Sibship in Low Fertility Settings: A Microsimulation Approach

THESIS

Presented in Partial Fulfillment of the Requirements for the Degree Master of Arts in the Graduate School of The Ohio State University

By

Colin Odden

Graduate Program in Sociology

The Ohio State University

2013

Master's Examination Committee:

Professor John Casterline, Advisor; Professor Edward Crenshaw;

Professor Zhenchao Qian
Abstract

This thesis examines the variation in lifespan sibling availability in low fertility populations. Demographic transition has had profound effects on family structure, shrinking kin networks while extending the duration of kin ties. Siblings are unique among these ties in their duration, degree of shared contexts, and salience for various outcomes (such as support of aging parents). While low fertility yields smaller sibships ceteris paribus, sibship distributions can vary among low fertility populations. Indeed, the variety of unique sibships – sib sets with only sibling dyads of a particular type – increases as fertility decreases. The composition of sib sets is dynamic, too: lifespan sibling availability varies, depending upon mothers’ fertility patterns. This study uses kinship microsimulation to model the lifespan composition of individuals’ sib sets, focusing on three critical life course stages: during childhood, at orphanhood, and near death. The microsimulations illustrate how sib set composition is linked to its roots in women’s fertility by varying: (i) women’s age at first union, (ii) women’s average number of children, and (iii) variance among women in number of children. The thesis demonstrates that low fertility allows for diversity and lifespan variation in sibship size (average and distribution). This finding has applicability to current and future low-fertility populations, especially in light of indications that low fertility in some non-Western societies may have a different structure than observed in the West and East Asia.
Vita

1993...........................................................East High School, Columbus Ohio
1998..........................................................B.A. Economics, Ohio State University
2010 - Present ...........................................Graduate Associate, Department of
                                                Sociology, The Ohio State University

Fields of Study

Major Field: Sociology
# Table of Contents

Abstract ........................................................................................................................................... ii

Vita ................................................................................................................................................... iii

List of Tables ..................................................................................................................................... v

List of Figures ................................................................................................................................. vi

Introduction ....................................................................................................................................... 1

Background ....................................................................................................................................... 4

Analysis ........................................................................................................................................... 18

Results ............................................................................................................................................ 27

Discussion ....................................................................................................................................... 36

References ....................................................................................................................................... 44

Appendix A: Tables and Figures ........................................................................................................ 54

Appendix B: SIMKIN .......................................................................................................................... 54

Appendix C: Simulation Inputs ........................................................................................................... 57
List of Tables

Table 1. Distributions of siblings resulting from three distributions of mothers’ completed parities................................................................. 13
Table 2. Manipulated specified parameters of eight simulated populations................... 49
Table 3. Fertility characteristics of mothers’ generation ............................................. 49
Table 4. Characteristics of ego’s generation .................................................................. 50
Table 5. Percent of egos ever having a sibling, by dyad type........................................ 51
Table 6. Percent of egos with combinations of sibling dyads, and ‘exclusion’ dyads. .... 52
Table 7. Sibling availability during childhood, at orphanhood, and at ego’s death......... 60
Table 8. Model Inputs: Distribution of ages at death.................................................... 61
Table 9. Model Inputs: Distribution of age difference between ego and partner.......... 61
Table 10. Model Inputs: Cumulative probability of union not dissolving.................... 62
Table 11. Model Inputs: Cumulative probability of period post-dissolution not resulting in subsequent union, by period duration (months)........................................ 62
Table 12. Model Inputs: Birth interval length (months), by percentage of births completed........................................................................................................... 63
List of Figures

Figure 1. Lifespan variation in sibling availability across eight simulated populations. 53
Introduction

Siblings are important. They are competitors and collaborators, conspirators and confidants. "Sibling-hood" is a long-lived social tie, marked by shared experience within a variety of contexts: household, family, neighborhood and historical period. The study of siblings has a long history in anthropology, demography of the family, and developmental psychology, sometimes catching the attention of the popular press (e.g. Kluger 2012). Sibling ties are “Simmelian ties,” with strong mutual ties within the sibling dyad and to other family members (Krackhardt 1999). Competing for resources while expected to behave altruistically with one another, sibling ties are also fraught with ambivalence. Schemas for relationships are informed by experience, shaped by the characteristics of one’s alters; to the extent that siblings contribute to individuals’ socialization, the composition of one's siblings is consequential for how one ultimately relates to others (Martin 2011). They tend to be the longest-lived relationships one can have, and are the ties most likely to be held both in childhood and adulthood. In some societies, sibling ties take priority over filiation (Carsten 2011).

Siblings are not chosen. Rather, they are "given" through parents' fertility and nuptiality and "lost" through death. Demographic processes shape the number and kind of siblings one has and how long they are known. These forces also shape the family contexts through which people come to know their siblings, and influence when they are likely to be competing for resources or providing mutual support. Declining fertility and mortality
tend to both decrease family size and extend the duration of family ties. In post-transition demographic regimes, siblings tend to be fewer but are known for a longer time. Demographic changes do not proceed along the same trajectory for all populations at all times, and they are not guaranteed to converge to uniform patterns of fertility, mortality and nuptiality. Family sizes vary and, to the extent that family structure matters, individuals with different family structures will have distinctive life experiences. More specifically, insofar as siblings are consequential to one's experiences, different sibling configurations give rise to distinctive life conditions. As demographic transition leads populations to lower fertility and smaller family sizes, the prevalence of unique sibling configurations may increase: a greater proportion of individuals may have only a brother, only a sister, only a younger or only an older sibling, and so on.

Despite siblings' importance, prior research has presented only the basic demographic facts of sibship, using family-level constructs such as sibship size to characterize a relationship that is dynamic over an individual’s life span. This lack is partly due to lack of measurement: the complexity of kinship poses nontrivial empirical challenges. This study uses microsimulation to compare the demography of sibship under different demographic scenarios, illustrating how modern demographic conditions can yield significant variation in an individual's available siblings.

The purpose of this paper is not to reinforce or challenge links between sibship size and outcomes. Rather, the goal is exploratory, with two major components: First, to illustrate variation in the distribution of sibship sizes in a child’s generation resulting from variation in fertility in the parent’s generation. Second, to show the life course variation
in sibling availability produced by variable fertility, emphasizing the variability of particular sibship configurations.

While sibling ties may be consequential throughout one’s life course, the focus here is on three stages that have been shown to be particularly important: during childhood, when one’s parents are dependent or dying, and near one’s own death. The focus, then, is on research relevant to the impact of sibship at these stages. The next section indicates the variety of sibling configurations possible in low-fertility, low-mortality populations, as well as the uncertainty of consequences of transition to low fertility and potential for variation within low fertility regimes.

This study is predicated on the idea that siblings are distinctive kin with a special role major life course stages. Thus, it does not consider the presence or role of other kin, nor does it situate siblings in broader non-kin networks. This is not to say that siblings are the primary alters of interest in one’s network, or that other kin and non-kin are not important (they clearly are), nor that one’s network alters cannot substitute at all for one another. Rather, siblings are a distinctive sort of kinship tie, they are not fully substitutable by other kin or non-kin, and are consequential sui generis in one’s support network.
Background

The term "sibship" is used alternately to abbreviate both sibling relationships and sibling configurations. "Structural features of sibship" refer to sibship size (number of siblings) and the gender and age composition of a given sib dyad. A "sibship configuration" is the set of structural features characterizing a given sib dyad; the plural "sibship configurations" refers to variety in these structural features across sibships.

*The importance of siblings*

Siblings are a primary feature of an individual’s family of origin. An individual shares with her siblings the contexts of family, neighborhood and historical period. For those with siblings, sibship is important throughout the entire life course (Cicirelli 1995; Conger and Little 2010; Connidis 2009; Riggio 2006). While the salience of sibship is not an historical or cultural constant, its grounding in childhood experience and broader kinship networks increase its durability over the life course. As part of individuals’ family of origin, siblings may fade into the background when one forms a conjugal family (Parsons 1943), but provide continuity in kin networks after transitions such as the death of parents and when one’s own children leave home and form families. Three life course phases have received particular attention: during childhood, when children have elderly parents, and in later life.
Siblings during childhood

Studies of siblings in the social sciences have focused on the relationship between the structural features of sibship, principally sibship size, and child outcomes. A great deal of attention has focused on effects of sibship size on resources available to children, as well as on child outcomes. The report Growing Up Global (National Research Council 2005) and the review by Steelman et al (2002) provide a thorough review of this large literature.

The effects of birth order and sibship size have been theorized alternately in terms of “resource dilution” (Blake 1981; Downey 2001) and “confluence” theories of the marginal influence of an additional child on household intellectual and cultural resources (Zajonc 2001). Studies of child development show positive effects of siblings on theory of mind (O’Brien et al 2011) and false belief consciousness (Ruffman et al. 1998).

Donwey & Condron (2004) find the common negative relationship between sibship size and cognitive skills, but also find that kindergarteners with at least one sibling are evaluated by their teacher as having better social skills than only children. These studies complement family research that increasingly reveals siblings as mutual support and not simply as competitors (Cicirelli 1995; Conger and Little 2010; White 2001).

The presence of siblings has been associated with a variety of behavioral outcomes. Work in developing countries has largely focused on child and maternal survival (Bhutta et al. 2010; Sear and Mace 2008), whereas studies of the effects of sibship on individuals in the developed world has focused on educational and labor market outcomes (Steelman et al. 2002). More recent work has examined more diverse outcomes, such as health and risk behaviors (Altonji et al 2010; Argys et al 2006) sexual debut (Widmer 1997) and deviance (Haynie and McHugh 2003). Ethnographies (Zukow-Goldring 2002) and family
studies (Whiteman, McHale, and Crouter 2007) illustrate the multifaceted nature of sibling relationships, where birth order and the presence of an older sibling contribute to social support, social learning, and individuating processes through de-identification with a close sibling. A meta-analysis by Buist, Deković, and Prinzie (2008) of thirty-four studies of child and adolescent siblings links sibling relationship quality, sib dyad gender composition and equal treatment by parents to fewer negative internalizing and externalizing behaviors.

The gender of one’s siblings is important as well. Sisters have been shown to reduce both boys’ and girls’ likelihood of feeling unloved or insecure (Padilla-Walker, Harper, and Jensen 2010). Akresh and Edmonds (2011), using data from Burkina Faso where household production and rates of child labor are high, find that sib set's gender composition is related to the level of education across the sib set, but this relationship only holds in households that do not engage in 'fostering networks' that exchange children's labor with other households. Zheng et al (2012), analyzing data on native Amazonians in Brazil, find that in poorer households younger siblings, particularly those with an older brother, tend to have lower educational attainment and are less likely to enroll in school, but that in richer households this association is weak and having an older sibling does not decrease girls' likelihood of enrolling in school.

Structural features of sibship are meaningful for an individual’s orientation toward extra-family relationships and institutions. Zajonc & Markus (1975) emphasized the configurational role of sibships in child outcomes. Shavit and Pierce (1991) show how greater sibship density (age concentration) has positive effects on the school attendance of Arab children in Israel. Kitzmann, Cohen, and Lockwood (2002), studying US
elementary school children, found that only children were similar to their sibling-having counterparts in number of friendships, but were both liked less by their peers and more likely both to be aggressive and victimized in their peer group. In a separate study of US elementary school children, Kitzmann et al (2002) find both that having siblings reduces peer rejection among children who experience high stress, and that children with siblings who also experience high stress exhibit fewer aggressive behaviors than do single children with a similar level of stress. The effects of sibship size do not operate independently of the population distribution of family size: Marteleto (2010), comparing 1963 and 1983 birth cohorts from Brazil, shows that the negative association between sibship size and adolescents’ educational attainment is stronger in the later cohort where the country’s mean family size is smaller.

