INTRODUCTION AND BACKGROUND

Multigenerational Effects. This paper reports analyses of the effects of demographic trends on the mutual exposure of grandparents and grandchildren in the United States and the consequences of trends in exposure for multigenerational transmission of educational inequality. With growing socioeconomic inequality and widening concern about how families pass their socioeconomic advantages to their offspring, social scientists have increasingly focused on the potential role of multigenerational influences. The dominant approach to the study of social mobility and other intergenerational processes is to focus on two-generation nuclear family relationships alone. Connections between more remote kin, in this approach, derive from a chain of two-generational family connections that follow Markovian processes. Yet individuals may also be affected by a wider set of kin, including grandparents and other remote kin. Grandparents and others may directly affect subsequent generations by complementing or substituting for parents or through a variety of other institutional mechanisms embedded in families, the law, educational institutions, and financial transactions (Coall and Hertwig 2010; Mare 2011). Multigenerational effects may arise from direct connections between the statuses and resources of grandparents and grandchildren (or more remote kin) or from the combined effects of differential fertility and mortality and social mobility, which enable individuals in one generation to affect the numbers and socioeconomic statuses of persons in later generations (Mare and Maralani 2006; Maralani 2013; Mare and Song 2014).

Grandparent Effects and Multigenerational Exposure. Recent studies have examined social mobility from the perspective of three or more generations and focused on whether grandparents’ characteristics are associated with those of their grandchildren, even when characteristics of parents are statistically controlled (for example, Chan and Boliver 2013; Pfeffer 2014; Zeng and Xie 2014). Although these studies have considerable merit, their capacity to establish the importance of grandparent effects is incomplete. The importance of grandparents is, broadly speaking, proportional to the mutual availability or exposure of grandparents and grandchildren. To be sure, grandparents may influence their grandchildren and possibly subsequent generations of kin even after they die, through such mechanisms as wills and trusts, college legacy admission provisions, and wealth creation (e.g., Madoff 2010). But many of the most important mechanisms through which grandparents may influence grandchildren, especially when grandparents assist parents in raising children, require mutual exposure of grandparent and grandchild generations. A strong form of mutual exposure is actual co-residence in three-generation households, which may provide the most effective form of grandparental influence on grandchildren (Zeng and Xie 2014). But even when grandparents live apart from their adult offspring and their grandchildren, they are likely to exert a much stronger influence while alive than after they die.
Demographic Trends and Shared Lifetimes. Demographic changes in fertility and mortality have profound impacts on population level distributions of kin relations and expected years spent in family roles as grandparents, parents, children, and grandchildren. With substantial increases in longevity over the 20th century, children on average spend a larger proportion of their lives with living grandparents. Yet with fertility decline or fertility postponement, members of the grandparent generation have grandchildren who are fewer in number and born later in their lives. The grandchildren themselves are not affected by fertility levels, but if they are born to older parents (and to parents who themselves were born to older grandparents), they may have somewhat shorter exposure to grandparents than their counterparts born to younger parents (and parents who were born to younger grandparents). Overall, the effect of mortality changes has outweighed that of fertility changes, leading to an increase in overlapping lifetimes of grandparents and grandchildren during the 20th century in the United States and other societies (Bengtson 2001).

Inequality, Attainment, and Multigenerational Exposure. Trends in mutual exposure of grandparents and grandchildren affect socioeconomic inequality and mobility through socioeconomic differences in exposure. In this paper we consider several underlying mechanisms in the context of differences in educational attainment and mobility. (1) In any given period or generation, more highly educated grandparents provide greater potential benefits to their grandchildren. (2) Grandparent effects on grandchildren are likely to be greater when grandparents and grandchildren have shared lifetimes and mutual contact. (3) Secular increases in mutual exposure of grandparents and grandchildren create greater inequalities in overall family backgrounds of grandchildren because more advantaged children experience more years of exposure to relatively well educated grandparents whereas less advantaged children experience more years of exposure to less well educated grandparents. (4) Trends in inequalities may be amplified or reduced by differences among education groups depending on the nature of mortality and fertility trends. (5) Secular increases in mutual exposure of grandparents and grandchildren are likely to increase the associations of the educational attainments of grandparents and grandchildren (both zero order and net of parental characteristics) because of the growing capacity of grandparents to affect their grandchildren, whether in a favorable or unfavorable direction.

