California Center for Population Research
University of California - Los Angeles

Heterogeneous Grandparent Effects: The Effect of Grandparents' Education on Grandchildren's Education in One-Parent and Two-Parent Families

Xi Song

PWP-CCPR-2016-001

January 28, 2016

California Center for Population Research
On-Line Working Paper Series

HETEROGENEOUS GRANDPARENT EFFECTS: THE EFFECT OF GRANDPARENTS' EDUCATION ON GRANDCHILDREN'S EDUCATION IN ONE-PARENT AND TWO-PARENT FAMILIES*

Xi SONG
University of California, Los Angeles

May 2014
Keywords: multigenerational inequality; grandparents; family structure; race; educational mobility.

Word count (including text, abstract, footnotes, references): 13,214

* Send correspondence to Xi Song, Department of Sociology, University of California, Los Angeles, 264 Haines Hall, Los Angeles, CA 90095-1551, USA; email: songxi@ucla.edu. I would like to thank Robert Mare for many helpful discussions at various stages of this paper, Judith Seltzer for her advice about the Panel Study of Income Dynamics and the research literature on single-parent families, Arah Onyebuchi for discussions about causal diagrams and causal models, Sung Park for her suggestions on the data analysis, Dwight Davis for comments and editorial assistance on early drafts. I am also grateful to Cameron Campbell, Benjamin Jarvis, Rahim Kurwa, James Lee, John Sullivan, Donald Treiman, Amber Villalobos, Aolin Wang, and Xiaolu Zang for their valuable suggestions. Any remaining errors are the sole responsibility of the author. Versions of this paper were presented at the Population Association of America Annual Meeting, Boston, MA, May 1-3, 2014; the UCLA family working group, May 19, 2014; and the XVIII ISA World Congress of Sociology, Yokohama, Japan, July 13-19, 2014. This research was supported by the National Science Foundation (SES-1260456). The author also benefited from facilities and resources provided by the California Center for Population Research at UCLA (CCPR), which receives core support (R24-HD041022) from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD).

ABSTRACT

This study examines the direct effect of grandparents' education on grandchildren's education and variations in the effect across different types of family structures for African Americans and whites in the United States. In particular, I test the "Markovian" assumption in intergenerational mobility theories, which argues that grandparents' influences on grandchildren are all mediated by parents. Relying 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. My results confirm a non-Markovian mechanism—namely, a positive direct effect of grandparents—for both racial groups. On average, grandparents' education has a greater effect on grandchildren's education in white families than in African American families. However, such a comparison obscures substantial heterogeneity associated with race and family structure: The grandparent effect is particularly strong among African American families in which grandchildren grew up in two-parent households, whereas it is largely homogeneous among different types of white families. The results suggest that the decline in two-parent households has undermined multigenerational transmission of educational status for African Americans, but has had little impact on whites.

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 of 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). Yet, few studies have situated this question in the context of the declining prevalence of two-parent families in recent decades, which may have led to a diversity of *grandparent effects* across different types of family structures.

This study examines (1) the direct effect of grandparents' education on grandchildren's education and (2) heterogeneity in this direct effect associated with childhood family structures experienced by both parent and grandchild generations for African American and white families in the United States. Specifically, the "direct effect" refers to the effect of grandparents on grandchildren that is not mediated by the parent generation. The term "heterogeneous grandparent effect" was first proposed by Bengtson (1985) who cautioned sociological researchers against stereotyping and overgeneralizing the grandparent role, for example, by race and social groups. In particular, research on African American families described typical grandparents as "rescuers" or "family stabilizers" who raise their grandchildren during family crises (such as single motherhood, parental divorce, and poverty), in contrast to studies on white

families that primarily focus on noncrisis contexts related to pleasant interaction and limited exchanges of services among family members (Hunter and Taylor 1998). Strictly speaking, prior results from these studies on grandparent effects of African Americans and whites are not directly comparable as they focus on different subgroups of grandparents. This study provides a fuller picture of heterogeneous grandparent effects within each racial group and in various contexts of family structure.

In this study, I define two-parent families as those in which both parents were continuously married during the offspring's entire childhood. I consider all other types of family structures as single-parent families in which one biological parent was often absent from the household and the other was never married, widowed, divorced, separated or remarried. Previous evidence has shown that by the early 2000s nearly one in two children lived in a single-parent household at some time before they reached age 18 (Ellwood and Jencks 2004). The proportion has been even higher among African American and less educated families (Bumpass and Lu 2000).

The growth in single-parent households has transformed American family life, leading to unequal social mobility opportunities for children who experienced various types of family structures (McLanahan 2004). Demographic studies show that children growing up in single-parent families often receive less education than their two-parent counterparts and are more likely to become single parents themselves and raise their children in ways similar to how they were raised (McLanahan and Bumpass 1988; Seltzer 1994; Thornton 1991; Wolfinger 1999; Wu and Martinson 1993). In particular, such a self-reinforcing trend has become a dominant family form among African Americans and partly explains trends in perpetuation of poverty, lower education, and higher unemployment over generations (Wilson 2002). Explanations for inferior

social outcomes of children who grow up with single parents include parental job insecurity and economic deprivation, elevated family stress, absence of fathers or mothers as role models, and social stigma of single-parent families (Brand and Thomas 2014; McLanahan 1985; Seltzer 1994).

In addition to the above two-generation perspective, the growth in single-parent households also has implications for multigenerational inequality between families as well as between racial groups. The formation of single-parent families may change not only parent-child relationships within nuclear families but also children's relationships with family members in their extended families, especially with their grandparents. Some grandparents may drift apart from their grandchildren after their own children's divorce or nonmarital childbirth, whereas in other cases grandparents become heavily involved in their grandchildren's upbringing (Cherlin and Furstenberg 1985, 1986). As a result, grandparents' influences on their grandchildren may be different between single-parent and two-parent families and may be further complicated by the length of time that they share lifespan, stay in contact, and live in the same household. Additionally, because the increase of single-parent families has been concentrated among African Americans, the unequal grandparent effect between racial groups, if there is any, may result from changing *compositions* of family structure within racial groups, rather than the changing grandparent effect within each type of family structure by race.

Given the mixed results in prior literature regarding grandparents' roles in grandchildren's social achievements, this study tests the "Markovian" assumption in intergenerational social mobility theories—that is, grandparents do not directly influence their grandchildren's economic and educational attainment. Instead, the parent generation serves as the intermediary: Grandparents influence only their own children, and they let the children

undertake the work of guiding and influencing the grandchildren. By quantifying grandparent effects, this study revisits the Markovian assumption for African American and white families respectively. Furthermore, this study examines heterogeneity in grandparent effects associated with types of childhood family structure in both parent and grandchild generations. The analysis adjudicates among several competing hypotheses—that is, whether the direct effect of grandparent is the same, bigger, or smaller in two-parent than single-parent families for both racial groups.

This study attempts to provide a causal interpretation for the grandparent effect on grandchildren's education in single-parent and two-parent families. Most previous studies on intergenerational transmission of family structure and social status have been criticized for their use of methods that fail to distinguish association from causation (McLanahan, Tach and Schneider 2013). The present study specifies assumptions about relationships among observed and unobserved factors that influence education across generations. These assumptions help identify circumstances under which a link between characteristics of grandparents and grandchildren is causal. The analysis adapts a newly developed statistical method—structural nested models (Robins 1994, 1999; Robins and Hernán 2009)—to cope with potential endogenous selection bias (Elwert and Winship forthcoming). The study further supplements the analyses with a sensitivity analysis that shows the extent to which the causal argument is still valid when some assumptions are violated.

Using data from the Panel Study of Income Dynamics, this study suggests that grandparents' education directly contributes to their grandchildren's educational success. On average, the grandparent effect is smaller for African American families than for whites. However, such a comparison obscures substantial heterogeneity associated with race and family

structure: The grandparent effect is the strongest among African American families in which grandchildren grow up with both their parents, but is largely homogeneous among white families. Additionally, the grandparent effect does not depend on the childhood family structure of parents for either racial group. These results suggest that the decline in two-parent households has undermined multigenerational transmission of educational status for African Americans, but has had a trivial impact on white families. Therefore, the demographic transition in family structures has contributed to new forms of multigenerational inequality in American families.

UNDERSTANDING LINKS BETWEEN INTERGENERATIONAL EFFECT AND INEQUALITY

Following the long tradition in intergenerational mobility studies that equates the association between parents' and grandparents' social statuses with the "parent effect" on offspring (Blau and Duncan 1967; Duncan 1966a, 1975), this study uses the term "grandparent effect" to describe influences of grandparents' education on their grandchildren's education. The use of "parent effect" in previous intergenerational mobility studies is often interchangeable with concepts such as immobility, status inheritance, and intergenerational association or resemblance. A strong effect means that offspring's social status is largely determined by their family background—children are likely to attain the same social status as their parents, and unlikely to fall far below or outperform their parents. At the family level, a strong effect can be either a blessing or a curse: Families in favorable social positions are capable of securing their status advantages and controlling their progeny's social destinies, whereas offspring from historically disadvantaged families can rarely escape from their family history of hardship. At the societal level, previous mobility studies characterized a society with a stronger parent effect as less open,

less mobile and offering fewer opportunities for families to rise from rags to riches (e.g., Blau and Duncan 1967; Featherman and Hauser 1978; Jencks et al. 1972).

Although a stronger parent effect implies widening social inequality between families, they are not identical. The overall inequality between families further depends on the interaction between the parent effect and families' demographic behaviors (Mare 1997; Mare and Maralani 2006). For example, Maralani (2013) shows that educational gaps between African American and white families are partly explained by racial differences in timing and duration of marriage, levels of fertility as well as the likelihood of experiencing single-parenthood and having nonmarital birth, all of which determine proportions of offspring who receive a strong versus weak parent effect in each racial group. Overall, differential demographic behaviors may magnify or diminish the aggregate-level educational inequality of families. In particular, educational inequality between families is greater if families with stronger parent effects also have more offspring. Furthermore, if we consider mobility opportunities in a society as variable rather than fixed, the overall educational inequality between families also depends on which families benefit first from growing opportunities. Raftery and Hout (1993) illustrate that if the expansion of higher education first benefits offspring from privileged family backgrounds, then a smaller parent effect caused by more upward mobility implies more entrenched inequality, not less.

This study extends the intergenerational perspective of "effect" to three generations by assessing influences of grandparents' education on grandchildren's education. Following intergenerational mobility studies that typically decomposed the effect of parents' SES on offspring's SES into an indirect effect through intervening factors such as education, and a net direct effect (e.g., Alwin and Hauser 1975; Duncan 1975; Featherman and Hauser 1976; Sewell,

Haller and Ohlendorf 1970), I assume that grandparents influence their grandchildren also through both direct and indirect pathways. While it is impossible to outline all indirect influences from grandparents to grandchildren, this study accounts for at least several important intervening factors that involve the mediating role of parents' education and childhood family structures of parents and grandchildren.

The focus of this study, however, is not to assess indirect effects of grandparents' education on grandchildren's education that work through family structures of parents and grandchildren, but how direct effects of grandparents on grandchildren vary across types of family structures. Several recent studies have shown that family history in hardship, not only family circumstances during the childhood of the present generation, has a legacy effect on children's later life outcomes (Sharkey and Elwert 2011; Wightman and Danziger 2014). Building upon such a multigenerational view, this study further investigates to what extent family history in single-parenthood versus two-parenthood in two consecutive generations modifies multigenerational transmission of educational status from grandparents to grandchildren. As discussed earlier, grandparents' effects may vary across different types of family structure because grandparents' behaviors and relationships with grandchildren may evolve with a family's transition to a single-parent household. The heterogeneity in the direct effect caused by the intervening factors—such as family structure examined in this study—helps reveal important forms of social inequality between subgroups in a population (Brand and Thomas 2013; Hout 1988: 1391; [1] Pearl 2001, 2012).

THE GRANDPARENT EFFECT AND THE MARKOVIAN ASSUMPTION

Sociological studies on intergenerational social mobility predominantly focus on parent-offspring pairs. Mare (2011) points out that such an approach suffices to explain mobility in three

or more generations if grandparents do not directly transmit socioeconomic status to their grandchildren. Rather, the parent generation serves as the intermediary: Grandparents influence their own children, and they let the children guide and rear their grandchildren. Such a mobility pattern is also known as the "Markovian" assumption in mobility theories (Bartholomew 1982; Boudon 1973; Duncan 1966b; Hodge 1966; Singer and Spilerman 1976). When this assumption holds, family influences in three generations amount to total influences in every two consecutive generations, without lagged influences from grandparents to grandchildren. Mare and Song (2012) show that when grandparents matter for individuals' social mobility, status boundaries between families are more rigid than when social mobility is Markovian.

Several empirical studies have provided evidence for the Markovian assumption. 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). While some grandparents may be heavily involved in taking care of their grandchildren or even serving as surrogate parents, the majority of grandparents who do not reside with their grandchildren provide little aid in their grandchildren's upbringing (Fuller-Thomson, Minkler and Driver 1997; Hogan, Eggebeen and Clogg 1993; Szinovacz 1998: 13). This is more common among African Americans than among whites, because African American grandparents have more grandchildren and fewer resources.