**siblings with dependent parents**

Family members provide the majority of care for dependent elders (Piercy and Chapman 2001), and among family members providing care adult children are the primary caregivers to their elderly parents (Connidis and Kemp 2008). In fact, Wolf (2004) notes that policymakers often reference family care as an alternative to institutional care in the face of shrinking retirement and pension budgets. Child characteristics are relevant to the caregiving relationship, but operate in larger family contexts. A larger sibship yields more kin who are nominally available to provide care, but attributes of those kin such as gender, marital status and parenthood may affect their availability and engagement. Daughters provide the most care for dependent parents "with almost every type of care giving task" (Huquembourg & Brailer, 2005). Unmarried only daughters may be the most likely to care for dependent parents, and married sons with a sister the least likely (Soldo,
D A Wolf, and Agree 1990). Thompson (2002) finds that "men are vital to caregiving networks," although Spitze and Logan (1990) note "…the key to receiving help is having at least one daughter." Children’s parenthood and union status affect availability, however, such that a married son who is also an only child may be more likely to provide care (Brody et al 1995). Connidis & Kemp (2008) emphasize the role of structural features of sibship in the negotiation of caring for parents.

Demographic transition has shifted the relationship between older and younger kin. The inversion of the “family pyramid” in China, for example, where one-child families produce a halving of generations within families, care for elders is distributed among fewer kin per generation. Zhan (2005) highlights this point in the gendered nature of the burden of care in China: women who care for elders are more likely to receive neither pension nor medical benefits than their male counterparts and obtain lower incomes than men when both employed and providing care.

_Siblings in older age_

Attention has been paid to sibling relationships beyond childhood (Spitze and Trent 2006; Tomassini and Wolf 2000; Weaver, Coleman, and Ganong 2003; White and Riedmann 1992; White 2001). Even when siblings are geographically distant and contact is infrequent, individuals nominate siblings as network ties they rely on for emotional and instrumental support. Gold (1987), studying Americans and Canadians over the age of sixty-five, observes that a lifetime of shared experiences make sibling relationships unique in the networks of older adults, and even those siblings whose relationships had historically been negative report more positive interactions with siblings in old age. Note
that these studies are limited to sibship in contemporary post-transition societies, and all but Tomassini & Wolf study the sibship dynamics of US or Canadian adults. The character and strength of sibling ties in older age appears to be influenced by the sib dyad's gender composition. Sisters tend to have stronger relationships than either brother-brother or brother-sister combinations (Campbell, Conนidis, and Davies 1999; Lee, Mancini, and Maxwell 1990; White and Riedmann 1992; White 2001). Cicirelli (1989), in a US study of 83 persons aged 61-91, finds that perceived closeness to a sister is associated with less depressive feeling for both men and women, and that women who report conflict or indifference toward a sister report greater depressive feeling than those who do not. While marriage may remove women from their family of origin, women have historically been families’ "kin-keepers" (Hagestad 1986) who help preserve family ties. Women are more likely both to initiate and to maintain these ties (Fischer 1982; Lee et al 1990; Reiss & Oliveri, 1983; Treas & Bengtson, 1987; White & Riedmann, 1992). While this study found no research on the availability of kin at death, measuring the prevalence of dying alone is a major challenge. Research on the experience of dying alone is minimal, although Klinenberg's (2001) "social autopsy" of Chicago heat wave deaths found that isolation strongly predicted mortality. Seale's (1995) study of 149 proxies to individuals in the UK who died alone showed that twice as many people with no known family died in an institution, alone, compared with those having at least one living family member. Older individuals’ nomination of a health care proxy provides an indication of available alters: Carr & Khodyakov (2007), using data from the Wisconsin Longitudinal Survey, find that, after spouses and children, persons in their early 60s are
most likely to nominate siblings for durable power of attorney for health care (DPAHC); among childless, unmarried individuals, siblings were the most frequent nominated.

_Sibship and low fertility_

_Sibling configurations through demographic transition_

The global portrait of sibship has shifted in the context of broad changes in the demography of the family. Pre-transition families, characterized by high fertility and high mortality, saw more births and relatively more deaths. Mortality declines typical of early demographic transition increased the number of children surviving to adulthood, creating unprecedented numbers of surviving lateral kin (not limited to siblings; cousins also, therefore, survived in greater numbers). This disrupted long-standing patterns of intergenerational transmission of resources, land tenure and family formation (Lenski 1964). The combination of low mortality and high fertility produced families that were both bigger and “wider,” with increases in both kinship ties and kin in or near one’s own cohort.

As both fertility and mortality decline, a child can expect to have fewer siblings but still quite a lot of aunts, uncles and cousins. Changes in children’s experiences accompany this change in family structure: compulsory schooling, reduced expectations of children’s labor both in and outside the home, and the emergence of “childhood” as a distinct life stage (Aries 1965) reshape children’s experiences, including increased contact with non-kin. Sustained low fertility makes families “narrower” and “longer,” leading to smaller families and longer generational spacing. The emergence of small families and an increased proportion of only children occurs jointly with a momentum of prior cohorts'
growth, leading to a stage of demographic transition during which cohort sizes grow while families shrink (Lam and Marteleto 2008).

In sum, an individual’s kin network depends upon her family's fertility and mortality. Fertility and mortality changes in a population, in turn, affect the composition of kin networks. At one extreme, a population of only children, sustained over generations, ultimately yields no brothers or sisters (or aunts, uncles, nephews or nieces). Eberstadt, citing the UN’s “low variant” projections, concludes that it is “… almost impossible today to imagine… a world in which the only biological relatives for many people – perhaps most people – will be their ancestors” (1997). At the other extreme, very large sib sets may blur or reduce the salience of particular sibling dyads, particularly as more children in the set have multiple siblings of the same or opposite sex, as well as both older and younger siblings.

Most studies of the relationship between sibship size and child outcomes focus on the distinction between only children and children with one or more siblings (cf Trent and Spitze 2011). Gondal (2012) finds significant differences between individuals with respect orientation to parents and non-kin alters between those having zero, one, two, three and more than three siblings. Earlier work, (Campbell et al, 2001; Ericksen and Gerstel 2002) focusing on intra-family sociation, shows similar sibship size relationships beyond the distinction between only children and having one or more. These studies find a decreasing marginal effect of additional siblings. That is, the difference between only-childhood and having a sibling or two is much greater than the difference between having two siblings versus three or four. If correct, sibship variation in low-fertility populations
is, therefore, of greater consequence than in those with larger average completed family size.

**Sibship variation under low fertility**

If demographic transition proceeded homogeneously, converging on low overall fertility with consistent age and sex distributions, there wouldn’t be much of a story to tell. As it happens, there’s ample evidence of variability of all of these factors in post-transition populations with low fertility (Goldstein, Sobotka, and Jasilioniene 2009). Micheli (2004), studying Europe, traces distinctive regional trajectories of fertility decline rooted in regionally distinct historical family structures. To date, there does not appear to be global convergence to a single pattern of low fertility or monolithic family structure.

Sibship variation is produced, unsurprisingly, by fertility variation in the parents’ generation. Fundamental to this study is Preston’s (1976) observation that family size from a mother’s perspective is different from that of her children, and that increasing the variance of fertility increases the mean sibship size (as well as possibly changing its variance). The distribution of completed parities (the number of children born to a woman by the end of her childbearing career), rather than the average number of children per woman, determines the distribution of sibship, and variation in completed family size is compatible with low population fertility. Thus, low fertility does not guarantee smaller sibships. Consider, for example, three populations each with equal mean completed parity (2.1), but each with a distinct distribution of completed parities:
<table>
<thead>
<tr>
<th>Completed Parity</th>
<th>% Women at parity</th>
<th># Siblings</th>
<th>% Children having # Sibs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>0</td>
<td>15%</td>
<td>5%</td>
<td>20%</td>
</tr>
<tr>
<td>1</td>
<td>25%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>2</td>
<td>35%</td>
<td>65%</td>
<td>30%</td>
</tr>
<tr>
<td>3</td>
<td>25%</td>
<td>10%</td>
<td>20%</td>
</tr>
<tr>
<td>4</td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
</tr>
</tbody>
</table>

*Mean completed parity: 2.1  2.1  2.1  
Mean # siblings: 1.6  1.47  2.01*

Table 1. Distributions of siblings resulting from three distributions of mothers’ completed parities.

The three populations have the same overall level of fertility, but the distribution of sibship sizes and average number of siblings varies substantially. Population C has twice the proportion of individuals having three siblings than the others, Population A has the highest proportion having two siblings, and Population B has nearly twice the proportion of single sibling pairs. The mean number of siblings per individual varies by a half sibling across the three examples. This variation results from the relationship between mother’s completed family size and number of sib dyads. An only child contributes zero sib dyads; a sibship of size two contributes two individuals each with one sib; size three contributes three individuals each with two; and a completed family size of four children contributes four individuals with three.

Having fewer siblings yields a lower probability of having a given kind of sibling dyad. The likelihood of having a brother and/or sister; of having a sibling of the same and/or opposite sex; and of being an older and/or younger sibling all increase with number of children in a sib set, all else being equal. Considering only sex and older versus younger siblings, someone with one sibling is 50% likely to have a brother (or a sister). S/he is
50% likely to have an older or a younger sibling. Adding another sibling increases the likelihood to 75% of having a sister or a brother to 75%, having both to 50%, and having only brothers or only sisters to 25%\textsuperscript{1,2}. A person with two siblings has a 2/3rds chance of having an older or a younger sibling, and a 1/3rd chance of having both, and a 1/3rd chance of only having older, or only younger, siblings. Adding a third sibling further increases the chance of having both sisters and brothers (to 87.5%), decreases the chance of only having brothers or only sisters (to 12.5%), and increases the chance of having both older and younger siblings (to 50%) and further reduces the chance of only having younger or only older siblings (to 25%). Paradoxically, a population with smaller families increases the potential range of sibling configurations: When completed family size is small, one is more likely to have only sisters, only brothers, only younger siblings, or only older ones.

*Life course variation in sibship sibling availability*

Sibship size is often treated as fixed within a family, the total children born to a mother. The number of siblings one has is not time-invariant, however. Variable birth spacing compounds the variety produced by other factors. The pattern of birth spacing is constrained by a woman’s reproductive career. In high fertility populations, children have more siblings and smaller mean spacing between them. The range of potential spacings increases as fertility decreases, conditional on starting, spacing and stopping behaviors (Bongaarts and Potter 1983). Women do not have static childbearing intentions (Bledsoe,

\textsuperscript{1} These same chances apply to having a sibling of the same sex or opposite sex, or both, respectively.

\textsuperscript{2} Note that these probabilities ignore parents’ sex preference. The male child of parents who prefer a boy is less likely to have brother, and the female child of those parents is more likely to have one. The child of parents with a preference for sex balance is more likely to have a sibling, because those parents are more likely to have two children, or more if the first two children are not of opposite sex.
Banja, and Hill 1998; Bledsoe 2002), and starting childbearing early and/or late in one’s reproductive career contributes to the variety of possible outcomes. With the exception of multiple births, siblings are spaced at least nine months apart, generally farther, and sometimes many years apart. The number and composition of an individual’s siblings, at a given time in her life, depend upon on her birth order, her mother’s birth spacing, and her and her siblings’ pattern of mortality. Again, the characterization of sibship size and other kinship configurations as effectively time-invariant does not aid our understanding of kin availability over the life course. More precise measurement of kin availability requires paying attention to the age pattern of fertility within families.

