 82(1): 1-54.

Sobel, Michael. 2008. "Identification of Causal Parameters in Randomized Studies with Mediating Variables." *Journal of Educational and Behavioral Statistics* 33(2): 230-31.

Solon, Gary. 2014. "Theoretical Models of Inequality Transmission Across Multiple Generations." *Research in Social Stratification and Mobility* 35: 13-18.

Swartz, Teresa Toguchi. 2009. "Intergenerational Family Relations in Adulthood: Patterns, Variations, and Implications in the Contemporary United States." *Annual Review of Sociology* 35: 191-212.

Sweeney, Megan M., and Julie A. Philips. 2004. "Understanding Racial Differences in Marital Disruption: Recent Trends and Explanations." *Journal of Marriage and Family* 66(3): 639-50.

Tach, Laura. 2015. "Social Mobility in an Era of Family Instability and Complexity." *The ANNALS of the American Academy of Political and Social Science* 657(1): 83-96.

Thomson, Elizabeth, Thomas L. Hanson, and Sara S. McLanahan. 1994. "Family Structure and Child Well-being: Economic Resources vs. Parental Behaviors." *Social Forces* 73(1): 221-42.

Thornton, Arland. 1991. "Influences of the Marital History of Parents on the Marital and Cohabitational Experiences of Children." *American Journal of Sociology* 96(4): 868-94.

Thornton, Arland, William G. Axinn, and Yu Xie. 2008. *Marriage and Cohabitation*. Chicago: University of Chicago Press.

Uhlenberg, Peter. 1996. "Mortality Decline in the Twentieth Century and Supply of Kin over the Life Course." *The Gerontologist* 36(5): 681-685.

Uhlenberg, Peter, and Bradley G. Hammill. 1998. "Frequency of Grandparent Contact with Grandchild Sets: Six Factors that Make a Difference." *The Gerontologist* 38(2): 276-85.

VanderWeele, Tyler J. 2009. "Marginal Structure Models for the Estimation of Direct and Indirect Effects." *Epidemiology* 20: 18-26.

VanderWeele, Tyler J. 2015. *Explanation in Causal Inference: Methods for Mediation and Interaction.* Oxford University Press.

Wang, Xiaolu, and Michael E. Sobel. 2013. "New Perspectives on Causal Mediation Analysis." Pp. 215-42 in *Handbook of Causal Analysis for Social Research* edited by Stephen L. Morgan. Netherland: Springer Series.

Warren, John Robert, and Robert M. Hauser. 1997. "Social Stratification Across Three Generations: New Evidence from the Wisconsin Longitudinal Study." *American Sociological Review* 62(4): 561-72.

Wightman, Patrick, and Sheldon Danziger. 2014. "Multigenerational Income Disadvantage and the Educational Attainment of Young Adults." *Research in Social Stratification and Mobility* 35: 53-69.

Wilson, William Julius. 2012. T*he Truly Disadvantaged: The Inner City, the Underclass, and Public Policy*. 2nd Ed. Chicago, IL: University of Chicago Press.

Wodtke, Geoffrey T., Felix Elwert, and David J. Harding. 2012. "Poor Families, Poor Neighborhoods: How Family Poverty Intensifies the Impact of Concentrated Disadvantage." PSC Research Report No. 12-776. September 2012.

Wojtkiewicz, Roger A. 1993. "Simplicity and Complexity in the Effects of Parental Structure on High School Graduation." *Demography* 30(4): 701-717.

Wolfinger, Nicholas H. 1999. "Trends in the Intergenerational Transmission of Divorce." *Demography* 36(3): 415-20.

Wu, Lawrence L., and Brian C. Martinson. 1993. "Family Structure and the Risk of a Premarital Birth." *American Sociological Review* 58(2): 210-32.

Yahirun, Jenjira J., and Judith A. Seltzer. 2014. "*Grandparents' Involvement in Biological and Stepfamilies*." Presented at the annual meeting of the American Sociological Association, August 16-19, San Francisco, CA.

Zeng, Zhen, and Yu Xie. 2014. "The Effects of Grandparents on Children's Schooling: Evidence from Rural China." *Demography* 51(2): 599-617.

CHAPTER 3

Short-Term and Long-Term Educational Mobility of Families: A Two-Sex Approach

3.1 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.

3.2 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 by 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 family founders (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.

3.3 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.

3.4 SOCIAL AND DEMOGRAPHIC MOBILITY MODELS

3.4.1 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,

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

3.4.2 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.[13] 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.

[13] 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.

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 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,

$$Net\ SRE_{k|j} = \frac{\mu^{kk}(F,M)\left(r^s_{kk}p^s_{k|kk} + r^d_{kk}p^d_{k|kk}\right)}{M_k + F_k} - \frac{\mu^{jj}(F,M)\left(r^s_{jj}p^s_{k|jj} + r^d_{jj}p^d_{k|jj}\right)}{M_j + F_j} \tag{9}$$

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,

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

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.

3.5 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)[14] 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.[15]

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[14] "Family Identification Mapping System" is a tool developed by the PSID to create intergenerational linked samples (http://simba.isr.umich.edu/FIMS/)

[15] 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.

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 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.[16] 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.[17] 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.

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[16] 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.
[17] 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.

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 3A summarizes the education distribution for the offspring, parent and grandparent generations.[18] Our final mobility sample consists of 3,122 sons and 3,145 daughters, and 6,267 parents and 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.[19]

3.6 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 3.1), and daughters, mothers, and grandmothers (Table 3.2), respectively. For all models, we assume discrete, additive multigenerational effects, meaning that we do not include associations between an individual's

[18] Appendix Table 3A 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.

[19] 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 3A, which suggests an overrepresentation of African Americans and an underrepresentation of other races due to the sampling design of PSID.

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 3.1 and Table 3.2 suggest that a person's likelihood of getting married and the number of children depends on both his or her own and the 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.[20] 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 3.1]

[Table 3.2]

We present parameter estimates for the two-sex mating and fertility models in Table 3.3 and 3.4. As discussed earlier, one solution to consider the differential marital rates and mating

[20] 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.

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 3.3. 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 3B, which 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 3.3]

[Table 3.4]

Table 3.4 shows estimates of binary logistic models for marriage for men and women. The results are largely consistent with one-sex results in Table 3.1 and 3.2, 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 3.4 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 3.5]

Finally, we show the two-sex mobility results from ordinal logistic regressions in Table 3.5. Unlike the one-sex mobility models presented in Table 3.1 and 3.2, 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 3.5 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 3.5, 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 3.6 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 3B. For the same reason, two college couples produce 0.13 fewer college grandchildren than two high-school couples.

[Table 3.6]

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.

3.7 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 3.1 to 3.5. 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 3.1]

Figure 3.1 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 3.1 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 3.7). 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 3.1 refer to scenarios 10 and 2 respectively, which assume that mating and mobility both follow two-sex or one-sex rules.

[Table 3.7]

[Figure 3.2]

Figure 3.2 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.

3.8 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,[21] 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.

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[21] 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.

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 3.3]

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 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 3.3. 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 3.3 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.

Table 3.1 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 3.2 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 3.3 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 3.4 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 3.4
(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 3.5 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 3.5 (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 3.6 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 3.7 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.

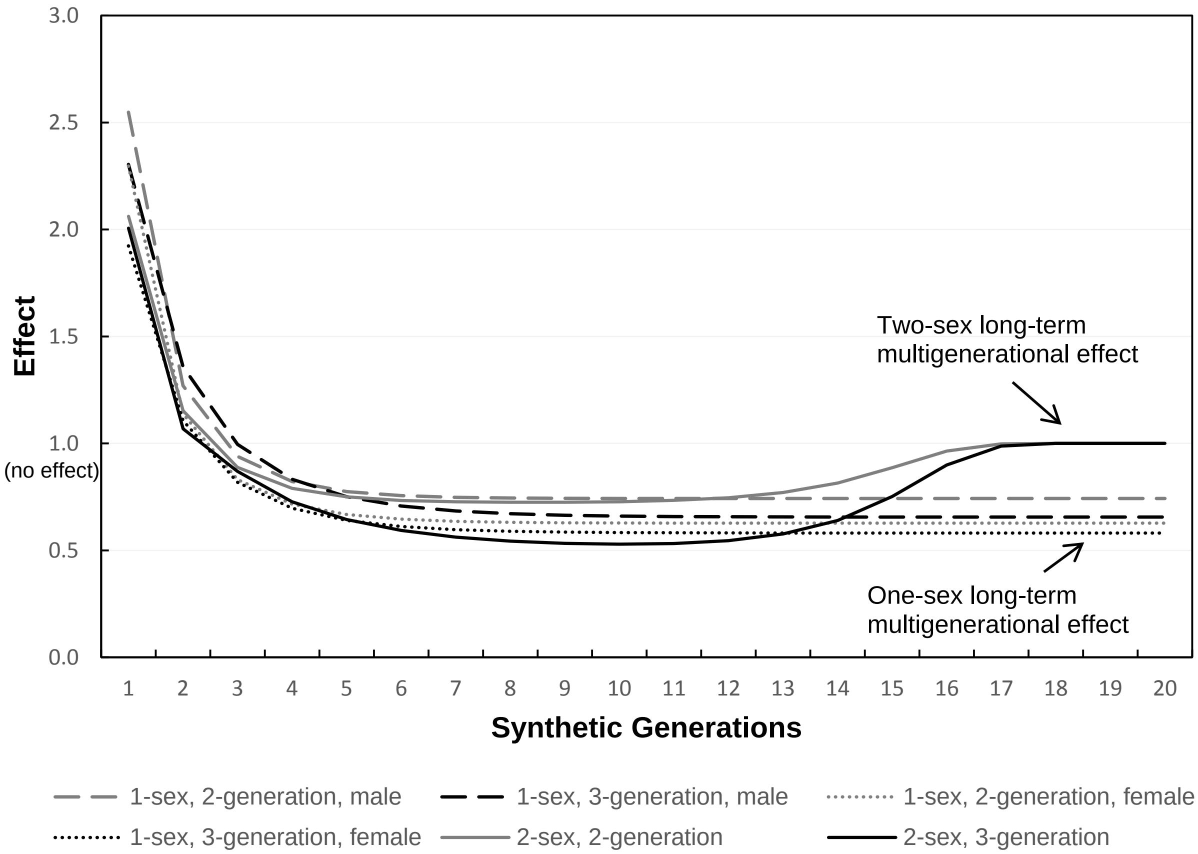

Figure 3.1 Multigenerational Reproduction of College Education

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.

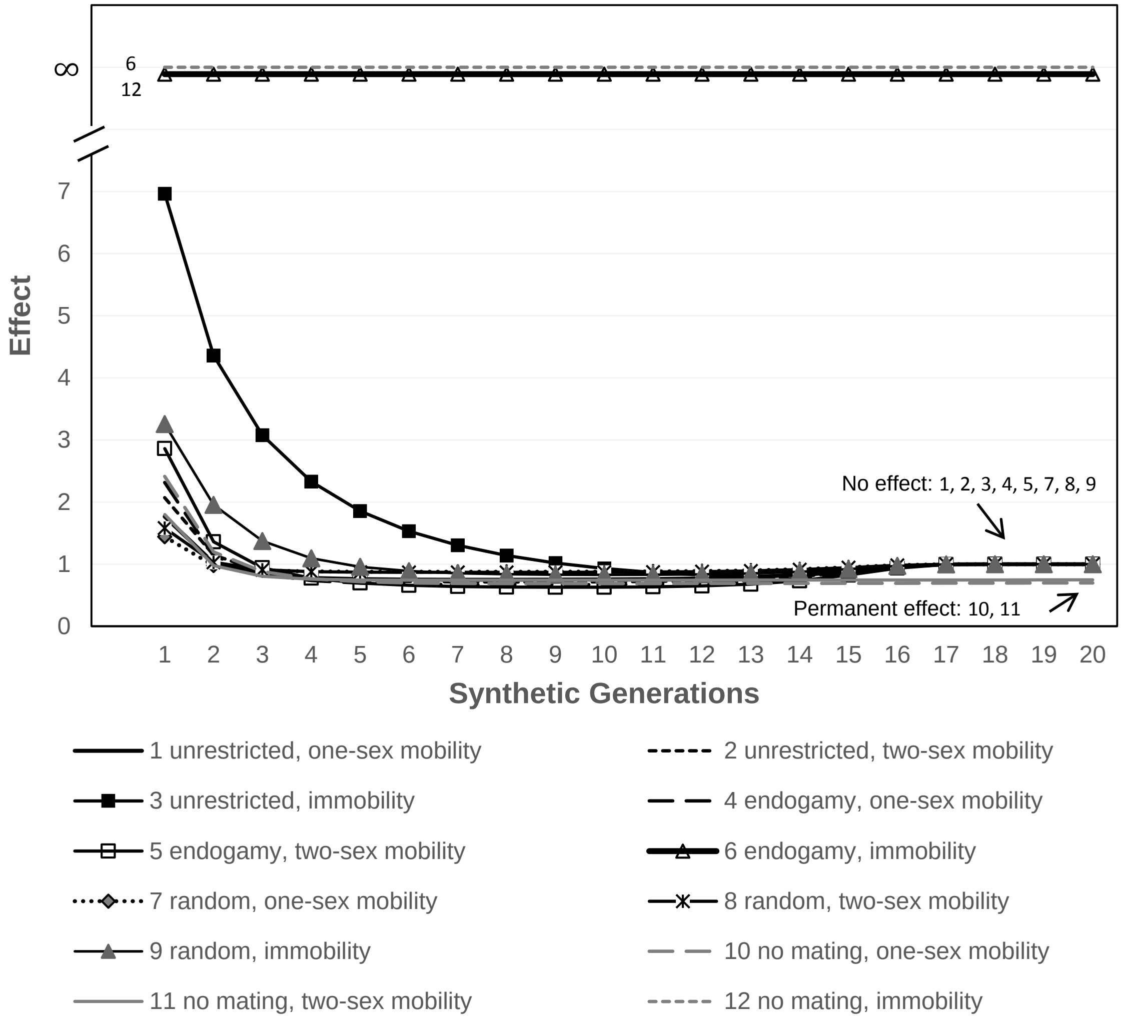

Figure 3.2 Multigenerational Reproduction of College Education based on Various Scenarios of Mating and Mobility Rules

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

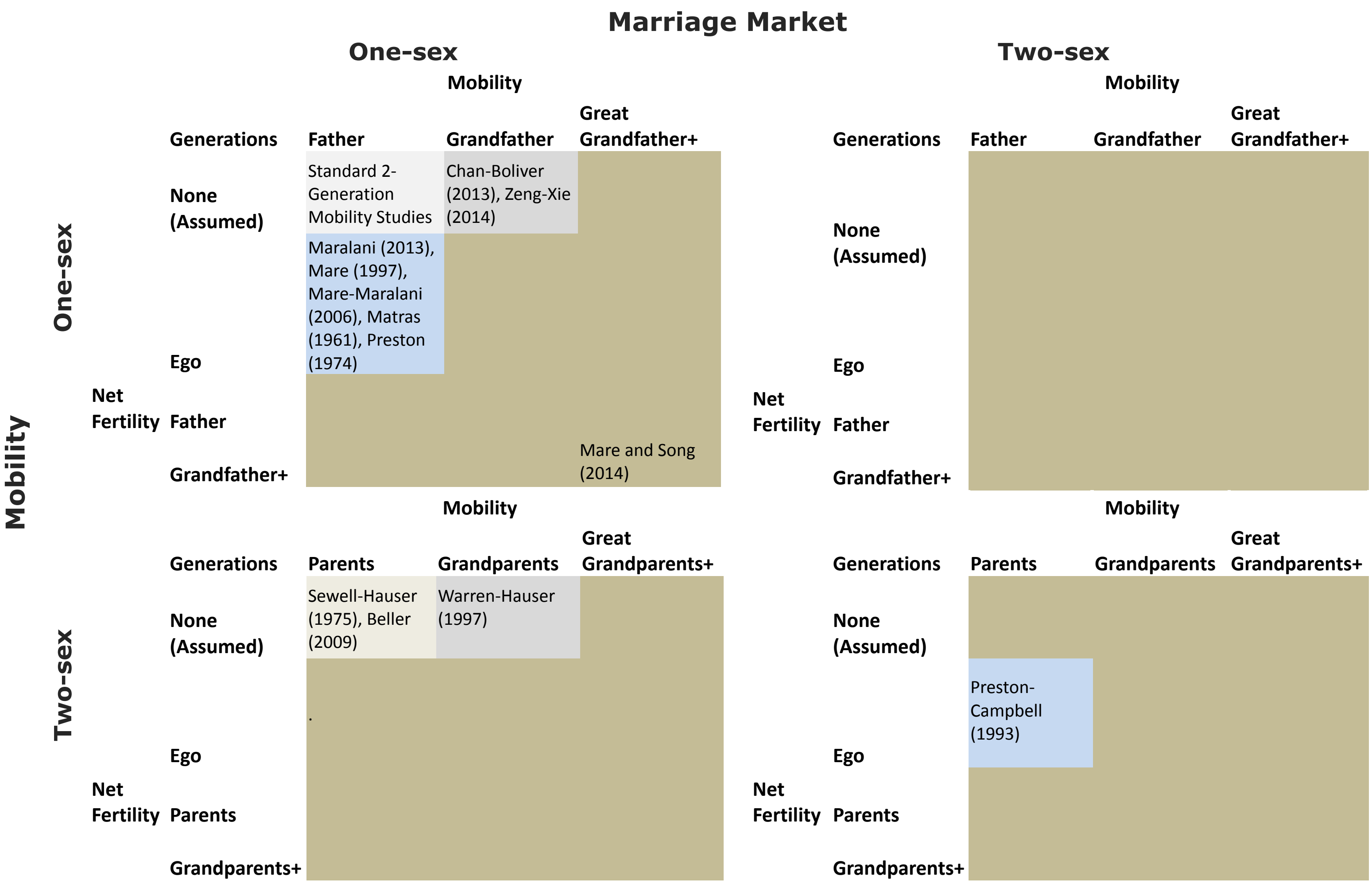

Figure 3.3 Taxonomy of Multigenerational Effects and Exemplary Studies

Appendix Table 3A 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 Table 3B 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 Table 3C 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.

REFERENCES

Bartholomew, D. J. (1982). *Stochastic models for social processes (third edition)*. New York: Wiley.

Beller, E. (2009). Bringing intergenerational social mobility research into the twenty-first century. *American Sociological Review,* 74, 507-528.

Bernheim, D. B. & Bagwell, K. (1988). Is everything neutral? *Journal of Political Economy,* 96, 308-338.

Blau, P. M. & Duncan, O. D. (1967). *The American occupational structure*. New York: Wiley.

Buchmann, C. & DiPrete, T. A. (2006). The growing female advantage in college completion: The role of family background and academic achievement. *American Sociological Review,* 71, 515-541.

Caswell, H. (2001). *Matrix population models: Construction, analysis, and interpretation (second edition)*. Sunderland, MA: Sinauer Associates.

Chan, T. W., & Boliver, V. (2013). The grandparent's effect in social mobility: Evidence from British birth cohort studies. *American Sociological Review,* 78, 662-678.

Cherlin, A. J. & Furstenberg, F. F. (1986). *The new American grandparent: A place in the family, a life apart*. New York: Basic Books.

DiPrete, T. A. & Eirich, G. M. (2006). Cumulative advantage as a mechanism for inequality: A review of theoretical and empirical developments. *Annual Review of Sociology,* 32, 271-297.

Duncan, O. D. (1966). Methodological issues in the analysis of social mobility. Pp. 51-97 in N. J. Smelser & S. M. Lipset (Ed.), *Social structure and mobility in economic development*. Chicago: Aldine.

Erikson, R. & Goldthorpe, J. H. (1992). *The constant flux: A study of class mobility in industrial societies*. Oxford: Clarendon Press.

Erola, J. & Moisio, P. (2007). Social mobility over three generations in Finland, 1950-2000. *European Sociological Review,* 23, 169-183.

Featherman, D. L. & Hauser, R. M. (1978). *Opportunity and change*. New York: Academic Press.

Goldstein, D. B. (2008). *Jacob's legacy: A genetic view of Jewish history*. New Heaven, CT: Yale University Press.

Goodman, L. A. (1953). Population growth of the sexes. *Biometrics,* IX, 212-225.