We report a systematic investigation of effects of mortality and fertility changes on the mutual exposure of grandchildren and grandparents in the United States over the 20th century, on inequalities in exposure among families with varying levels of educational attainment, and on the ways that exposure modify the associations between grandparents’ and grandchildren’s educational attainments. Our analysis of demographic effects extends the work of others, notably Margolis’ (2014) recent analysis of grandparenthood in Canada and Uhlenberg’s (1996; 2009) pioneering studies in the U.S. One novelty of our analysis is that we examine the mutual exposure of grandparents and grandchildren taking both a prospective and a retrospective approach (Song and Mare [forthcoming]). Additionally, we obtain estimates of exposure and the effects of demographic trends for grandparents and grandchildren specific to the education levels of grandparents. This shows the degree to which trends and differences in exposure affect trends in both socioeconomic inequality and grandparent-grandchild educational mobility.
MARE-SONG

METHODS

Synthetic Cohorts. We use formulas derived from stationary and stable population assumptions to estimate synthetic cohort estimates of grandparent-grandchild exposure for each decade between 1900 and 2010. We apply these formulas to historical information on fertility and mortality to estimate trends in shared lifetimes of grandparents and grandchildren for the population as a whole and for grandparents with varying levels of educational attainment. We also obtain counterfactual estimates based on varying assumptions about changes in fertility and mortality. In particular, we examine the effects of mortality, fertility levels (measured by the gross reproduction rate), mean age of childbearing, and variance of age at childbearing by varying each of these parameters while holding constant the others.

Prospective and Retrospective Approaches. Prospectively, we ask, from the perspective of a person in the grandparent generation, what is his or her exposure to grandchildren during the grandparent’s lifetime. We measure exposure in three ways: (1) years lived with *any* grandchild, (2) years lived with all grandchildren (grandchildren-years-lived), and (3) years lived per grandchild. The first two of these measures are sensitive to fertility levels and timing in the grandparent and parent generations as well as grandparent mortality. The third measure conditions on a given grandchild and is sensitive only to fertility timing and grandparent mortality. The prospective approach focuses on the capacity of a grandparent of a given status to produce progeny of varying characteristics in subsequent generations. From the perspective of grandparents, grandparenthood extends from the birth of the first grandchild to the grandparents’ end of life or, in rare cases, the death of the last grandchild.

Retrospectively, we ask, from the perspective of a grandchild, what is his or her exposure to grandparents during the grandchild’s lifetime. Again, we measure exposure in three ways: (1) years lived with any grandparent, (2) years lived with all grandparents (grandparent-years-lived), and (3) years lived per grandparent. The retrospective approach focuses on the “family background” of the grandchild. This is the most common way that kin relations are viewed in research on the effects of socioeconomic background and childhood family structure on the eventual socioeconomic attainment in the offspring generation. From the perspective of grandchildren, however, individuals from the same grandparents spent variable amounts of time with their grandparents; that is, grandchildren born earlier live longer with their grandparents than their later born siblings or cousins do.

Measures of Grandparent-Grandchild Exposure. In our initial analyses we assume a homogeneous one-sex, female population in which fertility and mortality rates are independent across generations within a family and individuals mate at random, although we will relax these assumptions in later analyses. For a given period, denote the probability that a woman survives to age $x$ by $l(x)$ and the probability that she gives birth between age $x$ and $x + dx$ by $m(x)$, which is non-negative between the limits of the childbearing ages $\alpha$ and $\beta$ and 0 outside these limits. Our estimates are based on the formulas discussed in this section applied to historical information on fertility and mortality. Our basic formulas are listed below. More details about their derivation and interpretation will appear in the full paper.