The variety of possible sibling configurations means that -- if we accept that single childhood, single sibship, and multiple sibships each has a distinct character -- the variety of potential sibling configurations in low-fertility regimes implies both different individual trajectories and networks, as well as distinct aggregate compositions. A population dominated by two-child families will have a different "character" from one with a mixture of single-, dual- and three-child families, even if they have the same population TFR. What are the consequences of variation within what we think of as low fertility for the distribution of sibship, and for individual life-course sibling availability?

Research Questions

This study seeks to address two main questions. First, what is the possible variation in sibling availability to individuals at key points in their life course in low fertility regimes? Second, in a constellation of interacting demographic factors, how does variation in sibling availability in the children’s generation correspond to variation in (a) onset of
childbearing, (b) the average level of childbearing, and (c) the distribution of completed parities in their mother’s generation?

Empirical challenges to measuring sibship over the life course

The measurement of sibships, particularly over their lifetime, is a massive task. In survey data, respondent reports about siblings are subject to nontrivial error. White (1998), comparing respondent reports in two waves of the National Survey of Families and Households, found discrepancies in the number of siblings reported across waves, particularly among respondents with complex families and complex family histories. More complex measurement – sex, age and mortality – increases both respondent burden and opportunities for error.

Abundant data are available if our concern is limited to sibling configurations during childhood. Many single-country and international survey programs\(^3\) collect data on women’s childbearing histories. These birth histories are usually limited to women in their childbearing years, typically defined as ages 15-49, so observed children may have only reached their mid-30s by the time their mother is interviewed. Also, the mother is the fundamental unit of analysis in these surveys; children of women who did not survive to the time of survey are not represented. Those who are orphaned at younger ages will be left unobserved\(^4\). Also, because these surveys almost exclusively collect data from the mother’s perspective, parent-child relations are recorded from the mother's perspective, such that full parent-child relations are not captured from the child's perspective. For example, a respondent reporting on her child from a union that dissolved may not report, or even be aware of, the other parent's subsequent nuptiality.

\(^3\) World Fertility Surveys; Demographic and Health Surveys; Multiple Indicator Cluster Surveys.

\(^4\) Note, however, that maternal mortality has declined worldwide, sharply in the period from 1990 to 2008 (WHO, 2010)
Measuring sibship over one’s full life course requires knowledge of the full sib set’s mortality. In the (typical) case of respondents who are alive, this means censoring not only for the respondent, but for all siblings who outlive her. Complete measurement of sibship requires data spanning the birth of the oldest sibling through the death of the longest surviving, for the full sib set, in addition to whatever other characteristics (nuptiality, etc.) are of interest. A single sibling dyad begins at the later of two births and ends at the earlier of two deaths. Two children born five years apart and dying at seventy-five years of age have seventy years of sibling-hood. This is a tall order.

Finally, even in the hypothetical case of a comprehensive study that accurately captures all demographic events of interest for the full sib set, measurement is only available for extant populations (and requires retrospective measurement at some point, unless mortality prediction becomes excellent). Uncertain demographic trajectories and the possibility of demographic “surprise” limit the usefulness of empirical techniques for speculating about the possible variation within low fertility. The analytic technique presented here -- demographic microsimulation -- is an appropriate method for such a task.
Analysis

This study uses demographic microsimulation to produce eight simulated “populations,” each comprising a cohort of women whose pattern of fertility produces a generation of children, hereafter termed ‘egos.’ Each population is produced via a unique fertility regime constituting a set of manipulated parameters as well as a set of fixed schedules. The three population parameters manipulated for comparison are the distribution of mothers’ age at first union; mothers’ mean completed parity; and the distribution of mothers’ completed parities.

Microsimulation

Pioneered by Orcutt (1957; Orcutt et al. 1976), microsimulation has been used extensively for demographic projection and for the analysis of historical and contemporary populations (for a review, see Morand et al. 2010). It is an attractive method for studying demographic phenomena at multiple levels: Simulations produce individual-level data and generate their results based on repeated random experiments rather than producing only population-level indicators. This random component makes microsimulation non-deterministic, exchanging a degree of realism for a degree of predictability. Microsimulation models are preferable over multistate life table models when one is interested in individual heterogeneity as well as population heterogeneity.

Note that ‘ego’ as used here is similar in meaning to ‘ego’ in network analysis, but the ‘egos’ in SIMKIN refer to the initial cohort of simulated individuals from whom kin networks initially extend. Once a multi-generational simulated population is generated, any simulated individual can be regarded as ego for the purpose of constructing an egocentric network around her/him.
That is, an individual’s behaviors and transitions are produced by random draw from a population’s probability distribution, subject to a set of behavioral rules. Demographic microsimulation excels at modeling change from the perspective of the individual, family and population, over the full life span.

Early social simulation approaches were plagued by unsupportable assumptions about the independence of social phenomena (Ruggles 1993). Contemporary microsimulation methods address these issues (Billari and Prskawetz 2003; Billari et al. 2005; Imhoff and Post 1998). Specifically, the probability of an event can be conditional on an individual's properties (for example, probability of age at first birth conditional on age at first union) and/or correlated among individuals (to capture, for example, associations among kin).

Microsimulation, as applied to demography, has two key features: the individual is the unit of analysis, and unknown attributes (variables) are assigned probabilistically or otherwise algorithmically. Microsimulation methods comprise two major types, *microsimulation models* (MSMs) and *agent-based models* (ABMs), also known as *multi-agent systems* (MAS) (for discussion, see Morand et al. 2010). Microsimulation models, MSMs, are the prevailing technique in demographic microsimulation.

Taking as its input a set of schedules of fertility, mortality and nuptiality, demographic microsimulation produces a population of simulated individuals, each with her own characteristics. These individuals can be followed over their simulated life course, observing features of the individual and her kin network along the way. Simulated individuals are born, they age and they die. They can form unions, those unions may dissolve, and individuals can subsequently form new ones (that in turn are at risk of dissolution). Individuals can produce offspring, who in turn are subject to their own

---

6 See Von Imhoff and Post (1998) for a discussion of microsimulation's demographic applications.
demographic schedules. Kinship linkages are created and preserved, so that the full lifespans of individuals within families can be modeled in ways that are typically too burdensome, or are subject to censoring, with elicited data.

The populations generated by microsimulation are fictional. However, the distributions that govern the probabilities of individual characteristics and outcomes need not be fictional: they may be derived from empirical research. The method's utility is due in part to its flexibility: microsimulation can utilize population parameters from empirical sources as well as “asserted” parameters chosen on theoretical rather than empirical grounds. This study uses a combination of theoretical and empirical schedules to situate manipulated parameters within a realistic context.

*Microsimulation as applied to the current study*

This study uses SIMKIN (Casterline, 2001, 2012), software for the microsimulation of kin sets\(^7\). The simulation generates a population of individuals, “egos,” and their kin. The modeling of kinship ties makes SIMKIN particularly appropriate to this study. Ego is guaranteed parents, but the presence of all other kin is conditional on the fertility, mortality and nuptiality patterns of ego and her kin network. SIMKIN produces the life span of every individual, so that each individual and her sib set can be modeled. Although this study focuses on close lateral kin, the kin networks produced by SIMKIN can be used to assess more complex kin configurations (Casterline & El-Zeini 2001, 2002).

Ego has the following characteristics:

- **Death**: Ego is assigned an age of death.
- **Union formation**: Ego enters a stable union if the randomly assigned age at union

---

\(^7\) The operational details of SIMKIN are outlined in Appendix A.
precedes her age at death. Otherwise, she is identified as never entering a union.

- **Age at first union**: If ego enters a union, this is her age at that first union.
- **Partner age difference**: if ego enters a stable union, this is the age difference with her partner.
- **Partner’s age at death**: If ego enters a stable union, her partner is assigned an age at death.
- **Time to union dissolution**: if ego enters a stable union and that union dissolves, this is the duration of the union.
- **Time to next union**: If ego's union ends in dissolution or in widowhood, she may enter another union. If she forms another, this event creates a second partner with her/his own birth year, age at death and date of dissolution (if applicable). *Note that the simulation affords up to two stable unions and two dissolutions or partner deaths.*
- **Completed parity**: Ego is assigned a completed parity (number of live births).
- **Birth history**: Ego is assigned an age at first birth, as well as a set of birth intervals based on her age at first birth and completed parity.

**Inputs to the Models**

This study uses a combination of empirical and theoretical (speculative) distributions to generate eight simulated populations. Each of the eight simulated populations in this study starts from a birth cohort of ten thousand women. It is their patterns of nuptiality, fertility and mortality that yields the population of egos (with siblings) whose sibship composition is examined. Appendix B presents the input data in detail. Some empirical distributions are held constant across models, while other distributions are manipulated to illustrate variation in outcomes corresponding to a change in inputs. Individual characteristics are derived via Monte Carlo, with random draws from the input distributions conditional on a set of decision rules (a woman may not enter a union or bear children after she dies, for example).

**Constants**

Mortality, nuptiality and some aspects of fertility are held constant across the eight
scenarios. These employ distributions derived from empirical sources chosen to represent plausible demographic patterns in a modern low-fertility, low-mortality population. Mortality distributions are derived from the Human Mortality Database (UC Berkeley & Max Planck Institute). Rates of union dissolution and re-formation, as well as the birth interval schedules, are derived from the National Survey of Family Growth (National Center for Health Statistics).

**Manipulations**

This study employs two manipulations: completed parity (four distributions), and age at first union (two distributions). The two manipulations are crossed, yielding the eight simulated populations. Table 2 outlines characteristics of each manipulation. The manipulations, while specified as they are to simplify interpretation and to represent meaningful variation within low-fertility settings, are intended to represent plausible, albeit hypothetical, populations.

**Distribution of Completed Parities and mean completed parity**

Four distributions of completed parities are used, producing three levels of completed fertility. In addition, two of these distributions specify the same level of overall fertility, but with different variance. These, and the distribution of siblings they produce in the children’s generation, are outlined in Table 2. These distributions are used twice in the eight scenarios, once for the younger median age at first union and again for the later median age. The distributions, labeled A, B, C and D, specify mean completed parities of 2.3, 1.7, 2.0 and 2.0 children per woman, respectively. Distributions A and B represent “high” and “low” versions of low overall fertility. Distributions C and D highlight the
consequences of preserving mean fertility while changing variance. Mean completed parity is functionally equivalent to total fertility rate.

Simulated women can have up to four children. Real populations will undoubtedly have some women with more than four children (therefore, children with more than three siblings), but a ‘ceiling’ of four births aids clear presentation of results. Although this limit is not totally inconsequential -- a theme of this paper is that larger sib sets receive proportionally greater representation in a population, and the future of low fertility is not certain -- sib sets of five and larger are comparatively rare in low fertility populations.