Hertel, F. R., & Groh-Samberg, O. (2014). Class mobility across three generations in the U.S and Germany. *Research in Social Stratification and Mobility,* 35, 35-52.

Hodge, R. W. (1966). Occupational mobility as a probability process. *Demography,* 3, 19–34.

Hout, M. (1983). *Mobility tables*. Beverly Hills, CA: Sage Publications.

Hout, M. (1988). More universalism, less structural mobility: The American occupational structure in the 1980s. *American Journal of Sociology,* 93, 1358-1400.

Jæger, M. M. (2012). The extended family and children's educational success. *American Sociological Review,* 77, 903-922.

Keyfitz, N. (1968). *Introduction to the mathematics of population*. Addison-Wesley Publishing Company.

Keyfitz, N. (1972). The mathematics of sex and marriage. *Proceedings of the Sixth Berkeley Symposium on Mathematical Statistics and Probability,* 4, 89-108.

Lam, D. (1986). The dynamics of population growth, differential fertility, and inequality. *American Economic Review,* 76, 1103-1116.

Lee, J. Z., & Campbell, C. D. (1997). *Fate and fortune in rural China: Social organization and population behavior in Liaoning, 1774-1873*. Cambridge University Press.

Lee, J. Z., & Wang, F. (1999). *One quarter of humanity: Malthusian mythology and Chinese realities, 1700-2000*. Harvard University Press.

Maralani, V. (2013). The demography of social mobility: Black-white differences in educational reproduction. *American Journal of Sociology,* 118, 1509-1558.

Mare, R. D. (1997). Differential fertility, intergenerational educational mobility, and racial inequality. *Social Science Research,* 26, 263–291.

Mare, R. D. (2000). Assortative mating, intergenerational mobility, and educational inequality. Working paper CCPR-004-00 UCLA California Center for Population Research

Mare, R. D. (2011). A multigenerational view of inequality. *Demography,* 48, 1-23.

Mare, R. D. (2014). Multigenerational aspects of social stratification: Issues for future research. *Research in Social Stratification and Mobility,* 35, 121-128.

Mare, R. D., & Schwartz, C. R. (2006). Educational assortative mating and the family background of the next generation: A formal analysis. *Riron to Hoho (Sociological Theory and Methods),* 21, 253–277.

Mare, R. D., & Maralani, V. (2006). The intergenerational effects of changes in women's educational attainments. *American Sociological Review,* 71, 542-564.

Mare, R. D., & Song, X. (2014). Social mobility in multiple generations. Unpublished manuscript. Los Angeles. California Center for Population Research.

Matras, J. (1961). Differential fertility, intergenerational occupational mobility and change in the occupational distribution: Some elementary interrelationships. *Population Studies*, 15, 187-197.

Matras, J. (1967). Social mobility and social structure: Some insights from the linear model. *American Sociological Review,* 32, 608-614.

Pfeffer, F. (2014). Multigenerational approaches to social mobility: A multifaceted research agenda. *Research in Social Stratification and Mobility,* 35, 1-12.

Pollak, R. A. (1986). A reformulation of the two-sex problem. *Demography,* 23, 247-259.

Pollak, R. A. (1987). The two-sex problem with persistent unions: A generalization of the birth matrix-mating rule model. *Theoretical Population Biology,* 32, 176-187.

Pollak, R. A. (1990). Two-sex demographic models. *Journal of Political Economy,* 98, 399-420.

Preston, S. H. (1974). Differential fertility, unwanted fertility, and racial trends in occupational achievement. *American Sociological Review,* 39, 492-506.

Preston, S. H., & Campbell, C. D. (1993). Differential fertility and the distribution of traits: The case of IQ. *American Journal of Sociology,* 98, 997-1019.

PSID Main Interview User Manual: Release 2013. Institute for Social Research, University of Michigan, July, 2013.

Qian, Z., & Preston, S. H. (1993). Changes in American marriage, 1972 to 1987: Availability and forces of attraction by age and education. *American Sociological Review,* 58, 482-495.

Schoen, R. (1981). The harmonic mean as the basis of a realistic two-sex marriage model. *Demography,* 18, 201-216.

Schoen, R. (1988). *Modeling multigroup populations*. New York: Plenum.

Sewell, W. H. & Hauser, R. M. (1975). *Education, occupation, and earnings: Achievement in the early career*. New York: Academic Press.

Warren, J. R., & Hauser, R. M. (1997). Social stratification across three generations: New evidence from the Wisconsin Longitudinal Study. *American Sociological Review,* 62, 561-572.

Wightman, P., & Danziger, S. (2014). Multigenerational income disadvantage and the educational attainment of young adults. *Research in Social Stratification and Mobility,* 35, 53-69.

Zeng, Z., & Xie, Y. (2014). The effects of grandparents on children's schooling: Evidence from rural China. *Demography,* 51, 599-617.

CHAPTER 4

Ancestry Matters: Descent Line Growth and Extinction

4.1 INTRODUCTION

We assess whether males in historical China successfully translated their high status into larger numbers of patrilineal descendants in subsequent generations. We focus on patrilineal descendants because family reproductive strategies in China and many other patriarchal societies focused on the growth or at least continuity of the male descent line (Cohen 1990; Freedman 1966; Harrell 1985; Lee and Wang 1999; Wolf and Huang 1980; Wolf 2001). We rely on direct, empirical analysis of multi-generational data to measure status influences on long-term reproductive success as reflected in the growth or extinction of descent lines. Previous demographic and population genetic studies of long-term reproductive success and resulting changes in population composition mostly extrapolated from data on two generations, by using measured relationships between parents' and children's outcomes as inputs to analytic models or simulations (Bodmer 1965; Cavalli-Sforza and Feldman 1981; Hartl and Clark 2007; Mare 1997; Preston and Campbell 1993; Wachter, Hammel and Laslett 1978).

We conceptualize representation by descendants in the population generations later as a demographic outcome of interest to population geneticists and evolutionary biologists and as a stratification outcome important to demographers, sociologists, and other social scientists. According to evolutionary theory, the animating force in the competition for status in each generation is the need to be represented in later generations (Fisher 1958). From the standpoint of a descent line founder, all of the outcomes normally considered in studies of the implications of status—including marriage, fertility, health, mortality, and the transmission of status—are simply the means to an end: representation, or overrepresentation, by descendants in later generations. The overarching importance of representation in later generations is not an abstract proposition emphasized in evolutionary theory. In historical China, the subordination of strategies for marriage, reproduction, and attainment to the overarching goal of having patrilineal descendants was explicit. By focusing directly on representation in later generations instead of the various demographic and social outcomes that interact to determine it, we introduce a new perspective that emphasizes the overall implication of social and economic status, not the separate, partial implications.

To examine the influence of male founders' characteristics on numbers of patrilineal descendants, we apply regression-based techniques to two large prospective, multi-generational demographic databases that describe populations at opposite ends of the social spectrum during the last imperial dynasty of China (Qing, 1644-1911): the Imperial Lineage, who lived largely in Beijing, and populations of farmers who lived in the northeast Chinese province of Liaoning (Lee, Campbell and Wang 1993; Lee, Campbell and Chen 2010). Since our data are prospective and the populations are closed, they are free of the survivor bias and loss to follow-up that are typical of family genealogies and other retrospective data. They allow us to follow not only the descent lines which flourished, but also the ones which became extinct. Even though the populations we study are not representative of historical Chinese populations in a formal, statistical sense, their positions at nearly opposite ends of the social spectrum make it reasonable to claim that observed similarities are indicative of basic processes common to historical Chinese populations, and perhaps other historical populations as well.

Relying on a one-sex population growth framework, we define a descent line to consist of a male founder and all his patrilineal male descendants, namely his son, his sons' sons, and so forth. We show that the status of a descent line founder influenced his representation in later generations not only because he had more sons, but also because for several more generations, his patrilineal descendants also had more sons. Descent lines founded by high status males eventually accounted for a disproportionately large share of the population. While the growth rate advantages of descent lines with high status founders emerged in the initial generation, these advantages eventually dissipated. As a result, the share of the population occupied by the descendants of high status descent line founders increased for several generations, then stabilized. The results suggest a long-term trend of regression to the mean for the growth rates of high status descent lines.

By assessing descent line extinction separately from descent line growth, we challenge a common belief that families in historical China (Hsu 1943; Wolf 1995:116-117; 2001) and elsewhere (e.g., Betzig 1986; Turke 1989; see a summary in Table 1 of Hopcroft 2006) always maximized their number of male births. Our results show that the social status of founders had a greater and more enduring effect on the chances of descent lines becoming extinct than it did on the growth rates of the lines that avoided extinction. The results imply that high-status descent lines achieved overrepresentation in succeeding generations by minimizing their extinction probabilities rather than by maximizing the number of male births in each generation. The results provide empirical evidence of short-term versus long-term and quantity-quality trade-offs in family reproductive success as suggested by life history theory (Hill and Kaplan 1999; Mace 2000).

This study enriches our understanding of multi-generational social stratification processes. Our results substantiate Mare's (2011) argument that traditional social mobility studies provide an incomplete picture of social inequality between families by focusing exclusively on surviving families or descent lines. In addition, our results imply a channel for an indirect influence of ancestor's characteristics on individuals' social attainments. Among surviving descent lines, if individuals' life chances depend on the characteristics of their kin networks (Campbell and Lee 2008a, 2011; Jæger 2012), the reproductive success of high status founders would influence the social characteristics of their descendants by shaping the size and composition of the patrilineal kin networks in which they were embedded. This would represent a novel channel by which a distant ancestor's characteristics influenced contemporary stratification outcomes.

4.2 BACKGROUND

4.2.1 Social Stratification, Demographic Differentials and Descent Line Dynamics

Classic approaches to the study of social stratification and mobility do little to illuminate the implications of status differentiation in one generation for long-term "processes of 'social metabolism'" (Duncan 1966). Intergenerational social mobility studies typically examine influences of parents' social status on social success of offspring independently of mortality and fertility patterns at the population level (e.g., Blau and Duncan 1967; Erikson and Goldthorpe 1992; Featherman and Hauser 1978; Long and Ferrie 2013). Only a few studies have examined how social mobility and demographic differentials interact to shape long-term population renewal as well as growth and decline of various social groups (Lam 1986; Maralani 2013; Mare 1997; Mare and Maralani 2006; Matras 1961, 1967; Preston 1974; Preston and Campbell 1993).

Because of a lack of multi-generational data, most of these studies rely on projections or simulations from two-generation models. Their results are heavily dependent on assumptions included in the model.

Studies of stratification processes and population composition should account for potentially complex interactions between status differentials in demographic behaviors. In many preindustrial societies, high status was associated with increased reproductive fitness, in the form of larger numbers of surviving offspring (Courtiol et al. 2012; Gillespie, Russell, and Lummaa 2008; Goodman et al. 2009; Hill 1984; Huber, Bookstein, and Feider 2010; Nettle and Pollet 2008). While the positive relationship between high status and reproductive fitness should have led to long-term growth of high status descent lines, life history theory also suggests that family trade-offs between quantity and quality of children as well as between current and future reproduction may have made relationships between male social status and the number of patrilineal descendants very complex (Hill and Kaplan 1999). Parents may have fewer children than they are physiologically capable of in order to enhance the chances that offspring will survive to adulthood, find an acceptable spouse, attain high status, or have children of their own (Boone and Kessler 1999; Goodman et al. 2012; Hill 1984; Huber et al. 2010; Liu and Lummaa 2011; Liu, Rotkirch and Lummaa 2012). Families may exercise control over current number of offspring in order to preserve resources for reproduction of future generations.

To account for trade-offs between maximization of total number of offspring and minimization of extinction chances, it is necessary to compare and contrast the effect of status on descent line growth rates and extinction probabilities. The influence of social status on the probability of childlessness may differ from its influence on the total number of children among couples who have at least one. For example, Fieder and Huber (2007) show that the relationship between socioeconomic status and reproductive success depends on the inclusion and exclusion of childless individuals. Most importantly, descent lines face hurdles in each generation that must be overcome to have any representation in the next generation. The most obvious of these hurdles in traditional societies is marriage (e.g., Dherbécourt 2013; Goodman and Koupil 2010). At least one man in each generation must marry and have one child for the descent line to be represented in the following generation. If the effects of social status on reproductive success in each generation differed by parity of births, high status may have had a more complex effect on descent line dynamics than a simple increase in the mean number of offspring.

Studies of descent lines confirm that extinction was common in historical populations, and that small numbers of descent lines eventually accounted for large shares of the population. Systematic efforts to study the long-term growth and extinction of descent lines date back at least to Francis Galton and H.W. Watson's (1874) application of branching theory to study aristocratic surnames. Lotka (1929, 1931, 1941) subsequently estimated family extinction probabilities for male descent lines in the United States white population in 1920. Wachter and Laslett (1978) analyzed the long-term influences of such demographic behaviors as marriage and reproduction on the extinction of British elite patrilines. Empirical, theoretical, and simulation studies in population genetics go further and show that over the long-term, the overwhelming majority of descent lines become extinct, and a small subset become dominant (Semino et al. 2000, Chang 1999; Lachance 2009; Murphy 2004; Rohde, Olson and Chang 2004).

Changes over time in the distribution of surnames in aggregated data provide additional insights into long-term processes of descent line growth and extinction (Matsen and Evans 2008). In societies that experience little immigration, surname distributions become highly concentrated and the distribution of their sizes highly skewed (e.g., Piazza et al. 1987; Yasuda et al. 1974). In China, less than 5% of the surnames in use account for 85% of the population (Du et al. 1992; Colantonio et al. 2003). Surname studies by population geneticists suggest that even if the evolution of surnames has no association with traits that are transmissible and related to reproduction, random drift will still generate inequality in descent line size that has nothing to do with founder's characteristics (Cavalli-Sforza, Menozzi and Piazza 1994).

Most studies of descent line growth and extinction focus on patrilineal descent lines. Substantive interest in male descent lines reflects the tendency in historical and/or patriarchal societies for important social processes such as surname transmission, inheritance of property and status, and the formal delineation of kin relationships to be based primarily on patrilineal descent. Matrilineal descent lines likely had fundamentally different dynamics, making it impossible to draw inferences from findings on patrilineal descent lines (Borgerhoff Mulder 2000; Hopcroft 2006; Lee and Wang 1999; Mann 2002; Turke 1989). Most importantly, variance in the number of offspring was larger for men than for women. Men not only had a longer reproductive span than women, but in many societies, had more opportunities for remarriage or polygyny, especially among those with high socioeconomic statuses.

Studies of descent line dynamics that simultaneously consider patrilineal and matrilineal descent are rare because of the complexity of the associated mathematical models. While two-sex models of population dynamics are certainly preferred from both a theoretical and substantive perspective, they pose considerable methodological challenges that have not been satisfactorily solved in previous literature (Caswell 2001: 568-590). For example, the famous "two-sex" problem in demographic literature shows that models based on patrilineal and matrilineal descent may yield inconsistent results if intermarriage between families is ignored (Pollak 1986, 1990). The double-counting of individuals in their patrilineal and matrilineal descent lines introduces additional complexity. Theoretical and empirical studies suggest that if matrilineal and patrilineal ancestry are both considered, very large proportions of the population have at least one relatively recent ancestor in common. For example, in Quebec, nearly 100% of the population has at least one common ancestor within the last nine generations (Tremblay et al. 2008).

4.2.2 The Chinese Context

We focus on patrilineal descent lines because family reproductive strategies in historical China focused heavily on their continuity. Sons not only carried on the family name, but remained in the household after marriage and provided support to aging parents, and were thought to be more valuable as sources of household labor (Hsu 1943; Lee and Wang 1999; Wolf 1995, 2001; Wolf and Huang 1980). Families were less interested in daughters because they left the family and joined their husband's household once they married. The preoccupation with sons was such that socially, production of only daughters was generally viewed to be as much of a reproductive failure as not having any children at all.

The patrilineal descent line was the most important unit of social organization outside the household in historical China. Lineage organizations with membership defined by patrilineal descent from a common male ancestor managed ancestral temples, owned property, operated schools for the children of members, and compiled lineage genealogies (Cohen 1990; Freedman 1966). Understanding the social determinants of differences in descent line growth and extinction is important for understanding inequality because the resulting kin networks shape the life outcomes of individuals embedded within them (Mare 2011). Empirical evidence suggests kin network size and composition influenced individual demographic behavior and social attainment, not only in China (Agree, Biddlecom and Valente 2005; Campbell and Lee 2008ab;

Hermalin, Ofstedal, and Chi 1992) but elsewhere (Sear et al. 2002, 2003). Descent group membership was therefore an important stratifying variable that conditioned the opportunities available to individuals. For example, inequality between descent lines in marriage and socioeconomic attainment was more pronounced than inequality between villages (Campbell and Lee 2011). Potentially, effects of status in one generation on the size and composition of the kin group many generations later was yet another indirect channel by which status might be transmitted over multiple generations.

In China, a variety of considerations may have led couples to have fewer sons than their social and economic circumstances might have allowed (Campbell and Lee 2010a; Mann 2002: 449; Wang et al. 1995, 2010). Even though high status males did have more sons than other males (Wang et al. 2010), that does not imply that they maximized their numbers of male births. Under plausible scenarios, forgoing male births would improve outcomes for the sons that couples did have by reducing resource dissolution. For example, sex ratio imbalances in the marriage market made finding wives for sons costly. In a partible inheritance system in which male kin divided family property at the time of household division, limiting the number of sons would slow the dissipation of landholdings and other material wealth. Under such conditions, families may have sought to maximize the chances that at least one son reached adulthood, married, and achieved high status, rather than maximizing their total number of male births. Families, in other words, may have sought to minimize the chances of extinction or downward mobility.

4.3 THEORETICAL FRAMEWORK

We begin by considering the classic population growth equation (Preston, Heuveline and Guillot. 2001:11):

$$N(T) = N(0)e^{\int_0^{T} r(t)\mathrm{d}t} \tag{11}$$

Here, $N(0)$ and $N(T)$ refer to descent line size (stock) at times 0 and T, respectively. The integrand $r(t)$ is the instantaneous growth rate (flow) at time t. In this one-sex model, each descent line has one male founder, and $N(0)$ is defined to be the number of that founder's male offspring through the male line. The effects of descent line founders' characteristics on the total number of descendants $N(T)$ can work through either the initial reproduction of the founders, i.e., $N(0)$, the growth rate of the descent line over time, $r(t)$, or both. We rely on this stock and flow framework to analyze the role of the mechanisms that governed descent line growth.

We specify three mechanisms—Initial Advantage, Permanent Advantage, and Advantage Dissipation — by which founder's characteristics may have influenced the subsequent size and growth rate of the descent line (see Figure 4.1). We also summarize potential implications of the three mechanisms for the growth trajectory of descent lines in Table 4.1

. We expect the actual impact of founder's characteristics on descent line growth to have included a combination of these three mechanisms.

Table 4.1

Figure 4.1

In Table 4.1, we assume that Initial Advantage affects descent line growth entirely through the reproduction of the founders, namely, $N(0)$ in Equation (11). In the Initial Advantage scenario, represented in Figure 4.1 with a grey dashed line, high fertility on the part of the founder multiplies the initial size of the descent line $N(0)$ by c but has no effect on the growth rate $r(t)$ in later generations. The number of high-origin descendants will always be c times the number of low-origin descendants. At the population level, this mechanism implies that high-origin descent line's share increases immediately in the generation after the founder, and then remains stable afterward.

Permanent Advantage and Advantage Dissipation allow for changes in the growth rate $r(t)$. In the Permanent Advantage scenario, represented as the black dashed line in Table 4.1

, founder's characteristics trigger a permanent increase in $r(t)$. Because the growth rate of the descent line experiences a permanent increase, the descent line accounts for a steadily increasing share of the population. Eventually, high-origin descendants dominate the population, and the share of low-origin descendants declines to insignificance.

Advantage Dissipation, represented by the dotted line in Table 4.1

, is an intermediate between Initial Advantage and Permanent Advantage. It assumes that high-origin descent lines will experience a higher growth rate for some number of generations, but the advantage will decline over time and eventually disappear. The share of the population accounted for by high-origin descent lines will grow until the differences in $r(t)$ dissipate, and remain stable afterwards.