Moreover, involvement of grandparents is not equivalent to "influence." Cherlin and Furstenberg (1986) showed that most grandparents accept the norm of "noninterference," in the sense that they consider a companionate relationship with their grandchildren, rather than a parent-like one. Although frequency of contact between grandparents and grandchildren may be a strong predictor of grandparent effects, Cherlin and Furstenberg (1986: 117-118) further

showed that frequency of contact is not associated with education and family income of grandparents. Therefore, grandparents' social status may play a neutral role in influencing the social success of their grandchildren. Their influences in the intergenerational transmission of social status within families either does not skip the parent generation, or their direct influences are associated with certain aspects of their grandchildren's lives, but not educational mobility.

On the other hand, findings from several recent studies have challenged the Markovian assumption, suggesting that grandparents with favorable social characteristics can transmit their advantages to their grandchildren, net of parents' characteristics (Chan and Boliver 2013; Hertel and Groh-Samberg 2014). Over the past half century, the increasing human life expectancy has created many families in which grandparents live through a substantial proportion of their grandchildren's childhood (Uhlenberg 1996). The concurrent trend in falling fertility rates have further allowed grandparents to invest their limited time and financial resources on a relatively small set of grandchildren (Bengtson 2001). Ethnographic studies have suggested multiple pathways through which grandparents' education may influence grandchildren's education, such as by setting up trust funds for their grandchildren's education (Aldous 1995), offering advice and discussing grandchildren's academic problems (Cherlin and Furstenberg 1986), serving as role models, and monitoring grandchildren's school progress (DeLeire and Kalil 2002). Additionally, grandparents' roles can be simply symbolic–the importance of grandparents may not be because of their actions but because of "their presence and what they mean for a family" (Bengtson 1985). While families may differ in their number of living grandparents, grandparenting styles, and closeness between grandparents and grandchildren, the evidence above implies that grandparents may play a significant role in grandchildren's educational achievements in general.

The magnitude of the grandparent effect on grandchildren may further differ by race because of socioeconomic, historical, and cultural reasons. Compared to white grandparents, African American grandparents are more likely to reside with their grandchildren, provide practical support and act like parents, as a result of parental incarceration, teen pregnancy and a long family tradition of multigenerational households that has its roots in West African culture (Fuller-Thomson et al. 1997; Ruggles 1994). While public discourse often emphasizes the image of multigenerational disadvantages of African American families by focusing on those that are located at the bottom of the society, this study examines African American grandparents from a broader perspective ranging from families that have experienced extreme economic hardship and single-parenthood in two consecutive generations to those that maintained family intactness and social advantages across generations. The next section discusses potential heterogeneity in the grandparent effect associated with family structure, but such heterogeneity may also be associated with race.

HETEROGENEOUS GRANDPARENT EFFECTS: THREE HYPOTHESES

A wealth of research has documented educational disadvantages of children being raised by single parents (e.g., Amato 2005; Aquilino 1996; Astone and McLanahan. 1991; Ginther and Pollak 2004; Kim 2011), but only a few studies have assessed heterogeneous effects of parents' and grandparents' education on children's education across different types of family structure (Kuo and Hauser 1995; Zeng and Xie 2014). Results from the limited amount of research that provide indirect evidence to this question are mixed. Below, I summarize previous empirical findings into three competing hypotheses based on their prediction about the relative strength of the grandparent effect in one-parent and two-parent families.

The present study adjudicates among these hypotheses for African American and white families respectively, because of historical racial differences in patterns of union formation, family disruption, educational mobility and cultural values on grandparenthood (Fomby and Cherlin 2007; Maralani 2013; McLanahan 1985; Sweeney and Philips 2004). As discussed earlier, African American grandparents are often more involved in raising their grandchildren, especially among low-income families. Yet Cherlin and Furstenberg (1986: 131) suggested that the distinctive racial pattern in grandparenting is not simply "a function of poverty or family structure." Instead, grandparenting styles developed during generations of adversity has become a cultural legacy of African American families, which both low-income and middle-class families share in common. The focus of this study is not to differentiate grandparenting styles by racial and family structure groups, but their consequences—namely, how grandparents' influences on their grandchildren's education vary across subgroups of families.

No Effect Variation by Family Structure

The first hypothesis assumes that the effect of grandparents' education on grandchildren's education does not vary by family structure, regardless of whether the effect is Markovian or non-Markovian. 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 (1985) characterized five grandparenting styles as detached, passive, supportive, authoritative and influential, but they found that none of these strategies 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 and unimportant

grandparents. Thus, on average, the grandparent effect on grandchildren within each type of family structure is similar.

While no research has directly tested heterogeneous grandparent effects across family structure groups, findings from two-generation studies have provided some indirect evidence based on heterogeneous parent effects. For example, Kuo and Hauser (1995) found that family structure—intact versus nonintact—is not associated with differences in the effect of fathers' and mothers' education on individuals' educational achievements. Evidence based on occupational mobility is also mixed: Biblarz and Raftery (1993) showed that the effect of fathers' occupation on sons' occupation is stronger in non-intact families than in intact families, whereas Beller (2009) suggested that when mother effects are taken into account, the effect of parents' occupation on offspring's occupation is stronger for respondents raised in single-parent families. If patterns of grandparent effects are consistent with those of parents, we would expect to see that grandparent effects may not vary by family structure either.

In addition, despite that families' transitions into single-parenthood may restructure grandparent-grandchild relationship and thrust some grandparents into active caregiving roles (King and Elder 1997; Robertson 1995), it is unknown whether family disruption or nonmarital childbearing alters grandparent effects on grandchildren. As most unmarried and divorced parents enter new cohabitation and marriage unions shortly after the end of their last relationship (Sweet and Bumpass 1987), the formation of new independent households often results in a declining support from grandparents (Burton and Bengtson 1985). Consequently, among most single-parent families, the high involvement of grandparents is often transient, which may not make a marked difference in the eventual educational attainment of grandchildren.

Stronger Grandparent Effects in Single-Parent Families

The second hypothesis assumes that grandparents' education has a stronger impact on grandchildren's education in single-parent families than in two-parent families. It is widely believed that grandparents as well as other kin provide a "latent safety net" for children, because their roles are not activated until a family crisis occurs (Bengtson 2001; Johnson 1985; Riley and Riley 1993). For example, 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). Even when grandparents live separately from their grandchildren, many grandparents may act like parents, providing financial, emotional and housekeeping support on a regular basis, or even becoming custodians of the grandchildren.

Grandparents' support enhances family cohesion and multigenerational bonds between grandparents and grandchildren. Several studies have shown that intergenerational inheritance in occupation and education between parents and offspring is weaker in single-parent than two-parent families often because of less effective parenting practices, fewer economic resources, and the absence of fathers as important figures in children's development (Biblarz and Raftery 1993; Martin 2012). Grandchildren may benefit from their grandparents' involvement, which compensates for diminished parental resources and helps them cope with stresses caused by the divorce or separation of parents (Deleire and Kalil 2002; Denham and Smith 1989; Hayslip and Kaminski 2005). Many grandchildren develop a deeper relationship with some of their grandparents than they had with either set of grandparents prior to their parents' marital disruption (Cherlin and Furstenberg 1986: 148-164). Thus, the experience of single-parenthood may increase interactions between grandparents and grandchildren, leading to a stronger

similarity between the education of grandparents and grandchildren in single-parent families than in two-parent families.

Stronger Grandparent Effects in Two-Parent Families

The third hypothesis provides an opposing view to that of the second hypothesis and predicts that the grandparent effect is stronger in two-parent families. Most studies on grandparents in single-parent families tend to focus on support from maternal grandparents, but fail to emphasize the loss of grandparental resources due to attenuated or broken paternal intergenerational ties since the divorce of the parents (Seltzer and Bianchi 1988; Silverstein and Bengtson 1997). In addition, because of the association between parental and grandparental marital statuses, grandchildren in two-parent families are more likely to have grandparents who are still married to each other and as a result more likely to provide assistance than separated grandparents (Swartz 2009). Overall, grandchildren in two-parent families may receive a greater total amount of support from both sets of grandparents than grandchildren in one-parent families.

Even if the quantity of support provided by grandparents does not vary by family structure, the quality of support is another matter. 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 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 time as well as 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 explain grandparenting in single-parent families,

especially among younger, low-income grandparents who have to juggle work and childcare of their children and grandchildren (Hayslip and Kaminski 2005).

With respect to racial differences, it is plausible that variations in grandparents' effects between single-parent and two-parent families are more striking among African Americans than whites, in part because grandparents' support is more constrained by needs and resources of parents and grandparents for African Americans. Most African American grandparents have more grandchildren but fewer financial and human capital resources. Hogan et al. (1993) show that on average, African American parents receive less assistance than whites from grandparents, because of the higher number of siblings who compete for grandparental support. The more unequal distribution of grandparental support between single-parent and two-parent families among African Africans may result in greater heterogeneity in grandparent effects for African Americans than whites.

METHODS

Data

I use multigenerational data from the Panel Study of Income Dynamics (PSID, 1968-2011) to assess the direct effect of grandparents' education on grandchildren's education. The PSID is an ongoing longitudinal survey with a nationally representative sample of roughly 5,000 American families. The study started with over 18,000 individuals in 1968 and covered more than 70,000 individuals from 1968-2011. The PSID 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.

To create a multigenerational sample, I link PSID respondents with their parents and grandparents, based on their unique PSID interview ID. The linked sample does not include immigrant families. For most families, only one set of parents and grandparents (either paternal or maternal) are available, because not all the four grandparents were PSID respondents or they were never part of a PSID household. Also, if an individual was born out of wedlock 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.

Measures

The observed outcome variable Y_i is a grandchild's education measured by years of schooling of an individual in generation 3. Let $\bar{X}_{t,i} = (X_{1,i}, X_{2,i})$ denote the treatment variable, the family history of education, which is measured by the highest years of schooling among grandparents and parents in generation 1 and 2 whose educational information is available. [2] 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.

The history of childhood family structure (namely, two-parent versus single-parent family) $\bar{S}_{t,i} = (S_{2,i}, S_{3,i})$ is treated as a generation-varying covariate. If either the father or the mother grew up in a single-parent household, then $S_{2,i}$ is treated as a single-parent family in generation 2, and only when both parents grew up in two-parent families, $S_{2,i}$ is coded as a two-parent family. $S_{3,i}$ refers to the childhood family structure of individuals in the grandchild

generation, namely generation 3. If an individual's parents were married throughout his or her entire childhood from age 0-17, then $S_{3,i}$ is coded as a two-parent family; otherwise, it would be a single-parent family. To find out whether grandparents or parents were married during the parents' and individuals' childhood, I make use of the retrospective marriage history file 1985-2011, which contains detailed information of marriage timing and circumstances of grandparents and parents who are PSID respondents. Strictly speaking, the definition of family structure is based on marital status of parents, rather than living arrangements of children.

Other time-invariant covariates *C* include gender, age group and current residential region of grandchildren.[3] These variables help control for gender, time and geographic variations in the educational distribution in the grandchild generation for each racial group. The analytical sample is restricted to grandchildren who are aged 25 to 65 years old in the most recent wave of the survey in 2011. I conduct separate analyses for non-Hispanic white and non-Hispanic African American families and omit other racial groups because the PSID has an oversampling of low-income African American families and a very small sample of Hispanic and Asian families. The present study defines the race variable based on the race of the head of household in the grandchild generation, using the latest data available.

Covariate Selection Criteria

I omit many other variables that have been traditionally considered as important covariates or control variables in examining effects of parents' and grandparents' education and family structure on individuals' education. For example, these variables include intellectual ability, occupational status, number of siblings, mental illness, drinking and drug use behaviors, domestic violence, incarceration and welfare status of grandparents and parents (McLanahan 2009). I omit these variables in the analyses either because measures of some variables are not

available in the PSID data or because controlling for some variables would lead to the over-control or overadjustment bias (Elwert and Winship forthcoming). The overcontrol problem arises when researchers control variables on a causal path from the treatment variable to the outcome variable, namely variables that result from grandparents' and parents' education and are causes of grandchildren's education. I assume that grandparents' and parents' occupation, fertility and welfare status are such intermediate variables that link grandparents' and parents' education to grandchildren's education, and therefore, omitting these variables yields unbiased estimates of grandparents' effects on grandchildren. For the omitted variable bias problem, I supplement the results with a sensitivity analysis to assess the extent to which the results drawn from the analysis are robust to violations of the assumptions implied in the model.

ANALYTICAL FRAMEWORK

The Definition of Controlled Direct Effect

To explicate the causal relationship between grandparents' education and grandchildren's education, I rely on a hypothesized directed acyclic graph (DAG) shown in Figure 1. Assume that we observe a group of grandparents at time *t*, and record their education X_1, which is determined by a set of unobserved variables W_1. The education of grandparents subsequently affects parents' childhood family structure, parents' education, grandchildren's childhood family structure, and grandchildren's education. In the causal inference literature, grandparents' education X_1 is called the exposure variable, and parents' education is a mediator between educational outcomes of grandparents and grandchildren. The endogenous variable, family structure over generations, is treated as a generation-varying covariate, which is associated with

grandchildren's education but also serves as a moderator that alters grandparents' direct effects on grandchildren.