**Median Age at First Union**

The four parity distributions are simulated twice: once for a population of women whose median age at first union is twenty years, then separately for a population in whom it is thirty years. 'Union' is used here to characterize a stable sexual union, without implication of marriage or cohabitation. All women in the simulated populations are assigned an age at entry into first union (and enter the union if they survive to that age). The concept of a “stable union” is imperfect, but precise definitions are made more difficult by the decoupling of fertility from nuptiality that is a hallmark of contemporary low-fertility societies. Entrance into a union marks the onset of risk of pregnancy. All else being equal, earlier childbearing increases the likelihood of higher completed parity (among other reasons, because of risk of unintended birth after desired parity has been attained) and for broader child spacing. In contrast, delaying childbearing affects spacing of generations but has limited impact on completed parity, despite the impression one might get from popular media, because most women desire few children. (Subfecundability
(Wood 1994) will truncate the fertility careers of some women.) All else being equal, later onset of childbearing increases intergenerational spacing.

A note about inputs and determinism

As mentioned in the case of parity distributions, simulated populations are not a carbon-copy of their specified distributions. Microsimulation’s random component yields distributions of demographic events that do not perfectly resemble the inputs and, as noted earlier, demographic processes are not independent of one another. Input distributions represent potentials, rather than actuals. Actual realized distributions are a function of outcome of random draws from the specified distributions and on the dependence of one kind of demographic event (childbearing) upon another (sexual exposure, here characterized as being in a stable sexual union). The specified parity distributions represent potential fertility, that is, the numbers of births women would have if they were continuously in union and with a fertility career neither truncated by infecundity nor death. In fact, some women will have fewer births than specified by this schedule, and some will have more. Some careers will be truncated by subfecundity or death, and union dissolution and subsequent union formation can shift the pattern of births to exceed what is otherwise specified.

Measurement

This study takes the individual, ego, as the unit of analysis. Ego’s siblings are measured as those who are alive at the same time that ego herself is alive. Those who die before ego is born, or are born after ego dies, are excluded. This study focuses on two primary components of sibship: first, the number of siblings ever had by ego; second, the number
of siblings had at different points during egos’ life span, with a focus on egos’ childhood, orphanhood, and death.

Defining ‘sibling’

A sibling in this study is defined as having the same two biological parents as ego. This is a departure from a more inclusive definition of siblings as sharing at least one biological or affinal (marital/union) parent. Siblings under this latter definition includes step-siblinghood (sharing neither biological parents but with an affinal kinship tie created through a subsequent union formed by one or the other parent), and half-siblinghood (sharing one biological parent through the union and subsequent fertility by one or the other parent with someone who is not ego's biological parent). While there is evidence for meaningful differences among these three types of sibling relationship, making the distinction is beyond the scope of this study.

While it may seem self-evident, siblings are only counted if alive at the same time as ego. No doubt a sibling had, then lost, is still consequential for an individual, but this study is concerned with the availability of kin who are alive at the time in question.

Siblings during ego's childhood

As discussed earlier, the possible configurations of siblings experienced during childhood can vary widely. While this variation can be visualized continuously over ego's life, three ages are used: birth, ages ten years and eighteen years (exact ages, on ego's birthday). The simulated populations in this study have very low child mortality, and sibship sizes are largely, albeit not entirely, set by eighteen years of age; populations with lower rates of child survival would of course exhibit more variation across these ages.

---

8 For example, reflecting on one's sibling, posthumously, may serve as a source of psychic support, or distress, such that having had a sibling is meaningfully different from not having had one, albeit different yet from having one.
**Siblings at the death of last surviving parent**

In most families, the composition of sibship near parents' death is *prima facie* more stable than during ego's childhood. Sibship is therefore measured at the moment of ego's orphanhood, that is, when her longer-surviving biological parent dies (irrespective of ego’s age). Children are often involved not only in care for dependent parents, especially near death, but are also involved in processes near and after death, such as funeral preparation and handling of the parents' estate.

Union dissolution and the formation of new unions complicate the definition of orphanhood (i.e. moment of death of longer-surviving biological parent), as ego may have ties to step parents as strong as, or stronger than, those to biological parents. For the purpose of this study, orphanhood is defined as the death of the second biological parent. This is not to say that biological parents are the only parents who receive care from children and for whose resources those children compete. Rather, the limitation is designed to provide analytic clarity without rejecting the diversity of family ties.

**Siblings at ego's death**

Sibship during the period preceding ego's death is measured at ego's moment of death, similar to the measurement at orphanhood. Substantively, it is the period preceding ego's death, not the exact moment, which is consequential. For practical purposes, however, sibship at the moment of death is an appropriate proxy for sibship prior to death.  

---

9 To test the validity of moment of orphanhood as an adequate proxy for the period surrounding orphanhood, I compare the count of living siblings at moment of orphanhood with one year prior to orphanhood and one year after, and find a difference in count of less than 0.1%.

10 To test the validity of this measure, I compare sibling counts at ego’s death with counts at one year prior to ego's death and find differences in mean sibling counts of less than 0.1%.
Results

**Presentation**

There is a tradeoff between highlighting the variation in sibship under low fertility and highlighting the influence of a particular parameter. This paper responds to the tradeoff by presenting both. The eight scenarios constitute combinations of values for the manipulated characteristics (median age at first union and distribution of completed parities). Comparing scenarios that represent extremes highlights possible variation within low fertility. Comparing extrema is meaningful, but averaging the results across scenarios yields comparisons that highlight the effect of each manipulation. Scenarios within a specified median age at first union are averaged to compare mother's median age at first union at twenty and thirty years of age, respectively. The high- and low-fertility distributions of completed parities (distributions A and B) are compared to highlight variation in overall level of fertility, and the scenarios with distributions C and D are compared to highlight the effect of changing the variance of completed parity within a similar overall level of fertility. Note that pooling in no way constitutes "controlling" for variation, and microsimulation does not produce demographic patterns that are a linear, additive function of its inputs. Note, also, that the distributions of completed parities also span different mean completed parity, so comparisons among them require some additional caution.

11 Averages are across population summary measures, not across individuals pooled across populations.
12 This is a perennial challenge in microsimulation modeling, and in nondeterministic modeling in general.
Background characteristics

Fertility characteristics of mothers’ cohort

Table 3 shows the fertility characteristics of the mother’s cohort for each of the scenarios. Women (who have a child) in early fertility scenarios bear their first child, on average across scenarios, at median age 23.1 years. Women in later fertility scenarios bear their first at, on average, median 32.8 years of age. Unsurprisingly, scenarios with earlier childbearing, higher fertility and lower variance of completed parities have lower rates of childlessness. The higher variance and low fertility scenarios with later fertility yield childlessness of over twenty-five percent, more than double that of earlier fertility scenarios with higher fertility and lower variance. The proportions of single children are similar in the high overall fertility and low variance scenarios with earlier fertility, nearly eleven percent, and about twice as high in the corresponding later fertility scenarios. Single-child families are most prevalent in scenarios with low fertility and late childbearing. The proportional differences are not as dramatic among completed family sizes of two (ratio approximately 1.7), but ranges from 56.8 percent in the early fertility, low variance scenario to 32.7 percent in the later fertility, higher variance scenario. These distributions yield mean completed parities that fall short of specified, ranging from 2.3 children/woman (earlier fertility, higher fertility) to 1.5 children/woman (later fertility, lower fertility), a range of not quite one child. The grand mean across scenarios is 1.8 children per woman, below replacement but a half child above ‘lowest low’ fertility. Women with higher specified completed parity often fell short, and some women with lower specified parity had actual childbearing in excess of what was specified (often
due to subsequent fertility after union dissolution and reconstitution). The range is similar to the range of specified mean parities (from 2.45 children/woman to 1.7 children/woman, a range of 0.75 children/woman). Distributions of age at first birth are skewed right in the case of simulated populations with earlier childbearing, and slightly left in populations with later childbearing.

*General portrait of sibship*

Table 4 presents the characteristics of ego’s generation. Mortality characteristics are very close, albeit not identical, across the simulated populations. The average age of orphanhood across *later fertility* scenarios is about fifty-nine years (sd=11.8 years), and among scenarios with *earlier fertility* the average age is about 7.5 years younger, 51.6 years (sd=10.6 years). The age span of sibships ranges between five years and just over eight years and averages six and a half years across all scenarios. The age span varies most between *earlier* and *later childbearing* scenarios, on average a difference of a little over two years. Variation resulting from overall fertility and fertility variance are more modest, less than a year’s difference on average.

Egos across the simulated populations, on average, have ever had a mean 1.6 siblings. Note that this is not the same as mothers’ mean completed parity minus one. The range between highest and lowest availability spans about half a sibling across scenarios: *earlier fertility, higher fertility* scenario has the highest mean sibs ever had, 1.9; and the *later fertility* scenarios with *lower fertility* or *lower variance* had the fewest on average, 1.3. The influence of timing of first birth and overall level of fertility are intuitive: younger childbearing and higher fertility each result in more available siblings. The less intuitive result comes from a difference in variance, where the *higher variance* scenarios
have 0.3 more siblings available to egos at some point in their life course than do egos in the lower variance scenarios. Results are presented individually for brothers and sisters to indicate that, while modest, a secondary sex ratio slightly favoring male births combined with slightly higher male mortality at younger ages produces asymmetrical proportions of brothers and sisters ever known. Where present, these differences amount to 0.1 siblings/ego on average and favor sisters.

The scenarios’ parameters produce difference distributions of siblings ever had as well as differences in the mean number of siblings. The lower fertility, later childbearing scenario has the highest proportion of children with no siblings, 15.3 percent, but this is similar to the proportion sibling-less in the later fertility, higher variance scenario (14.6 percent). The higher fertility, earlier childbearing scenario yields the lowest proportion with no siblings, 5.1 percent, but close is the early childbearing, lower variance scenario (5.9 percent). The majority of egos in all scenarios except the higher fertility, earlier childbearing population have a majority of egos with one sibling, ranging from about thirty-five percent (early childbearing, higher fertility) to over sixty-two percent (later childbearing, lower variance). Earlier childbearing, higher variance and higher overall fertility all yield lower proportions of single sib dyads. The means for higher variance and higher fertility are very similar, about thirty-nine percent with one sibling. Notably, the greatest difference exists between the lower variance and higher variance conditions, sixty percent versus forty percent, respectively, having one sibling. The proportion with only one sibling has consequences, as we will see, for the distribution of unique sib dyads in a population.
Variation in sibships of size three is more modest, ranging from 13.5 percent to nearly twenty-five percent. The higher fertility scenarios have the largest proportion with two siblings (average seventeen percent); lower variance and lower fertility scenarios have slightly less than half (8.4 and 7.1 percent, respectively). The differences across manipulated parameters are most similar in the case of proportion with three siblings: later childbearing, lower fertility and low variance scenarios have about two-thirds the proportion of egos with three siblings of their earlier-childbearing, higher-fertility and higher-variance counterparts. Yet, the range of proportions having three siblings is wider than for those having two: nearly thirty-six percent of simulated individuals in the higher fertility, earlier childbearing scenario have three siblings, whereas the lower variance, later childbearing scenario has about three fifths fewer (13.4 percent).