Prospective average years lived with any grandchild. For a woman at birth, her number of years lived with any granddaughter (daughter’s daughter) during her expected lifetime $e_0$ is
$$P_1 = \int_{2a}^{e_0} \min \left( \int_a^{e_0-x} l(x)m(x) \frac{l(a)}{l(x)} l(y)m(y)l(a-x-y)dydx, 1 \right) da$$

where the term \( \int_a^{e_0-x} l(x)m(x) \frac{l(a)}{l(x)} l(y)m(y)l(a-x-y)dydx \) is the number of living granddaughters that a woman has at age \( a \).

**Prospective average person years lived with all grandchildren.** For a woman at birth, her total number of years lived with all granddaughters during her expected lifetime \( e_0 \) is

$$P_2 = \int_a^{e_0-e_0-x} l(x)m(x) \frac{l(e_0)}{l(x)} l(y)m(y)l(e_0-x-y) \cdot (e_0-x-y)dydx.$$

**Prospective average years lived per grandchild.** At a woman’s birth, her expected number of years lived with an average granddaughter (daughter’s daughter) during her lifetime \( e_0 \) is

$$P_3 = \frac{P_2}{\int_a^{e_0-e_0-x} l(x)m(x) \frac{l(e_0)}{l(x)} l(y)m(y)l(e_0-x-y)dx},$$

where \( \int_a^{e_0-e_0-x} l(x)m(x) \frac{l(e_0)}{l(x)} l(y)m(y)l(e_0-x-y)dx \) is the number of granddaughters the woman has at age \( e_0 \).

**Retrospective average years lived with any grandparent by age 25.** By the time a woman reaches age 25 her average years lived with her maternal grandmother is:

$$R_1^* = \int_0^{25} P_{mm}(a) = \int_0^{25} \int_0^{\beta} e^{-r(x+y)} l(y)m(y)l(x)m(x) \frac{l(x+y+a)}{l(y)} dx dy da,$$

where \( P_{mm}(a) \) denotes the probability that a woman’s maternal grandmother is alive when the woman is aged \( a \). To estimate average years lived with any grandparent, including maternal and paternal grandmother and grandfather, we estimate the corresponding probabilities for each of the four grandparents. The probability that this woman at age \( a \) has at least one living grandparent is \( P_g(a) = 1 - (1 - P_{mm}(a))(1 - P_{mm}(a))(1 - P_{m}(a))(1 - P_{ff}(a)) \) and her average years lived with any grandparent is

$$R_1 = \int_0^{25} P_g(a) da.$$

**Retrospective average grandparent-years lived.** A woman’s expected person years lived with all grandparents up to age 25 is:

$$R_2 = \int_0^{25} (P_{mm}(a) + P_{m}(a) + P_{mf}(a) + P_{ff}(a)) da.$$

**Retrospective average grandparent-years lived per grandparent.** Assuming that each woman has exactly four grandparents, her average number of years she will be exposed to each grandparent is: \( R_3 = R_2/4 \).
DATA

To obtain mortality estimates for the nation as a whole, we rely on published decennial life tables for 1900 to 2010 (Carter et al. 2006; U. S. National Center for Health Statistics 1964, 1975, 1985, 1997, 2008, 2014; U.S. Bureau of the Census 1921; U.S. Department of Health Education and Welfare 1954; U.S. Public Health Service 1947). For age-specific fertility rates (ASFR), we use national vital registration data (U.S. Bureau of the Census 1975; U.S. Centers for Disease Control and Protection 2013) for the period from 1940 to 2010 and vital registration data adjusted for geographic incompleteness for 1900 to 1940 (Linder and Grove 1947; Haines 1989). We estimate total fertility rates (TFR) based on ASFRs for five-year age groups and convert each TFR to a Gross Reproduction Rate (GRR). Instead of assuming constant age-specific fertility rates within each age group, we assume a truncated normal distribution of fertility within the range of reproductive ages 15 to 45 for women and 15 to 60 for men. The means ($\mu$) and variances ($\sigma^2$) of the age of childbearing are estimated from the observed distributions of age-specific fertility rates by year. We provide more detailed description of the method in the final paper.