Let $Y(x_1)$ denote a family's educational outcome in generation 3 if treatment x_1 was set in generation 1. The variable $Y(x_1)$ is referred to as counterfactual outcomes or potential outcomes. For example, if X_1 is binary then an individual would have 2 potential educational outcomes $Y(x_1=1)$ and $Y(x_1=0)$, or simply Y_1 and Y_0. Assume that we increase a grandparent's education and allow all future family changes to respond to this change. The *direct* effect refers to the increase in grandchildren's education that is directly affected by this change, instead of being mediated by other associated family changes, such as the change in family structure and educational attainments of parents. As discussed earlier, if such a direct effect differs for children or their parents who were raised in single-parent as compared to two-parent families, then the direct effect is heterogeneous, also known as effect modification (VanderWeele and Robins 2007).

According to Pearl's (2001) causal mediation formula, I define the controlled direct effect as [4]

$$CDE = E[Y(x_1 = x', x_2 = x_0) - Y(x_1 = x, x_2 = x_0)]$$

$$= \sum_C \{E[Y(x_1 = x', x_2 = x)|\, C]\}\, P(C) - \sum_C \{E[Y(x_1 = x, x_2 = x)|C]\}\, P(C) \qquad (1)$$

The controlled effect is interpreted as the expected increase in the outcome Y as the treatment changes from $X_1 = x$ to x', while the mediator is set to a pre-specified level $x_2 = x$ uniformly over the entire population. In the early mediation analysis literature, researchers typically did not consider heterogeneous controlled direct effect caused by endogenous variables, but such problems have been addressed in recent causal mediation analyses (Pearl 2000, 2001; Robins and Greenland 1992).[5] The present study only focuses on heterogeneity in the direct effect of

grandparents caused by childhood family structures S_2 and S_3, but not by parents' educational levels and other controlled variables.

Assumptions

According to Pearl (2001), to identify the controlled direct effect of grandparents' education (X_1) on grandchildren's education (Y), the following two assumptions must be made

(1) No unmeasured confounders for the exposure-outcome relationship

$$Y(x_1, x_2) \coprod X_1 | C$$

where X_1, X_2, and Y refer to the exposure, mediator and outcome respectively. This assumption is also known as conditional exchangeability, which means that controlling for characteristics C, grandparents who are exposed to a certain educational level are generally exchangeable with those who are not. In other words, the counterfactual grandchildren's education under every exposure value of grandparent's education is the same in the exposed and in the unexposed. When this assumption is violated, we cannot obtain the unbiased total effect of X_1 on Y, because of omitted variable biases. Based on this assumption, the unobserved variable W_1 that influences X_1 in Figure 1 needs to be independent of Y.

(2) No unmeasured confounders for the mediator-outcome relationship

$$Y(x_1, x_2) \coprod X_2 | X_1, C$$

This assumption requires that all confounders of the association between the mediator and the outcome are included in X_1 and C. When this assumption is violated, we cannot estimate any kind of direct effect from X_1 to Y. This is because to estimate the direct effect of X_1, we need to control X_2, but this would yield biased effect of X_1 on Y, due to the collider bias between X_1 and any controlled confounder C that is associated with both X_2 and Y (Elwert and Winship

forthcoming). According to this assumption, the unobserved variable W_2 that influences X_2 needs to be independent of Y. These two assumptions are encoded into the DAG shown in Figure 1.

When these two assumptions are satisfied, the controlled direct effect of grandparents in equations (1) can be identified and are equivalent to

$$CDE = E[Y(x_1 = x', x_2 = x) - Y(x_1 = x, x_2 = x)]$$
$$= \sum_C \{E[Y|x_1 = x', x_2 = x, C]\} P(C) - \sum_C \{E[Y|x_1 = x, x_2 = x, C]\} P(C) \quad (2)$$

The controlled direct effect moderated by family structures S_2 and S_3, namely the heterogeneous controlled direct effect CDE_H, is

$$CDE_H = E[Y(x_1 = x', x_2 = x) - Y(x_1 = x, x_2 = x)|S_2, S_3]$$
$$= \sum_C \{E[Y|x_1 = x', x_2 = x, S_2, S_3, C] - E[Y|x_1 = x, x_2 = x, S_2, S_3, C]\} P(C) \quad (3)$$

Potential Problems of Standard Regression Models

Standard regression models, however, do not provide unbiased estimates of the controlled direct effect of X_1. Consider a conventional ordinary least square regression model, which includes X_1, X_2, S_2, S_3, C, and interactions between any X and S.

$$E(Y|X_1, S_2, X_2, S_3)$$
$$= \beta_0 + \beta_1 S_2 + \beta_2 S_3 + X_1(\beta_3 + \beta_4 S_2 + \beta_5 S_3) + X_2(\beta_6 + \beta_7 S_2 + \beta_8 S_3) + \beta_9 C \quad (4)$$

where β_9 consists of a set of coefficients corresponding to the time-invariant covariate set C, such as gender, residential region, age group of grandchildren.

Using this equation to estimate the controlled direct effect of grandparents poses several problems. First, conditioning on S_2 and S_3, we remove the indirect effect of grandparent's education X_1 on X_3 that is transmitted through the formation of family structure. If we want to keep this effect as part of the direct effect of X_1 and only consider the indirect effect as that mediated by parents' education, we should not control S_2 and S_3 in the equation, but that causes

another problem—we are unable to examine how the direct effect of grandparent's education is moderated by family structures.

Second, when we adjust for the childhood family structures (S_2, S_3), we introduce potential biases for the estimates of X_1 and X_2, due to the omission of (U_1, U_2). The causal structure shown in Figure 1 illustrates how this problem arises. As S_2 is a collision in the paths $X_1 \rightarrow S_2 \leftarrow U_1$, adjusting for S_2 creates a spurious (namely, noncausal) association between X_1 and U_1. Since U_1 is an unobserved factor that is also correlated with Y, the omission of U_1 leads to a biased estimate of X_1. Yet the omission of U_1 would not be a problem if we do not control S_2 in the equation. This bias is also known as the "collider-stratification bias" (Greenland, Pearl and Robins 1999; Morgan and Winship 2007). Similar problems also exist when we control for S_3 in the equation.

Therefore, instead of modeling a single regression to evaluate the direct effect of grandparents, we need several submodels to estimate these effects by parts. This is the rationale for the structural nested mean model described below.

Structural Nested Mean Model

I use the two-stage regression-with-residuals estimator, which is a special case of the more general and flexible semi-parametric approach of structural nested mean models, also known as the sequential G-estimator (Almirall et al. 2013; Daniel et al. 2013. Robins 1999; Vansteelandt 2009; Wodtke, Elwert and Harding 2012). I first assume that

$$E(S_2|X_1) = \alpha_0 + \alpha_1 X_1 \tag{5}$$

$$E(S_3|X_1, S_2, X_2) = \gamma_0 + \gamma_1 X_1 + \gamma_2 X_2 + S_2(\gamma_3 + \gamma_4 X_1 + \gamma_5 X_2) \tag{6}$$

Then I estimate the residuals as

$$\delta(S_2) = S_2 - E(S_2|X_1) \tag{7}$$

$$\delta(S_3) = S_3 - E(S_3|X_1, S_2, X_2) \quad (8)$$

The residual of S_2 is independent of X_1, and the residual of S_3 is independent of X_1, S_2, and X_2. I assume no interaction between continuous variables X_1 and X_2, so that both equations (5) and (6) are saturated models.

The structural nested mean model is estimated by regressing observed outcome Y on grandparents' and parents' educations X and the residualized S_2 and S_3.

$$E(Y|X_1, S_2, X_2, S_3)$$
$$= \eta_0 + \eta_1\delta(S_2) + \eta_2\delta(S_3) + X_1(\eta_3 + \eta_4 S_2 + \eta_5 S_3) + X_2(\eta_6 + \eta_7 S_2 + \eta_8 S_3) + \eta_{9\cdot} C \quad (9)$$

where $\eta_1 = \beta_1 + \beta_2\gamma_3$, $\eta_2 = \beta_2$, $\eta_3 = \beta_3 + \beta_1\alpha_1 + \beta_2\gamma_1 + \beta_2\gamma_3\alpha_1$, $\eta_4 = \beta_4 + \gamma_4$, $\eta_5 = \beta_5$, $\eta_6 = \beta_6 + \beta_2\gamma_2$, $\eta_7 = \beta_7 + \gamma_5$, $\eta_8 = \beta_8$ and $\eta_{9\cdot} = \beta_{9\cdot}$. Therefore, the relationship between η and β shows that some but not all of the coefficients β from the OLS are biased. All the coefficients related to S_2 and S_3 (namely η) are potentially biased due to the presence of U_1 and U_2, but the coefficients of X_1 and X_2 are unbiased. The standard errors of the coefficients in the second stage are estimated from bootstrap methods.[6]

Note that model assumptions in the causal structure shown in Figure 1 allow unobserved characteristics of parents and grandparents U that are correlated with parents' and grandchildren's family structure and grandchildren's educational outcomes. These unobserved factors may include shared traits of parents and grandparents, such as mental health, drinking and drug use behaviors, which contribute both to childhood family stability of parents and grandchildren and educational outcomes of grandchildren. Previous studies have resorted to different analytical strategies—for example, fixed-effect models (Cherlin et al. 1998) and bivariate probit analysis (Astone and McLanahan 1991)—to either eliminate all unmeasured variables that do not change over time or allow unobserved variables to be correlated. The

presence of these unobserved variables, however, do not influence our estimates of the grandparent effect based on the SNMM illustrated above.

RESULTS

Sample Characteristics

Table 1 summarizes educational and demographic characteristics of grandparent, parent and grandchild generations in the PSID sample. On average, grandchildren from African American families are disadvantaged in their educational attainments compared to those from white families. The gap in the average years of schooling between African Americans and whites is close to one year in the grandchild generation, as compared to 1.2 years in the parent generation and 2.1 years in the grandparent generation. The multigenerational disadvantages of black families exist not only in their families' educational histories but also in their family structures across generations. While the educational gap between African American and white families from the parent to the grandchild generation shows 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 displays the link between average years of schooling and types of family structures. The trend suggests that childhood family structures in two consecutive generations bring cumulative advantages or disadvantages to grandchildren' educational attainment. If both grandchildren and their parents grew up in two-parent families, the grandchildren received, on average, 14 years of education for whites and 13 years for African Americans. By contrast, the

most disadvantaged group is that in which grandchildren and their parents were both raised in single-parent families. This trend is especially true for white families, as the statistical tests show that the education of African American grandchildren significantly varies only by their own childhood family structure, not by that of their parents.

Given the negative impact of single-parent families on children's educational outcomes, we would expect that if African Americans had not experienced the fast growth of single-parent families, their average education in the grandchild generation would be more similar to that of whites. While most white grandchildren grew up in two-parent households, the descriptive results suggest that the disadvantaged family structure has a more enduring and negative impact on grandchildren's educational attainments for whites than for African Americans—the educational gaps between the least and the most advantaged group are 0.9 years for African American grandchildren and 1.5 years for white grandchildren.

Direct Effect of Grandparents

Table 3 presents model estimates for the direct effect of grandparents on grandchildren based on both conventional OLS models and structural nested mean models. The additive models test the Markovian assumption about the grandparent effect, namely, whether grandparents' education has a direct effect on grandchildren's education. Overall, the OLS models overestimate the direct effect of grandparents for African Americans and underestimate that for whites. The SNMM estimates suggest that grandparents' education has a statistically significant positive effect on grandchildren's education for both African American and white populations. The average grandparent effect is greater for white families than for African American families (η =0.06 versus 0.03). The smaller association between grandparents' and grandchildren' educations for African Americans than for whites is consistent with findings from previous studies on racial

patterns in parent-offspring mobility, which suggests that African Americans are less likely to transmit their socioeconomic statuses across generations (Blau and Duncan 1967: 207-227; Duncan 1968; Featherman and Hauser 1978; Hout 1984; Hauser et al. 2000).

Figure 2 presents point estimates and 95 percent confidence intervals of parents' and grandparents' direct effects by race. Compared to the effect of parents' education, the direct effect of grandparents' education is marginal. For example, for African American families, each one year increase in parents' education explains an increase of 0.3 years in their own children's education, whereas each one year increase in grandparents' education explains an increase of only 0.03 years in grandchildren's education. For whites, the grandparent effect is far smaller than the parent effect: The former is only 14 percent as large as the latter (=0.06/0.44). Therefore, the results support a non-Markovian explanation for the grandparent direct effect on grandchildren, but such an effect is very small compared to the indirect effect of grandparents on grandchildren that works through the parent generation.

The coefficients of childhood family structure experienced by parents and grandchildren (S_2 and S_3) show that white grandchildren are more vulnerable to the negative impact of single-parenthood than African American grandchildren. African American grandchildren's educational outcomes are associated with only their own childhood family structure, but not that of their parents, whereas for whites, family structure in the parent generation has a legacy effect on children's educational attainment. Everything else being equal, white grandchildren who themselves or whose parents grew up in single-parent households receive roughly 0.5 year less education than their two-parent counterparts. These patterns confirm earlier findings from two-generation studies, which show 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 S_2 and S_3 suggest only associations of these variables with grandchildren's educational outcomes, not causation, because of the model assumptions (shown in Figure 1) about correlations between unobserved variables.