_configurations of sibship_

Table 5 shows the proportion of egos with one or more of a particular type of sibling. The vast majority of individuals across all scenarios have had at least one sibling, ranging from a little over eighty-five percent and just under ninety-five percent (grand mean ninety percent). Scenarios with earlier childbearing, higher overall fertility or lower variance tend to have higher proportions of egos with at least one sibling (as they have lower rates of single-childhood). The proportions having particular sibling dyads are, of course, lower across all scenarios, and they vary in similar ways with respect to the manipulated parameters. The proportions of egos having a brother or sister are similar within each scenario, albeit not identical due to the influences of sex ratio and sex-differential young mortality. On the whole, about two percent more egos have ever had a brother than have ever had a sister. Note that while the higher variance scenarios,
compared with *higher fertility* and *lower variance* scenarios, have fewer egos with a any kind of sibling, they do not have the lowest proportion with particular kinds of siblings. While Table 5 details the differences in detail, the overall pattern is the same across scenarios: the *higher fertility, earlier childbearing* scenario has the largest proportion with siblings of any type. The proportions with an older, or a younger, sibling are slightly smaller than for brothers or sisters due to the dependence upon ego’s birth order (among multiple births).

More pronounced differences emerge when examining the proportion having combinations of dyads within ego’s sib network, as well as those having only one kind of sib dyad or other. Table 6 shows the proportions of egos with a combination of types of siblings. Combinations of different kinds of sib dyads – having had at least one sister and at least one brother, or having had at least one older sibling and at least one younger sibling – are limited to egos in sib sets of three or larger. In particular, having both an older and a younger sibling is limited to siblings who are neither the youngest nor oldest in the sib set; proportions having both are essentially a measure of the proportion of middle children. In addition to having the highest proportion of simulated individuals with one or more siblings, the high-fertility, early-childbearing population shows the highest proportion having had various sib dyads and combinations of dyads. The later-childbearing, lower-fertility population has the fewest proportion having had any type of dyad or combination thereof. This pattern is largely as expected, but the proportions of egos having a given combination in *higher variance* scenarios are very similar to the proportions in *higher fertility* scenarios. The same correspondence exists for *lower variance* and *lower fertility* scenarios.
The proportions of egos having only one sort of sibling or other, for example, only a brother or only a sister, do not vary a great deal across scenarios. With this more modest variation, the higher variance scenarios have the smallest proportions, driven by higher rates of both single childhood (that contribute zero sib dyads) and larger sibships (that contribute greater likelihood of multiple kids of siblings). Lower variance scenarios contribute the greatest number of unique sibships through greater proportions of egos with only one sibling. By comparison, the differences between higher fertility and lower fertility, and earlier childbearing and later childbearing scenarios are models, differing by two to three percent.

**Sibship over ego’s life course**

The age pattern of sibling availability

As noted earlier, sibling availability varies over ego’s life. This age-variability produces a distinctive pattern of sibship. Figure 1 illustrates this variation: the proportions with zero, one, two, and three siblings are shown over egos’ life span. At birth, nearly fifty-four percent of egos are born to one or more siblings; seventeen percent are born to two or more sibs. By age five, almost eighty-two percent have one or more siblings; this increases to nearly eighty-eight percent by age ten. At those ages the proportions having two or more siblings are 26.6% and 33%. At ages fifteen and eighteen the proportions having one or more and two or more siblings are nearly identical, and are near their maximum. The distribution of sibship is nearly flat until age 40, where mean available siblings shrink by one to two percent. The decrease is more pronounced between ages forty and fifty, nearly four percent on average, and between ages fifty and sixty decrease in the percentage of egos having at least one sibling is nearly eight percent. This increases
to over fifteen percent between ages sixty and seventy, and the magnitude of decrease
(absolute change in proportion, rather than proportional change between percentages) is
greatest between seventy and eighty years of age, an average of nearly forty percent
across scenarios.

During childhood
Table Egos in the simulated populations are born, on average, to 0.8 siblings; fifty-four
percent have a sibling at birth. The range of proportion having a sibling at birth is about
twelve percent (48.1 percent to 60.5 percent), but siblings-had at birth varies from an
average 0.6 to a full sibling. By age ten, thirty-four percent have gained one or more
siblings, on average gaining 0.6 siblings. Between ages ten and eighteen, egos’ sibship
does not change a great deal: mean siblings increases by only 0.1, and most egos who
will ever have a sibling have gotten them by age ten: 1.5 percent of egos gain a sibling
during this period. While the difference is not dramatic, egos in the earlier childbearing,
higher variance scenario have the smallest proportion transitioning from only-childhood
to having a sibling (thirty percent), but the largest going from zero to one siblings
between ages ten and eighteen (two percent).

At Orphanhood
Overall, nearly eighty-seven percent of egos have a sibling at the death of their remaining
parent, and the range of proportion egos with at least one sibling is about ten percent,
from 81.7 to 91.2 percent. Put another way, the proportion without a sibling at
orphanhood ranges from about one in ten to about one in five. The average number of
siblings available to egos is consistently 0.2 fewer than the mean number of siblings ever
had. The mean ages at orphanhood are between ages fifty and sixty, when decline in
siblings has just begun to increase; most members of sibships are still alive (alternately, most parents do not outlive any of their children). In every scenario, the proportion with one or more sisters at orphanhood is very similar to the proportion at age eighteen, on average 0.1 fewer and with an average two percent of egos who have a sister at eighteen not having one at orphanhood.

At Ego’s Death

Between age eighteen and death, egos lose, on average, 0.7 siblings, and thirty-four percent lose their only or all of their siblings such that the average having one or more siblings is 55.5 percent (alternately, about forty-five percent have no siblings at death). The population composition of sibship at death is similar to at birth: 1.5 percent more egos die with a sibling than are born to one, and the mean number of siblings available to egos at death is nearly identical to the number available at birth. The greatest degree of sibling loss between age eighteen and death is to the lower variance scenarios, the smallest in the higher variance scenarios. The proportion having one or more sisters ranges from forty-five and fifty-five percent, and differences are greatest between lower fertility and higher fertility scenarios; differences in timing of the mother’s fertility career and variance in fertility amount to differences of about two percent in sister availability.
Discussion

Demographic change during the past two centuries has radically reshaped kin configurations, with a general trend toward fewer kin known for a longer time. While the general path of transition comprises declining fertility and mortality, fertility postponement and increases in both union dissolution and cohabitation, contemporary demographic transitions are not all progressing along identical trajectories, nor will they necessarily all converge to a single demographic regime. Heterogeneous childbearing preferences and capacities yield variation in childbearing; heterogeneous childbearing patterns in the parents' generation yield variation in the availability of kin in the children's generation. Insofar as lateral kin such as siblings are consequential for individuals' experiences and perspectives, variation in sibling configurations will produce variation in individuals' experiences and perspectives.

Unsurprisingly, lower fertility tends to reduce available siblings, but as mentioned earlier this depends on the distribution of mothers' completed parities. In particular, increased proportion of childlessness in a mother's generation can, while contributing to fertility decline, shift the distribution of children such that the mean number of siblings in the children's generation increases. Variance in completed family size, even with moderate overall fertility, can yield a large proportion of children with multiple siblings as well many only children.
Variance in completed family size generates distinctive distributions of sibship sizes, in simulated populations largely through greater childlessness on one hand, balanced with larger sibships on the other. This in turn produces a child’s generation with greater proportions having multiple siblings, and combinations of sibling dyad types. Narrower variance producing the same mean completed family size gave rise to a greater number of sibships of size two, each only having one kind of sibling with respect to sex or relative age, resulting in greater population diversity of unique sibships. A later median age at first union produces fewer children given the fixed birth interval schedule. This is as expected: childbearing careers are finite. The per-woman reduction in completed parity depends upon specified potential fertility, such that women who otherwise may have had four births may only have two, but most women with a potential of two indeed have two. The composition of siblings is largely stabilized by age ten, and remains stable through much of adulthood. This extended period with full sibships intact implies more years to know one’s siblings as adults, outside the context of childhood resource competition, and yet have those siblings present when facing the responsibility of caring for one’s elderly parents and handling their estate. This may also be when egos’ children are forming their own families, depending on their generation’s pattern of union formation and fertility (and including egos’ nuptiality and fertility would be an important extension of this kind of study).

Children provide a great deal of old-age support to their parents, and the studies cited in this paper emphasize emotional rather than material support from siblings. The decrease in the social connectedness of older adults generally, combined with greater life expectancy, may make siblings take a foreground role in individuals’ connections to
supportive alters. The loss of siblings among those who had them is not trivial in any of the scenarios presented, with almost having of those who had a sibling transitioning to having zero siblings by the time of their death. This may be a greater loss than for those who never had any siblings; there is evidence that non-kin alters can ‘fill in’ to some extent for kin, although it is unclear whether those ties are durable into old age (Cornwell, Laumann, and Schumm 2008; Gondal 2012).

Some of the percentage differences appear trivial. However, particularly in the case of siblings at orphanhood and in older age, a few percentage points’ difference in populations with post-transition age structures constitutes a large gap in the number of people having kin with whom one can share a care burden or share and compete for family resources. In the case of the United States, where nearly twenty-two percent of its 2010 population are ages 45-64 years old, and almost twelve and a half percent are 65 and older, such a difference amounts to hundreds of thousands of people (United States Census Bureau 2011).

Analysis of differences in available siblings associated with a particular manipulation has received focus, but the scenarios represent configurations of demographic parameters, and taken as such demonstrate possible (and plausible) variation within settings typically characterized as “low fertility.” Further, although specific sibling dyads may have their own unique character, and bigger sib sets may be distinct from two-child families, some phenomena of interest may depend most on whether one has any siblings versus none, irrespective of that sibling's characteristics. One sibling may be adequate, during childhood, for providing the requisite interaction for developing social skills; or perhaps the marginal benefit of additional siblings is negligible. Yet, if the marginal effect of
adding a sibling to a sib set for some phenomenon of interest is very small or at least decreasing, the variation shown here may be as consequential as proportional variation in high fertility settings. That is, variation within low fertility regimes may, proportionally, be more consequential than the same magnitude of variation in higher fertility regimes. It is also possible that, particularly during coresident childhood, sibling relationships are formative ones. Further, where social dynamics depend upon scale, some social processes and structures do not emerge with the dyad but rather with the triad or larger. Here higher-order sib sets may be key to the emergence of certain social skills, albeit only for those children whose personal network largely or exclusively comprises kin -- namely, younger children in the sibship.

As the transition to low fertility is coupled with population aging, the demand for old-age support falls on shrinking numbers of children within families. Unions leading to matrilocal or patrilocal residence limit old-age support for parents in the son's or daughter's household, respectively, transferring that support to the spouse's family. Where unions lead to neolocal residence, movement from one's family of origin to a new conjugal family may cause the former to take a background role for both partners. However, factors including but not limited to union dissolution and children leaving home may lead siblings to reconnect and exert greater reliance on one another as they enter old age. The rise in divorce among older-age persons as identified in the United States (Brown & Lin, 2011) suggests that kin from divorced persons' family of origin may have increased importance: brothers and sisters may be less likely to be contested alters in a dissolved couple's friend network, and where personal networks shrink in later age (Krackhardt 1999) kin such as siblings can provide continuity when the composition
of non-kin networks changes. Here sex differences in available siblings may matter a great deal: the relatively high proportion of men with no siblings may make them, perhaps and/or their conjugal partner, more likely to bear the care burden, but an increased rate of dissolution at ages where caring for elders is likely may dilute care resources and make an increasing proportion of men the only eligible descendant caregiver.