4.3.1 Initial Advantage

The sociological literature on stratification frequently invokes Initial Advantage as part of cumulative advantage theory to explain the evolution of inequality over time. In this conception, the advantage of one group over another depends on *initial* positions, and the subsequent growth of inequality is path-dependent. Initially minor and possibly random disparities may widen over time because success begets success. Empirical tests make use of evidence from a variety of areas, including academic publication records (Allison, Long and Krauze 1982; Merton 1968, 1988), cognitive development (Guo 1998), and health (Pampel and Rogers 2004). Merton (1988) describes this phenomenon as, "the ways in which initial comparative advantage of trained capacity, structural location, and available resources make for successive increments of advantage such that the gaps between the haves and the have-nots…widen" (p.606). For Merton, Initial Advantage is the essential characteristic of a cumulative advantage process. From this perspective, any exogenous events that generate an initial advantage can have long-term consequences on patterns of inequality (DiPrete and Eirich 2006).

For our outcome of interest, descent line size in later generations, the Initial Advantage mechanism is analogous to 'founder effects' in the genetics literature (Falconer 1960). If reproductive differentials between descent lines exist only in the founder generation, the ratio of descent line sizes increases in that generation, but remains constant afterward (the grey dashed line in Table 4.1

). Differences in lineage size therefore reflect a path-dependent process driven solely by differences in the reproduction of the founders.

4.3.2 Permanent Advantage

Disparities in descent line size according to the socioeconomic status of founders may continue to widen after the first generation if the founder's status affects the reproduction of members of later generations, whether directly or indirectly. We refer to this scenario as Permanent Advantage, in which 'permanent' refers to the possibility that high status origin descent lines continue to grow faster than other descent lines. Our inspiration is Allison et al.'s (1982) observation that cumulative advantage does not produce additional changes in patterns of inequality later in time unless the rate of accumulation continues to vary between population subgroups.

The relevance of Permanent Advantage depends on whether or not a founder transmits traits to his offspring that affect their reproduction. For example, if a high status founder not only has more children, but also in turn transmits the high status that leads to high fertility to these children, the share of the population accounted for by the descent lines of high status founders will expand steadily over time. The ratio of the sizes of high- and low-origin lineages would steadily increase, until the high status lineage accounts for nearly the entire population (the black dashed line in Table 4.1

).

4.3.3 Advantage Dissipation

Advantage Dissipation (the dotted line in Figure 4.1) addresses the reality that founder characteristics are unlikely to trigger the permanent increases in growth rates assumed in the Permanent Advantage scenario. More concretely, in the multi-generational process of descent line growth, resource dissipation and downward social mobility may serve as a ‘brake’ that attenuates fertility differentials (DiPrete and Eirich 2006). When the status and demographic behavior of descendants of high status founders finally becomes indistinguishable from the rest of the population, relative sizes of descent lines stabilize.

Previous discussion of the phenomenon of “regression to the mean” in family advantage suggests the likely importance of advantage dissipation. Becker (1991: 273) argues that “almost all earnings advantages and disadvantages of ancestors are wiped out in three generations. Poverty would not seem to be a ‘culture’ that persistent for several generations.” Similarly, centuries before Becker, a common folk expression in China was that “wealth doesn’t last for three generations.” In an empirical study based on genealogies, biographies and local histories, Ho (1964) found that even under a very relaxed standard for defining high social status, the average descent line fell into complete oblivion, or at least mediocrity, in some eight generations. All these observations are in line with Galton's early conceptualization of "regression toward mediocrity" (Zimmerman 1992).

Our data and methods allow us to discern the relative importance of these three mechanisms. Prior sociological theory suggests that Initial Advantage, Permanent Advantage, and Advantage Dissipation alone or in combination will generate different patterns of results in empirical studies (DiPrete and Eirich 2006). Because we can measure the influence of founder's characteristics on descent line size and growth rate in each generation, we can assess the relative importance of the three processes. Our approach therefore advances on the indirect one based on surname studies.

4.4 ANALYTIC APPROACH

4.4.1 Modeling Stock and Flow

To distinguish the roles of Initial Advantage, Permanent Advantage, and Advantage Dissipation in explaining the effect of founder's status on subsequent descent line growth, we apply a stock-flow analytic framework. Equation (11) shows a continuous time model of descent line growth. In the discrete-time model that we adopt for our empirical analysis, we redefine *stock* as the number of members of the descent line alive at time t and *flow* to refer to growth from time t-1 to t. We assess the relative importance of the three proposed mechanisms by estimation of regression models from four different families: linear, exponential, Poisson, and negative binomial. Each makes different assumptions about the relationships of stocks and flows to the right-hand side variables. The linear stock and flow models shown below assume that the number of descendants at time *t* and the changing number of descendants from time *t*-1 to *t* are linear in founder's characteristics ***X***.

$$N_i(t) = \boldsymbol{X}_i\beta + \varepsilon_i$$

$$N_i(t) - N_i(t-1) = \boldsymbol{X}_i\beta + \varepsilon_i$$

The exponential stock and flow models assume an exponential relationship of founder's characteristics ***X*** to the number of descendants at time *t* and the change in the number of descendants from time *t*-1 to *t*:

$$\log(N_i(t)) = \boldsymbol{X}_i\beta + \varepsilon_i$$

$$\log(N_i(t)) - \log(N_i(t-1)) = \boldsymbol{X}_i\beta + \varepsilon_i$$

To keep the extinct descent lines in the analyses, we replace log(N_i) with -1 when N_i is zero.[22]

In an early model of descent line growth, Fisher (1922) applied the Poisson distribution and assumed that the probability of extinction is determined by the average number of offspring per individual. Following this tradition, our third set of models assumes that the number of descendants at time *t* for the *i*th descent line, $N_i(t)$, follows a Poisson distribution with parameter $\mu > 0$.

$$\mathrm{P}(N_i(t)|\mu_{it}) = \frac{\exp(-\mu_{it})\mu_{it}{}^{N_i(t)}}{N_i(t)!} \qquad (12)$$

In Equation (12), $\mu_{\mathrm{i}t}$ is the expected number of descendants at time *t*. The assumption of the Poisson distribution also requires that the expected number of descendants equals the variance of the number of descendants, ∀ i: $E(N_i(t)) = Var(N_i(t))$.

[22] We also experimented with other values, such as 0, -0.5, and -2, and none of the conclusions changed.

The Poisson stock model assumes that the conditional mean of the number of descendants at time t is a function of independent variables ***X*'s** that describe time-invariant founder's characteristics:

$$\mu_{it} = E(N_i(t)|\boldsymbol{X_i}) = \exp(\boldsymbol{X}_i\beta) \tag{13}$$

The Poisson flow model represented in (14) is similar except that it introduces a control for the count of descendants at time t-1.

$$\mu_{it} = E(N_i(t)|\boldsymbol{X_i}, N_i(t-1)) = \exp(\log(N_i(t-1)) + \boldsymbol{X}_i\gamma)^{23} \tag{14}$$

Equivalently,

$$E\left(\frac{N_i(t)}{N_i(t-1)}\middle|\boldsymbol{X_i}, N_i(t-1)\right) = \exp(\boldsymbol{X}_i\gamma) \tag{15}$$

We also estimate a fourth set of models, negative binomial regression models, to account for the possibility that the Poisson model's assumption of equality of the variance and mean of the number of descendants is violated because of over-dispersion. In that situation, the relationship between founder's characteristics and the expected number of descendants still follow Equations (13) and (14). However, the variance in the number of descendants is assumed to follow a gamma distribution with a parameter that is estimated separately.

We use 'stock effect' to refer to the ratio of expected mean number of descendants of high-status founders to that of low-status founders. We use 'flow effect' to refer to the ratio of the expected growth rate of descent lines with high-status founders to that with low-status

[23] For the linear flow models, we set the dependent variable for extinct descent lines to zero. For extinct lines in the exponential, Poisson and negative binomial flow models, we replace the logged previous descent line size with -1. This allows us to keep the numbers of cases the same across different estimations. We also experimented with other imputations, including log(N(t-1)+0.1) or setting log(N(t-1)) to 0, and with dropping extinct descent lines. The results are consistent with those reported in Table 4.4. These results are available upon request.

founders. In either case, if the ratio is 1, the founder's characteristics do not influence descent line size (stock) or growth rate (flow).

Initial Advantage, Permanent Advantage, and Advantage Dissipation predict different patterns of effects of founder's characteristics on stock and flow. If Initial Advantage is present, we expect to observe an effect on stock in every generation. However, we only expect to see an effect on flow in the first generation. This is because the growth rate of the descent line is elevated only in the founding generation, and then reverts to be the same as other descent lines in later generations. If Permanent Advantage is present, both the stock effect and the flow effect should be apparent in every generation, because high status not only increases the total number of the descendants but also their growth rate. If Advantage Dissipation is present, the stock effect may keep increasing until the flow effect disappears, because founder's effect on growth rate fades away with time.

4.4.2 Modeling Extinction and Growth

The models above assume that the probability of extinction is a byproduct of the distribution of the number of offspring. For example, the Poisson model introduced above requires that the proportion of observed zeroes (extinctions) in the empirical data matches the proportion of zeroes predicted by the Poisson distribution. This implies an assumption that the same underlying process accounts for the influence of founder's status on the probability of extinction, and conditional on avoiding extinction, the probabilities of having different numbers of descendants.

To allow founder's characteristics to have separate effects on extinction probabilities, and conditional on avoiding extinction, the growth rate, we introduce a mixture negative binomial distribution that models processes of extinction and growth jointly (Johnson, Kemp and Kotz

2005). Suppose that π and $1-\pi$ are the probabilities of failure and success for overcoming a 'hurdle' that conditions success at reproduction, and thereby avoiding extinction. For example, π might be the probability that no sons survived to adulthood and married, and $1-\pi$ the probability that at least one son survived and married. Again, the assumption is that these are independent of the distribution assumed for the number of offspring for those who did marry. Let the probability of having *j* descendants in a truncated distribution be written as p_j. Then we have

$$\mathrm{P}[N_i(t)=0|Z_i]=\pi, \tag{16}$$

$$\mathrm{P}[N_i(t)=j|\boldsymbol{X}_i,\ N_i(t)>0]=\frac{(1-\pi)p_j}{1-p_0},$$

where $\mathrm{P}[N_i(t)=j]$ is the probability that the number of descendants for the *i*th descent line at time *t* is *j*. $\boldsymbol{Z}$ is the set of covariates to explain extinction and $\boldsymbol{X}$ is the set of covariates to explain descent line growth[24].

For the sake of simplicity, we use a logistic model to predict $\mathrm{P}[N_i(t)=0]$ and assume the truncated part $\mathrm{P}[N_i(t)=j\mid N_i(t)>0]$ still follows a negative binomial distribution. Then

$$\mathrm{P}[N_i(t)=0|\boldsymbol{Z}_i]=\frac{1}{1+\exp(\boldsymbol{Z}_i\gamma)}$$

$$\mathrm{P}[N_i(t)=j|\boldsymbol{X}_i,N_i(t)>0]$$
$$=\frac{1-\mathrm{P}[N_i(t)=0|\boldsymbol{Z}_i]}{1-\frac{\theta_{it}{}^{\theta_{it}}}{(\mu_{it}+\theta_{it})^{\theta_{it}}}}\cdot\frac{\Gamma(N_i(t)+\theta_{it})}{\Gamma(\theta_{it})\cdot\Gamma(N_i(t)+1)}\cdot\frac{\mu_{it}{}^{N_i(t)}\cdot\theta_{it}{}^{\theta_{it}}}{(\mu_{it}+\theta_{it})^{N_i(t)+\theta_{it}}} \tag{17}$$

[24] We test the differences between negative binomial models, mixture negative binomial models and mixture Poisson models based on the Bayesian Information Criterion (BIC), as the models are not nested. The results suggest that the mixture negative binomial models significantly improve the goodness-of-fit of the model compared to the regular negative binomial models and mixture Poisson models (test results are available upon request).

4.5 DATA AND MEASURES

4.5.1 Data

Our data are derived from the China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL) and the China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN). Published studies of demographic behavior have already established the suitability of these two sources for the analysis here (Campbell and Lee 2008ab, 2010a, 2011; Lee and Campbell 1997; Wang et al. 1995). The CMGPD-IL records 83,256 males in the Aisin Gioro imperial lineage from 1652 to 1936. The lineage originated in northeast China and founded the Qing dynasty (1644-1911). Specifically, the CMGPD-IL records the grandfather of the Qing founder, his four brothers, and their male descendants from approximately 1550 to 1936 (Lee et al. 1993). At the beginning of the Qing Dynasty, the imperial lineage was a small, elite group. Many but not all members held official positions or noble titles. As the lineage grew, steadily larger proportions of men were distant relatives of the emperors and held neither official position nor noble title. The genealogy from which the CMGPD-IL was constructed was maintained by the Qing Office of the Imperial Lineage. Because the genealogy was prospective, maintained by a bureaucracy, and used for administration, it has minimal loss to follow up. In contrast with traditional, privately compiled family genealogies, it records low status, never-married, and childless lineage males. Unfortunately, the CMGPD-IL only allows for the reconstruction of male pedigrees: because like most Chinese genealogies it focused explicitly on patrilineal descent, daughters were lost to follow-up when they married out and joined their husband's family.

The China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN) is derived from triennial household registers of farming populations who produced for the Qing Imperial Household Office (Lee et al. 2010). The complete dataset and documentation are now public and available for download at the Interuniversity Consortium for Political and Social Research.[25] Whereas the imperial lineage is an elite urban population concentrated in Beijing and Shenyang, the CMGPD-LN covers a large, rural population spread over a very large area in what is now Liaoning province in northeast China. The farmers covered by the CMGPD-LN were descended from Han-Chinese immigrants who migrated from Shandong and other locations into Liaoning in the late 17th and early 18th century. The data consist of 29 sets of triennial household registers with 1.5 million observations of more than 260,000 unique individuals between 1749 and 1909.

The Liaoning household registers provide far more comprehensive and accurate demographic and sociological data than other available household registers for China before the twentieth century (Lee and Campbell 1997; Lee et al. 2010). The format and organization of the data closely resemble a linked triennial census. Entries in each register were grouped first by village, then by household group and then by household. The population is closed, in the sense that the registers follow families that moved from one village to another within the region, thus the registers are uniquely suited to the reconstruction of descent lines through intergenerational record linkage, and study of the predictors of descent line growth, decline, and extinction[26] (Campbell and Lee 2010b). Once again reflecting the emphasis on patrilineal descent in historical China, the data only allow for construction of male pedigrees. While the data record the characteristics of married women and widows in more detail than any other historical Chinese source, it does not allow them to be traced back to their records as daughters in their natal household and then linked to their mothers.

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[25] See http://www.icpsr.umich.edu/icpsrweb/CMGPD/ for CMGPD-LN data and documentation.

[26] Variables in the datasets identify all individuals who migrate out. For the CMGPD-LN, such cases only consist of 0.1% of the data (shown in the CMGPD-LN user guide). For the CMGPD-IL data, a small group of individuals (about 10%) migrated to Shengjing, a city in Liaoning which was also the old capital city of Qing dynasty. Descendants of these cases were no longer followed, and thus we excluded these lines from the analyses.

4.5.2 Measures

In both the CMGPD-IL and the CMGPD-LN, we specify an analytic definition for descent line founders, and then reconstruct their patrilineal descent lines through automated record linkage. Our analytic definitions of founders and descent lines reflect a balance between having enough descent lines to make meaningful comparisons, and having enough generational depth to examine processes over the long term. The Imperial Lineage grew very rapidly in the 17th century, thus choosing men born earlier would dramatically reduce the numbers of descent lines. Because the members of the Lineage were nearly all of very high status until the middle of the 17th century, it would also reduce variation in the characteristics of the founders. In the population recorded in the CMGPD-LN, the actual founders were mostly settlers whose arrival predated the registration system, and about whom we have almost no data.

To create an analytic sample of descent lines in the CMGPD-IL, we define *descent line founders* as all men born between 1675 and 1725 who survived at least to age 25. The definition we apply yields 3,314 founders whose patrilineal descent lines could be traced for the next 150 years, or about six generations. Similarly, in the CMGPD-LN we define descent line founders to be all men born between 1715 and 1765.[27] We treat the year of the founder's birth as the founding year of the descent line, and track each descent line for 125 years, or about five generations. In both cases, we experimented with alternative definitions for descent line founders and the results are consistent with the ones reported here.

[27] We did not restrict the sample to founders who survived to age 25 or above, because in rare cases age at death are not available (Lee et al. 2010: 19-20). Instead, we restrict the sample to adult founders who have a social status recorded. In our final sample, roughly 94% of the founders survived at least to age 16 *sui*, and 90% survived at least to age 25 *sui*.

For our basic outcome variable, descent line size, we count the numbers of living patrilineal male biological and adopted descendants of each founder every 25 years.[28] To do this in the CMGPD-IL, we transform it from a person file in which each record represented the life history of one male into a person-year file in which each record described a male in a specific calendar year. For the CMGPD-LN, we first transform the original triennial observations into a person file like the CMGPD-IL in which each record is the life history of one male. We then use that entry to produce person-year files like the one for the CMGPD-IL. In both datasets, we attach founder identifiers to the person-year records, and then count up the numbers of male descendants at 25-year intervals. At time zero, defined as the founder's year of birth, the number of male descendants is zero. 25 years later, it includes any surviving sons of the founder. The descent line size could be still zero if the founder had not yet had any sons. 50 years later, the count would include any living sons and grandsons. Again, the focus on numbers of male descendants reflects the data limitations described earlier.

We construct dichotomous variables for the status of the descent line founder. For the CMGPD-IL, we define high-status origin descent lines to consist of the ones founded by men who worked in the Qing bureaucracy (e.g., ministers, military generals) or held bestowed or inherited noble titles (e.g., princes and dukes). We define the remaining descent lines as low-status origin. For the CMGPD-LN, we defined the high-status origin lines to consist of ones founded by men who held salaried official positions, examination titles, purchased and honorary titles, or served as unsalaried heads of household groups. These constituted the local elite (Campbell and Lee 2010b). The positions held by high-status founders in the CMGPD-LN were

[28] Because the CMGPD-IL specifies the identities of biological and adoptive fathers for each boy who was adopted between families, we calculated numbers of descendants separately based on biological descent and on social descent. The results were similar, as most adoption was between closely related male kin, and had little or no net effect on a descent line founder's total number of descendants.

much more mundane than the ones held by their counterparts in the CMGPD-IL. The most common were soldier, scribe, or artisan. We include men who held honorary and purchased titles because they indicate substantial personal or family resources. Though heads of household groups held the lowest rank position in the administrative hierarchy and were unsalaried, they were supposed to be selected by household group members on the basis of ability.

We also include control variables to distinguish the lines according to their administrative status. For the CMGPD-IL, we distinguish between the members of the Main Line and Collateral Line. Men descended from the grandfather of the Qing founder are the *Zongshi* or Main Line. Men descended from his brothers are the *Jueluo*, or Collateral Line. We control for membership in the Main or Collateral Lines because men in the former were accorded more privileges than men in the latter. Similarly, we include a control variable to divide the lines in the CMGPD-LN into two status groups according to their type of administrative population. Most members of regular administrative populations were hereditary tenants who farmed state-owned land. Members of specialized populations provided services to the state such as collecting honey, raising bees, fishing, picking cotton, and tanning and dyeing. These specialized populations had a lower status than the regular populations (Lee et al. 2010).

We include seniority among siblings and total number of male siblings as additional controls in the regression analysis of effects of founder's status on stock and flow. Founder's total number of siblings is intended to account for the tendency in historical China for men with more male siblings to have higher chances of both marriage and attainment (Campbell and Lee 2008b). With this control, we hope to account for the possibility that unmeasured characteristics simultaneously affected a founder's chances of attaining high status, and his chances of having more offspring. The control for whether or not a founder was an eldest brother is intended to account for advantages that first sons had in terms of attainment and marriage.

4.6 RESULTS

4.6.1 Descriptive Statistics

According to basic descriptive results, high-status origin descent lines increased in size over time, but low-status origin descent lines were stagnant. Figure 4.2 presents the numbers of men in the CMGPD-IL according to whether they are in high- or low-origin descent lines. From 1725 to 1875, the descent lines with high-status founders experienced rapid growth. By contrast, growth in the numbers of males in low-status descent lines was negligible. As a result of this disparity, even though men in high-status lines originally accounted for less than one-third of the population, by the end of the period they accounted for more than one-half of the population. This trend is consistent with the Initial Advantage and Advantage Dissipation mechanisms summarized in Figure 4.1 and Table 4.1

. According to Figure 4.3, there were also differences in the cumulative probability of extinction. After 150 years, only half of high-status origin descent lines were extinct, in contrast with nearly three-quarters of low-status origin descent lines.