Heterogeneous Grandparent Effect

The interactive models in Table 4 show variations in grandparent effects by family structure. For African American families, the direct effect of grandparents' education on grandchildren's education varies substantially across types of childhood family structure in the grandchild generation. Specifically, grandparents play a much more influential role in grandchildren's education in two-parent families than in one-parent families, as suggested by the interaction coefficient between grandparents' education (X_1) and grandchildren's family structure (S_3). There is no significant variation in the grandparent effect by family structure in the parent generation (S_2). By contrast, the direct effect of grandparents does not differ across types of childhood family structures in either the parent or the grandchild generations for white families.

Figure 4 shows a diversity of grandparent effects by types of family structure and racial groups, based on estimates from Table 4. For African Americans, grandparent effects are especially strong among families that remained intact during the childhoods of grandchildren. The point estimate of the grandparent effect is 0.11, which is close to half as large as the parent effect, 0.25. Yet such intact families constitute a minority of the African American population—only 34 percent (=782/(1508+782)) in the African American sample, as shown in Table 2. For the majority of African American families, namely families that experienced single-parenthood in the grandchild generation, the grandparent effect is negligible, as the coefficient of the effect, 0.02 is not statistically significant from zero. The last two estimates in the graph show that the difference in the grandparent effect between single-parent and two-parent households is even

more remarkable if we assess the grandparent effect by family structure in two successive generations. African American families that have remained intact in both parent and grandchild generations display a cumulative advantage in the grandparent effect, whereas families that have lived through two consecutive generations of single-parenthood are the least likely to transmit educational statuses from grandparents to grandchildren.[7]

Conversely, grandparent effects across different types of family structure are relatively homogeneous for whites. Grandparent effects vary between 0.01 and 0.06, but a large proportion of confidence intervals of these estimates overlap, suggesting that differences among these effects are statistically insignificant. Comparing white families that experienced one generation and two successive generations of two-parent (or single-parent) households, we do not observe cumulative advantage (or disadvantage) mechanisms in grandparent effects caused by the history of family structure.

Taken together, results from interactive models in Table 4 suggest distinct patterns of grandparent effects by family structure and race: African American families that have raised their children in two-parent households show strong multigenerational bonds in educational status between grandparents and grandchildren, whereas for whites such multigenerational connections are not contingent upon family structure.

Sensitivity Analysis

The causal interpretation for results presented in Table 3 and Table 4 rests on the assumption that unobserved confounding variables that affect education of grandparents, parents and grandchildren (namely *W* in Figure 1) do not correlate. This assumption may be invalid because unmeasured factors such as childhood family income and welfare status, and the 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 variable (W) and education (X) across generations (shown in Figure A1), the sensitivity analysis assesses the extent to which the causal effect of grandparents' education is robust to the selection bias caused by intergenerational transmission of unobserved variables.

The sensitivity analysis follows two steps. In the first step, I assume a single variable W 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 X_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 both W_t and X_t are standardized, the parameter π can be roughly interpreted as the intergenerational correlation in the unobserved variable. The parameter θ refers to the correlation between education and the unobserved variable in each generation, which reflects the magnitude of the selection bias. In the second step, I estimate grandparent effects by including the simulated unobserved variable into all the SNMM that produce previous results in Tables 3 and 4, and compare the bias-corrected estimates of grandparent effects with the original ones.

Figure 4 displays adjusted average grandparent effects and heterogeneous grandparent effects by family structure, 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 variable [8] (as shown in Figure 1), the estimated grandparent effects simply replicate previous estimates shown in Figures 2 and 3. Despite a wide range of possible combinations between values of θ and π, Figure 4 only presents results from scenarios when $\theta = \pi$.

In general, the estimated grandparent effects decline with the increase of θ or π. The vertical lines refer to thresholds of the parameters at which the average grandparent effects, represented by the red lines, are not significantly different from zero. This result means that we need to reconsider the causal interpretation for influences of grandparents' education on grandchildren's education because of potential selection mechanisms. In addition, grandparent effects that fall below zero imply potential unrealistic scenarios under which grandparent effects become negative and strong enough to overturn the positive impact of 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 variable as well the correlation between education and the unobserved variable are both below 0.5. For whites, the causal effect of grandparents persists even if the correlations are as high as 0.7. In terms of the heterogeneous grandparent effect, the thresholds for a valid causal interpretation for some groups are even higher than those based on the average grandparent effect.

To provide a more substantive understanding of the bias-corrected grandparent effect, I borrow previous evidence from studies on intergenerational correlation of income as an example of the unobserved variable *W*. The correlations range from 0.15 to 0.4 (Becker and Tomes 1986; Bowles and Nelson, 1974; Solon 1992; Zimmerman 1992), all of which do not exceed the thresholds reported in Figure 4.[9] Overall, the sensitivity analysis indicates that the magnitude of the intergenerational transmission of the unobserved variable, if there is any, would have to be unreasonably large to alter our inferences about the causal effect 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 variable.

DISCUSSION

Using multigenerational data from the Panel Study of Income Dynamics, this study tests whether grandparents' education directly influences grandchildren's educational outcomes and whether the effects vary across types of family structures. The analyses yield three principle findings. First, the results suggest a non-Markovian mechanism of grandparent effect—that is, grandparents' education directly influences their grandchildren's educational attainments, for both African American and white families. Thus, 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 addition, even if grandparents fail to pass on their advantages to the parents, they can extend their influence and secure advantages for the grandchildren.

The second finding indicates that the overall direct effect of grandparents is greater in white families than in African American families. This results is consistent with findings from prior intergenerational mobility studies, which show that the inheritance of status from parents to offspring is stronger for whites than for African Americans (e.g., Duncan 1968; Featherman and Hauser 1976; Hout 1984). For any given educational levels of parents and grandparents, African American grandchildren are unlikely to obtain the same level of education as compared to whites. The lower intergenerational association in educational status among African Americans as compared to whites may be explained by racial differences in the effectiveness of parenting skills within families but may also be attributable to racial differences in social experiences that are related to residential segregation, parental unemployment and incarceration, or even discrimination in the educational system.

The third finding shows that substantial heterogeneity in the grandparent effect prevails in families that experience diverse household structures. The effect is the strongest among African American families in which grandchildren grew up in two-parent households but is largely homogeneous among white families. While intergenerational ties in educational status are weaker in African American families than in white families, the results show that multigenerational effects in education from grandparents to grandchildren are extremely pronounced in two-parent African American families. Previous ethnographic studies described African American grandparents, especially grandmothers, as "guardians of the generations" (Frazier 1939), who hold families together during hard times, provide discipline, guidance and financial assistance to their children, and transmit family history, values and wisdoms across generations. Thus, the stronger connections in educational status between grandparents and grandchildren among African American families shown in this paper may be attributed to higher levels of involvement of African American grandparents. In contrast, in single-parent families, grandchildren's educational attainment depends more on their own efforts or various random factors than on the educational background of their families. Overall, the substantial variations in grandparent effects by family structure among African Americans, but not among whites, imply that the growth in single-parent families have weakened the effect of grandparents' education on grandchildren's education for African Americans, but has had little impact on white families.

Several limitations of the present study are worth noting. First, the simple, dichotomous classification—single-parent versus two-parent families—may obscure further heterogeneity within both groups. For example, given the rapid growth of cohabitation, children growing up with two-parents who are unmarried may be different from those with two married parents. Likewise, children who experienced parental divorce may be different from those who were born

out of wedlock or who experienced parental death (DeLeire and Kalil 2002; McLanahan and Percheski 2008; Sweeney 2011). Grandparent influences on children in the single-parent group may further depend on the age of grandparents (Silverstein and Marenco 2001), the number of living grandparents, the family tradition in grandparent-grandchild relationship (King and Elder 1997), the living arrangement (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 age of grandchildren when their parents separated or divorced. Compared to whites, African Americans in the single-parent group are more likely to be born out of wedlock and less likely to experience parental divorce. [10]

Second, 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 direct effects of paternal and maternal grandparents or between grandfathers and grandmothers. The heterogeneous grandparent effects for African Americans are mostly explained by grandmother effects. The results confirm Cherlin and Furstenberg's (1986: 123-127) findings that grandfathers and grandmothers are almost equally likely to visit their grandchildren, take on a parentlike role, 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." Given that the missing at

random assumption may be violated, I consider these supplementary results as tentative. A refined analyses would require data that follow both paternal and maternal sides of all families over generations.

Third, the multigenerational causal mechanisms may be more complicated than displayed in the analyses, because the current study is not able to examine all possible pathways through which grandparents influence grandchildren. In addition, the identification of causal mechanisms in the present study relies on assumptions about the relationship between observed and unobserved factors. The sensitivity analyses simulate a broad range of scenarios when selection bias problems caused by unobserved variables occur, but future research that directly measure the intergenerational transmission of the unobserved variables may help further test validity of the results.

American families are in transition, as are grandparents' roles in grandchildren's lives. Results from this study show that the formation of single-parent families due to recent trends in divorce, remarriage, and premarital and multi-partner fertility has altered socioeconomic connections 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 roles of step-grandparents—be they a supplement or replacement to roles of biological kindred. The joint role of the kin network, rather than parents and grandparents alone, may contribute to persistent inequalities between families across generations.

CONCLUSION

This study provides an example of multigenerational influences from grandparents that create, reproduce, and potentially change educational inequality among families. The results suggest that not only does the recent demographic transition in family structure lead to

"diverging destinies" of U.S children (McLanahan 2004), but it has multigenerational implications for diverging destinies of American families. Findings from this study suggest that the decline in two-parent families has undermined multigenerational transmission of educational advantages among African Americans, but has had inconsequential impact on whites.

Realistic family strategies for maintaining social advantages across generations, however, may be more complex than those described in this study. For example, the strength and patterns of grandparent effects may vary by dimensions of social statuses, ranging from "stocks" of social advantages such as business, 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 result in stronger effects of some grandparents relative to others and different mobility outcomes for grandsons and granddaughters (Bengtson 2001; Cherlin and Furstenberg 1986: 122-127; Coall and Hertwig 2010; Spitze and Ward 1998).

Generations within the same family are connected by not only social statuses but also demographic behaviors (Mare 1997, 2011). On the one hand, family decisions on whether, when, and whom to marry and whether to have children may interact with intergenerational mobility processes, combining to influence aggregate-level racial disparity in education (Maralani 2013), economic polarization, and poverty (Lam 1986; Musick and Mare 2004) as well as future educational, genetic and occupational distributions in a population (Mare and Maralani 2006; Matras 1961, 1967; Preston 1974; Preston and Campbell 1993). On the other hand, families' demographic behaviors also modify status connections across generations (Biblarz and Raftery 1993; Zeng and Xie 2014). The history of family disruption and reconstitution investigated in the

present study is only a part of these demographic processes. Parents' and grandparents' demographic behaviors, such as marriage, living arrangement, fertility, mortality, adoption, migration, and timing of these events may all influence the strength of intergenerational resemblance in social status across generations. Future research may help uncover more heterogeneity in the interaction between demographic behaviors and social mobility of families.

NOTES

[1] Hout (1988: 1391) argued that the additive model specification in status attainment models based on a path analysis is inaccurate, as he found that the effect of origins on destinations differs by the intervening factor, namely the level of education.

[2] I also experimented with using the average education rather than the highest education of parents and grandparents. The results are consistent with those presented below, although the results are slightly less significant.

[3] 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 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.

[4] In recent causal mediation literature, some researchers proposed another definition of the direct effect called the pure natural direct effect (Pearl 2001, 2013; Robins and Greenland 1992; Sobel 2008).

$$DE = E\left[Y\left(x_1 = x', M(x_1 = x)\right) - Y\left(x_1 = x, M(x_1 = x)\right)\right]$$
$$= \sum_{C,M} \{E[Y|x_1 = x', M(x_1 = x), C]\} P(M|x_1 = x, C)P(C) - \sum_{C,M} \{E[Y|x_1 = x, M(x_1 = x), C]\} P(M|x_1 = x, C)P(C)$$

It can be interpreted as the expected increase in the educational outcome of *Y*, as the treatment variable, grandparent's education, changes from $X_1 = x$ to $X_1 = x'$, while setting the mediator variables to whatever values they would have attained prior to the change, i.e., under $X_1 = x$. This study does not examine the pure natural direct effect, because it requires more stringent assumptions about the unobserved variables (Pearl 2013).

[5] Traditional sociological studies often relied on a path analysis or structural equation model framework to estimate direct and indirect effects of variables. Such a method has limitations in identifying conditions when associations can be interpreted as causations, as well as extending linear models to situations when nonlinearities and interactions are permitted (Sobel 2008; Wang and Sobel 2013).

[6] SNMM models used in this paper only assume two-way interactions between family structures and parents' education as well as grandparents' education. For the sake of simplicity, I omit the two-way interaction between family structure in two generations and all the three-way interaction terms, namely S_2*S_3, X_1*S_2*S_3 and X_2*S_2*S_3. As a robustness check, I experimented with a wide variety of model specifications. The results suggest that estimates of grandparents' education in Table 3 and 4 are robust to possible model misspecification. The online supplement provides more details about the SNMM estimators as well as a simulation example to illustrate the method.

[7] Auxiliary analyses shown in the supplemental file provide further evidence to distinguish between the transmission of multigenerational advantages and disadvantages in two-parent and single-parent families. The analyses show that weaker grandparent effects in single-parent families result from weaker multigenerational transmission of educational advantages, rather than more upward mobility from grandparents to grandchildren.