Change in population health and health care also affect the need for long-term instrumental support, regardless of the source. As state welfare systems and their viability are challenged, reliance on informal sources, including kin, for material support may increase (cf. Folbre & Bittman 2004). Of course, siblings are neither the only informal source of support available to parents or to egos at those events, nor are all siblings equally available to provide it. Further, those with siblings may have weaker ties to parents than only children (Gondal, 2012), such that the support one can expect from one’s children may increase with family size, but marginally decreasing with each additional child.

Network composition is affected by modernization, and one school of thought hypothesizes a decline in the salience of kin with urbanization and economic development (Lee 2003; Parsons 1943). Fischer (2005) and Gondal (2012) show, however, that kin and non-kin ties are not fungible, and the presence of siblings, in particular, influences not only personal network composition but also individuals’ orientations toward, and expectations of support from, other kin such as parents. Willigen (1989) shows that short-term alters tend to be non-kin, while long-term alters are split 50/50 between kin and nonkin (p104); longer lives, with a greater fraction lived outside
of educational and labor force contexts that provide non-kin networks, may actually foreground siblings in personal networks for a greater fraction of the lifespan.

While it is not part of the conceptual focus of this paper, siblings are not only useful in caring for their parents and each other. Alloparenting\textsuperscript{13}, for example, may have been critical to humans' success as a species. On the other hand, Dickson (Dickson 1992) observes that one 'unsuccessful' hominid, Neanderthal, formed groups that rarely included non-kin, and other scholars (Bingham and Souza 2009; Wilson 2007) emphasize the importance of humans' to form groups that extend beyond and cut across kin lines. That is, non-kin (or fictive kin) may be effective substitutes for some kinds of support, particularly in populations where small kin sets are the norm and individuals are integrated into institutions largely or entirely comprising non-kin (Hrdy 2011). A study of Dutch adults finds that siblings and friends resemble each other in practical support, albeit not in emotional support (Voorpostel et al. 2007), while Himes & Reidy (2000) find that non-kin are both less likely to provide, and less likely to be expected to provide, care for older adults.

\textit{Limitations and directions for future research}

This study makes necessary first steps toward the life course measurement of sibship. In order to make these first steps, the complex nature of sibship was simplified in some critical ways. Inclusion of other dimensions of kinship and networks is essential to a more fully considered analysis. Future work needs to attend to the complexity of non-nuclear families, the variation in siblings' availability conditional on their own kin networks, the role of sex preference, and the situating of sibship in broader kin networks.

\textsuperscript{13} Care for children by kin other than one's parents, by non-kin and, by society as a whole (Bentley & Mace 2009).
Links between kin and mortality / fertility

This study takes mortality as independent of the size and composition of kinship networks. This is a strong assumption. It is a necessary limitation for a study of this scope, and including feedbacks between kin availability and mortality would further limit conceptual clarity. However, any inferences linking age patterns of mortality and kin availability should consider the possibility that such relationships are unlikely to be unidirectional. SIMKIN has the capability to specify inter-kin associations in fertility behavior, and including an association would be important in a study that considers aunts, uncles and cousins. However, specifying intra-family fertility associations is a smaller concern when examining only children and their parents.

Complex families

Families have the capacity for greater complexity than is presented in this study. While demographic transition causes families to "narrow" and "lengthen," increased union dissolution and reformation create opportunities for more complex and quite possibly more ambivalent sibships. Families characterized by long, narrow chains of close biological kin are distinctive, but they are complicated by half- and step-siblings for whom norms of care for elderly relatives, intergenerational transmission of resources and sibling solidarity are not well established. Analyses that consider half- and step-siblings will provide a more nuanced and complete portrait of sibship.

siblings' conjugal families

Children have limited opportunities to define their affiliations. In adulthood, however, they may form unions, have children, and in doing so significantly shift the balance between their family of origin and the new family of affiliation. For example, an
unpartnered, childless sibling may be more connected to ego than one who is in union and with children. This study considers all children equal irrespective of union status and parenthood, however. A more nuanced examination of the ego-sibling dyad, one that distinguishes siblings' union and parenthood status, would be a useful extension to the study presented here.

*Parents' sex preference*

Sex preference may play a role in the size and sex composition of smaller sibships even in populations where sex-selective abortion or infanticide is rare. Using US National Health Interview Survey data, Stansfield and Carlton (Stansfield and Carlton 2007) find that sibships of size two are disproportionately mixed-sex. Further, they find that the first two children in sibships of size three are disproportionately same-sex. Accounting for sex preference would enhance studies of sibship composition.

*Single births*

The births in these simulations are singletons; there are no multiple births. In the United States, the 2007 rate of twin births was 32.2 per thousand. The rate of triplets and quadruplets for that year were 1.38 per 1,000 and 0.11 per 1,000, respectively (*National Vital Statistics Reports 2010*). As each twin birth contributes two children with one additional sibling each (triplets contributing three with two additional siblings, and so on), simulations that ignore multiple births slightly understate sibling counts, net of differences in mortality and association between multiple births and births per woman.
References


Retrieved September 22, 2012


Appendix A: Tables and Figures

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Median age at first union</th>
<th>Completed Parity</th>
<th>Mean Completed Parity</th>
<th>% Women with # Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Zero</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>Higher</td>
<td>2.45</td>
<td>5%</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>Lower</td>
<td>1.70</td>
<td>15%</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>Medium (Lower Variance)</td>
<td>2.00</td>
<td>5%</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>Medium (Higher Variance)</td>
<td>2.00</td>
<td>15%</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>Higher</td>
<td>2.45</td>
<td>5%</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>Lower</td>
<td>1.70</td>
<td>15%</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>Medium (Lower Variance)</td>
<td>2.00</td>
<td>5%</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>Medium (Higher Variance)</td>
<td>2.00</td>
<td>15%</td>
</tr>
</tbody>
</table>

Table 2. Manipulated specified parameters of eight simulated populations.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Median Age at First Birth</th>
<th>% Mothers with # Children</th>
<th>Mean Completed Parity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Zero</td>
<td>One</td>
</tr>
<tr>
<td>1</td>
<td>23.2</td>
<td>10.6%</td>
<td>10.7%</td>
</tr>
<tr>
<td>2</td>
<td>23.1</td>
<td>20.6%</td>
<td>16.7%</td>
</tr>
<tr>
<td>3</td>
<td>23.1</td>
<td>11.2%</td>
<td>10.9%</td>
</tr>
<tr>
<td>4</td>
<td>23.1</td>
<td>20.4%</td>
<td>16.5%</td>
</tr>
<tr>
<td>5</td>
<td>32.9</td>
<td>15.6%</td>
<td>16.9%</td>
</tr>
<tr>
<td>6</td>
<td>32.8</td>
<td>25.1%</td>
<td>21.4%</td>
</tr>
<tr>
<td>7</td>
<td>32.7</td>
<td>15.9%</td>
<td>16.7%</td>
</tr>
<tr>
<td>8</td>
<td>32.8</td>
<td>25.2%</td>
<td>22.0%</td>
</tr>
<tr>
<td>Grand Mean</td>
<td>28.0</td>
<td>18.1%</td>
<td>16.5%</td>
</tr>
</tbody>
</table>

Table 3. Fertility characteristics of mothers’ generation
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Age Span</th>
<th>Siblings Ever Known</th>
<th>% Egos with # sibs</th>
<th>Mean age at Orphanhood</th>
<th>Death</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Either Sex</td>
<td>Brothers</td>
<td>Sisters</td>
<td>Zero</td>
</tr>
<tr>
<td>1</td>
<td>8.1</td>
<td>1.9</td>
<td>0.93</td>
<td>0.98</td>
<td>5.1%</td>
</tr>
<tr>
<td>2</td>
<td>7.2</td>
<td>1.5</td>
<td>0.74</td>
<td>0.76</td>
<td>10.4%</td>
</tr>
<tr>
<td>3</td>
<td>7.2</td>
<td>1.6</td>
<td>0.75</td>
<td>0.80</td>
<td>5.9%</td>
</tr>
<tr>
<td>4</td>
<td>8.0</td>
<td>1.8</td>
<td>0.88</td>
<td>0.92</td>
<td>9.1%</td>
</tr>
<tr>
<td>5</td>
<td>5.8</td>
<td>1.6</td>
<td>0.78</td>
<td>0.84</td>
<td>9.3%</td>
</tr>
<tr>
<td>6</td>
<td>4.9</td>
<td>1.3</td>
<td>0.62</td>
<td>0.64</td>
<td>15.3%</td>
</tr>
<tr>
<td>7</td>
<td>5.0</td>
<td>1.3</td>
<td>0.64</td>
<td>0.66</td>
<td>10.4%</td>
</tr>
<tr>
<td>8</td>
<td>5.6</td>
<td>1.5</td>
<td>0.72</td>
<td>0.78</td>
<td>14.6%</td>
</tr>
<tr>
<td>Grand Mean</td>
<td>6.5</td>
<td>1.6</td>
<td>0.8</td>
<td>0.8</td>
<td>10.0%</td>
</tr>
<tr>
<td>Early Childbearing</td>
<td>7.6</td>
<td>1.7</td>
<td>0.8</td>
<td>0.9</td>
<td>7.6%</td>
</tr>
<tr>
<td>Late Childbearing</td>
<td>5.3</td>
<td>1.4</td>
<td>0.7</td>
<td>0.7</td>
<td>12.4%</td>
</tr>
<tr>
<td>Lower Variance</td>
<td>6.1</td>
<td>1.4</td>
<td>0.7</td>
<td>0.7</td>
<td>8.2%</td>
</tr>
<tr>
<td>Higher Variance</td>
<td>6.8</td>
<td>1.7</td>
<td>0.8</td>
<td>0.9</td>
<td>11.8%</td>
</tr>
<tr>
<td>Higher Fertility</td>
<td>6.9</td>
<td>1.8</td>
<td>0.9</td>
<td>0.9</td>
<td>7.2%</td>
</tr>
<tr>
<td>Lower Fertility</td>
<td>6.1</td>
<td>1.4</td>
<td>0.7</td>
<td>0.7</td>
<td>12.8%</td>
</tr>
</tbody>
</table>

Table 4. Characteristics of ego’s generation.
### Table 5. Percent of egos ever having a sibling, by dyad type.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Any sibling</th>
<th>Brother</th>
<th>Sister</th>
<th>Opposite Sex</th>
<th>Same Sex</th>
<th>Older (or younger)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>95.3%</td>
<td>68.5%</td>
<td>66.3%</td>
<td>67.9%</td>
<td>67.0%</td>
<td>60.8%</td>
</tr>
<tr>
<td>2</td>
<td>90.2%</td>
<td>58.2%</td>
<td>56.6%</td>
<td>57.8%</td>
<td>57.0%</td>
<td>53.3%</td>
</tr>
<tr>
<td>3</td>
<td>94.6%</td>
<td>61.2%</td>
<td>58.5%</td>
<td>59.7%</td>
<td>60.0%</td>
<td>55.6%</td>
</tr>
<tr>
<td>4</td>
<td>91.3%</td>
<td>65.0%</td>
<td>62.7%</td>
<td>63.7%</td>
<td>63.9%</td>
<td>57.8%</td>
</tr>
<tr>
<td>5</td>
<td>91.1%</td>
<td>62.3%</td>
<td>58.7%</td>
<td>60.7%</td>
<td>60.3%</td>
<td>55.6%</td>
</tr>
<tr>
<td>6</td>
<td>85.2%</td>
<td>52.1%</td>
<td>50.5%</td>
<td>51.5%</td>
<td>51.0%</td>
<td>48.4%</td>
</tr>
<tr>
<td>7</td>
<td>90.3%</td>
<td>54.5%</td>
<td>52.8%</td>
<td>53.5%</td>
<td>53.8%</td>
<td>50.9%</td>
</tr>
<tr>
<td>8</td>
<td>85.9%</td>
<td>57.7%</td>
<td>55.2%</td>
<td>55.4%</td>
<td>57.6%</td>
<td>52.2%</td>
</tr>
<tr>
<td>Grand Mean</td>
<td>90.5%</td>
<td>59.9%</td>
<td>57.7%</td>
<td>58.8%</td>
<td>58.8%</td>
<td>54.3%</td>
</tr>
</tbody>
</table>