Figure 4.2

Figure 4.3

Table 4.2

Table 4.2 contrasts key features of the high- and low-status origin descent lines. Of the 3,314 descent lines in the CMGPD-IL, 1,082 are of high-status origin and 2,232 are of low-status origin. High-status founders are more likely to come from larger families and to be affiliated with the Main Line (*zongshi*).[29] In the CMGPD-LN sample, founders tend to be more similar on the distributions of the control variables. Descent lines in the CMGPD-LN were in general smaller than in the CMGPD-IL, reflecting its overall lower growth rate. Higher proportions of males married later, or not at all, and therefore had more limited opportunities for reproduction. We also calculate the generation length—defined as the difference between the birth year of a father and that of his first son—for both populations. Overall the generation length for the two populations was between 25 to 30 years. High-status descent lines had shorter generation length than low-status descent lines. As a result, for both populations the analytic samples represent the experience of roughly five to six generations.

4.6.2 Determinants of Stock and Flow

We begin our presentation of results by examining the influence of founder's characteristics on descent line size (*stock*) and growth rates (*flow*) at 25-year intervals. Based on the results, we assess the relative importance of Initial Advantage, Permanent Advantage and Advantage Dissipation in accounting for differences in the dynamics of the high- and low-origin descent lines. As a robustness check, we not only estimate the model described in Equation (12) that assumes that numbers of descendants follow a Poisson distribution, but we also estimate linear, exponential, and negative binomial models that incorporate different assumptions about the distribution of numbers of descendants. In all cases, we assume that the process determining descent line size and growth also accounts for extinction probabilities.

Results for stock models summarized in Table 4.3 demonstrate that in both the CMGPD-IL and the CMGPD-LN, the influences of founder's social status on the total number of

[29] When calculating the number of founder's male siblings, we include all the males born to the descent line founders' father, regardless of how long they lived.

descendants increase over time. They hold regardless of the assumptions about the appropriate distribution for the total number of descendants. Alpha parameter tests in Appendix A suggest that in general, the negative binomial models provide better estimates than the Poisson models.[30] Results from the two datasets are broadly similar: the gap in the sizes of the high- and low-origin descent lines widens with time.

Table 4.3

Results for flow models summarized in Table 4.4 reveal that founder's status has long-term effects on the growth rate of descent lines. More than one century later, differences in the growth rates of high- and low-origin descent lines remain statistically significant. Results for the CMGPD-IL from the negative binomial model show that the ratio of growth rates between the high- and low-origin descent lines after 25 years is 1.54(= $e^{0.432}$). For the CMGPD-LN, the corresponding ratio is 1.73(= $e^{0.548}$). After 125 years, the ratio is 1.17 (= $e^{0.159}$) and 1.19 (= $e^{0.172}$) for the two populations. These differences are not an artifact of the founder's success at transmitting high status to his sons, grandsons, or later descendants, and their resulting higher fertility: they persist after the introduction of controls for the number of descendants in later generations who were themselves of high status.[31]

Table 4.4

Figure 4.4 and Figure 4.5 plot size and growth rate ratios from Table 4.3 and Table 4.4 for high- and low-origin descent lines in the CMGPD-IL and CMGPD-LN. In both figures, the horizontal line at 1 corresponds to a hypothetical null founder effect, in which the descent line

[30] We plot the actual growth from the empirical data and the predicted growth of descent lines based on different models in Figure 4A and 4B. To compare the models across time, we fixed all the other independent variables at their means. The results suggest that the Poisson and the negative binomial model provide the best estimates for descent line growth trajectories, though they may yield biased estimates for the mean number of descendants toward the end of the period, perhaps because the models do not account for excess zeroes (i.e., extinction) in later years.
[31] Results not shown here, but available from the authors upon request.

size or growth rates of the high- and low-origin descent lines are equal. The solid black lines represent the stock effect estimated from the negative binomial models. Overall, the time trends in stock effects show that the larger size of the high-origin descent lines is apparent as early as 25 years after the founding of the line. Moreover, descent line founders who have more offspring in the first 25 years also have more descendants in the long run. This is consistent with the Initial Advantage mechanism.

Flow effects, represented as solid gray lines in Figure 4.4 and Figure 4.5, were more consistent with Advantage Dissipation than Permanent Advantage. In both populations, the magnitude of effects of founder's status on descent line growth rates declines steadily over time. Though in both the CMGPD-LN and CMGPD-IL an effect of founder's status on growth rates is still discernible and statistically significant at the end of the observation period, it is much smaller than in the earlier periods. Extrapolation from the trends in the figures suggests that within another generation or two, the growth rates of the high- and low-origin descent lines would be equal. Afterward, the ratio of the sizes of the descent lines would be constant.

Figure 4.4

Figure 4.5

4.6.3 Extinction and Growth as Separate Processes

We next examine whether the mechanisms that govern descent line growth differ from the ones that govern extinction. Results from models based on Equation (16) allow for the determinants of extinction probabilities to differ from the determinants of descent line size or growth. Specifically, we apply a mixture negative binomial model to fit the extinction probability and the size of growth rate simultaneously.[32] The stock models treat extinction as a cumulative process, so after a descent line is extinct it is still included in the analyses for later periods, during which it continues to be recorded as extinct. The flow models include controls for descent line size twenty-five years previously, and exclude descent lines that are already extinct, and thus account for the possibility that higher extinction probabilities now might be an artifact of a smaller descent line size twenty five years earlier.

Table 4.5 presents the relevant results. Coefficients from the logistic regression represent effects on the probability of descent line not being extinct, that is, its size being non-zero. Positive coefficients imply higher odds of descent line survival. Coefficients from the truncated negative binomial regression represent effects on descent line size or growth rate, conditional on the descent line not being extinct. To help clarify implications of the results from the mixture negative binomial regressions and facilitate comparisons with results in Table 4.3 and Table 4.4, dashed lines in Figure 4.3 and Figure 4.4 present stock effects and flow effects for surviving descent lines.

Table 4.5

Results from the stock models reveal that in both populations, high-origin lines were much more likely to avoid extinction, and that differential extinction probabilities account for much of the differences in mean descent line size in Table 4.3. The truncated negative binomial portion of the stock models suggests that in the CMGPD-IL, surviving high-origin descent lines are about 1.76 times (= $e^{0.568}$) the size of surviving low-origin descent lines 150 years after

[32] To compare the mixture negative binomial model to the regular negative binomial model, Appendix C provides Vuong likelihood ratio tests (Vuong 1989) comparing all models in the same year. Failure of the likelihood ratio test for alpha=0 indicates zeroes are generated by the same process as non-zero counts. Substantively, this implies that founder's socioeconomic status has the same effects on the extinction and growth processes. Overall, the Vuong likelihood ratio tests prefer the mixture negative binomial over the regular negative binomial models. For both the stock and flow models at most of the years, test statistics show a p-value < 0.001.

founding. By contrast, in the stock results in Table 4.3 that include extinct descent lines, high-origin descent lines were on average 2.43 times (= $e^{0.888}$) the size of low-origin descent lines. Extinction processes were perhaps even more important in the CMGPD-LN. Whereas in Table 4.3, high-origin descent lines in the CMGPD-LN were 2.02 (= $e^{0.703}$) times the size of low-origin descent sizes overall after 125 years, according to Table 4.5, non-extinct high-origin descent lines were only 1.18 (= $e^{0.168}$) times the size of non-extinct low-origin descent lines.

Results for extinction in the flow models in Table 4.5 reveal that at each point in time, extant high-origin descent lines were more likely to survive to the next time period than low-origin descent lines of the same size. In the CMGPD-IL, comparison of same-sized high- and low-origin descent lines 125 years after founding reveals that the high-origin descent lines had 1.70 (= $e^{0.533}$) times the odds of surviving to year 150. In the CMGPD-LN, a high-origin descent line 100 years after founding has about 1.24 (= $e^{0.219}$) times the odds of surviving another 25 years.

The processes that governed growth among surviving lines were very different. According to the flow results for descent line size in Table 4.5, the effects of founder's status on descent line growth declined over time. For both the CMGPD-LN and CMGPD-IL, the growth rates of surviving high- and low-origin descent lines were indistinguishable by the end of the period of observation. The coefficients were small and statistically insignificant. The contrast with the comparatively stable effects of founder's original status on extinction probabilities suggests that toward the end of the period for which data are available, most if not all of the small but persistent and statistically significant effect of founder's characteristics on descent line growth rates in Table 4.4 was due to effects on extinction chances.

One plausible interpretation of these results is that later generations minimized the chances of having no surviving descendants in the next generation, rather than maximizing the total number of births. This is most apparent in the contrast between the trends in the effects on founder's status on extinction probabilities and descent line growth in the flow models in Table 4.5. Figure 4.6 converts the coefficients in the flow results into probability of extinction for surviving lines in next 25 years. Trends in both populations suggest that the probability of extinction first declined in the first 50 to 75 years because founders and their children had not yet finished reproducing, then grew afterward. Toward the end of the period under observation, high status continues to reduce the probability of extinction by the next time period, even though its effect on the number of descendants among the descent lines that persist to the next time period has disappeared.

Figure 4.6

At this point, we can only speculate as to how descent lines minimized chances of extinction, and whether their behavior was deliberate. It may be that the lines with high status founders tended to be families that made a trade-off between quantity and quality of children, such that they invested more in each son, and raised the chances that at least one of them would survive to adulthood, marry, and have offspring. Such behavior may have reflected a desire to avoid downward mobility, or a specific desire to avoid extinction. Having a high-status founder may simply have been an observable proxy for the existence of such a strategy, or the high-status founder may have introduced such a strategy, which persisted in later generations.

4.7 DISCUSSION

Using empirical evidence from two Chinese multi-generational population databases, each of which spans 125 to 150 years, we have shown that male social status in one generation has long-term implications not only for their total number of patrilineal descendants, but for their own reproductive success. First, men of high status are especially successful in the competition for representation by patrilineal descendants in later generations, and these descendants also are especially successful at reproduction. The effect of founder's social status on the growth rates of descent lines lasts for several generations, and is large enough to affect the composition of the male population in later generations. Nevertheless, the patrilineal descendants of high status males in one generation never come to completely dominate the male population, since their share of the population stabilizes when their growth rate advantage dissipates. In our samples, the share of the population accounted for by the patrilineal descendants of high-status males in one generation stabilized after 150 years, or roughly six generations.

Second, the key long-term effect of high status on the reproductive behavior of patrilineal descendants was that it reduced their chances of having no surviving male offspring, rather than increasing the average number of offspring among those who survived. In other words, high social status among descent line founders had more enduring effects on the chances of descent line extinction than it did on the growth rates of surviving descent lines. While the effect of founder's social status on the growth rate of surviving descent lines becomes negligible after 150 years, effects on the chances of extinction are still apparent.

The apparent influence of founder's social status on the reproductive success of descendants later and associated overrepresentation in later generations may reflect transmission of other forms of socioeconomic status that are not recorded in our data. This may have been property and other forms of material wealth that were accumulated rapidly in one generation and dissipated slowly over succeeding generations. Attainment of socioeconomic status may also have been influenced by knowledge, attitudes, aspirations, and other forms of intangible social, economic, or cultural capital that were transmitted within families across multiple generations (Borgerhoff Mulder et al. 2009; Cavalli-Sforza and Feldman 1981).

While genetic transmission of traits that directly or indirectly influence reproductive success is one possible mechanism, the potential significance of such processes is difficult to assess. Existing findings on the direct role of genetic transmission on reproductive success is mixed: some studies suggest a strong genetic effect through a single gene or a suite of genes that either control individuals' latent fixed traits (Cam et al. 2002; Saifl and Chandra 1999), or influence behaviors related to reproduction, such as mating, cooperation, parenting, and aggression (Robinson, Fernald and Clayton 2008; Brown et al. 2011), whereas others suggest that genotype and maternal environment contribute to a very small portion of reproductive variability compared to the roles of phenotype and stochastic environment factors (Gustafsson 1986; Tuljapurkar et al. 2009). As for suggestions that genetic transmission of traits conducive to the attainment of status had indirect effects on reproductive success and could lead to the diffusion of these traits through the population (Clark 2010; Unz 2013), we are skeptical. Estimates of the heritability of cognitive ability and other relevant traits generally suggest mild associations. Analysis of two-sex models suggests that in the absence of completely assortative mating, heritability of traits conducive to the attainment of status and which indirectly affected reproduction would not lead those traits to become universal (Preston and Campbell 1993).

We can rule out some other explanations. Indirect effects on descent line growth rates in later generations via intergenerational transmission of the forms of status recorded in our data are unlikely to account for the results shown here. The same results are apparent in calculations not shown here that control for the social status of men in later generations. Tentatively, we can also rule out polygyny as a key mechanism in accounting for differential growth rates, since it was extremely rare in the largely rural CMGPD-LN population, and became rare in the CMGPD-IL. Adoption was also unlikely to have played a role because in historical China, it was usually between closely related male kin who belonged to the same descent line (Lee and Wang 1999), and would have had little net effect on the total number of descendants. The CMGPD-IL has detailed records of adoption, and in calculations not shown here we found little or no difference in the total number of descendants according to whether we applied a biological or social definition of ancestry when constructing pedigrees.

These findings are subject to caveats. First, even though the populations analyzed here are from nearly opposite ends of the social spectrum in late Imperial China, the possibility remains that their experience is atypical of historical Chinese populations, and that populations located elsewhere on the social spectrum were characterized by other dynamics. It is also possible that the processes reported here are limited to China, or societies like China, and do not generalize to other human populations. The findings may also be less germane to contemporary populations, where variances in reproduction may be smaller than those in the past, and where the chances of not having any children at all may be less tied to social status.

Second, the results are only for patrilineal descent lines, not matrilineal ones, because the data do not allow for women to be linked to their mothers and do not provide measures of social status for women. Effects of founder's characteristics on the total number of patrilineal and matrilineal descendants might differ considerably from the ones here for reasons discussed earlier. Thus while the results here provide insight into the dynamics of the patrilineal descent lines that were an important unit of social organization in historical China, they do not illuminate other substantively important processes that also involve matrilineal kin networks.

Future studies will need to parcel out the roles of differentials in component demographic behaviors such as fertility, mortality, marriage, remarriage, polygyny, and adoption in accounting for these patterns. The most important next steps are to produce an accounting of the specific demographic components of the link between founder's status and subsequent descent line growth, locate and analyze more encompassing measures of status than the official titles and positions used here, and identify the traits that affect reproductive success and are transmitted within families. A very basic question is whether the advantage of the high-origin lines in avoiding extinction reflected higher marriage chances of descendants. Alternatively, it may be that married men in high-origin lines were more successful at ensuring that at least one of their sons survived to adulthood. A refined analysis would examine effects of high status in one generation on the fertility, mortality and marriage of descendants many generations later.

These analyses should also be replicated using other multi-generational databases that also record matrilineal descent lines. These include the Quebec genealogical databases PRDH and BALSAC (Tremblay et al. 2008), the Uppsala Multi-generational Birth Cohort Study (UBCoS) (Goodman et al. 2012; Goodman and Koupil 2009) and the Utah Population Database (Bean et al. 1990). None of these societies was as explicitly focused on the continuity of the patrilineal descent line as historical China, thus comparison would help clarify the extent to which the results here are specific to the Chinese context. Results from analysis of these databases would also illuminate the role of marital endogamy and other processes in accounting for patterns like the ones reported here, and would allow for comparison between the dynamics of patrilineal and matrilineal descent lines.

4.8 CONCLUSION

The results here underscore the importance of Mare's (2011) call for studies of stratification not only to take a multi-generational approach, but also account for interactions between status transmission and demographic behavior in shaping population composition. We show that social differentiation in one generation alters the composition of the population in future generations. Also, social status of one generation has a longer term influence on the reproductive success of descent lines than is commonly assumed in "two-generation" studies. The influence, however, would dissipate, rather than perpetuate as suggested by the cumulative advantage theory, resulting in reproductive behaviors of descendants of high-status founders eventually becoming indistinguishable from the rest of the population.

The most important substantive implication of these results is that future studies need to reevaluate many of the assumptions that inhere in studies of kin network influences on individual outcomes. In particular, characteristics of kin networks assumed to be exogenous to individual characteristics may in fact be endogenous. The size, composition, and other characteristics of the kin networks in which we are all embedded are themselves shaped by the characteristics of ancestors who lived many generations ago. This represents a novel form of indirect transmission of status. Studies of kin networks cannot simply equate regression coefficients estimated for characteristics of kin networks with effects of these kin. The results are subject to a subtle form of omitted variable bias associated with absence of data on the distant ancestor from whom everyone in the kin networks is descended, and whose status influenced the observed characteristics of the kin network. Without recognizing this problem, studies may yield biased estimates of the influence of kin networks on individuals' demographic and socioeconomic outcomes.

Our results also suggest that analysis of relationships between social status and reproduction in human populations need to account separately for extinction and, conditional on avoidance of extinction, numbers of offspring. Status influenced the number of descendants many generations later, and did so in large part by reducing the chances that the members of one generation would have no descendants at all in next generation. If founders' characteristics have a more important effect on the probability of avoiding extinction than on the growth rates of descent lines that did survive, studies based on retrospective surveys or data from bequests based on only surviving descent lines may underestimate the importance of founder effects. If the more complex strategies for descent line continuity suggested by the results were typical of historical populations more generally, future simulation studies of population dynamics and kinship networks over the long term (e.g., Lavely and Wong 1998; Murphy 2004; Bongaarts, Burch and Wachter 1987) will need to reconsider many of their assumptions.

Our findings from two large, multi-generational databases in 18th and 19th century China have suggested that social differentiation and demographic behaviors in the past have long-term implications for surviving kin networks and population composition of the present day. New, very different socio-demographic patterns have emerged in the last century or two, and will shape the world that our descendants experience. We eagerly await the results of empirical analyses that use large, contemporary, multi-generational population databases to ascertain the saliency and relevance of these historic patterns in contemporary settings.

Table 4.1 Implications of Changes in Growth Equation Components for a Descent Line's Share of the Population

		Increase in growth rate r(t)		
		No	Yes	
			Permanent*	Transitory
Founder's reproduction *N*(0) is above average	No	No change in the descent line's share of population	**Permanent Advantage** Descent line's share of population increases steadily	**Advantage Dissipation** Descent line's share of the population increases for several generations, then stabilizes
	Yes	**Initial advantage** Descent line's share of population increases in next generation, then remains stable	**Initial Advantage + Permanent Advantage**	**Initial Advantage + Advantage Dissipation**

Note: * permanent means that the acceleration of growth rate is constant or positive. This implies that the growth rate of high-origin descent lines is always higher than the low-origin descent lines. Transitory means that the acceleration of growth rate is negative, though the growth rate itself is positive. This implies that the growth rate of high-origin descent lines will eventually drop down to the same level as that of the low-origin descent lines.

Table 4.2 Descriptive Statistics for Descent Line Characteristics

	CMGPD-Imperial Lineage			CMGPD-Liaoning		
	All	High-origin descent line	Low-origin descent line	All	High-origin descent line	Low-origin descent line
Founder's Characteristics						
Eldest brother in the family (%)	26.07	24.77	26.70	73.99	75.46	73.63
Number of male siblings	5.84	6.91	5.32	1.26	1.26	1.27
	(4.96)	(5.99)	(4.28)	(1.37)	(1.37)	(1.37)
Imperial lineage main line (%)	48.4	59.9	42.8	--	--	--
Regular status population (%)	--	--	--	82.1	82.9	82.0
Generation length	25.6	24.4	26.2	29.8	29.2	30.0
	(7.4)	(6.9)	(7.6)	(8.5)	(8.4)	(8.5)
Average number of descendants						
After 25 years	0.62	0.84	0.51	0.25	0.38	0.22
	(0.88)	(1.02)	(0.77)	(0.54)	(0.66)	(0.51)
After 50 years	1.81	2.61	1.42	1.07	1.70	0.92
	(2.06)	(2.62)	(1.57)	(1.43)	(1.68)	(1.31)
After 75 years	2.65	4.15	1.93	1.66	2.73	1.40
	(3.49)	(4.67)	(2.44)	(2.58)	(3.20)	(2.32)
After 100 years	3.07	5.15	2.05	1.95	3.27	1.62
	(5.00)	(6.96)	(3.25)	(3.65)	(4.61)	(3.28)
After 125 years	3.20	5.75	1.97	2.20	3.70	1.83
	(6.32)	(9.15)	(3.75)	(4.93)	(6.29)	(4.45)
After 150 years	3.22	5.93	1.91	--	--	--
	(7.08)	(10.44)	(4.05)			
Observations	3,314	1,082	2,232	18,997	3,761	15,236

Note: Figures in parentheses are standard deviations.
Sources: China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL), China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN).