[8] Likewise, when the parameter θ is equal to 0, namely, no selection effect of the unobserved variable on education, the estimated grandparent effects simply replicates previous estimates shown in Figure 2 and 3. In terms of the DAG in Figure 4, we would expect to see no arrows pointing from the unobserved variable *W* to the education variable *X*.

[9] Additionally, since the calculation of these intergenerational income correlations does not include controls for the effect of education in one generation on childhood family income in the next generation, the intergenerational correlations of income net of education may be smaller than those reported in prior studies. Such a fact further substantiates the causal effect of grandparents' education on grandchildren's education.

[10] The supplemental file presents some robustness checks by restricting the single-parent group to only grandchildren who experienced parental divorce.

REFERENCES

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

Almirall, Daniel, Beth Ann Griffin, Daniel F. McCaffrey, Rajeev Ramchand, Robert A. Yuen, and Susan A. Murphy. 2013. “Time-Varying Effect Moderation Using the Structural Nested Mean Model: Estimation Using Inverse-Weighted Regression with Residuals.” *Statistics in Medicine* doi: 10.1002/sim.5892.

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.

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 McLanahan. 1991. “Family Structure, Parental Practices, and High School Completion.” *American Sociological Review* 56(3): 309-20.

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

Bartholomew, David J. 1982. *Stochastic Models for Social Processes (third edition)*. New York: Wiley.

Becker, Gary S., and Nigel Tomes. 1986. “Human Capital and the Rise and Fall of Families.” *Journal of Labor Economics* 4(3): S1-39.

Beller, Emily. 2009. “Bringing Intergenerational Social Mobility Research into the Twenty-first Century.” *American Sociological Review* 74: 507-28.

Bengtson, Vern L. 1985. “Diversity and Symbolism in Grandparental Roles.” 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.

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.

Bowles, Samuel and Valerie Nelson. 1974. “The ‘Inheritance of IQ’ and the Intergenerational Reproduction of Economic Inequality.” *The Review of Economics and Statistics* 56(1): 39-51.

Brand, Jennie E. and Juli Simon Thomas. 2013. “Causal Effect Heterogeneity.” In *Handbook of Causal Analysis for Social Research*, pp. 189-214 edited by Stephen L. Morgan. Netherland: Springer Series.

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, 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.” 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., and Frank F. Furstenberg, Jr. 1985. “Style and Strategies of Grandparenting” In *Grandparenthood* edited by Vern L. Bengtson and Joan F. Robertson. CA: Sage Publications, Inc.

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.

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.

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

Daniel, R. M., S. N. Cousens, B. L. De Stavola, M. G. Kenward, and J. A. C. Sterne. 2013. “Methods for Dealing With Time-Dependent Confounding.” *Statistics in Medicine* 32(9): 1584-618.

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, 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.” 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?” In *Social Inequality*, edited by Kathryn Neckerman. New York: Russell Sage Foundation.

Elwert, Felix and Christopher Winship. forthcoming. “Endogenous Selection Bias: The Problem of Conditioning on a Collider Variable.” *Annual Review of Sociology*.

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.

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

Frazier, Edward F. 1939. *The Negro Family in the United States*. Chicago: University of Chicago Press.

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.

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.

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

Hauser, Robert M., John Robert Warren, Min-Hsiung Huang, and Wendy Y. Carter. 2000. “Occupational Status, Education, and Social Mobility in the Meritocracy.” 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.

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

Hout, Michael. 1988. “More Universalism, Less Structural Mobility: The American Occupational Structure in the 1980s.” *American Journal of Sociology* 93: 1358-400.

Hunter, Andrea G., and Robert J. Taylor. 1998. “Grandparenthood in African American Families.” In *Handbook on Grandparenthood* edited by Maximiliane E. Szinovacz. CT: Greenwood Press.

Jencks, Christopher, Marshall Smith, Henry Acland, Mary Jo Bane, David Cohen, Herbert Gintis, Barbara Heyns, and Stephan Michelson. 1972. *Inequality: A Reassessment of the Effect of Family and Schooling in America.* New York: Basic Books.

Johnson, Colleen L. 1985. “Grandparenting Options in Divorcing Families: An Anthropological Perspective.” In *Grandparenthood* edited by Vern L. Bengtson and Joan F. Robertson. Beverly Hill: Sage.

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

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

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.

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.

Kuo, Daphne Hsiang-Hui and Robert M. Hauser. 1995. “Trends in Family Effects on the Education of Black and White Brothers.” *Sociology of Education* 68(2): 136-60.

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

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

Mare, Robert D., and Xi Song. 2012. “Social Mobility in Multiple Generations.” Paper presented at the annual meeting of the Population Association of America, San Francisco, CA.

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. 2009. “Fragile Families and the Reproduction of Poverty.” *The Annals of the American Academy of Political and Social Science* 621(1): 111-31.

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

McLanahan, Sara, and Laura Tach, and Daniel Schneider. 2013. "The Causal Effects of Father Absence." *Annual Review of Sociology* 39: 399-427.

Morgan, Stephen L., and Christopher Winship. 2007. *Counterfactuals and Causal Inference: Methods and Principles for Social Research*. 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. 2000. *Causality: Models, Reasoning and Inference*. Cambridge: MIT press.

Pearl, Judea. 2001. "Direct and Indirect Effects." In Proceedings of the Seventeenth Conference on Uncertainty and Artificial Intelligence. San Francisco, CA Morgan Kaufmannl 411-20.

Pearl, Judea. 2012. "The Causal Mediation Formula—A Guide to the Assessment of Pathways and Mechanisms." *Prevention Science* 13: 426-36.

Pearl, Judea. 2013. "Interpretation and Identification of Causal Mediation." Technical Report R-389 September 2013. ftp://ftp.cs.ucla.edu/pub/stat_ser/r389.pdf

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, July, 2013.

Raftery, Adrian E., and Michael Hout. 1993. “Maximally Maintained Inequality: Expansion, Reform, and Opportunity in Irish Education, 1921-75.” *Sociology of Education* 66(1): 41-62.

Riley, Matilda W. and John W. Riley. 1993. “Connections: Kin and Cohort.” In *The Changing Contract across Generations*, edited by Vern L. Bengtson and W. Andrew Achenbaum. New York: Aldine.

Robertson, Joan F. 1995. “Grandparenting in an Era of Rapid Change.” In *Handbook of Aging and the Family*, edited by Rosemary Blieszner and Victoria. H. Bedford. Westport, CT: Greenwood Press.

Robins James M. 1994. “Correcting for Non-Compliance in Randomized Trials Using Structural Nested Mean Models.” *Communications in Statistics* 23: 2379-412.

Robins, James M. 1999. “Testing and Estimation of Direct Effects by Reparameterizing Directed Acyclic Graphs with Structural Nested Models.” In *Computation, Causation, and Discovery* Eds. C. Glymour and G. Cooper. Menlo Park, CA, Cambridge, MA: AAAI Press/The MIT Press pp. 349-405.

Robins, James M., and Sander Greenland. 1992. “Identifiability and Exchangeability for Direct and Indirect Effects.” *Epidemiology* 3(2): 143-55.

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

Ruggles, Steven. 1994. “The Origins of African-American Family Structure.” *American Sociological Review* 59(1): 136-51.

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

Seltzer, Judith A. and Suzanne M. Bianchi. 1988. “Children’s Contact with Absent Parents.” *Journal of Marriage and Family* 50(3): 663-77.

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., Archibald O. Haller, and George W. Ohlendorf. 1970. “The Educational and Early Occupational Status Attainment Process: Replication and Revision.” *American Sociological Review* 35(December): 1014-1027.

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 Anne Marenco. 2001. “How Americans Enact the Grandparent Role Across the Family Life.” *Journal of Family Issues* 22(4): 493-522.

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.

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. 1992. “Intergenerational Income Mobility in the United States.” *The American Economic Review* 82(3): 393-408.

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

Spitze, Glenna and Russell A. Ward. 1998. “Gender Variations.” In *Handbook on Grandparenthood* edited by Maximiliane E. Szinovacz. CT: Greenwood Press.

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.

Sweeney, Megan M. 2011. “Family Structure Instability and Adolescent Educational Outcomes: A Focus on Families with Stepfathers.” 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.

Sweet, James A., and Larry L. Bumpass. 1987. *American Families and Households*. New York: Russel Sage Foundation.

Szinovacz, Maximiliane E. 1998. “Grandparent Research: Past, Present, and Future.” In *Handbook on Grandparenthood* edited by Maximiliane E. Szinovacz. CT: Greenwood Press.

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.

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

VanderWeele, Tyler J., and James M. Robins. 2007. “Four Types of Effect Modification: A Classification Based on Directed Acyclic Graphs.” *Epidemiology* 18(5): 561-68.

Vansteelandt, Stijn. 2009. “Estimating Direct Effects in Cohort and Case–Control Studies.” *Epidemiology* 20(6): 851-60.

Wang, Xiaolu, and Michael E. Sobel. 2013. “New Perspectives on Causal Mediation Analysis.” 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 (Second Edition).* London: 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.

Wolfinger, Nicholas H. 2001. "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*." Paper prepared for presentation at the annual meeting of the American Sociological Association, 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.

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

Table 1. Multigenerational Sample Characteristics

Variable Means	African Americans	Whites
Grandchildren (G3)		
Years of schooling	12.5	13.4
	(2.1)	(2.2)
Growing up in single-parent families, %	65.9	35.3
Male, %	51.1	50.2
Age group in 2011, %		
25-34	49.8	59.5
35-44	38.0	34.8
45-54	8.9	4.0
55-65	3.4	1.7
Current region, %		
Northeast	5.6	18.0
North central	16.0	27.2
South	71.8	33.5
West	6.7	21.3
Number of siblings	2.4	1.8
	(1.7)	(1.1)
Parents (G2)		
Highest years of schooling	12.5	13.7
	(2.2)	(2.3)
Growing up in single-parent families, %	29.6	16.3
Birth year		
Median	1953	1953
	(8.7)	(6.8)
Minimum	1917	1905
Maximum	1967	1970
Grandparents (G1)		
Highest years of schooling	9.5	11.6
	(3.1)	(3.2)
Birth year		
Median	1926	1927
	(9.5)	(8.8)
Min	1890	1883
Maximum	1960	1954
N	2,290	2,534

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in the parentheses are standard deviations for continuous variables. Birth cohorts of parents and grandparents are calculated based on information from all available parents and grandparents in the sample.

Table 2. Multigenerational Family Structure and Grandchildren's (G3) Educational Outcome

			African Americans		Whites	
			Childhood family structure, G3		Childhood family structure G3	
			Single-parent	Two-parent	Single-parent	Two-parent
Childhood family structure, G2	Single-parent	Mean	12.2	13.0	12.4	13.2
		S.D	2.0	2.0	1.9	2.1
		N	457	221	176	236
	Two-parent	Mean	12.2	13.1	12.8	13.9
		S.D	1.9	2.2	2.2	2.2
		N	1051	561	719	1,403
	Total	Mean	12.2	13.1	12.7	13.8
		S.D	2.0	2.1	2.2	2.2
		N	1,508	782	895	1,639

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in the parentheses are standard deviations for continuous variables.

Table 3. Additive Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education

	African Americans		Whites	
	OLS	SNMM	OLS	SNMM
Intercept	8.705***	8.040***	7.098***	6.363***
	(0.344)	(0.348)	(0.284)	(0.282)
Grandparent, G_1				
Education, X_1	0.041**	0.032*	0.056***	0.062***
	(0.014)	(0.014)	(0.014)	(0.014)
Parent, G2				
Education, X_2	0.270***	0.295***	0.411***	0.441***
	(0.020)	(0.023)	(0.019)	(0.020)
Childhood 1-parent household	0.001	-0.016	-0.467***	-0.505***
$\delta(S_2)$	(0.088)	(0.090)	(0.104)	(0.105)
Grandchild, G3				
Childhood 1-parent household	-0.668***	-0.660***	-0.530***	-0.535***
$\delta(S_3)$	(0.086)	(0.089)	(0.083)	(0.081)
N	2,290	2,290	2,534	2,534

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in the parentheses are standard errors. Standard errors for SNMM are obtained from 1,000 bootstrap samples. $p^* < .05$, $p^{**} < .01$, $p^{***} < .001$ (two-tailed tests). Coefficients of variables including age groups, sex and current region are not presented in the table.

Table 4. Interactive Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education by Family Structures

	African Americans		Whites	
	OLS	SNMM	OLS	SNMM
Intercept	7.816***	8.473**	6.433***	7.212***
	(0.524)	(0.387)	(0.360)	(0.449)
Grandparent, G1				
Education, X_1	0.120***	0.124***	0.072***	0.061**
	(0.026)	(0.029)	(0.018)	(0.020)
Education*childhood	-0.043	-0.032	-0.005	-0.014
1-parent household S_2	(0.029)	(0.032)	(0.037)	(0.036)
Education*childhood	-0.096***	-0.096**	-0.040	-0.040
1-parent household S_3	(0.029)	(0.031)	(0.028)	(0.027)
Parent, G2				
Childhood 1-parent household	0.307	0.058	0.900	1.034
$\delta(S_2)$	(0.521)	(0.682)	(0.646)	(0.677)
Education, X_2	0.280***	0.255***	0.445***	0.420***
	(0.036)	(0.028)	(0.025)	(0.028)
Education*childhood	0.011	0.023	-0.098*	-0.098*
1-parent household S_2	(0.040)	(0.047)	(0.048)	(0.049)
Education*childhood	-0.024	-0.024	-0.038	-0.038
1-parent household S_3	(0.041)	(0.046)	(0.039)	(0.039)
Grandchild, G3				
Childhood 1-parent household	0.554	0.554	0.429	0.429
$\delta(S_3)$	(0.521)	(0.618)	(0.470)	(0.493)
N	2,290	2,290	2,534	2,534

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in the parentheses are standard errors. Standard errors for SNMM are obtained from 1,000 bootstrap samples. $p^* < .05$, $p^{**} < .01$, $p^{***} < .001$ (two-tailed tests). Coefficients of variables including age groups, sex and current region are not presented in the table.