- Early Childbearing: 92.8% 63.2% 61.0% 62.3% 62.0% 56.9%
- Late Childbearing: 88.1% 56.6% 54.3% 55.3% 55.7% 51.7%
- Lower Variance: 92.4% 57.8% 55.6% 56.6% 56.9% 53.2%
- Higher Variance: 88.6% 61.3% 59.0% 59.6% 60.7% 55.0%
- Higher Fertility: 93.2% 65.4% 62.5% 64.3% 63.6% 58.2%
- Lower Fertility: 87.7% 55.1% 53.6% 54.7% 54.0% 50.8%
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Older and younger</th>
<th>Brother and Sister</th>
<th>Only brother(s)</th>
<th>Only sister(s)</th>
<th>Only opposite sex</th>
<th>Only same sex</th>
<th>Only older (or younger)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26.3%</td>
<td>39.5%</td>
<td>29.0%</td>
<td>26.8%</td>
<td>28.4%</td>
<td>27.5%</td>
<td>34.5%</td>
</tr>
<tr>
<td>2</td>
<td>16.4%</td>
<td>24.7%</td>
<td>33.5%</td>
<td>32.0%</td>
<td>33.1%</td>
<td>32.4%</td>
<td>36.9%</td>
</tr>
<tr>
<td>3</td>
<td>16.6%</td>
<td>25.1%</td>
<td>36.1%</td>
<td>33.4%</td>
<td>34.6%</td>
<td>34.9%</td>
<td>39.0%</td>
</tr>
<tr>
<td>4</td>
<td>24.2%</td>
<td>36.4%</td>
<td>28.6%</td>
<td>26.3%</td>
<td>27.3%</td>
<td>27.5%</td>
<td>33.5%</td>
</tr>
<tr>
<td>5</td>
<td>20.0%</td>
<td>29.9%</td>
<td>32.4%</td>
<td>28.8%</td>
<td>30.8%</td>
<td>30.4%</td>
<td>35.6%</td>
</tr>
<tr>
<td>6</td>
<td>11.5%</td>
<td>17.3%</td>
<td>34.7%</td>
<td>33.1%</td>
<td>34.2%</td>
<td>33.7%</td>
<td>36.9%</td>
</tr>
<tr>
<td>7</td>
<td>11.5%</td>
<td>17.0%</td>
<td>37.5%</td>
<td>35.8%</td>
<td>36.5%</td>
<td>36.8%</td>
<td>39.4%</td>
</tr>
<tr>
<td>8</td>
<td>18.4%</td>
<td>27.0%</td>
<td>30.7%</td>
<td>28.2%</td>
<td>28.4%</td>
<td>30.6%</td>
<td>33.8%</td>
</tr>
<tr>
<td>Grand Mean</td>
<td>18.1%</td>
<td>27.1%</td>
<td>32.8%</td>
<td>30.6%</td>
<td>31.7%</td>
<td>31.7%</td>
<td>36.2%</td>
</tr>
<tr>
<td>Early Childbearing</td>
<td>20.9%</td>
<td>31.4%</td>
<td>31.8%</td>
<td>29.6%</td>
<td>30.8%</td>
<td>30.6%</td>
<td>36.0%</td>
</tr>
<tr>
<td>Late Childbearing</td>
<td>15.3%</td>
<td>22.8%</td>
<td>33.8%</td>
<td>31.5%</td>
<td>32.5%</td>
<td>32.9%</td>
<td>36.4%</td>
</tr>
<tr>
<td>Lower Variance</td>
<td>14.1%</td>
<td>21.1%</td>
<td>36.8%</td>
<td>34.6%</td>
<td>35.5%</td>
<td>35.8%</td>
<td>39.2%</td>
</tr>
<tr>
<td>Higher Variance</td>
<td>21.3%</td>
<td>31.7%</td>
<td>29.7%</td>
<td>27.3%</td>
<td>27.9%</td>
<td>29.1%</td>
<td>33.6%</td>
</tr>
<tr>
<td>Higher Fertility</td>
<td>23.1%</td>
<td>34.7%</td>
<td>30.7%</td>
<td>27.8%</td>
<td>29.6%</td>
<td>28.9%</td>
<td>35.0%</td>
</tr>
<tr>
<td>Lower Fertility</td>
<td>14.0%</td>
<td>21.0%</td>
<td>34.1%</td>
<td>32.6%</td>
<td>33.7%</td>
<td>33.0%</td>
<td>36.9%</td>
</tr>
</tbody>
</table>

Table 6. Percent of egos with combinations of sibling dyads, and ‘exclusion’ dyads.
Figure 1. Lifespan variation in sibling availability across eight simulated populations.
SIMKIN is software for the microsimulation of kin sets (Casterline 2001, 2012), written in Stata (StataCorp 2012). It takes as its input demographic schedules for fertility, mortality and nuptiality, as well as a set of parameters for specifying associations among outcomes and upper bounds to the input distributions. Its output is a simulated population of individuals, with data on kin-network ties. This study uses SIMKIN version 3. Eight input distributions are required for each simulated population, described in detail below. These comprise a combination of fixed parameters and schedules, as well as parameters that are varied specifically to illustrate variation in outcomes. Details on data sources for this study are outlined in Appendix B. The simulation’s inputs are defined as follows:

**Distribution of ages at death:** This is the d_x column of a life table, proportion dying at a given age. Different distributions for females and males are specified.

**Probability of ever forming a union:** This input contains the proportion of women who have entered a marriage or cohabiting union by a given age. Note that the distribution is formed for women, as husbands enter the simulated population through marriage to an existing woman.

**Difference in age between spouses:** This is the distribution of age difference, in years, between ego and her partner. Different distributions are specified, conditional on ego’s age at union.

**Probability of union not dissolving:** This is, for ego’s current union, the cumulative probability that the union will not dissolve (end in divorce, separation, etc.). Note that widowhood is established by ego’s husband’s date of death. Also, dissolution does not include the transition from cohabitation to marriage with the same partner.

**Probability of not forming another union post-dissolution:** This is the cumulative probability by duration since dissolution that ego will not form another union. It yields the period between the dissolution of a union and formation of a subsequent one, if one occurs.

**Completed parity distribution:** This is a distribution of completed parities. If a union dissolves and ego forms another union, ego’s fertility “restarts” with her
new partner, subject to the limitation. An optional upper bound (maximum completed parity) can be specified for the population.

Birth Interval Distribution: This represents the distribution of months between births, specified separately for each birth interval of n intervals. It comprises the first birth interval (duration from union to first birth) through higher parities, but the highest birth interval is applied to the highest birth interval specified, through the upper bound specified for maximum completed parity.

**Fundamental Assumptions**

Open marriage market

No search for a union partner is conducted; rather, partners are created *ex nihilo* as required, and at the precise time required, by nuptiality processes (first union, formation of a second union in case of prior dissolution). However, the nuptiality outcomes specified in this study -- likelihood of union formation, age at first union, spousal age difference -- are undoubtedly affected by marriage market dynamics. As this study is concerned with kin close to ego, the spontaneous generation of partners is less problematic than in a study whose goals bear directly on issues of mate selection.

Stable population

The probability distributions for outcomes of interest are time-invariant. That is, ego, her parents and children are all subject to the same set of demographic probabilities. A stable population assumption is untenable in analyses of population change, but this study is concerned with post-transition populations experiencing sustained low fertility.

**Associations among outcomes**

Following Ruggles’ (1993) criticism of independence assumptions in microsimulation models, the microsimulation algorithm does not treat all outcomes as independent; rather, associations can be specified among outcomes. These comprise two basic types: Intra- and inter-individual. Intra-individual association of outcomes can be specified for age at first union and age at first birth. Inter-individual associations can be specified for age at death between ego and her husband/partner and/or among ego and her siblings, and for age at first marriage among ego and her siblings.

Second, some associations occur not by explicit design, but are instead intrinsic to the algorithm. These include associations caused by the truncating effect of death (resulting
in an inverse association between age at death and completed parity, and an inverse association between age at death and the likelihood of marital dissolution due to divorce), and associations caused by the truncating effect of the termination of fecundity at age 50 (an inverse association between age at first marriage and completed parity). While this microsimulation allows for intra-person dependencies among certain pairs of demographic outcomes, other plausible associations are ignored. For example, age at death is assumed independent of completed parity, and the likelihood of union dissolution, and of subsequent reformation, is assumed independent of fertility performance.
Appendix C: Simulation Inputs

**Empirical Sources**

Demographic schedules for fertility and mortality are derived from the National Survey of Family Growth (Centers for Disease Control) and Human Mortality Database (UC Berkeley & Max Planck Institute). While the microsimulation models the experience of a cohort, period measures are used where cohort measures are not available, are incomplete, or are unrepresentative of contemporary populations. Tables 7 through 11 present the distribution of the following parameters.

*Age at death distribution (for males and females)*

The distribution of age at death can be viewed as the \( d_x \) column in a life table. Period life tables are used in order to include the mortality of younger cohorts; the downside is that this downwardly biases estimates of mortality for older cohorts at younger ages and upwardly biases mortality for younger cohorts at older ages. This study uses the 2007 period life tables for men and women from *the Human Mortality Database*.

*Probability of ever entering a union (for males and females)*

These are the proportion of men and women age 40 who have ever entered a union. US data are used here, 0.86 (86%) for females and 0.81 for males. *Source: Goodwin et al 2009.*

*Distribution of spousal age difference*

This is defined as the age difference, in years, between ego and her spouse, calculated in months and rounded to nearest year. *Source: National Survey of Families and Households 2006-08.*

*Cumulative probability of union not dissolving through divorce or separation*

This is the life table’s survivor function, computed from duration (in months) since beginning of the union. Unions that begin and terminate in the same month are recoded to duration of 0.5 months. Cohabitations that "terminate" into
marriage are treated as a single union whose duration is the total duration of the cohabitation and subsequent marriage. *Source: National Survey of Families and Households 2006-08.*

*Cumulative probability of not forming another union (for females)*
In the event of union dissolution, this represents the probability of forming another union. This is the life table’s survival function, computed by duration since dissolution. In the case of cohabitations that "dissolve" into marriage, the date of dissolution of marriage is used as the onset of risk. Other periods between unions that are zero-length are recoded to 0.5 months. Negative periods are interpreted as coding error and are dropped from the estimation. *Source: National Survey of Families and Households 2006-08.*

*Birth interval distribution*
This comprises percentiles of the distribution of observed closed birth intervals. Three birth spacing distributions are used: women whose first birth occurs between ages 16-19, women whose first birth occurs between ages 20-30, and women whose first birth occurs after age 30. Birth spacing distributions for the first and third categories of women are slightly longer than for the second to account for subfecundity at younger and at older ages. *Source: National Survey of Families and Households 2006-08.*

**Manipulations**
Some characteristics and distributions thereof are deliberately varied to illustrate the relationship between inputs and outcomes. In this study, the distribution of completed parities, overall level of fertility, and age at first birth are manipulated to illustrate consequences of fertility variation for sibship configurations.