Table 4.3 Regressions of Descent Line Sizes (Stocks)

Stock Model	Years					
	t=25	*t*=50	*t*=75	*t*=100	*t*=125	*t*=150
CMGPD-IL						
Linear						
High status founder	0.286***	1.057***	1.927***	2.607***	3.098***	3.248***
	(0.032)	(0.074)	(0.124)	(0.176)	(0.222)	(0.250)
Exponential						
High status founder	0.224***	0.500***	0.655***	0.734***	0.747***	0.739***
	(0.025)	(0.034)	(0.040)	(0.044)	(0.047)	(0.048)
Poisson						
High status founder	0.432***	0.538***	0.663***	0.769***	0.871***	0.909***
	(0.046)	(0.027)	(0.022)	(0.020)	(0.020)	(0.020)
Negative Binomial						
High status founder	0.432***	0.536***	0.658***	0.766***	0.864***	0.888***
	(0.050)	(0.037)	(0.043)	(0.051)	(0.061)	(0.070)
N	3,314	3,314	3,314	3,314	3,314	3,314
CMGPD-LN						
Linear						
High status founder	0.160***	0.779***	1.321***	1.641***	1.862***	--
	(0.010)	(0.025)	(0.046)	(0.065)	(0.089)	
Exponential						
High status founder	0.144***	0.504***	0.627***	0.646***	0.613***	--
	(0.009)	(0.015)	(0.020)	(0.021)	(0.023)	
Poisson						
High status founder	0.548***	0.612***	0.663***	0.698***	0.701***	--
	(0.032)	(0.015)	(0.012)	(0.011)	(0.010)	
Negative Binomial						
High status founder	0.548***	0.612***	0.664***	0.700***	0.703***	--
	(0.035)	(0.022)	(0.029)	(0.036)	(0.045)	
N	18,997	18,997	18,997	18,997	18,997	

Note: Figures in the table are excerpted from Appendix A. Standard errors of the coefficients are in parentheses. p* < .05, p** < .01, p*** < .001 (two-tailed tests).
Sources: China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL), China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN).

Table 4.4 Regressions of Descent Line Growth Rates (Flows)

Flow Model	Years					
	t=25	*t*=50	*t*=75	*t*=100	*t*=125	*t*=150
CMGPD-IL						
Linear						
High status founder	0.286***	0.771***	0.870***	0.679***	0.491***	0.150
	(0.032)	(0.063)	(0.077)	(0.084)	(0.092)	(0.087)
Exponential						
High status founder	0.224***	0.276***	0.155***	0.079***	0.013	-0.008
	(0.025)	(0.031)	(0.024)	(0.022)	(0.022)	(0.021)
Poisson						
High status founder	0.432***	0.267***	0.179***	0.149***	0.153***	0.098***
	(0.046)	(0.027)	(0.022)	(0.021)	(0.020)	(0.020)
Negative Binomial						
High status founder	0.432***	0.315***	0.194***	0.153***	0.159***	0.110***
	(0.050)	(0.035)	(0.025)	(0.023)	(0.025)	(0.025)
N	3,314	3,314	3,314	3,314	3,314	3,314
CMGPD-LN						
Linear						
High status founder	0.160***	0.619***	0.542***	0.320***	0.221***	--
	(0.010)	(0.022)	(0.028)	(0.033)	(0.043)	
Exponential						
High status founder	0.144***	0.359***	0.123***	0.019*	-0.033***	--
	(0.009)	(0.013)	(0.010)	(0.009)	(0.010)	
Poisson						
High status founder	0.548***	0.410***	0.186***	0.135***	0.096***	--
	(0.032)	(0.015)	(0.012)	(0.011)	(0.010)	
Negative Binomial						
High status founder	0.548***	0.459***	0.203***	0.172***	0.172***	--
	(0.035)	(0.018)	(0.014)	(0.014)	(0.016)	
N	18,997	18,997	18,997	18,997	18,997	

Note: Figures in the table are excerpted from Appendix B. Standard errors of the coefficients are in parentheses. p* < .05, p** < .01, p*** < .001 (two-tailed tests).
Sources: China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL), China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN).

Table 4.5 Mixture Negative Binomial Regressions of Male Descendants Growth and Extinction

	Years					
	t=25	*t*=50	*t*=75	*t*=100	*t*=125	*t*=150
CMGPD-IL						
Stock Model: P(N(t))						
Logistic model: N(t)>0						
High status founder	0.575***	1.126***	1.185***	1.116***	0.981***	0.970***
	(0.077)	(0.101)	(0.099)	(0.089)	(0.082)	(0.080)
N	3,314	3,314	3,314	3,314	3,314	3,314
Truncated negative binomial: N(t) | N(t)> 0						
High status founder	0.352***	0.431***	0.484***	0.543***	0.606***	0.568***
	(0.090)	(0.049)	(0.048)	(0.055)	(0.062)	(0.068)
N	1,419	2,374	2,306	2,088	1,801	1,592
Flow Model: P(N(t)|N(t-1)>0)						
Logistic model: N(t)>0						
High status founder	0.575***	0.728***	0.632***	0.585***	0.381**	0.533***
	(0.077)	(0.201)	(0.171)	(0.151)	(0.135)	(0.152)
N	3,314	1,419	2,374	2,306	2,088	1,801
Truncated negative binomial: N(t) | N(t)>0, N(t-1)>0						
High status founder	0.352***	0.252***	0.145***	0.102***	0.102***	0.037
	(0.090)	(0.050)	(0.029)	(0.025)	(0.025)	(0.026)
N	1,419	1,261	2,306	2,088	1,801	1,592
CMGPD-LN						
Stock Model: P(N(t))						
Logistic model: N(t)>0						
High status founder	0.659***	1.153***	1.123***	1.058***	0.974***	--
	(0.051)	(0.041)	(0.039)	(0.038)	(0.037)	
N	18,997	18,997	18,997	18,997	18,997	
Truncated negative binomial: N(t) | N(t)>0						
High status founder	0.254***	0.307***	0.243***	0.211***	0.168***	--
	(0.079)	(0.027)	(0.023)	(0.027)	(0.033)	
N	3,975	10,247	9,423	8,111	6,820	
Flow Model: P(N(t))						
Logistic model: N(t)>0 | N(t-1)>0						
High status founder	0.659***	0.702***	0.411***	0.401***	0.219**	--
	(0.041)	(0.140)	(0.081)	(0.072)	(0.069)	
N	18,997	3,975	10,247	9,423	8,111	
Truncated negative binomial: N(t) | N(t) >0, N(t-1) >0						
High status founder	0.254**	0.195***	0.056***	0.031*	0.001	--
	(0.079)	(0.027)	(0.014)	(0.013)	(0.013)	
N	3,975	3,584	9,423	8,111	6,820	

Notes: Figures in the table are excerpted from Appendix C. Standard errors of the coefficients are in parentheses. p* < .05, p** < .01, p*** < .001 (two-tailed tests).
Sources: China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL), China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN).

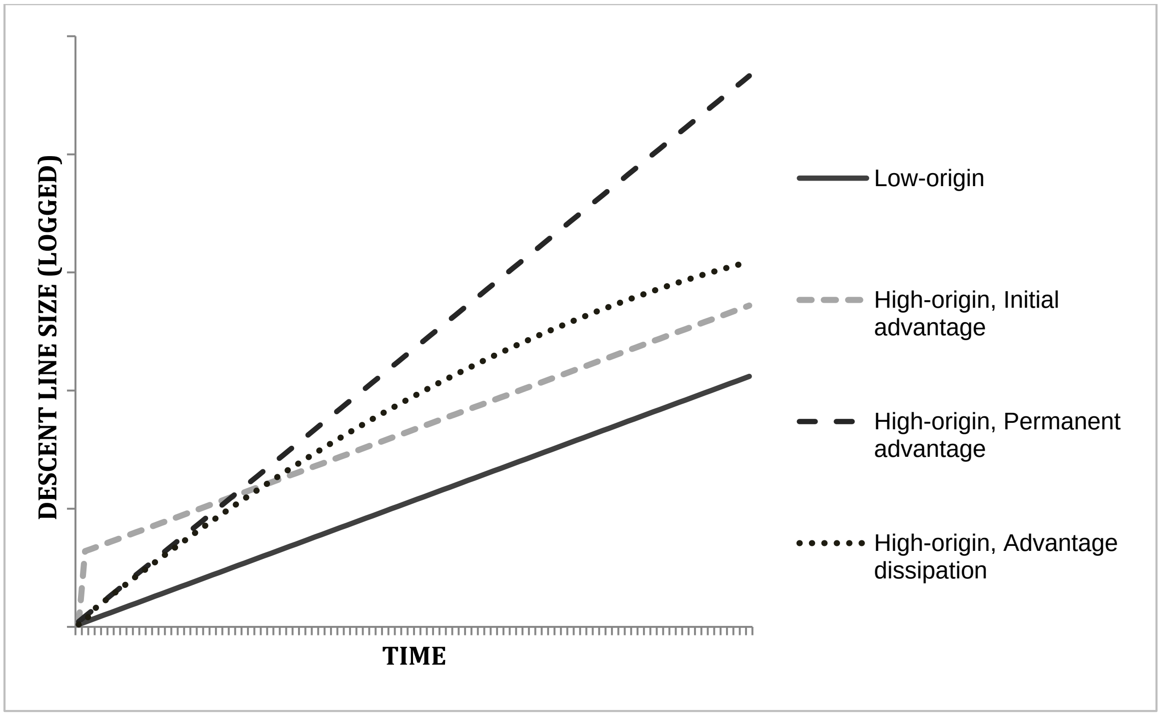


Figure 4.1 Three Mechanisms for Effects of Founder's Characteristics on Descent Line Growth

Notes: For the low-origin descent line, we assume its growth function is $\mathrm{N}(T) = \mathrm{N}(0)e^{\int_0^T r(t)dt}$. Under the assumption of initial advantage, the growth function of the high-origin descent line becomes $\mathrm{N}(T) = \mathrm{c} \cdot \mathrm{N}(0)e^{\int_0^T r(t)dt}$, where *c* is constant multiplier to N(0). Under the assumption of permanent advantage, the growth function of the high-origin descent line becomes $\mathrm{N}(T) = \mathrm{N}(0)e^{\int_0^T \mathrm{c} \cdot r(t)dt}$, where *c* is constant multiplier to *r*(*t*) for high-origin descent lines. Under the assumption of advantage dissipation, the growth function of the high-origin descent line becomes $\mathrm{N}(T) = \mathrm{N}(0)e^{\int_0^T \left(\mathrm{c} \cdot r(t) - \int_0^T a(t)dt\right)dt}$, where $\int_0^T a(t)\,dt$ accumulates over time and counteracts the effect of *c* for a high-origin descent line.

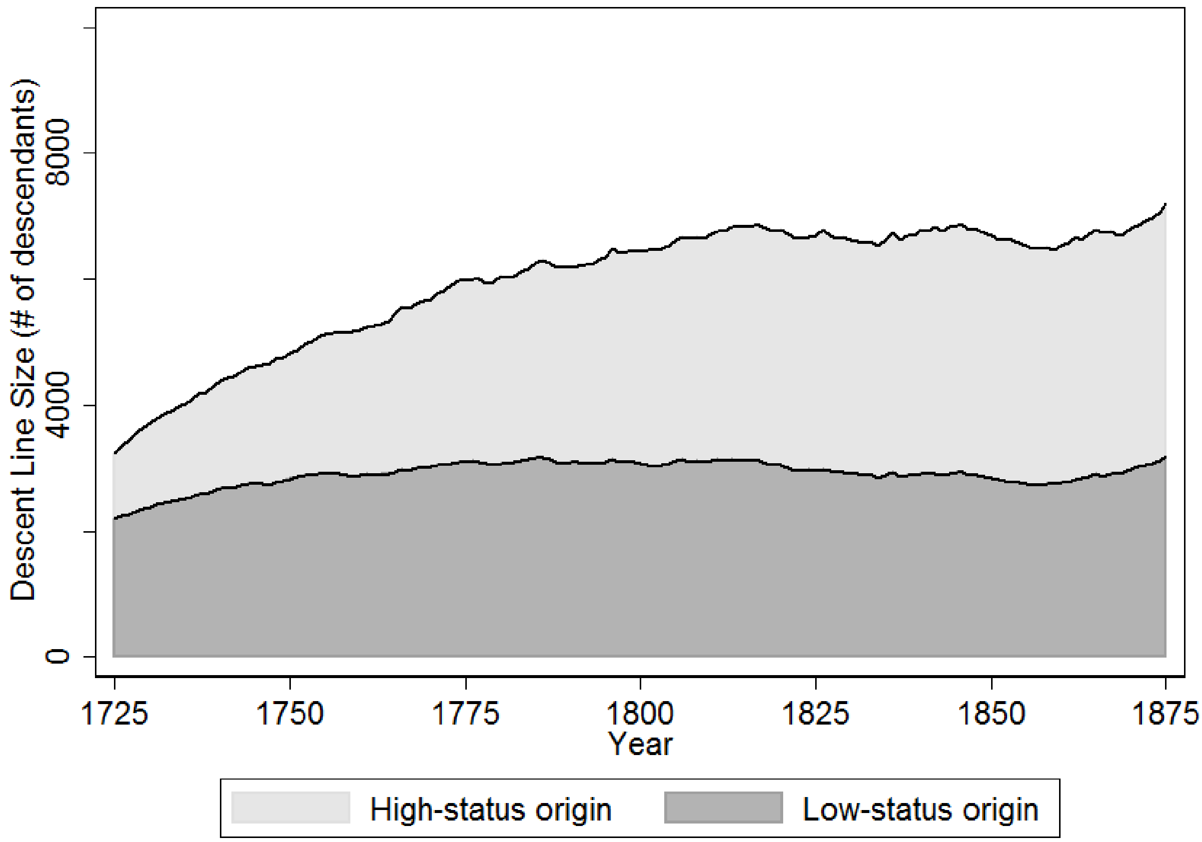


Figure 4.2 Descent Line Size over Time, by Founder's Status (CMGPD-IL)

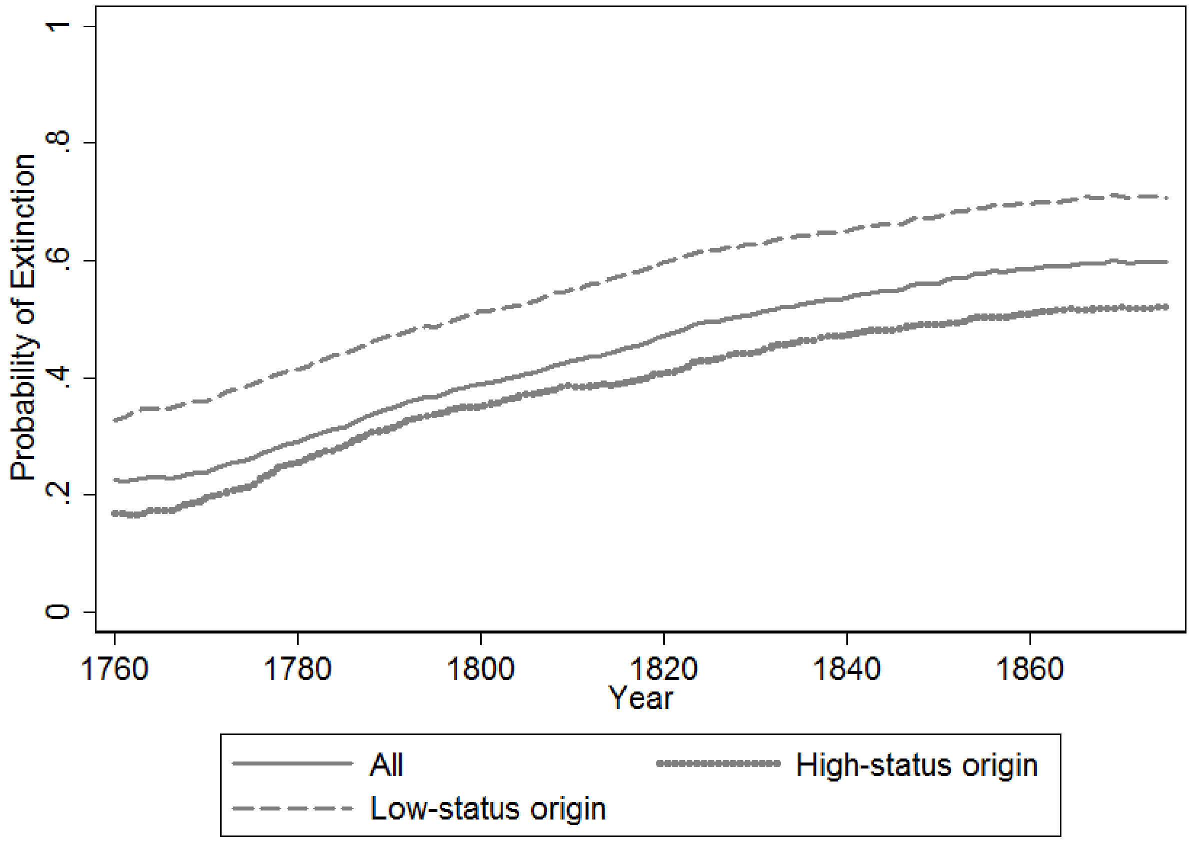


Figure 4.3 Descent Line Extinction by Founder's Social Status: CMGPD-IL

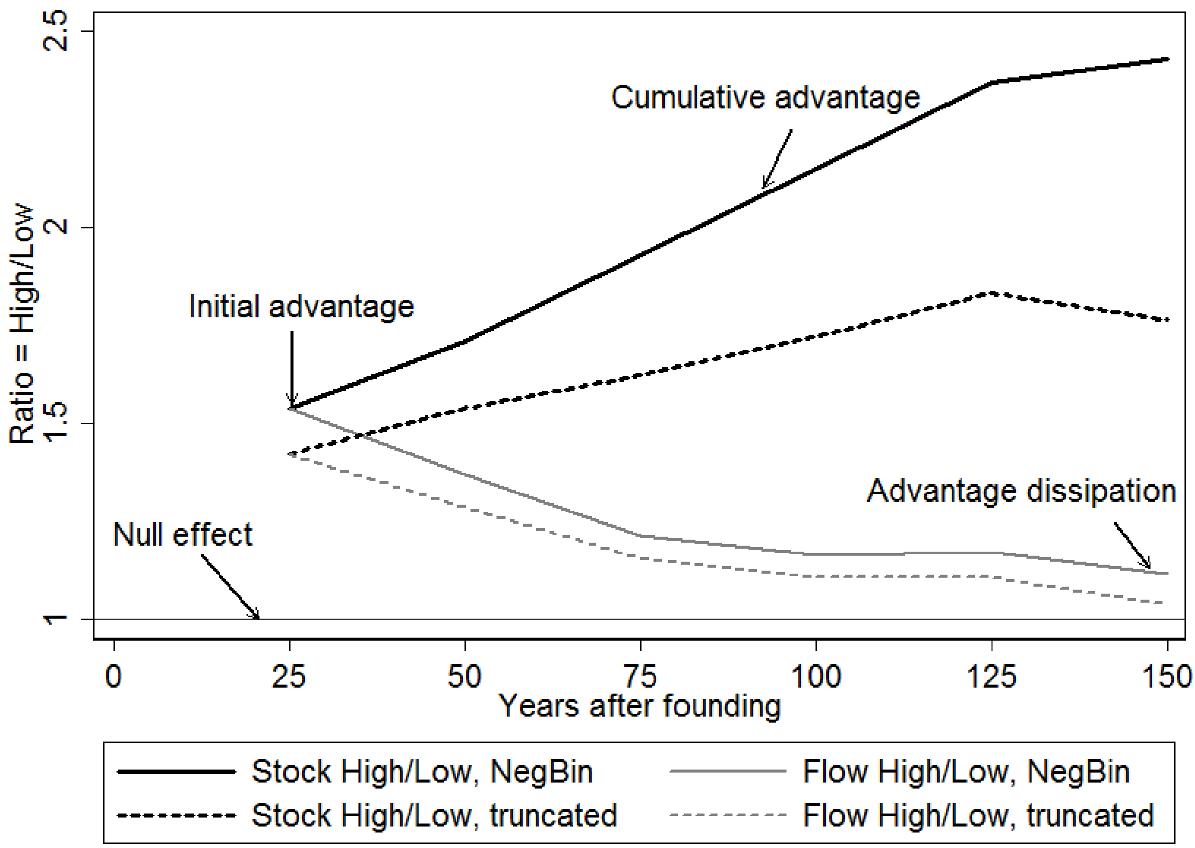


Figure 4.4 The Effect of Founder's Status on Relative Descent Line Sizes and Growth Rates over Time: CMGPD-IL