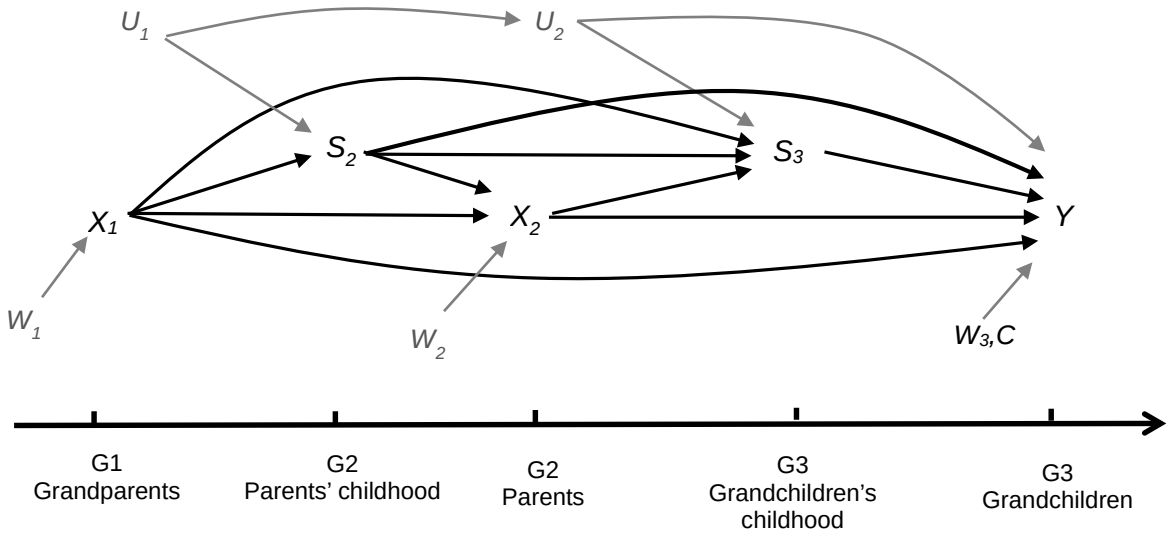

Figure 1. Directed acyclic graph showing hypothesized causal relationship

Notes: X_1 = grandparents' education, S_2 = childhood family structure of parents, X_2 = parents' education, S_3 = childhood family structure of grandchildren, *U*, *W* = unmeasured variables, *Y* = grandchildren's education. *C* = exogeneous variables that influence *Y*, such as gender, race, region and age group.

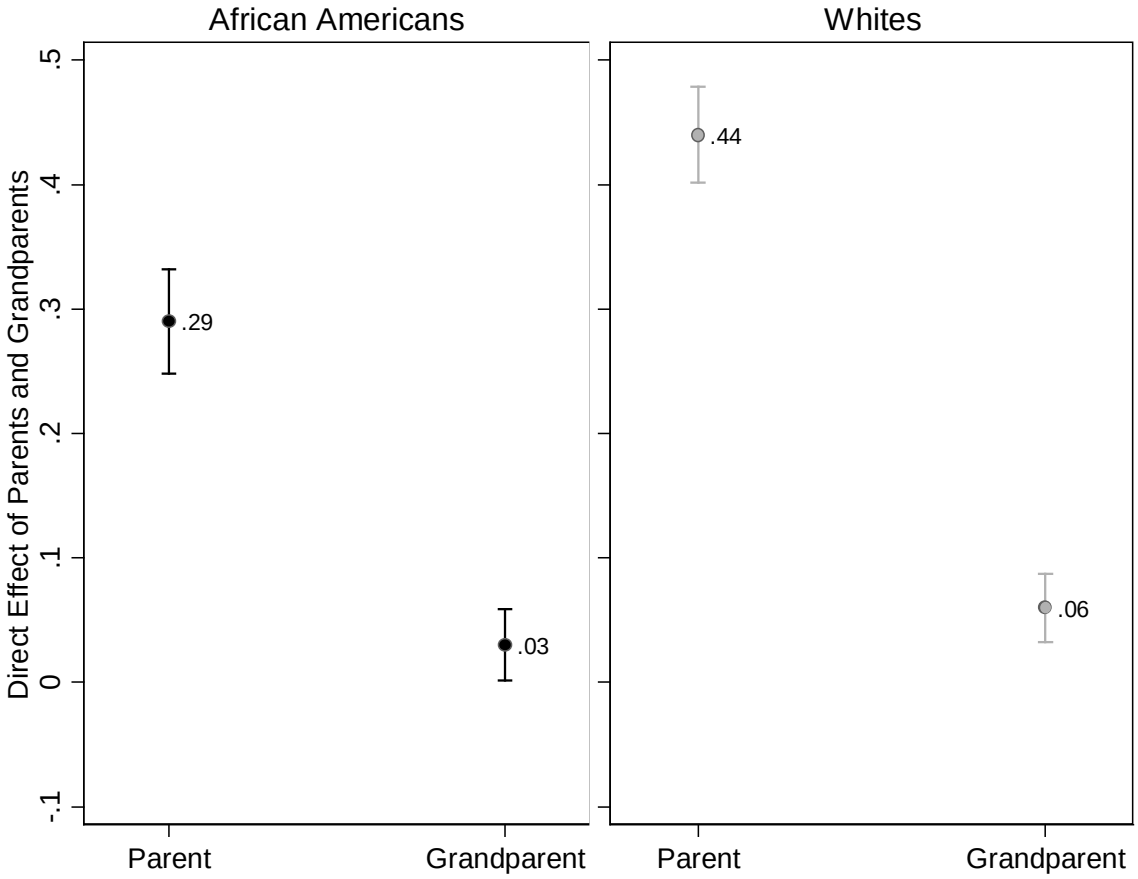

Figure 2. Direct Effects of Parents' and Grandparents' Education on Grandchildren's Education by Race

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: Points refer to mean estimates and capped spikes refer to 95 percent confidence intervals of the estimates. All other variables are fixed at their means.

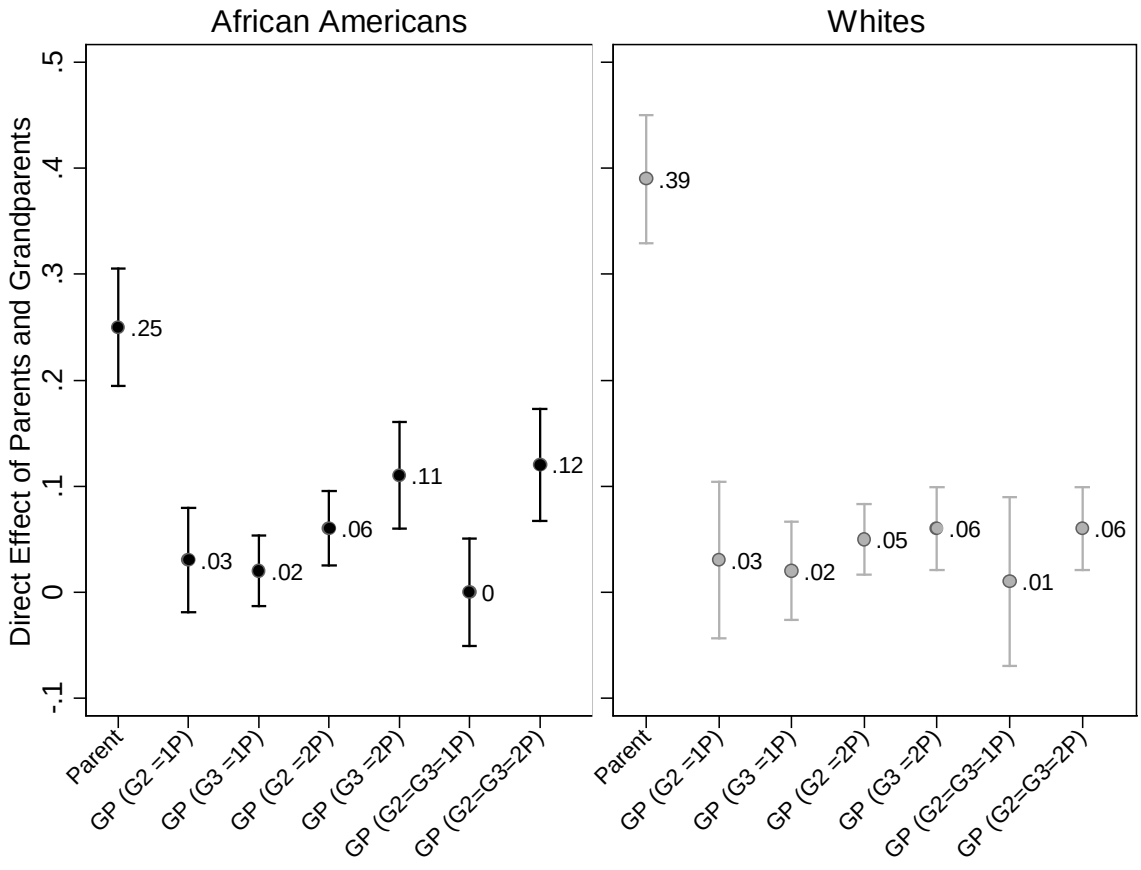

Figure 3. Heterogeneous Direct Effects of Parents' and Grandparents' Education on Grandchildren's Education by Family Structure and Race

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: Points refer to mean estimates and capped spikes refer to 95 percent confidence intervals of the estimates. GP refers to the grandparent effect. G2 and G3 refer to childhood family structure in parent and grandchild generations respectively. 1P and 2P refer to single-parent and two-parent family respectively. All the other variables are fixed at their means.

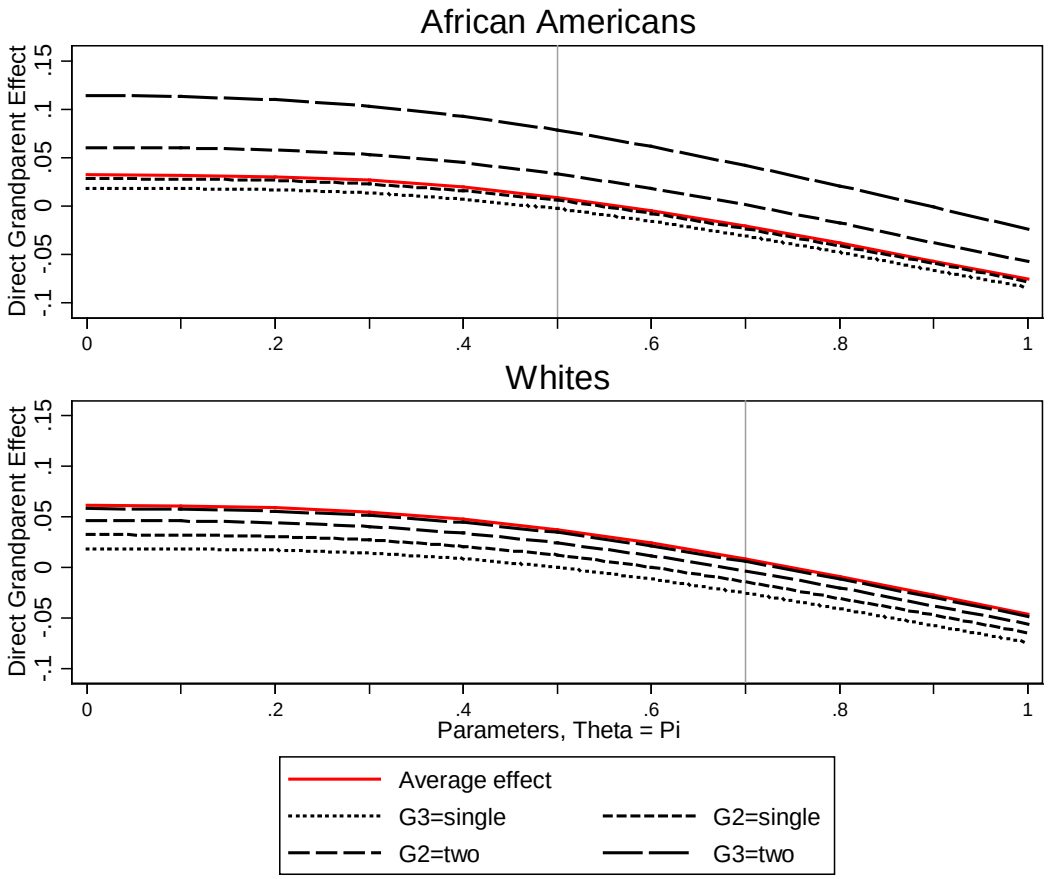

Figure 4. Sensitivity Analyses for Effects of Grandparents' Education on Grandchildren's Education under Various Assumptions about Strengths of Unobserved Variable W.