*Completed parity distribution and Variance of completed parity*
This study uses four distributions of completed parities, outlined in Table XX. These represent four fertility scenarios comprising three levels of population fertility. The *higher fertility* scenario (A) specifies an average 2.45 births per woman, distributed as follows: 5% childless, 5% with one child, 50% with two children, 20% with three, and 20% with four children. The *lower fertility* scenario(B) specifies an average 1.70 births per woman, distributed as follows: 15% childless, 15% with one child, 60% with two children, 5% with three children and 5% with four.
Two scenarios specify a more moderate 2.0 births per woman, but differ in variance to illustrate the differences in sibship distribution resulting from differential variance when mean completed parity is similar. The lower variance scenario (C) has the following distribution of completed parities: 5% childless, 5% with one child, 80% with two, 5% with three, and 5% with four. The higher variance scenario (D) is distributed as follows: 15% childless, 15% with a single child, 40% with two children, 15% with three children, and 15% with four.

**Age at mother’s first union**

Two median ages at first union are specified to illustrate consequences of union timing and consequent onset of risk of pregnancy: age 20, earlier fertility, and age 30, later fertility. The values are chosen to illustrate contrast, but are informed by the 2006-10 National Survey of Family Growth for women with an associate's degree or higher (median age at first birth = 27) and women with some college or less education (median age at first birth = 20.5) (irrespective of race). The upper bound of the distribution is fixed at age 45.
<table>
<thead>
<tr>
<th>Scenario</th>
<th>% Egos with a sibling</th>
<th>Mean # Siblings / Ego</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Birth</td>
<td>10</td>
</tr>
<tr>
<td>1</td>
<td>60.5%</td>
<td>93.1%</td>
</tr>
<tr>
<td>2</td>
<td>53.0%</td>
<td>87.1%</td>
</tr>
<tr>
<td>3</td>
<td>55.3%</td>
<td>92.1%</td>
</tr>
<tr>
<td>4</td>
<td>57.5%</td>
<td>88.3%</td>
</tr>
<tr>
<td>5</td>
<td>55.3%</td>
<td>89.4%</td>
</tr>
<tr>
<td>6</td>
<td>48.1%</td>
<td>83.1%</td>
</tr>
<tr>
<td>7</td>
<td>50.5%</td>
<td>88.4%</td>
</tr>
<tr>
<td>8</td>
<td>51.9%</td>
<td>83.9%</td>
</tr>
<tr>
<td>Grand Mean</td>
<td>54.0%</td>
<td>88.2%</td>
</tr>
<tr>
<td>Early Childbearing</td>
<td>56.6%</td>
<td>90.2%</td>
</tr>
<tr>
<td>Late Childbearing</td>
<td>51.4%</td>
<td>86.2%</td>
</tr>
<tr>
<td>Lower Variance</td>
<td>52.9%</td>
<td>90.2%</td>
</tr>
<tr>
<td>Higher Variance</td>
<td>54.7%</td>
<td>86.1%</td>
</tr>
<tr>
<td>Higher Fertility</td>
<td>57.9%</td>
<td>91.3%</td>
</tr>
<tr>
<td>Lower Fertility</td>
<td>50.5%</td>
<td>85.1%</td>
</tr>
</tbody>
</table>

Table 7. Sibling availability during childhood, at orphanhood, and at ego's death.
<table>
<thead>
<tr>
<th>Age</th>
<th>Proportion Dying Males</th>
<th>Proportion Dying Females</th>
<th>Age</th>
<th>Proportion Dying Males</th>
<th>Proportion Dying Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td>0.0074</td>
<td>0.00612</td>
<td>55-59</td>
<td>0.04019</td>
<td>0.02503</td>
</tr>
<tr>
<td>5-9</td>
<td>0.00123</td>
<td>0.00101</td>
<td>60-64</td>
<td>0.0558</td>
<td>0.03769</td>
</tr>
<tr>
<td>10-14</td>
<td>0.00098</td>
<td>0.00068</td>
<td>65-69</td>
<td>0.07626</td>
<td>0.05526</td>
</tr>
<tr>
<td>15-19</td>
<td>0.00429</td>
<td>0.00177</td>
<td>70-74</td>
<td>0.1019</td>
<td>0.07936</td>
</tr>
<tr>
<td>20-24</td>
<td>0.00711</td>
<td>0.00238</td>
<td>75-79</td>
<td>0.13196</td>
<td>0.1125</td>
</tr>
<tr>
<td>25-29</td>
<td>0.00687</td>
<td>0.0028</td>
<td>80-84</td>
<td>0.15769</td>
<td>0.15206</td>
</tr>
<tr>
<td>30-39</td>
<td>0.00721</td>
<td>0.00356</td>
<td>85-89</td>
<td>0.15593</td>
<td>0.18138</td>
</tr>
<tr>
<td>35-39</td>
<td>0.00897</td>
<td>0.00522</td>
<td>90-94</td>
<td>0.11464</td>
<td>0.16944</td>
</tr>
<tr>
<td>40-44</td>
<td>0.01313</td>
<td>0.00809</td>
<td>95-99</td>
<td>0.04705</td>
<td>0.09384</td>
</tr>
<tr>
<td>45-49</td>
<td>0.01983</td>
<td>0.01245</td>
<td>100-104</td>
<td>0.01025</td>
<td>0.02715</td>
</tr>
<tr>
<td>50-54</td>
<td>0.0295</td>
<td>0.01791</td>
<td>105-109</td>
<td>0.00103</td>
<td>0.00349</td>
</tr>
<tr>
<td>55-59</td>
<td>0.04019</td>
<td>0.02503</td>
<td>110+</td>
<td>0.00005</td>
<td>0.00019</td>
</tr>
</tbody>
</table>

Table 8. Model Inputs: Distribution of ages at death.
Source: United States 5x1 Period Life Tables, 2007, World Mortality Database.

<table>
<thead>
<tr>
<th>Years Older</th>
<th>Percent</th>
<th>Years Older</th>
<th>Percent</th>
<th>Years Older</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.2</td>
<td>1</td>
<td>12.4</td>
<td>9</td>
<td>2.0</td>
</tr>
<tr>
<td>9</td>
<td>0.1</td>
<td>2</td>
<td>11.8</td>
<td>10</td>
<td>1.9</td>
</tr>
<tr>
<td>8</td>
<td>0.2</td>
<td>3</td>
<td>9.0</td>
<td>12</td>
<td>1.5</td>
</tr>
<tr>
<td>7</td>
<td>0.2</td>
<td>4</td>
<td>6.8</td>
<td>14</td>
<td>1.1</td>
</tr>
<tr>
<td>6</td>
<td>0.3</td>
<td>5</td>
<td>5.7</td>
<td>15</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>0.7</td>
<td>6</td>
<td>4.0</td>
<td>17</td>
<td>1.2</td>
</tr>
<tr>
<td>4</td>
<td>1.1</td>
<td>7</td>
<td>3.0</td>
<td>20</td>
<td>0.3</td>
</tr>
<tr>
<td>3</td>
<td>1.7</td>
<td>8</td>
<td>2.5</td>
<td>24</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>2.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9. Model Inputs: Distribution of age difference between ego and partner.
<table>
<thead>
<tr>
<th>Time (months)</th>
<th>Proportion remaining in union</th>
<th>Time (months)</th>
<th>Proportion remaining in union</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.983</td>
<td>120</td>
<td>0.641</td>
</tr>
<tr>
<td>12</td>
<td>0.968</td>
<td>144</td>
<td>0.597</td>
</tr>
<tr>
<td>24</td>
<td>0.929</td>
<td>168</td>
<td>0.556</td>
</tr>
<tr>
<td>36</td>
<td>0.886</td>
<td>192</td>
<td>0.512</td>
</tr>
<tr>
<td>48</td>
<td>0.845</td>
<td>216</td>
<td>0.480</td>
</tr>
<tr>
<td>60</td>
<td>0.806</td>
<td>240</td>
<td>0.445</td>
</tr>
<tr>
<td>72</td>
<td>0.766</td>
<td>300</td>
<td>0.367</td>
</tr>
<tr>
<td>96</td>
<td>0.696</td>
<td>360</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 10. Model Inputs: Cumulative probability of union not dissolving, 

<table>
<thead>
<tr>
<th>Duration</th>
<th>% remaining</th>
<th>Duration</th>
<th>% remaining</th>
<th>Duration</th>
<th>% remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.972</td>
<td>14</td>
<td>0.846</td>
<td>96</td>
<td>0.531</td>
</tr>
<tr>
<td>2</td>
<td>0.962</td>
<td>16</td>
<td>0.830</td>
<td>120</td>
<td>0.503</td>
</tr>
<tr>
<td>3</td>
<td>0.954</td>
<td>18</td>
<td>0.812</td>
<td>144</td>
<td>0.470</td>
</tr>
<tr>
<td>4</td>
<td>0.940</td>
<td>20</td>
<td>0.795</td>
<td>168</td>
<td>0.459</td>
</tr>
<tr>
<td>5</td>
<td>0.933</td>
<td>22</td>
<td>0.780</td>
<td>192</td>
<td>0.447</td>
</tr>
<tr>
<td>6</td>
<td>0.924</td>
<td>24</td>
<td>0.766</td>
<td>216</td>
<td>0.439</td>
</tr>
<tr>
<td>7</td>
<td>0.916</td>
<td>36</td>
<td>0.695</td>
<td>240</td>
<td>0.430</td>
</tr>
<tr>
<td>8</td>
<td>0.904</td>
<td>48</td>
<td>0.642</td>
<td>300</td>
<td>0.421</td>
</tr>
<tr>
<td>9</td>
<td>0.894</td>
<td>60</td>
<td>0.608</td>
<td>360</td>
<td>0.000</td>
</tr>
<tr>
<td>10</td>
<td>0.887</td>
<td>72</td>
<td>0.573</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>0.866</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11. Model Inputs: Cumulative probability of period post-dissolution not resulting in subsequent union, by period duration (months). 
*Source*: National Survey of Family Growth 2006-08.
<table>
<thead>
<tr>
<th>% Births</th>
<th>Median age at first birth</th>
<th>20 years of age</th>
<th>30 years of age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1st</td>
<td>2nd</td>
</tr>
<tr>
<td>1%</td>
<td></td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>5%</td>
<td></td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>10%</td>
<td></td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>25%</td>
<td></td>
<td>10</td>
<td>21</td>
</tr>
<tr>
<td>50%</td>
<td></td>
<td>18</td>
<td>34</td>
</tr>
<tr>
<td>75%</td>
<td></td>
<td>37</td>
<td>56</td>
</tr>
<tr>
<td>90%</td>
<td></td>
<td>75</td>
<td>84</td>
</tr>
<tr>
<td>95%</td>
<td></td>
<td>105</td>
<td>107</td>
</tr>
<tr>
<td>99%</td>
<td></td>
<td>171</td>
<td>158</td>
</tr>
<tr>
<td>100%</td>
<td></td>
<td>240</td>
<td>215</td>
</tr>
</tbody>
</table>

Table 12. Model Inputs: Birth interval length (months), by percentage of births completed.

*Source:* National Survey of Family Growth 2006-08.