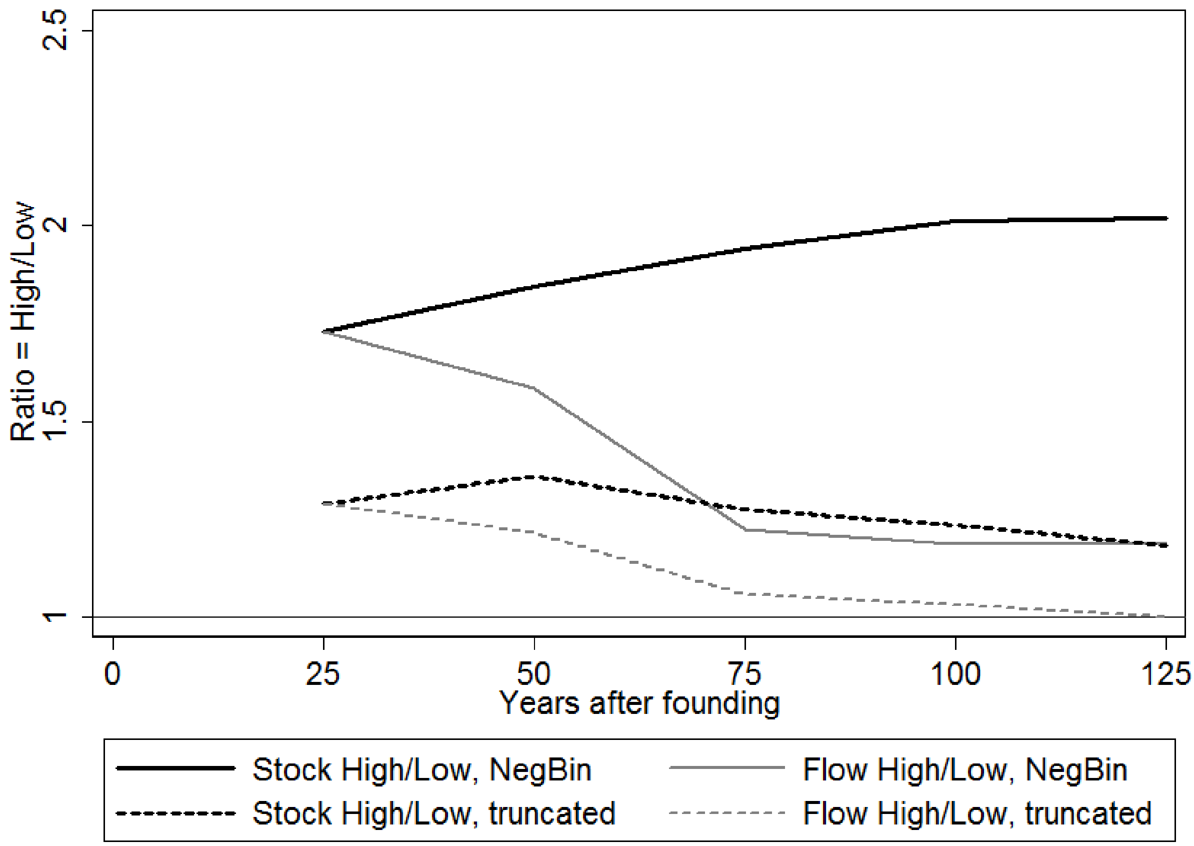


Figure 4.5 The Effect of Founder's Status on Relative Descent Line Sizes and Growth Rates over Time: CMGPD-LN

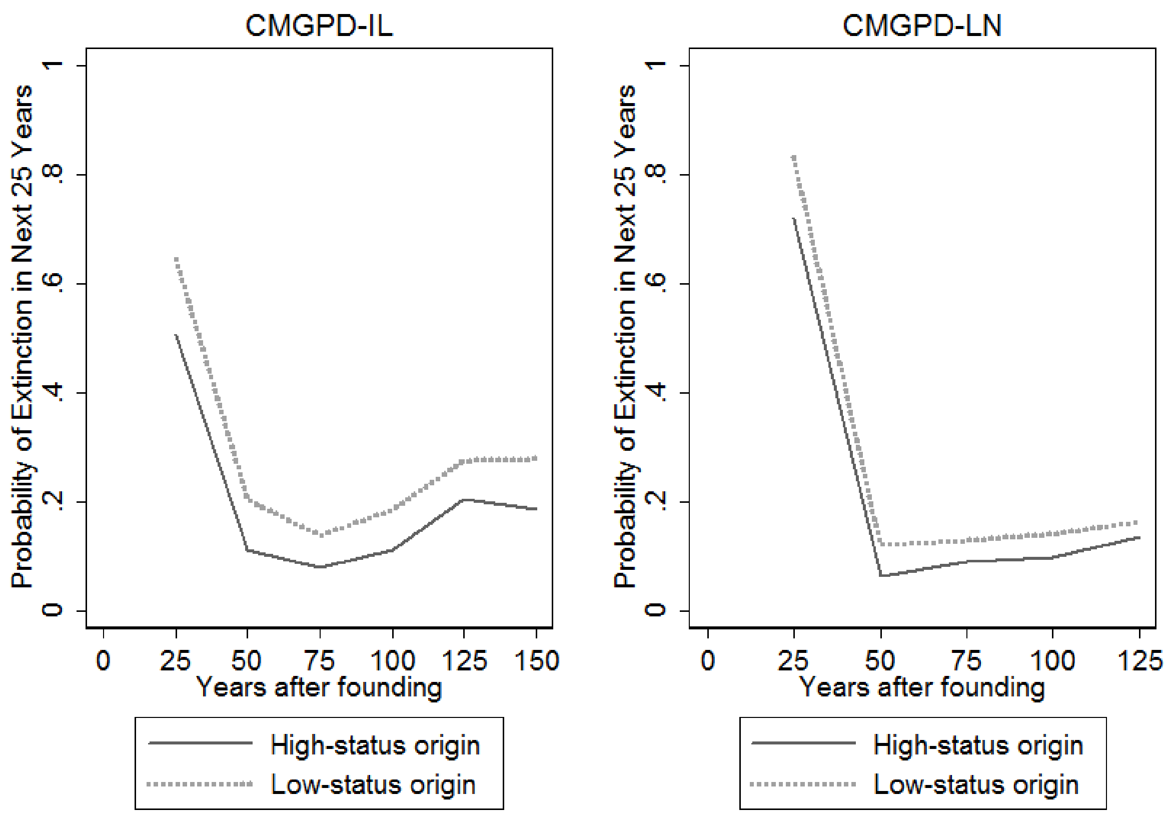


Figure 4.6 Probability of Extinction in the Next 25 Years for High-origin and Low-origin Descent lines: CMGPD-IL & CMGPD-LN

Appendix Table 4A Regressions of Male Descendant Stocks

	CMGPD-IL						CMGPD-LN				
Stock Model	*t*=25	*t*=50	*t*=75	*t*=100	*t*=125	*t*=150	*t*=25	*t*=50	*t*=75	*t*=100	*t*=125
Linear Model											
Founder's status:	0.286***	1.057***	1.927***	2.607***	3.098***	3.248***	0.160***	0.779***	1.321***	1.641***	1.862***
(Ref: low)	(0.032)	(0.074)	(0.124)	(0.176)	(0.222)	(0.250)	(0.010)	(0.025)	(0.046)	(0.065)	(0.089)
Eldest brother	0.063	0.026	-0.022	-0.058	0.111	-0.026	0.023*	0.074**	0.118*	0.178**	0.285**
	(0.036)	(0.083)	(0.138)	(0.196)	(0.248)	(0.278)	(0.010)	(0.026)	(0.047)	(0.066)	(0.090)
Number of male	0.018***	0.040***	0.082***	0.128***	0.181***	0.197***	0.010**	0.036***	0.079***	0.078***	0.066*
siblings	(0.003)	(0.007)	(0.013)	(0.018)	(0.022)	(0.025)	(0.003)	(0.008)	(0.015)	(0.021)	(0.029)
Imperial Lineage	-0.116***	-0.417***	-0.955***	-1.702***	-2.344***	-2.669***	--	--	--	--	--
(Ref: Main Line)	(0.031)	(0.070)	(0.117)	(0.166)	(0.210)	(0.236)					
Population status	--	--	--	--	--	--	-0.054***	-0.163***	-0.323***	-0.259***	-0.065
(Ref: Regular)							(0.010)	(0.026)	(0.048)	(0.068)	(0.093)
Intercept	0.463***	1.442***	2.043***	2.361***	2.319***	2.393***	0.198***	0.849***	1.272***	1.436***	1.548***
	(0.036)	(0.082)	(0.136)	(0.194)	(0.245)	(0.275)	(0.011)	(0.028)	(0.051)	(0.073)	(0.099)
R-square	0.047	0.096	0.125	0.136	0.139	0.132	0.016	0.051	0.046	0.034	0.023
N	3,314	3,314	3,314	3,314	3,314	3,314	18,997	18,997	18,997	18,997	18,997
Exponential Model											
Founder's status:	0.224***	0.500***	0.655***	0.734***	0.747***	0.739***	0.144***	0.504***	0.627***	0.646***	0.613***
(Ref: low)	(0.025)	(0.034)	(0.040)	(0.044)	(0.047)	(0.048)	(0.009)	(0.015)	(0.020)	(0.021)	(0.023)
Eldest brother	0.057*	-0.006	-0.026	-0.052	-0.022	-0.050	0.020*	0.062***	0.085***	0.095***	0.108***
	(0.028)	(0.038)	(0.045)	(0.049)	(0.052)	(0.053)	(0.009)	(0.016)	(0.020)	(0.022)	(0.023)
Number of male	0.013***	0.015***	0.022***	0.026***	0.030***	0.028***	0.010***	0.022***	0.034***	0.028***	0.022**
siblings	(0.003)	(0.003)	-0.004	(0.004)	(0.005)	(0.005)	(0.003)	(0.005)	(0.006)	(0.007)	(0.007)
Imperial Lineage	-0.084***	-0.174***	-0.263***	-0.396***	-0.525***	-0.578***	--	--	--	--	--
(Ref: Main Line)	(0.024)	(0.032)	(0.038)	(0.042)	(0.044)	(0.045)					
Population status	--	--	--	--	--	--	-0.048***	-0.058***	-0.073***	-0.018	0.049*
(Ref: Regular)							(0.009)	(0.016)	(0.020)	(0.022)	(0.024)
Intercept	-0.581***	0.061	0.202***	0.184***	0.092	0.039	-0.813***	-0.353***	-0.259***	-0.310***	-0.391***
	(0.028)	(0.037)	(0.044)	(0.049)	(0.051)	(0.053)	(0.010)	(0.017)	(0.022)	(0.024)	(0.025)
R-square	0.045	0.092	0.118	0.140	0.154	0.153	0.017	0.056	0.054	0.047	0.038
N	3,314	3,314	3,314	3,314	3,314	3,314	18,997	18,997	18,997	18,997	18,997

Appendix Table 4A (Cont.)

	CMGPD-IL						CMGPD-LN				
Stock Model	*t*=25	*t*=50	*t*=75	*t*=100	*t*=125	*t*=150	*t*=25	*t*=50	*t*=75	*t*=100	*t*=125
Poisson Model											
Founder's status:	0.432***	0.538***	0.663***	0.769***	0.871***	0.909***	0.548***	0.612***	0.663***	0.698***	0.701***
(Ref: low)	(0.046)	(0.027)	(0.022)	(0.020)	(0.020)	(0.020)	(0.032)	(0.015)	(0.012)	(0.011)	(0.010)
Eldest brother	0.086	-0.001	-0.040	-0.073**	-0.043	-0.106***	0.091*	0.068***	0.069***	0.091***	0.131***
	(0.054)	(0.032)	(0.027)	(0.025)	(0.025)	(0.025)	(0.037)	(0.018)	(0.014)	(0.013)	(0.013)
Number of male	0.022***	0.016***	0.021***	0.025***	0.030***	0.031***	0.039***	0.032***	0.045***	0.038***	0.029***
siblings	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.011)	(0.006)	(0.004)	(0.004)	(0.004)
Imperial Lineage	-0.192***	-0.235***	-0.375***	-0.597***	-0.824***	-0.960***	--	--	--	--	--
(Ref: Main Line)	(0.046)	(0.027)	(0.023)	(0.022)	(0.023)	(0.023)					
Population status	--	--	--	--	--	--	-0.233***	-0.161***	-0.210***	-0.140***	-0.030*
(Ref: Regular)							(0.041)	(0.019)	(0.016)	(0.014)	(0.013)
Intercept	-0.719***	0.389***	0.746***	0.892***	0.898***	0.923***	-1.601***	-0.149***	0.262***	0.389***	0.474***
	(0.052)	(0.030)	(0.025)	(0.023)	(0.022)	(0.022)	(0.041)	(0.020)	(0.016)	(0.015)	(0.014)
Log-likelihood	-3465	-6234	-8584	-10645	-12212	-13179	-11828	-28487	-42792	-55003	-69692
N	3,314	3,314	3,314	3,314	3,314	3,314	18,997	18,997	18,997	18,997	18,997
Negative Binomial Model											
Founder's status:	0.432***	0.536***	0.658***	0.766***	0.864***	0.888***	0.548***	0.612***	0.664***	0.700***	0.703***
(Ref: low)	(0.050)	(0.037)	(0.043)	(0.051)	(0.061)	(0.070)	(0.035)	(0.022)	(0.029)	(0.036)	(0.045)
Eldest brother	0.088	0.005	-0.038	-0.070	-0.051	-0.110	0.091*	0.071**	0.071**	0.098**	0.132**
	(0.058)	(0.043)	(0.050)	(0.059)	(0.070)	(0.079)	(0.040)	(0.024)	(0.030)	(0.037)	(0.046)
Number of male	0.022***	0.016***	0.020***	0.026***	0.029***	0.026***	0.040**	0.035***	0.052***	0.047***	0.039**
siblings	(0.005)	(0.004)	(0.004)	(0.005)	(0.006)	(0.007)	(0.012)	(0.008)	(0.010)	(0.012)	(0.015)
Imperial Lineage	-0.188***	-0.225***	-0.358***	-0.583***	-0.804***	-0.922***	--	--	--	--	--
(Ref: Main Line)	(0.050)	(0.037)	(0.042)	(0.050)	(0.059)	(0.068)					
Population status	--	--	--	--	--	--	-0.232***	-0.154***	-0.197***	-0.120**	-0.012
(Ref: Regular)							(0.044)	(0.026)	(0.032)	(0.039)	(0.047)
Intercept	-0.723***	0.385***	0.743***	0.880***	0.902***	0.950***	-1.602***	-0.156***	0.249***	0.369***	0.457***
	(0.057)	(0.042)	(0.048)	(0.057)	(0.068)	(0.077)	(0.044)	(0.027)	(0.033)	(0.042)	(0.051)
Alpha	0.256	0.467	0.952	1.533	2.290	3.051	0.601	0.741	2.027	3.531	5.641
Log-likelihood	-3446	-5841	-6875	-7054	-6782	-6474	-11740	-26854	-32193	-32266	-30813
N	3,314	3,314	3,314	3,314	3,314	3,314	18,997	18,997	18,997	18,997	18,997

*Notes***:** Standard errors of the coefficients are in parentheses. p* < .05, p** < .01, p*** < .001 (two-tailed tests).
Sources: China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL), China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN).

Appendix Table 4B Regressions of Male Descendant Flows

	CMGPD-IL						CMGPD-LN				
Flow Model	*t*=25	*t*=50	*t*=75	*t*=100	*t*=125	*t*=150	*t*=25	*t*=50	*t*=75	*t*=100	*t*=125
Linear Model											
Founder's status:	0.286***	0.771***	0.870***	0.679***	0.491***	0.150	0.160***	0.619***	0.542***	0.320***	0.221***
(Ref: low)	(0.032)	(0.063)	(0.077)	(0.084)	(0.092)	(0.087)	(0.010)	(0.022)	(0.028)	(0.033)	(0.043)
Eldest brother	0.063	-0.036	-0.048	-0.036	0.169	-0.137	0.023*	0.051*	0.044	0.059	0.107*
	(0.036)	(0.070)	(0.086)	(0.094)	(0.102)	(0.097)	(0.010)	(0.022)	(0.029)	(0.033)	(0.043)
Number of male	0.018***	0.022***	0.042***	0.046***	0.053***	0.016	0.010**	0.026***	0.043***	-0.001	-0.012
siblings	(0.003)	(0.006)	(0.008)	(0.009)	(0.009)	(0.009)	(0.003)	(0.007)	(0.009)	(0.011)	(0.014)
Imperial Lineage	-0.116***	-0.300***	-0.539***	-0.746***	-0.643***	-0.324***	--	--	--	--	--
(Ref: Main Line)	(0.031)	(0.059)	(0.073)	(0.079)	(0.087)	(0.082)					
Population status	--	--	--	--	--	--	-0.054***	-0.110***	-0.160***	0.064	0.194***
(Ref: Regular)							(0.010)	(0.023)	(0.029)	(0.034)	(0.044)
Descendants at t-1	--	offset	offset	offset	offset	offset	--	offset	offset	offset	offset
Intercept	0.463***	0.979***	0.601***	0.318***	-0.041	0.074	0.198***	0.651***	0.423***	0.164***	0.111*
	(0.036)	(0.069)	(0.085)	(0.093)	(0.101)	(0.096)	(0.011)	(0.024)	(0.031)	(0.036)	(0.047)
R-square	0.047	0.068	0.082	0.073	0.047	0.010	0.016	0.044	0.022	0.005	0.003
N	3,314	3,314	3,314	3,314	3,314	3,314	18,997	18,997	18,997	18,997	18,997
Exponential Model											
Founder's status:	0.224***	0.276***	0.155***	0.079***	0.013	-0.008	0.144***	0.359***	0.123***	0.019*	-0.033***
(Ref: low)	(0.025)	(0.031)	(0.024)	(0.022)	(0.022)	(0.021)	(0.009)	(0.013)	(0.010)	(0.009)	(0.010)
Eldest brother	0.057*	-0.062	-0.020	-0.027	0.030	-0.028	0.020*	0.042**	0.022*	0.010	0.014
	(0.028)	(0.035)	(0.027)	(0.024)	(0.025)	(0.024)	(0.009)	(0.014)	(0.010)	(0.009)	(0.010)
Number of male	0.013***	0.001	0.007**	0.005*	0.004	-0.002	0.010***	0.012**	0.012***	-0.006*	-0.006
siblings	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)
Imperial Lineage	-0.084***	-0.090**	-0.088***	-0.134***	-0.128***	-0.053**	--	--	--	--	--
(Ref: Main Line)	(0.024)	(0.030)	(0.023)	(0.021)	(0.021)	(0.020)					
Population status	--	--	--	--	--	--	-0.048***	-0.011	-0.014	0.054***	0.068***
(Ref: Regular)							(0.009)	(0.014)	(0.010)	(0.010)	(0.010)
Descendants at t-1	--	offset	offset	offset	offset	offset	--	offset	offset	offset	offset
Intercept	-0.581***	0.642***	0.141***	-0.018	-0.092***	-0.053*	-0.813***	0.460***	0.094***	-0.051***	0.081***
	(0.028)	(0.034)	(0.026)	(0.024)	(0.024)	(0.023)	(0.010)	(0.015)	(0.011)	(0.010)	(0.011)
R-square	0.045	0.031	0.027	0.024	0.015	0.002	0.017	0.038	0.009	0.003	0.004
N	3,314	3,314	3,314	3,314	3,314	3,314	18,997	18,997	18,997	18,997	18,997

Appendix Table 4B (Cont.)