Notes: The parameter θ can be roughly interpreted as the selection bias, or the correlation between *w* and *x*. The parameter π refers to the intergenerational correlation between w_t and w_{t+1}. Specifically, I assume that the unobserved variable $w_{t+1} = \theta * x'_{t+1} + \pi * w'_t + \epsilon_i$ where w'_t and x'_{t+1} are standardized variables of w_t and x_{t+1}. 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 1,000 simulated samples. The vertical lines refer to thresholds of the parameters below which the average grandparent effects are greater than zero.

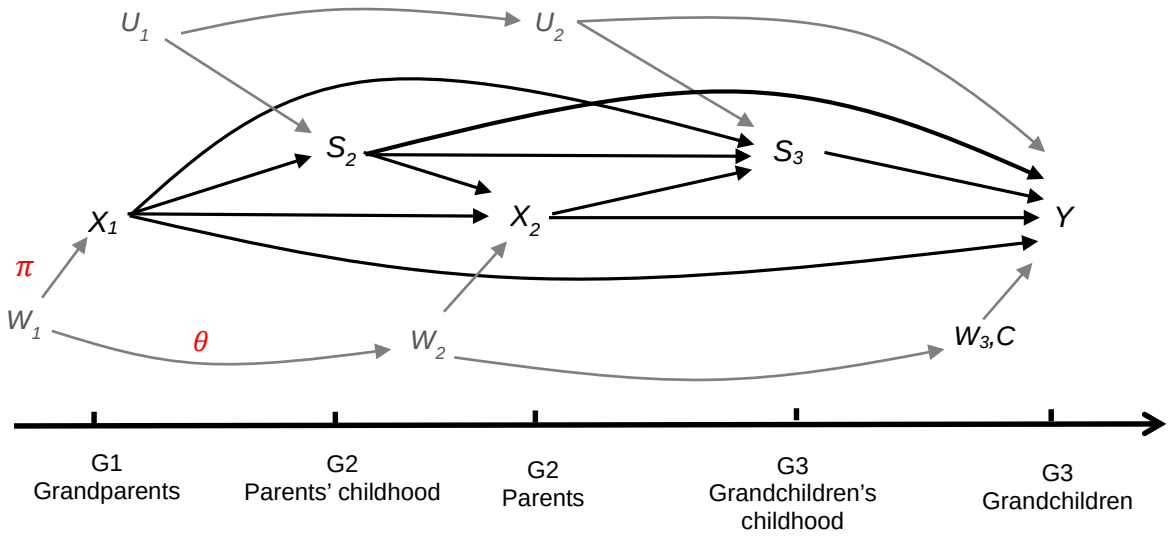

Figure A1. Hypothesized Causal Relationship with Unmeasured Generation-Varying Covariates

Notes: X_1 = grandparents' education, S_2 = childhood family structure of parents, X_2 = parents' education, S_3 = childhood family structure of grandchildren, U, W = unmeasured variables, Y = grandchildren's education. C = exogeneous variables that influence Y, such as gender, race, region and age group. π refers to the selection effect of the unobserved variable on education. θ refers to the intergenerational transmission of the unobserved variable.

ONLINE SUPPLEMENT

This supplemental file consists of two parts. Part I includes results from auxiliary analyses, which provide robustness checks regarding my conclusion about stronger multigenerational educational ties in two-parent families especially among African Americans. Part II provides a simulation example to show differences between OLS and SNMM estimates, as well as the unbiasedness of the SNMM estimates when some unobserved variables are missing from the analysis.

PART I: AUXILIARY ANALYSIS

1. Model Misspecification

The SNMM estimates may be sensitive to different specifications of the causal and residual functions in equations (6) and (9). Equation (6) and (9) are not saturated in the sense that the two-way interaction between childhood family structure of parents and grandchildren, as well as all three-way interactions are excluded from the model. Since X_1 and X_2 are continuous variables, I assume no interactions between X_1 and X_2. The results presented in Table S1 suggest that fitting a saturated model does not change our conclusion about heterogeneous grandparent effects among African Americans and homogeneous grandparent effects among whites. Because none of these extra interactions are significant for African Americans and they add extra complexity to the model, the original models are preferred.

2. Relative Mobility

Results in Table 4 show that the multigenerational transmission of educational status is stronger in two-parent than single-parent families among the African Americans. To distinguish between the transmission of multigenerational advantages and disadvantages, it is necessary to consider relative educational mobility from grandparents to grandchildren by family structure and race. A general trend shown in Table S2 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 ($r = 0.11$) than for whites ($r = 0.30$). 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 S3 further shows that the occurrence of upward mobility is higher among two-parent households than single-parent households, especially for African Africans. More than 80 percent of African American families have experienced upward mobility from the grandparent to the grandchild generation if the grandchildren grew up in two-parent families. The results substantiate conclusions from the paper that grandparents have a stronger effect on

grandchildren's education in two-parent families because these families are more capable of maintaining their multigenerational advantages and gaining opportunities for achieving higher education.

3. Paternal versus Maternal Grandparents and Grandfathers versus Grandmothers

As discussed earlier, analyses in Table 3 and 4 measure grandparents' education based on the highest year of schooling among grandparents whose information is available in PSID. It is meaningful to further parcel out influences of different sets of grandparents. Tables S4 and S5 present results from SNMM additive models and interactive models for paternal grandparents, maternal grandparents, grandfathers and grandmothers, respectively. Overall, the results show little difference between the average direct effects of paternal and maternal grandparents or between grandfathers and grandmothers. The heterogeneous grandparent effect for African Americans are mostly explained by grandmother effects. Yet the sizes of grandfather samples and paternal grandparent samples are much smaller than those for grandmother samples and maternal grandmother samples, which means that the missing grandparent information in the PSID may not be at random. Therefore, I consider these supplementary results as tentative. A refined analyses would require data that follow both paternal and maternal sides of all families over generations.

4. Heterogeneity within the Single-Parent Group

The definition of single-parent families in this paper may obscure heterogeneity within the group. For example, African American grandchildren who grew up in single-parent families are more likely to be born out of wedlock than white grandchildren, whereas the majority of white grandchildren were children whose parents divorced rather than children from nonmarital births. Thus, racial differences between grandparent effects may result from the unequal distribution of grandchildren from divorced families and nonmarital families by race. To check the robustness of results presented in Tables 3 and 4, I fit structural nested mean models for African American and white families by restricting the single-parent group to only grandchildren who experienced parental divorce. Results presented in Table S6 are consistent with those in Tables 3 and 4, suggesting that on average, grandparents' education has a greater effect on grandchildren's education in white families than in African American families. However, the grandparent effect is particularly strong among African American families in which grandchildren grew up in two-parent households, whereas it is largely homogeneous among different types of white families.

Table S1. SNMM Model Estimates for Direct Effects of Grandparents under Different Model Specifications

	African Americans		Whites	
	Original	Saturated	Original	Saturated
Intercept	8.473***	8.742***	7.212***	6.296***
	(0.387)	(0.569)	(0.449)	(0.615)
Grandparent, G1				
Education, X_1	0.124***	0.152***	0.061**	0.089***
	(0.029)	(0.038)	(0.020)	(0.021)
Education*childhood	-0.032	-0.094	-0.014	-0.018
1-parent household S_2	(0.032)	(0.056)	(0.036)	(0.052)
Education*childhood	-0.096**	-0.131***	-0.040	-0.053
1-parent household S_3	(0.031)	(0.040)	(0.027)	(0.032)
Education* childhood	-	0.102	-	0.063
1-parent household S_2 *		(0.066)		(0.074)
1-parent household S_3				
Parent, G2				
Childhood 1-parent	0.058	0.482	1.034	-0.991
household $\delta(S_2)$	(0.682)	(1.112)	(0.677)	(1.080)
Education, X_2	0.255***	0.239***	0.420***	0.429***
	(0.028)	(0.031)	(0.028)	(0.029)
Education*childhood	0.023	0.037	-0.098*	0.040
1-parent household in S_2	(0.047)	(0.075)	(0.049)	(0.070)
Education*childhood	-0.024	-0.021	-0.038	0.007
1-parent household in S_3	(0.046)	(0.053)	(0.039)	(0.045)
Education* childhood	-	-0.008	-	-0.259**
1-parent household S_2*		(0.102)		(0.099)
1-parent household S_3				
Grandchild, G3				
Childhood 1-parent	0.554	0.857	0.429	-0.057
household $\delta(S_3)$	(0.618)	(0.712)	(0.493)	(0.543)
1-parent household S_2*	-	-0.892	-	3.044*
1-parent household S_3		(1.459)		(1.332)
N	2,290	2,290	2,534	2,534

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in the parentheses are standard errors. Standard errors for SNMM are obtained from 1,000 bootstrap samples. $p^* < .05$, $p^{**} < .01$, $p^{***} < .001$ (two-tailed tests). Coefficients of variables including age groups, sex and current region are not presented in the table. The original models refer to ones reported in Table 4.

Table S2. Multigenerational Educational Mobility

	African Americans (N = 2,290)		
	Grandparent-Parent	Parent-Grandchild	Grandparent-Grandchild
Upward mobility	76.0	33.9	73.5
Immobility	14.8	27.2	13.0
Downward mobility	9.3	38.9	13.5
Total, %	100	100	100
Correlation	0.27	0.30	0.11
	Whites (N = 2,534)		
	Grandparent-Parent	Parent-Grandchild	Grandparent-Grandchild
Upward mobility	64.3	31.0	61.4
Immobility	22.5	27.7	17.3
Downward mobility	13.3	41.3	21.3
Total, %	100	100	100
Correlation	0.47	0.49	0.30

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.

Table S3. 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, %	65.6	80.1	70.3	83.1
Immobility	12.7	12.7	14.7	10.3
Downward mobility	21.7	7.2	15.0	6.6
N	457	221	1,051	561
Chi-square	22.7***		34.7***	

	Parents' and grandchildren's childhood family structures			
Whites	Single, Single	Single, Two	Two, Single	Two, Two
Grandparent-Grandchild				
Upward mobility, %	68.2	66.1	56.1	62.4
Immobility	10.8	16.5	17.4	18.3
Downward mobility	21.0	17.4	26.6	19.3
N	176	236	719	1,403
Chi-square	3.1		14.9***	

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. $p^* < .05$, $p^{**} < .01$, $p^{***} < .001$ (Chi-square tests).

Table S4. Additive SNMM Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education

	African Americans				Whites			
	Grandfather	Grandmother	Paternal grandparent	Maternal grandparent	Grandfather	Grandmother	Paternal grandparent	Maternal grandparent
Intercept	7.294***	8.072***	9.329***	8.020***	6.566***	6.391***	8.024***	6.335***
	(0.465)	(0.349)	(0.693)	(0.459)	(0.323)	(0.286)	(0.411)	(0.362)
Grandparent, G_1								
Education, X_1	0.046**	0.031*	0.032	0.026	0.061***	0.053***	0.048*	0.080***
	(0.016)	(0.015)	(0.031)	(0.021)	(0.014)	(0.014)	(0.021)	(0.020)
Parent, G2								
Education, X_2	0.328***	0.293***	0.223***	0.305***	0.436***	0..449***	0.376***	0.432***
	(0.032)	(0.021)	(0.043)	(0.029)	(0.023)	(0.019)	(0.026)	(0.027)
Childhood 1-parent household $\delta(S_2)$	-0.238	-0.037	-0.149	-0.126	-0.641***	-0.510***	-0.402*	-0.536***
	(0.178)	(0.092)	(0.195)	(0.112)	(0.154)	(0.107)	(0.180)	(0.130)
Grandchild, G3								
Childhood 1-parent household $\delta(S_3)$	-0.743***	-0.629***	-0.881***	-0.688***	-0.636***	-0.547***	-0.729***	-0.580***
	(0.114)	(0.092)	(0.183)	(0.112)	(0.093)	(0.083)	(0.128)	(0.110)
N	1,273	2,196	487	1,359	2,024	2,463	1,085	1,340

Data sources: Panel Study of Income Dynamics, 1968-2011.

Notes: Figures in the parentheses are standard errors. Standard errors for SNMM are obtained from 1,000 bootstrap samples. $p^* < .05$, $p^{**} < .01$, $p^{***} < .001$ (two-tailed tests). Coefficients of variables including age groups, sex and current region are not presented in the table. The parent's education refers to fathers' education in the paternal grandparent models, mothers' education in the maternal grandparent models, and the parent with the higher education in the grandfather models and grandmother models.