For education-specific trends in mortality, we rely mainly on the published estimates of life expectancy at age 25 (Kitagawa and Hauser 1973; Elo and Preston 1996; Rogot et al. 1992; and U.S. Centers for Disease Control 2011, 2014; U.S. National Center for Health Statistics 2012) and construct period life tables for education groups based on regional model life tables (Coale, Demeny, and Vaughan 1983) and unpublished United Nations life tables for populations with higher expectations of life than are included in the Coale-Demeny-Vaughan model tables. For fertility, we use age-education-specific rates for 1940-90 computed by the own children method Mare (1997) and for 2000-10 computed directly from vital registration, Census, and American Community Survey data. For social mobility, we create period-specific intergenerational educational mobility tables by pooling data from the 1962 and 1973 Occupational Changes in a Generation surveys, the 1972-2014 General Social Surveys (GSS), and the 1968 wave of the Panel Study of Income Dynamics (PSID), as well as estimates from Mare (1997) based on wave 2 data from the 1986, 1987, and 1988 Survey of Income and Program Participation (SIPP), GSS data from 1972 to 1994, and the 1987-1988 National Survey of Families and Households. For historical changes in the educational attainment distribution we rely on published aggregate data on years of school completed for people age 25 years and over by age and year (U.S. Bureau of the Census 2014).

For simulating how trends in multigenerational exposure may change the associations between grandparents’ and grandchildren’s educational attainment, we use microdata from all waves (1968-2013) of the PSID, which provide a large sample of mutual exposure and educational attainment measures for three generations of family members.

PRELIMINARY RESULTS

Trends in Mutual Exposure. Table 1 summarizes, in qualitative terms, the effects of mortality and fertility trends on our six measures of exposure. (Detailed quantitative estimates will be included in the final paper.) Figures 1 and 2 highlight several patterns contained in the detailed estimates. Figure 1 shows that, over the 20th century, the expected number of years that a person could expect to live with any grandchild increased markedly from less than 5 years to almost 35
years. This trend is overwhelmingly due to increased longevity. Absent changes in fertility levels and age patterns, the trend would be much the same, even somewhat more in the direction of increased exposure. All fertility effects on this exposure outcome are relatively modest, although changes in average age of childbearing (in both grandparent and parent generations) tended to increase exposure through the baby boom years and then reduce it somewhat as average childbearing age increases. Because of interaction between mortality and fertility levels, the fertility effect would be bigger if we fix the mortality level a lower level than observed in Figure 1. Figure 2 shows that, from the standpoint of grandchildren, their exposure to grandparents increased as well, albeit only about 5 years over the course of the century. Increases in longevity are primarily responsible for this trend although, again, grandchildren’s exposure to grandparents also varies inversely with average age at childbearing over this period.

Figure 3 illustrates how trends in mutual exposure vary by the educational attainment group of grandparents, as measured prospectively by the years a grandparent shares with any grandchild. For the most part, the education-specific trends mirror the trends for all groups combined. However, in the early 20th century, mutual exposure of grandparents and grandchildren was greater for the least educated grandparents than for families in which grandparents had more schooling. This differential results from the higher and earlier fertility in less educated families during this period and, compared to later periods, a somewhat smaller mortality differential among education groups. In contrast, 100 years later, exposure is greatest for grandparents with 12 years of schooling and least for the lowest education groups. These changes reflect a compression of fertility differences among education groups combined with somewhat higher mortality differentials in the recent period. The final version of the paper will present trends in all six of our exposure measures for each of five levels of grandparents’ educational attainment and for the population as a whole.