	CMGPD-IL						CMGPD-LN				
	t=25	*t*=50	*t*=75	*t*=100	*t*=125	*t*=150	*t*=25	*t*=50	*t*=75	*t*=100	*t*=125
Poisson Model											
Founder's status:	0.432***	0.267***	0.179***	0.149***	0.153***	0.098***	0.548***	0.410***	0.186***	0.135***	0.096***
(Ref: low)	(0.046)	(0.027)	(0.022)	(0.021)	(0.020)	(0.020)	(0.032)	(0.015)	(0.012)	(0.011)	(0.010)
Eldest brother	0.086	-0.046	-0.040	-0.035	0.024	-0.070**	0.091*	0.035*	0.024	0.036**	0.056***
	(0.054)	(0.046)	(0.027)	(0.025)	(0.025)	(0.025)	(0.037)	(0.018)	(0.014)	(0.013)	(0.013)
Number of male	0.022***	0.001	0.005**	0.005**	0.006***	0.001	0.039***	0.020***	0.021***	0.001	-0.003
siblings	(0.004)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.011)	(0.006)	(0.004)	(0.004)	(0.004)
Imperial Lineage	-0.192***	-0.103***	-0.160***	-0.242***	-0.264***	-0.200***	--	--	--	--	--
(Ref: Main Line)	(0.046)	(0.027)	(0.023)	(0.022)	(0.023)	(0.023)					
Population status	--	--	--	--	--	--	-0.233***	-0.081***	-0.061***	0.053***	0.102***
(Ref: Regular)							(0.041)	(0.019)	(0.016)	(0.014)	(0.013)
Descendants at t-1	--	offset	offset	offset	offset	offset	--	offset	offset	offset	offset
Intercept	-0.719***	0.717***	0.280***	0.088***	-0.055*	-0.046*	-1.601***	0.533***	0.195***	-0.030*	-0.067***
	(0.052)	(0.031)	(0.025)	(0.022)	(0.022)	(0.022)	(0.041)	(0.020)	(0.016)	(0.015)	(0.014)
Log-likelihood	-3465	-5692	-5344	-4994	-4710	-4449	-11828	-24899	-23529	-22537	-22749
N	3,314	3,314	3,314	3,314	3,314	3,314	18,997	18,997	18,997	18,997	18,997
Negative Binomial Model											
Founder's status:	0.432***	0.315***	0.194***	0.153***	0.159***	0.110***	0.548***	0.459***	0.203***	0.172***	0.172***
(Ref: low)	(0.050)	(0.035)	(0.025)	(0.023)	(0.025)	(0.025)	(0.035)	(0.018)	(0.014)	(0.014)	(0.016)
Eldest brother	0.088	-0.065	-0.040	-0.036	0.016	-0.063*	0.091*	0.048**	0.033*	0.048**	0.070***
	(0.058)	(0.041)	(0.030)	(0.028)	(0.030)	(0.031)	(0.040)	(0.021)	(0.016)	(0.016)	(0.019)
Number of male	0.022***	0.001	0.006**	0.005**	0.005**	0.001	0.040**	0.022***	0.023***	0.004	0.002
siblings	(0.005)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.012)	(0.007)	(0.005)	(0.005)	(0.006)
Imperial Lineage	-0.188***	-0.107**	-0.156***	-0.238***	-0.264***	-0.188***	--	--	--	--	--
(Ref: Main Line)	(0.050)	(0.035)	(0.026)	(0.024)	(0.026)	(0.027)					
Population status	--	--	--	--	--	--	-0.232***	-0.080***	-0.056**	0.068***	0.132***
(Ref: Regular)							(0.044)	(0.022)	(0.017)	(0.017)	(0.019)
Descendants at t-1	--	offset	offset	offset	offset	offset	offset	offset	offset	offset	offset
Intercept	-0.723***	0.776***	0.267***	0.068**	-0.075**	-0.079**	-1.602***	0.514***	0.157***	-0.121***	-0.261***
	(0.057)	(0.040)	(0.029)	(0.026)	(0.027)	(0.028)	(0.044)	(0.023)	(0.018)	(0.019)	(0.022)
Alpha	0.256	0.264	0.065	0.039	0.059	0.058	0.601	0.231	0.066	0.116	0.252
Log-likelihood	-3446	-5533	-5307	-4972	-4657	-4404	-11740	-24635	-23427	-22138	-21378
N	3,314	3,314	3,314	3,314	3,314	3,314	18,997	18,997	18,997	18,997	18,997

Notes: Standard errors of the coefficients are in parentheses. p* < .05, p** < .01, p*** < .001 (two-tailed tests).

Sources: China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL), China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN).

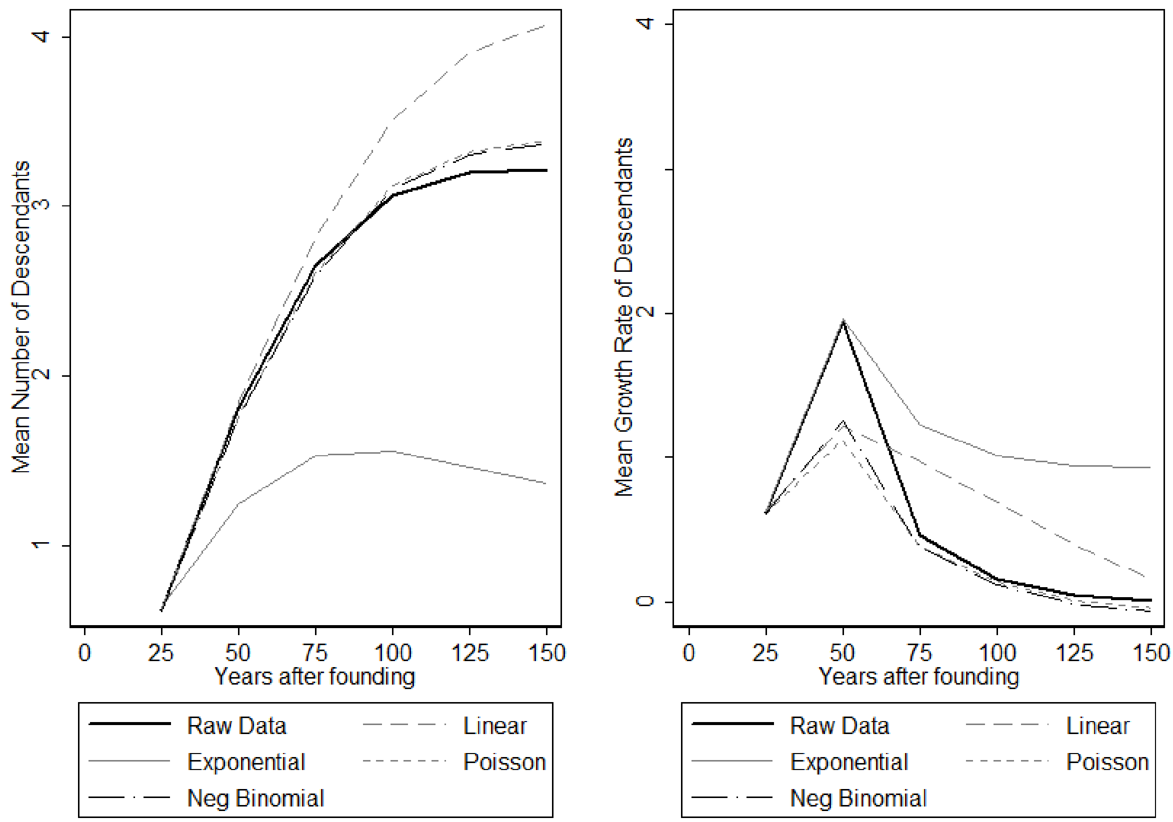
Appendix Table 4C Mixture Negative Binomial Regressions of Number of Male Descendants

	CMGPD-IL						CMGPD-LN				
Stock Model: P(N(t))											
	t=25	*t*=50	*t*=75	*t*=100	*t*=125	*t*=150	*t*=25	*t*=50	*t*=75	*t*=100	*t*=125
Logistic model:											
N(t)> 0 (survival=1)											
Founder's status:	0.575***	1.126***	1.185***	1.116***	0.981***	0.970***	0.659***	1.153***	1.123***	1.058***	0.974***
(Ref: low)	(0.077)	(0.101)	(0.099)	(0.089)	(0.082)	(0.080)	(0.041)	(0.041)	(0.039)	(0.038)	(0.037)
Eldest brother	0.154	-0.137	-0.086	-0.110	-0.025	-0.079	0.101*	0.175***	0.174***	0.165***	0.193***
	(0.087)	(0.096)	(0.095)	(0.091)	(0.089)	(0.090)	(0.046)	(0.038)	(0.038)	(0.039)	(0.040)
Number of male	0.033***	0.021*	0.028**	0.032***	0.039***	0.040***	0.055***	0.039**	0.039**	0.025*	0.027*
siblings	(0.008)	(0.010)	(0.010)	(0.009)	(0.009)	(0.009)	(0.014)	(0.012)	(0.012)	(0.012)	(0.013)
Imperial Lineage	-0.185*	-0.339***	-0.287***	-0.340***	-0.514***	-0.638***	--	--	--	--	--
(Ref: Main Line)	(0.073)	(0.082)	(0.081)	(0.077)	(0.074)	(0.075)					
Population status	--	--	--	--	--	--	-0.246***	0.085*	0.054	0.075	0.127**
(Ref: Regular)							(0.050)	(0.039)	(0.039)	(0.039)	(0.040)
Intercept	-0.603***	0.760***	0.557***	0.265**	-0.060	-0.255**	-1.606***	-0.287***	-0.454***	-0.707***	-1.016***
	(0.086)	(0.098)	(0.096)	(0.092)	(0.089)	(0.088)	(0.051)	(0.042)	(0.042)	(0.042)	(0.044)
N	3,314	3,314	3,314	3,314	3,314	3,314	18,997	18,997	18,997	18,997	18,997
Truncated negative binomial:											
N(t) | N(t) > 0											
Founder's status:	0.352***	0.431***	0.484***	0.543***	0.606***	0.568***	0.254**	0.307***	0.243***	0.211***	0.168***
(Ref: low)	(0.090)	(0.049)	(0.048)	(0.055)	(0.062)	(0.068)	(0.079)	(0.027)	(0.023)	(0.027)	(0.033)
Eldest brother	0.008	0.062	-0.020	-0.039	-0.044	-0.078	0.070	-0.019	-0.021	0.003	0.014
	(0.107)	(0.059)	(0.057)	(0.066)	(0.075)	(0.082)	(0.097)	(0.032)	(0.027)	(0.033)	(0.039)
Number of male	0.018*	0.017***	0.018***	0.021***	0.020***	0.017**	-0.018	0.031**	0.038***	0.035***	0.018
siblings	(0.008)	(0.005)	(0.004)	(0.005)	(0.006)	(0.006)	(0.031)	(0.010)	(0.009)	(0.010)	(0.012)
Imperial Lineage	-0.227*	-0.205***	-0.371***	-0.617***	-0.766***	-0.793***	--	--	--	--	--
(Ref: Main Line)	(0.094)	(0.050)	(0.048)	(0.056)	(0.064)	(0.071)					
Population status	--	--	--	--	--	--	-0.214	-0.400***	-0.325***	-0.227***	-0.128***
(Ref: Regular)							(0.112)	(0.036)	(0.029)	(0.033)	(0.039)
Intercept	-0.700***	0.324***	0.894***	1.119***	1.278***	1.435***	-1.497***	0.162***	0.944***	1.221***	1.507***
	(0.146)	(0.064)	(0.058)	(0.068)	(0.075)	(0.082)	(0.213)	(0.040)	(0.032)	(0.038)	(0.046)
N	1,419	2,374	2,306	2,088	1,801	1,592	3,975	10,247	9,423	8,111	6,820
Log-likelihood	-3,423	-5,775	-6,802	-6,977	-6,704	-6,387	-11,730	-26,660	-31,630	-31,700	-30,310
Vuong Test	0.80	3.20***	3.46***	3.96***	4.53***	5.69***	2.44**	9.93***	17.52***	17.73***	16.81***

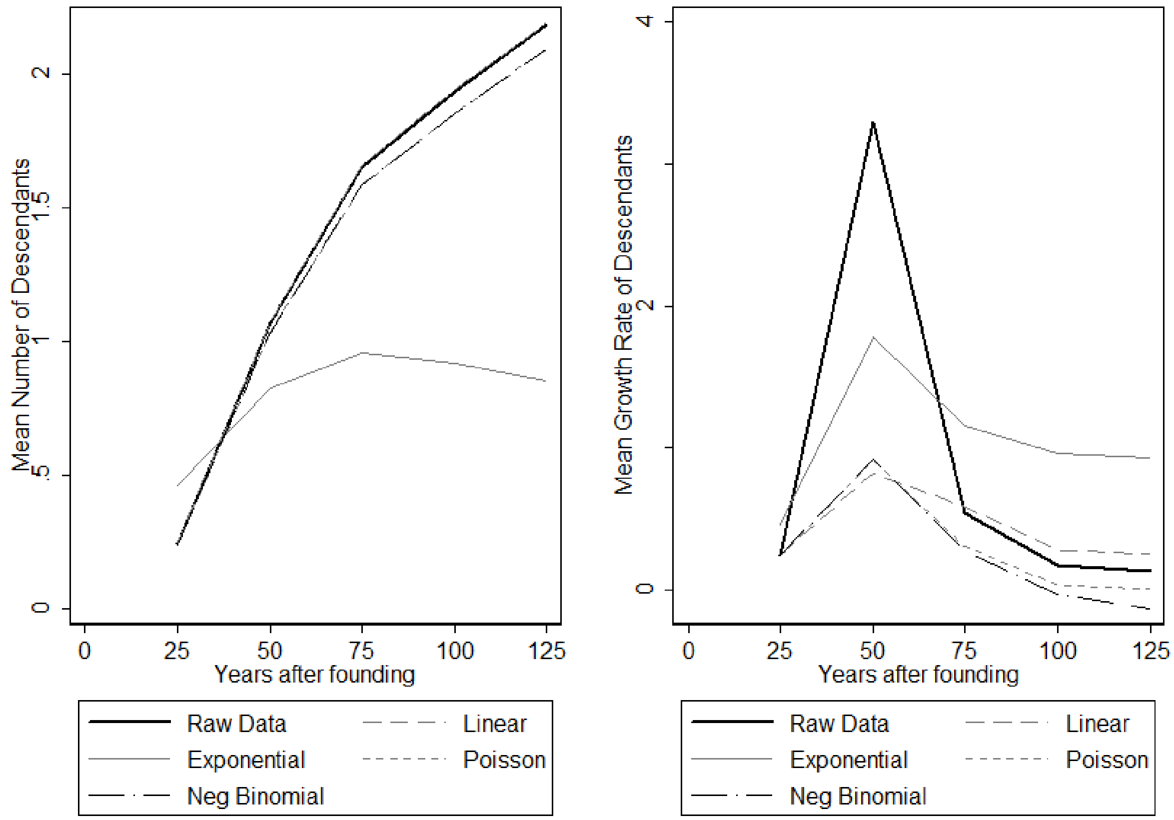
Appendix Table 4C (Cont.)

	CMGPD-IL						CMGPD-LN				
Flow Model: P(N(t)|N(t-1)>0)	*t*=25	*t*=50	*t*=75	*t*=100	*t*=125	*t*=150	*t*=25	*t*=50	*t*=75	*t*=100	*t*=125
Logistic model: N(t) > 0 | N(t-1)> 0											
Founder's status:	0.575***	0.728***	0.632***	0.585***	0.381**	0.533***	0.659***	0.702***	0.411***	0.401***	0.219**
(Ref: low)	(0.077)	(0.201)	(0.171)	(0.151)	(0.135)	(0.152)	(0.041)	(0.140)	(0.081)	(0.072)	(0.069)
Eldest brother	0.154	0.179	0.032	-0.105	0.188	-0.093	0.101*	0.447***	0.010	0.036	0.178*
	(0.087)	(0.211)	(0.179)	(0.158)	(0.155)	(0.165)	(0.046)	(0.131)	(0.087)	(0.076)	(0.078)
Number of male	0.033***	0.015	0.049*	0.049**	0.046**	0.056**	0.055***	0.034	0.043	-0.034	0.023
siblings	(0.008)	(0.020)	(0.020)	(0.018)	(0.016)	(0.019)	(0.014)	(0.044)	(0.028)	(0.024)	(0.026)
Imperial Lineage	-0.185*	-0.780***	-0.137	-0.345*	-0.715***	-0.788***	--	--	--	--	--
(Ref: Main Line)	(0.073)	(0.185)	(0.152)	(0.138)	(0.131)	(0.145)					
Population status	--	--	--	--	--	--	-0.246***	0.327	-0.144	0.093	0.237**
(Ref: Regular)							(0.050)	(0.168)	(0.083)	(0.080)	(0.084)
Descendants at t-1	--	control	control	control	control	control	--	control	control	control	control
Intercept	-0.603***	2.146***	1.973***	1.830***	1.684***	1.739***	-1.606***	1.659***	2.056***	1.718***	1.399***
	(0.086)	(0.225)	(0.180)	(0.168)	(0.161)	(0.180)	(0.051)	(0.143)	(0.097)	(0.086)	(0.087)
N	3,314	1,419	2,374	2,306	2,088	1,801	18,997	3,975	10,247	9,423	8,111
Truncated negative binomial: N(t) | N(t) > 0, N(t-1) > 0											
Founder's status:	0.352***	0.252***	0.145***	0.102***	0.102***	0.037	0.254**	0.195***	0.056***	0.031*	0.001
(Ref: low)	(0.090)	(0.050)	(0.029)	(0.025)	(0.025)	(0.026)	(0.079)	(0.027)	(0.014)	(0.013)	(0.013)
Eldest brother	0.008	0.033	-0.029	-0.021	0.010	-0.057	0.070	-0.062	0.001	0.027	0.031
	(0.107)	(0.058)	(0.035)	(0.030)	(0.031)	(0.032)	(0.097)	(0.032)	(0.016)	(0.016)	(0.016)
Number of male	0.018*	0.006	0.006*	0.004*	0.003	-0.001	-0.018	0.020	0.018***	0.002	-0.007
siblings	(0.008)	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)	(0.031)	(0.010)	(0.005)	(0.005)	(0.005)
Imperial Lineage	-0.227*	-0.051	-0.173***	-0.244***	-0.223***	-0.116***	--	--	--	--	--
(Ref: Main Line)	(0.094)	(0.052)	(0.030)	(0.026)	(0.028)	(0.029)					
Population status	--	--	--	--	--	--	-0.214	-0.201***	-0.088***	0.053**	0.114***
(Ref: Regular)							(0.112)	(0.039)	(0.019)	(0.017)	(0.017)
Descendants at t-1	--	offset	offset	offset	offset	offset	--	offset	offset	offset	offset
Intercept	-0.700***	0.489***	0.304***	0.132***	0.021	0.022	-1.497***	0.671***	0.386***	0.131***	0.127***
	(0.146)	(0.059)	(0.033)	(0.027)	(0.028)	(0.028)	(0.213)	(0.036)	(0.019)	(0.018)	(0.019)
N	1,419	1,261	2,306	2,088	1,801	1,592	3,975	3,584	9,423	8,111	6,820
Log-likelihood	-3,423	-2,814	-4,745	-4,679	-4,388	-3,939	-11,730	-7,137	-18,900	-19,040	-17,800
Vuong Test	0.80	0.42	2.98**	7.77***	9.88***	10.07***	2.44**	1.39	7.04***	13.48***	3.80***

Notes: The Vuong test statistics compare mixture negative binomial models with the corresponding negative binomial models in Appendices A and B. Standard errors of the coefficients are in parentheses. p* < .05, p** < .01, p*** < .001 (two-tailed tests).
Sources: China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL), China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN).



Appendix Figure 4A Predicted Growth and Growth Rate of Different Regression Models: CMGPD-IL



Appendix Figure 4B Predicted Growth and Growth Rate of Different Regression Models: CMGPD-LN

REFERENCES

Data

Lee, James Z., and Cameron D. Campbell. China Multi-Generational Panel Dataset, Liaoning (CMGPD-LN), 1749-1909 [Computer file]. ICPSR27063-v6. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2011-09-02. doi:10.3886/ICPSR27063.v6

Publications

Agree, Emily M., Ann E. Biddlecom, and Thomas W. Valente. 2005. "Intergenerational Transfers of Resources between Older Persons and Extended Kin in Taiwan and the Philippines." *Population Studies* 59(2): 181-95.