Table S5. Interactive SNMM Model Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education

	African Americans				Whites			
	Grandfathers	Grandmothers	Paternal grandparents	Maternal grandparents	Grandfathers	Grandmothers	Paternal grandparents	Maternal grandparents
Intercept	7.130***	8.412***	9.534***	7.976***	6.936***	7.136***	8.198***	7.361***
	(0.694)	(0.432)	(0.936)	(0.483)	(0.479)	(0.439)	(0.422)	(0.612)
Grandparent, G_1								
Education, X_1	0.084**	0.113***	0.081	0.175***	0.055**	0.062**	0.010	0.048
	(0.029)	(0.030)	(0.056)	(0.042)	(0.019)	(0.020)	(0.035)	(0.032)
Education*childhood 1-parent household S2	-0.076	-0.025	-0.043	-0.029	0.003	-0.014	-0.009	-0.043
	(0.051)	(0.035)	(0.068)	(0.042)	(0.056)	(0.040)	(0.068)	(0.053)
Education*childhood 1-parent household S3	-0.030	-0.087**	-0.037	-0.150***	-0.012	-0.040	0.012	-0.025
	(0.032)	(0.031)	(0.061)	(0.044)	(0.030)	(0.030)	(0.048)	(0.041)
Parent, G2								
Education, X_2	0.321***	0.266***	0.116	0.299***	0.432***	0.425***	0.417***	0.433
	(0.036)	(0.030)	(0.073)	(0.040)	(0.029)	(0.028)	(0.035)	(0.035)
Childhood 1-parent household $\delta(S_2)$	0.285	0.342	-1.114	1.276	1.336	0.754	2.247*	1.480
	(1.155)	(0.786)	(1.556)	(0.847)	(1.090)	(0.645)	(1.045)	(0.808)
Education*childhood 1-parent household S_2	0.009	-0.008	-0.043	-0.078	-0.150	-0.078	-0.195*	-0.115
	(0.101)	(0.054)	(0.068)	(0.064)	(0.095)	(0.049)	(0.082)	(0.067)
Education*childhood 1-parent household S_3	0.022	-0.016	-0.037	0.013	-0.018	-0.042	0.016	-0.047
	(0.064)	(0.046)	(0.061)	(0.060)	(0.049)	(0.041)	(0.061)	(0.059)
Grandchild, G3								
Childhood 1-parent household $\delta(S_3)$	-0.801	0.371	-1.873	0.557	-0.268	0.460	-1.069	0.309
	(0.802)	(0.635)	(1.320)	(0.797)	(0.592)	(0.521)	(0.729)	(0.679)
N	1,273	2,196	487	1,359	2,024	2,463	1,085	1,340

Data sources: Panel Study of Income Dynamics, 1968-2011.

Notes: Figures in the parentheses are standard errors. Standard errors for SNMM are obtained from 1,000 bootstrap samples. $p^* < .05$, $p^{**} < .01$, $p^{***} < .001$ (two-tailed tests). Coefficients of age groups, sex and current region are not presented in the table. The parent's education refers to fathers' education in the paternal grandparent models, mothers' education in the maternal grandparent models, and the parent with the higher education in the grandfather models and grandmother models.

Table S6. Additive and Interactive SNMM Estimates for Direct Effects of Grandparents' Education on Grandchildren's Education by Family Structure (Two-parent vs. Divorced)

	African Americans		Whites	
	Additive	Interactive	Additive	Interactive
Intercept	8.059***	8.018***	6.545***	7.191***
	(0.473)	(0.484)	(0.314)	(0.465)
Grandparent, G1				
Education, X_1	0.053*	0.142***	0.070***	0.077***
	(0.021)	(0.033)	(0.015)	(0.021)
Education*childhood divorced household S_2	-	-0.066	-	-0.017
		(0.053)		(0.048)
Education*childhood divorced household S_3	-	-0.109**	-	-0.032
		(0.041)		(0.032)
Parent, G2				
Childhood divorced household $\delta(S_2)$	-0.008	1.004	-0.526***	0.701
	(0.144)	(1.249)	(0.115)	(0.740)
Education, X_2	0.293***	0.280***	0.429***	0.409***
	(0.030)	(0.035)	(0.020)	(0.030)
Education*childhood divorced household S_2	-	-0.030	-	-0.074
		(0.081)		(0.056)
Education*childhood divorced household S_3	-	0.010	-	-0.041
		(0.063)		(0.045)
Grandchild, G3				
Childhood divorced household $\delta(S_3)$	-0.595***	0.325	-0.503***	0.412
	(0.127)	(0.835)	(0.087)	(0.565)
N	1,146	1,146	2,301	2,301

Data sources: Panel Study of Income Dynamics, 1968-2011.
Notes: Figures in the parentheses are standard errors. Standard errors for SNMM are obtained from 1,000 bootstrap samples. $p^* < .05$, $p^{**} < .01$, $p^{***} < .001$ (two-tailed tests). Coefficients of age groups, sex and current region are not presented in the table.

PART II: OBTAINING SNMM ESTIMATES

To obtain the SNMM estimates for the direct effect of grandparents, I first assume that

$$E(Y|X_1, S_2, X_2, S_3) = \beta_0 + \beta_1 S_2 + \beta_2 S_3 + X_1(\beta_3 + \beta_4 S_2 + \beta_5 S_3) + X_2(\beta_6 + \beta_7 S_2 + \beta_8 S_3) + \beta_9 C \quad \text{(A1)}$$

Then I model S_2 and S_3 by the following equations based on the data generating process shown in Figure 1.

$$E(S_2|X_1) = \alpha_0 + \alpha_1 X_1 \quad \text{(A2)}$$

$$E(S_3|X_1, S_2, X_2) = \gamma_0 + \gamma_1 X_1 + \gamma_2 X_2 + S_2(\gamma_3 + \gamma_4 X_1 + \gamma_5 X_2) \quad \text{(A3)}$$

The residuals from the above two equations are

$$\delta(S_2) = S_2 - E(S_2|X_1) \quad \text{(A4)}$$

$$\delta(S_3) = S_3 - E(S_3|X_1, S_2, X_2) \quad \text{(A5)}$$

Substituting equation (A2)-(A5) into equation (A1), we obtain

$$E(Y|X_1, S_2, X_2, S_3) = \beta_0 + \beta_1[\delta(S_2) + \alpha_0 + \alpha_1 X_1] + \beta_2[\delta(S_3) + \gamma_0 + \gamma_1 X_1 + \gamma_2 X_2 + S_2(\gamma_3 + \gamma_4 X_1 + \gamma_5 X_2)] + X_1(\beta_3 + \beta_4 S_2 + \beta_5 S_3) + X_2(\beta_6 + \beta_7 S_2 + \beta_8 S_3) + \beta_9 C \quad \text{(A6)}$$

$$= \text{constant} + \beta_1\delta(S_2) + \beta_2\delta(S_3) + X_1[(\beta_3 + \beta_1\alpha_1 + \beta_2\gamma_1) + (\beta_4 + \gamma_4)S_2 + \beta_5 S_3] + X_2[(\beta_6 + \beta_2\gamma_2) + (\beta_7 + \gamma_5)S_2 + \beta_8 S_3] + \beta_2\gamma_3 S_2 + \beta_9 C \quad \text{(A7)}$$

$$= \text{constant} + (\beta_1 + \beta_2\gamma_3)\delta(S_2) + \beta_2\delta(S_3) + X_1[(\beta_3 + \beta_1\alpha_1 + \beta_2\gamma_1 + \beta_2\gamma_3\alpha_1) + (\beta_4 + \gamma_4)S_2 + \beta_5 S_3] + X_2[(\beta_6 + \beta_2\gamma_2) + (\beta_7 + \gamma_5)S_2 + \beta_8 S_3] + \beta_9 C \quad \text{(A8)}$$

$$= \eta_0 + \eta_1\delta(S_2) + \eta_2\delta(S_3) + X_1(\eta_3 + \eta_4 S_2 + \eta_5 S_3) + X_2(\eta_6 + \eta_7 S_2 + \eta_8 S_3) + \eta_9 C \quad \text{(A9)}$$

where $\eta_1 = \beta_1 + \beta_2\gamma_3$, $\eta_2 = \beta_2$, $\eta_3 = \beta_3 + \beta_1\alpha_1 + \beta_2\gamma_1 + \beta_2\gamma_3\alpha_1$, $\eta_4 = \beta_4 + \gamma_4$, $\eta_5 = \beta_5$, $\eta_6 = \beta_6 + \beta_2\gamma_2$, $\eta_7 = \beta_7 + \gamma_5$, $\eta_8 = \beta_8$, and $\eta_9 = \beta_9$. Standard errors of the coefficients in the second stage are needed to be estimated from bootstrap or delta methods (Daniel et al. 2013). Note that we do not need to substitute S_2 by its residual in the interaction of X and S in equation (A6) because the interaction transformation is deterministic and the coefficient is not subject to the omitted variable bias caused by U.

Given the assumptions shown in Figure (1), $\delta(S_2)$ is no longer related to X_1 and thus conditioning on $\delta(S_2)$ does not lead to the collider bias due to the association between X_1 and the omitted factor U_1. We also remove similar problems by using $\delta(S_3)$ instead of S_3. Additionally, by conditioning on $\delta(S_2)$ and $\delta(S_3)$, we do not control away part of the influences of X_1 on Y

that is associated with S_2 and S_3. This is because the main effect of X_1 on Y, namely η_3, is no longer equal to β_3, but subsumes an additional part $\beta_1\alpha_1 + \beta_2\gamma_1 + \beta_2\gamma_3\alpha_1$, which is generated by the association between X_1 and S_2 and X_1 and S_3 estimated from equations (A2) and (A3) respectively. Therefore, the SNMM estimates avoid the two problems of the standard regression methods discussed earlier. The supplementary materials have provided a simulation example to illustrate why the OLS estimates do not equal to the CDE of grandparents defined in equation (1) and why we can obtain unbiased SNMM estimates even if U and W are unobserved.

PART III: A SIMULATION EXAMPLE OF SNMM ESTIMATES

I simulate a dataset based on the data generating process shown in Figure 1. This example illustrates that we can obtain unbiased controlled direct effects (CDE) of grandparents using structural nested mean models (SNMM) described in this paper even if we do not observe time-varying variables *U* and *W*. The STATA codes are shown below.

```
clear all
      set obs 5000
      set seed 666666
      gen u1 = rnormal()
      egen u2 = std(0.5*u1+rnormal())

      gen w1 = rnormal()
      egen x1 = std(0.5*w1+rnormal())
      egen s2 = std(0.5*x1+0.5*u1+rnormal())

      gen w2 = rnormal()
      egen x2 = std(0.5*x1+0.5*s2+0.5*w2+rnormal())

      gen w3 = rnormal()
      egen s3 = std(0.5*x2+0.5*s2+0.25*x1+0.5*w3+rnormal())
      gen x1s3 = x1 * s3  //interaction between x1 and s3
      gen y = 0.5*x2+0.5*s3+0.25*s2+0.25*x1+0.25*x1s3+0.5*u2+0.5*w3+rnormal()

      /* step 1: regular OLS - additive model */
      reg y x1 x2 s2 s3   //coef(x1) = 0.172
      reg y x1 x2 s2 s3 u2 w3 //coef(x1) = 0.274

      /* step 2: regular OLS - interactive model */
      reg y x1 x2 s2 s3 x1s3  //coef(x1) = 0.170; coef(x1s3) = 0.233
      reg y x1 x2 s2 s3 x1s3 u2 w3 //coef(x1) = 0.272; coef(x1s3)= 0.233

/* note: (1) the omitted variables will affect the OLS estimates of x1 */
/* because u2 is correlated with x1 and y when s2 and s3 are controlled*/
/*(2) the OLS estimates do not give us the CDE of grandparents we want */
/* because we control away the effect of x1 on y that is transmitted   */
/* through s2 and s3; (3) the coefficient of x1s3 is not biased due to */
/* the omission of u2 and w3 because it is not correlated with both u2 */
/* (or w3) and y when s2 and s3 are controlled. I've shown this point  */
/* in Appendix A.                                                      */


      /* step 3: SNMM - additive model */
      /* remove X1 from S2 */
      reg s2 x1
      gen r_s2 = s2 - _b[_cons] - _b[x1]*x1

      /* remove X1, X2, S2 from S3 */
      reg s3 x1 x2 s2
      gen r_s3 = s3 - _b[_cons] - _b[s2]*s2 - _b[x1]*x1 - _b[x2]*x2

      /* structural nested model */
```

```
      xi: reg y x1 x2 r_s2 r_s3  //coef(x1)=0.496 (assuming we don't observe
u2 and w3)
      xi: reg y x1 x2 r_s2 r_s3 u2 w3 //coef(x1)=0.507 (assuming full
information for all variables)

      /* step 4: SNMM - interactive model */
      xi: reg y x1 x2 r_s2 r_s3 x1s3 //coef(x1)= 0.493; coef(x1s3)= 0.232
      xi: reg y x1 x2 r_s2 r_s3 x1s3 u2 w3 //coef(x1)= 0.503; coef(x1s3)=
0.233

/* note: (1) the omitted variables u and w will not affect estimates   */
/* of x1 and x1s3; (2) the snmm estimates are bigger than the OLS      */
/* estimates because they do not remove parts of grandparent CDE       */
/* that work through s2 and s3; (3)the estimates are slightly different*/
/* in models w/ and w/o u2 and w3 because the correlation between x1   */
/* and w3 and between x1 and u2 are not exactly equal to 0 in the      */
/*  simulated data. See this in the correlation matrix below.          */

      corr x1 x2 r_s2 r_s3 s2 s3 u1 u2 w1 w2 w3 y
```

REFERENCES

Hout, Michael and Alexander Janus. 2011. “Educational Mobility in the United States Since the 1930s.” 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.

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