Mutual Exposure and Family Inequality. Figure 4 illustrates how grandparent exposure and educational attainment combine to reveal greater inequality and greater growth in inequality of family backgrounds than one can see from the distribution of grandparents’ educational attainments alone. We weight grandparent’s years of school completed by the expected number of years of mutual exposure between a grandparent and any grandchild. From the standpoint of this measure, exposure-weighted educational attainment grows for all grandparent education groups over the past 100 years, but much more so for highly educated grandparents. The expected gap between the highest and lowest education groups is approximately 75 years at the beginning of the 20th century, but grows to almost 500 years over the subsequent 100 years. In the full paper we will show how robust this trend is across our six measures of mutual exposure and for measures that relax the assumption in Figure 4 that each year of grandparent educational attainment and each year of shared lifetime make an equal contribution to grandchildren’s eventual educational attainments.

Exposure and Multigenerational Transmission. Figure 5 shows the hypothetical relationship between mutual exposure of grandparents and grandchildren and the association between grandparent’s and grandchildren’s educational attainments. For the purposes of this calculation we assume that the association of grandparent’s and grandchild’s educational attainment is fixed over periods or generations but increases linearly with the number of shared lifetime years of grandparent and grandchild (up to a maximum of 25 years). Given this assumption and the estimated trends in shared lifetime between 1900 and 2010, Figure 5 shows that the zero order
regression between grandparent’s and grandchild’s schooling is expected to increase by a factor of more than three during this period, illustrating that grandparent effects are stronger when grandparents live long enough to influence their grandchildren. This calculation merely illustrates the guiding hypothesis of this paper. In the final paper, we will present empirical estimates of grandparent-grandchild associations from three generation PSID data, explore the robustness of our results to alternative exposure measures, and examine both zero order associations in educational attainments of grandparents and grandchildren and also net associations that control for parents’ educational attainments. Additionally, we will examine a variety of measures of intergenerational association, including linear regression, probability models for attainment of key educational milestones (e.g., college attendance), and measures developed in our earlier work for the combined effects of differential fertility and intergenerational transmission on the reproduction of educational hierarchies (Mare and Maralani 2006; Mare and Song 2014; Song and Mare 2014).

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## Table 1. Summary of Relationships between Demographic Changes and Grandparent-Grandchild Exposure

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Independent Variables</th>
<th>Fertility Level</th>
<th>Fertility Timing</th>
<th>Mortality</th>
<th>Interactions between fertility level and mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean age of childbearing</td>
<td>Std. Dev. of net maternity function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prospective</td>
<td></td>
<td>Fertility Level</td>
<td>Fertility Timing</td>
<td>Mortality</td>
<td>Interactions between fertility level and mortality</td>
</tr>
<tr>
<td>Average years lived with any grandchild</td>
<td>Positive</td>
<td>Negative</td>
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<td>Negative</td>
<td>A bigger fertility effect when mortality is low</td>
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<tr>
<td>Average years lived sum over all grandchildren</td>
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<td>Negative</td>
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<td>Negative</td>
<td>None</td>
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<tr>
<td>Average grandchild-years lived per grandchild</td>
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<td>Negative</td>
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<tr>
<td>Average grandparent-years sum over all grandparents</td>
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<td>Negative</td>
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<tr>
<td>Average grandparent-years lived per grandparent</td>
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<td>Negative</td>
<td>None</td>
<td>Negative</td>
<td>None</td>
</tr>
</tbody>
</table>
Figure 1. Prospective Years of Shared Life with Any Grandchild

Figure 2. Retrospective Years of Shared Life with Any Grandparent
Figure 3. Prospective Years of Shared Life with Any Grandchild by Grandparent’s Educational Attainment

Figure 4. Education-Weighted Expected Years of Exposure to Any Grandchild
Figure 5. Simulated Multigenerational Exposure and Regression of Grandchild’s on Grandparent’s Educational Attainment