Allison, Paul D., J. Scott Long, and Tad K. Krauze. 1982 "Cumulative Advantage and Inequality in Science." *American Sociological Review* 47(5): 615-25.

Bean, Lee, Geraldine Mineau, and Doug Anderton. 1990. *Fertility Change on the American Frontier: Adaptation and Innovation*. Berkeley: University of California Press.

Becker, Gary S. 1991. *A Treatise on the Family (2nd edition)*. Cambridge: Harvard University Press.

Betzig, Laura L. 1986. *Despotism and Differential Reproduction: A Darwinian View of History*. Hawthorne, NY: Aldine Pub.

Blau, Peter M. and Otis Dudley Duncan. 1967. *The American Occupational Structure*. New York: Wiley.

Bongaarts, John, Thomas K. Burch, and Kenneth W. Wachter. 1987. *Family Demography: Methods and Their Application*. Oxford: Clarendon Press.

Bodmer, Walter F. 1965. “Differential Fertility in Population Genetics Models.” *Genetics* 51(3): 411-24.

Boone, James, and Karen L. Kessler. 1999. “More Status or More Children? Social Status, Fertility Reduction, and Long-Term Fitness.” *Evolution and Human Behavior* 20(4): 257-77.

Borgerhoff Mulder, Monique. 2000. “Optimizing Offspring: The Quantity-Quality Tradeoff in Agropastoral Kipsigis.” *Evolution and Human Behavior* 21(6): 391-410.

Borgerhoff Mulder, Monique, Samuel Bowles, Tom Hertz, Adrian Bell, Jan Beise, Greg Clark, Ila Fazzio et al. 2009. “Intergenerational Wealth Transmission and the Dynamics of Inequality in Small-scale Societies.” *Science* 326(5953): 682-88.

Brown, Gillian R., Thomas E. Dickins, Rebecca Sear, and Kevin N. Laland. 2011. “Evolutionary Accounts of Human Behavioural Diversity.” *Philosophical Transactions of The Royal Society B: Biological Sciences* 366(1563): 313-324.

Cam, Emmanuelle, William A. Link, Evan G. Cooch, Jean-Yves Monnat, and Etienne Danchin. 2002. “Individual Covariation in Life-History Traits: Seeing the Trees Despite the Forest.” *The American Naturalist* 159(1): 96-105.

Campbell, Cameron, and James Z. Lee. 2008a. “Kin Networks, Marriage, and Social Mobility in Late Imperial China.” *Social Science History* 32(2): 175-214.

Campbell, Cameron, and James Z. Lee. 2008b. “Villages, Descent Groups, Households and Individual Outcomes in Rural Liaoning, 1789-1909.” Pp. 73-104 in *Kinship and Demographic Behavior in the Past*, edited by T. Bengtsson and G Mineau. Springer.

Campbell, Cameron, and James Z. Lee. 2010a. “Fertility Control in Historical China Revisited: New Methods for an Old Debate.” *History of the Family* 15:370-85.

Campbell, Cameron, and James Z. Lee. 2010b. "Social, Economic, and Demographic Determinants of Descent Line Growth and Extinction over the Long Term in Historical China." *CCPR* Working Paper.

Campbell, Cameron, and James Z. Lee. 2011. "Kinship and the Long-Term Persistence of Inequality in Liaoning, China, 1749-2005." *Chinese Sociological Review* 44(1):71-104.

Caswell, Hal. 2001. Matrix Population Models. MA: Sinauer, Sunderland.

Cavalli-Sforza, Luigi Luca, and Marcus W. Feldman. 1981. *Cultural Transmission and Evolution: A Quantitative Approach*. NJ: Princeton University Press.

Cavalli-Sforza, L. Luigi Luca, Paolo Menozzi, and Alberto Piazza. 1994. *The History and Geography of Human Genes*. NY: Princeton University Press.

Chang, Joseph T. 1999. "Recent Common Ancestors of All Present-day Individuals." *Advances in Applied Probability* 31(4): 1027-38.

Clark, Gregory. 2010. "Regression to Mediocrity? Surnames and Social Mobility in England, 1200-2009." Available at SSRN: http://dx.doi.org/10.2139/ssrn.1651904

Colantonio, Sonia E., Gabriel W. Lasker, Bernice A. Kaplan, and Vicente Fuster. 2003. "Use of Surname Models in Human Population Biology: A Review of Recent Developments." *Human Biology* 75(6): 785-807.

Cohen, Myron L. 1990. "Lineage Organization in North China." *Journal of Asian Studies*. 49(3):509-534.

Courtiol, Alexandre, Jenni E. Pettay, Markus Jokela, Anna Rotkirch, and Virpi Lummaa. 2012. "Natural and Sexual Selection in a Monogamous Historical Human Population." *Proceedings of the National Academy of Sciences* 109(21): 8044-49.

Dherbécourt, Clément. 2013. “La Fortune des Héritiers. Essais sur la transmission du capital en France du Second Empire à la Seconde Guerre mondiale.” PhD dissertation in Economics, École des Hautes Etudes en Sciences Sociales.

DiPrete, Thomas A., and Gregory M. Eirich. 2006. “Cumulative Advantage as a Mechanism for Inequality: A Review of Theoretical and Empirical Developments.” *Annual Review of Sociology* 32: 271-97.

Du, Ruofu, Yuan Yida, Juliana Hwang, Joanna Mountain, and L. Luca Cavalli-Sforza. 1992. “Chinese Surnames and the Genetic Differences between North and South China.” *Working paper series (Morrison Institute for Population and Resource Studies); no. 27.*

Duncan, Otis Dudley. 1966. “Methodological Issues in the Analysis of Social Mobility.” Pp. 51-97 in *Social Structure and Mobility in Economic Development*, edited by N. J. Smelser and S. M. Lipset. Chicago: Aldine.

Erikson, Robert and John H. Goldthorpe. 1992. *The Constant Flux: A Study of Class Mobility in Industrial Societies.* Oxford: Clarendon Press.

Falconer, Douglas S. 1960. *Introduction to Quantitative Genetics*. New York: Ronald Press.

Featherman, David L. and Robert M. Hauser. 1978. *Opportunity and Change.* New York: Academic Press.

Fieder, Martin, and Susanne Huber. 2007. “The Effects of Sex and Childlessness on the Association between Status and Reproductive Output in Modern Society.” *Evolution and Human Behavior* 28(6): 392-98.

Fisher, Ronald A. 1922. “On the Dominance Ratio.” *Proceedings of the Royal Society of Edinburgh* 42: 321-41.

Fisher, Ronald A. 1958. *The Genetical Theory of Natural Selection*. New York: Dover Publications.

Freedman, Maurice. 1966. *Chinese Lineage and Society: Fukien and Kwangtung*. London: Athlone Press.

Galton, Francis, and Henry W. Watson. 1874. "On the Probability of the Extinction of Families." *Journal of the Royal Anthropological Institute* 6: 138-44.

Gillespie, Duncan OS, Andrew F. Russell, and Virpi Lummaa. 2008. "When Fecundity Does Not Equal Fitness: Evidence of An Offspring Quantity Versus Quality Trade-off in Pre-industrial Humans." *Proceedings of the Royal Society B: Biological Sciences* 275(1635): 713-22.

Goodman, Anna, and Ilona Koupil. 2009. "Social and Biological Determinants of Reproductive Success in Swedish Males and Females Born 1915-1929." *Evolution and Human Behavior* 30(5): 329-41.

Goodman, Anna and Ilonia Koupil. 2010. "The Effect of School Performance Upon Marriage and Long-Term Reproductive Success in 10,000 Swedish Males and Females Born 1915–1929." *Evolution and Human Behavior* 31(6):425-435.

Goodman, Anna, Ilona Koupil, and David W. Lawson. 2012. "Low Fertility Increases Descendant Socioeconomic Position But Reduces Long-term Fitness in a Modern Post-Industrial Society." *Proceedings of the Royal Society B: Biological Sciences* 279: 4342-51.

Guo, Guang. 1998. "The Timing of the Influences of Cumulative Poverty on Children's Cognitive Ability and Achievement." *Social Forces* 77(1): 257-87.

Gustafsson, Lars. 1986. “Lifetime Reproductive Success and Heritability: Empirical Support for Fisher's Fundamental Theorem.” *The American Naturalist* 128(5): 761-64.

Harrell, Stevan J. 1985. “The Rich Get Children: Segmentation, Stratification, and Population in Three Chekiang Genealogies.” In Susan B. Hanley and Arthur P. Wolf, eds., *Family and Population in East Asian History*. Stanford: Stanford University Press.

Hartl, Daniel L., and Andrew G. Clark. 2007. *Principles of Population Genetics (4th edition)*. Sunderland: Sinauer Associates.

Hermalin, Albert I., Mary Beth Ofstedal, and Li Chi. 1992. “Kin Availability of the Elderly in Taiwan: Who Is Available And Where Are They?” Elderly in Asia Research Report No. 92-18. Ann Arbor: University of Michigan.

Hill, Jack. 1984. “Prestige and Reproductive Success in Man.” *Ethology and Sociobiology* 5(2): 77-95.

Hill, Kim and Hillard Kaplan. 1999. “Life History Traits in Humans: Theory and Empirical Studies,” *Annual Review of Anthropology* 28: 397-430.

Ho, Ping-ti. 1964. *The Ladder of Success in Imperial China: Aspects of Social Mobility, 1368-1911*. New York: Science Editions.

Hopcroft, Rosemary L. 2006. “Sex, Status, and Reproductive Success in the Contemporary United States.” *Evolution and Human Behavior* 27(2): 104-20.

Hsu, Francis Lang-Kwang. 1943. “The Myth of Chinese Family Size.” *American Journal of Sociology* 48(5): 555-62.

Huber, Susanne, Fred L. Bookstein, and Martin Fieder. 2010. “Socioeconomic Status, Education, and Reproduction in Modern Women: An Evolutionary Perspective.” *American Journal of Human Biology* 22:578-87.

Jæger, Mads Meier. 2012. "The Extended Family and Children's Educational Success." *American Sociological Review* 77(6): 903-22.

Johnson, Norman L., Adrienne W. Kemp, and Samuel Kotz. 2005. *Univariate Discrete Distributions* (*3rd edition*). New Jersey: John Wiley & Sons, Inc..

Lachance, Joseph. 2009. "Inbreeding, Pedigree Size, and the Most Recent Common Ancestor of Humanity." *Journal of Theoretical Biology* 261(21): 238-47.

Lam, David. 1986. "The Dynamics of Population Growth, Differential Fertility, and Inequality." *American Economic Review* 76: 1103-16.

Lavely, William, and R. Bin Wong. 1998. "Revising the Malthusian Narrative: The Comparative Study of Population Dynamics in Late Imperial China." *Journal of Asian Studies* 57:714-48.

Lee, James Z., and Cameron Campbell. 1997. *Fate and Fortune in Rural China: Social Organization and Population Behavior in Liaoning, 1774-1873*. Cambridge University Press.

Lee, James Z., Cameron Campbell, and Shuang Chen. 2010. *China Multi-Generational Panel Dataset, Liaoning (CMGPD-LN) 1749-1909. User Guide*. Ann Arbor, MI: Inter-university Consortium for Political and Social Research.

Lee, James Z., Cameron Campbell, and Feng Wang. 1993. "An Introduction to the Demography of the Qing Imperial Lineage, 1644-1911." Pp. 361-82 in *Old and New Methods in Historical Demography*, edited by R. Schofield and D. Reher. Oxford: Oxford University Press.

Lee, James Z. and Feng Wang. 1999. *One Quarter of Humanity: Malthusian Mythology and Chinese Realities, 1700-2000*. Harvard University Press.

Liu, Jianghua and Virpi Lummaa. 2011. “Age at First Reproduction and Probability of Reproductive Failure in Women.” *Evolution and Human Behavior* 32(6): 433-43.

Liu, Jianghua, Anna Rotkirch, and Virpi Lummaa. 2012. “Maternal Risk of Breeding Failure Remained Low throughout the Demographic Transitions in Fertility and Age at First Reproduction in Finland.” *PLoS ONE* 7(4): e34898.

Long, Jason, and Joseph Ferrie. 2013. “Intergenerational Occupational Mobility in Great Britain and the United States Since 1850.” *American Economic Review* 103(4): 1109-1137.

Lotka, Alfred J. 1929. “The Spread of Generations.” *Human Biology* 1(3): 305-20

Lotka, Alfred J. 1931. “The Extinction of Families.” *Journal of the Washington Academy of Sciences* XXI 377-453.

Lotka, Alfred J. 1941. “The Progeny of an Entire Population.” *The Annals of Mathematical Statistics* 13(2): 115-26.

Mace, Ruth. 2000. “Evolutionary Ecology of Human Life History” *Animal Behaviour* 59(1): 1-10.

Mann, Susan. 2002. “Women, Families, and Gender Relations.” in Willard J. Peterson eds. *The Cambridge History of China. Vol.9: The Ch’ing Dynasty, Part 1: To 1800*. Cambridge University Press.

Maralani, Vida. 2013. “The Demography of Social Mobility: Black-White Differences in the Process of Educational Reproduction.” *American Journal of Sociology* 118(6): 1509-1558.

Mare, Robert D. 1997. “Differential Fertility, Intergenerational Educational Mobility, and Racial Inequality.” *Social Science Research* 26: 263-91.

Mare, Robert D. 2011. “A Multigenerational View of Inequality.” *Demography* 48:1-23.

Mare, Robert D. and Vida Maralani. 2006. "The Intergenerational Effects of Changes in Women's Educational Attainments." *American Sociological Review* 71(4): 542-64.

Matras, Judah. 1961. "Differential Fertility, Intergenerational Occupational Mobility, and Change in Occupational Distribution: Some Elementary Interrelationships." *Population Studies* 15: 187-97.

Matras, Judah. 1967. "Social Mobility and Social Structure: Some Insights from the Linear Model." *American Sociological Review* 32(4): 608-14.

Matsen, Frederick A., and Steven N. Evans. 2008. "To What Extent Does Genealogical Ancestry Imply Genetic Ancestry?" *Journal of Theoretical Biology* 74(2): 182-90.

Merton, Robert K. 1968 "The Matthew Effect in Science." *Science* 159: 56-63.

Merton, Robert K. 1988. "The Matthew Effect in Science, II: Cumulative Advantage and the Symbolism of Intellectual Property." *ISIS*, 79, 606–23.

Murphy, Michael. 2004. "Tracing Very Long-Term Kinship Networks Using SOCSIM." *Demographic Research* 10(7): 171-96.

Nettle, Daniel, and Thomas V. Pollet. 2008. "Natural Selection on Male Wealth in Humans." *The American Naturalist* 172(5): 658-66.

Piazza, Alberto, Sabina Rendine, Gianna Zei, Antonio Moroni, and Luigi Luca Cavalli-Sforza. 1987. "Migration Rates of Human Populations from Surname Distributions." *Nature* 329: 714-16.

Pampel, Fred C., and Richard G. Rogers. 2004. "Socioeconomic Status, Smoking, and Health: A Test of Competing Theories of Cumulative Advantage." *Journal of Health and Social Behavior* 45(3): 306-21.

Pollak, Robert A. 1986. "A Reformulation of the Two-Sex Problem." *Demography* 23(2): 247-259.

Pollak, Robert A. 1990. "Two-Sex Demographic Models." *Journal of Political Economy* 98(2): 399-420.

Preston, Samuel H. 1974. "Differential Fertility, Unwanted Fertility, and Racial Trends in Occupational Achievement." *American Sociological Review* 39(4): 492-506.

Preston, Samuel H. and Cameron Campbell. 1993. "Differential Fertility and the Distribution of Traits: The Case of IQ." *American Journal of Sociology* 98(5): 997-1019.

Preston, Samuel H., Patrick Heuveline, and Michel Guillot. 2001. *Demography: Measuring and Modeling Population Processes*. MA: Blackwell Publishing.

Robinson, Gene E., Russell D. Fernald, and David F. Clayton. 2008. "Genes and Social Behavior." *Science* 322(5903): 896-900.

Rohde, Douglas L. T., Steve Olson, and Joseph T. Chang. 2004. "Modelling the Recent Common Ancestry of All Living Humans." *Nature* 431: 562-66.

Saifl, G. Mustafa, and H. Sharat Chandra. 1999. "An Apparent Excess of Sex- and Reproduction-related Genes on the Human X Chromosome." *Proceedings of the Royal Society of London. Series B: Biological Sciences* 266(1415): 203-209.

Sear, Rebecca, Fiona Steele, Ian A. McGregor, and Ruth Mace. 2002. "The Effects of Kin on Child Mortality in Rural Gambia." *Demography* 39(1): 43-63.

Sear, Rebecca, Ruth Mace, and Ian A. McGregor. 2003. "The Effects of Kin on Female Fertility in Rural Gambia." *Evolution and Human Behavior* 24(1): 24-42.

Semino, Ornella, Giuseppe Passarino, Peter J. Oefner, Alice A. Lin, Svetlana Arbuzova, Lars E. Beckman, Giovanna De Benedictis, Paolo Francalacci, Anastasia Kouvatsi, Svetlana

Limborska, Mlladen Marcikiæ, Anna Mika, Barbara Mika, Dragan Primorac, A. Silvana Santachiara-Benerecetti, L. Luca Cavalli-Sforza, and Peter A. Underhill. 2000. “The Genetic Legacy of Paleolithic Homo sapiens in Extant Europeans: A Y Chromosome Perspective.” *Science* 290: 1155-59.

Tremblay, Marc, Hélène Vèzina, Bertrand Desjardins, and Louis Houde. 2008. “Distant Kinship and Founder Effects in the Quebec Population.” In Bengtsson, Tommy and Geraldine P. Mineau, eds. *Kinship and Demographic Behavior in the Past*. Springer, 259-277.

Tuljapurkar, Shripad, Ulrich K. Steiner, and Steven Hecht Orzack. 2009. “Dynamic Heterogeneity in Life Histories.” *Ecology Letters* 12(1): 93-106.

Turke, Paul W. 1989. “Evolution and the Demand for Children.” *Population and Development Review* 15(1): 61-90.

Unz, Ron. 2013. “How Social Darwinism Made Modern China.” *The American Conservative*. March/April: 16-27.

Vuong, Quang H. 1989. “Likelihood Ratio Tests for Model Selection and Non-Nested Hypotheses.” *Econometrica* 57(2): 307-33.

Wachter, Kenneth W., and Peter Laslett. 1978. “Measuring Patriline Extinction for Modeling Social Mobility in the Past” Pp. 113-135 in *Statistical Studies of Historical Social Structure*, edited by K. W. Wachter, E. A. Hammel and P. Laslett. London: Academic Press.

Wachter, Kenneth W., Eugene A. Hammel, and Peter Laslett (eds.) 1978. *Statistical Studies of Historical Social Structure*. London: Academic Press.

Wang, Feng, James Z. Lee, and Cameron Campbell. 1995. “Marital Fertility Control among the Qing Nobility: Implications for Two Types of Preventive Check.” *Population Studies* 49(3): 383-400.

Wang Feng, Cameron Campbell, and James Z. Lee. 2010. "Agency, Hierarchies, and Reproduction in Northeastern China, 1789 to 1840." Chapter 11 in Noriko Tsuya, Wang Feng, George Alter, James Z. Lee et al. *Prudence and Pressure: Reproduction and Human Agency in Europe and Asia, 1700-1900*. MIT Press, 287-316.

Wolf, Arthur P. 1995. *Sexual Attraction and Childhood Association: A Chinese Brief for Edward Westermarck*. Stanford, CA: Stanford University Press.

Wolf, Arthur P. 2001. “Is There Evidence of Birth Control in Late Imperial China?” *Population and Development Review* 27(1): 133-54.

Wolf, Arthur P. and Chieh-shan Huang. 1980. Marriage and Adoption in China: 1845-1945. Stanford, CA: Stanford University Press.

Yasuda, N., L. L. Cavalli-Sforza, M. Skolnick, and A. Moroni. 1974. “The Evolution of Surnames: An Analysis of Their Distribution and Extinction.” *Theoretical Population Biology* 5(1): 123-42.

Zimmerman, David J. 1992. “Regression Toward Mediocrity in Economic Stature.” *American Economic Review* 82(3): 409-29.