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Does the sex ratio at sexual maturity affect men's later-life mortality risks? Evidence from historical China

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ABSTRACT

This study examines the relationship between the male-to-female sex ratio (measured as the proportion male) at sexual maturity and later-life mortality risks in the context of pre-industrial northeast China, using registration data from the Qing Dynasty. We find that a higher male-to-female sex ratio at sexual maturity is associated with a *higher* later-life mortality risk among men. This association is likely due to the long-term adverse consequences of stress caused by low mate availability at sexual maturity. We further find that a high sex ratio at sexual maturity mitigates the health benefits of marriage and exacerbates the health disadvantages of holding an official position in Qing China.

1. Introduction

Mate availability may have long-term health consequences. However, little research has empirically examined the effect of mate availability on individual health outcomes such as mortality risks. The sex ratio at sexual maturity (SRSM) directly measures mate availability during adolescence and young adulthood when individuals are especially sensitive to marriage market conditions (Barclay, 2013a,b). Existing studies that examine the mortality consequences of SRSM are limited and produce mixed findings (Barclay, 2013a,b; Jin et al., 2010). Research is still unclear about whether SRSM affects later-life health outcomes, and if it does, by what mechanisms.

This study examines the long-term mortality consequences of the sex ratio (measured as the proportion male) at sexual maturity among males in pre-industrial northeast China. Data from a subset of the China Multigenerational Panel Dataset-Liaoning (CMGPD-LN) are used. This study has three goals. First, we examine whether there is an association between SRSM and later-life mortality in historical northeast China. Second, we discuss through which channels SRSM may influence later-life mortality. Our empirical analyses try to distinguish three proposed mechanisms: marriage outcomes, stress, and motivation, by excluding some of the alternative mechanisms. Third, most previous theoretical discussions on the consequences of low mate availability focus on individuals who are relatively disadvantaged in the marriage market. The consequences of low mate availability on the advantaged—individuals who are married or have high social status—are less well known. In this study, we also discuss and examine whether SRSM mitigates the health benefits of marriage and high occupational status.

This study has two distinguishing features. To our knowledge, it is the first study on the long-term mortality consequences of unbalanced sex ratios in a historical, non-Western setting. The degree of unbalanced sex ratio in our data is comparable to that of many developing countries nowadays, where it has become a great concern. Second, previous studies failed to clarify whether SRSM has an effect on later-life health regardless of marital status or whether this effect is completely mediated by marriage. This study aims to distinguish the effect of marriage from the effect of SRSM on later-life mortality.

2. Conceptual framework

Features of the social context in early life are of great significance to various aspects of later-life well-being. However, few studies have investigated the long-term mortality consequences of the social context in the period of sexual maturity. Mate availability, as one of the most important contextual features at an individual's sexual maturity, likely has a long-term impact on health outcomes. First, lower mate availability at sexual maturity may delay marriage or decrease one's opportunities to find a partner (Fossett and Kiecolt, 1993; Guillot, 2000). When women are in undersupply relative to men, “the breadwinner system” comes into play (Angrist, 2002; Becker, 1973; Davis, 1984). Men in the lower social hierarchy, who are less qualified as breadwinners, are disadvantaged in terms of finding marital partners. Compared to their unmarried counterparts, on average, married individuals have greater health benefits as a result of more material resources and

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social support from their partners (Chandra et al., 1983; Goodwin et al., 1987; Gordon and Rosenthal, 1995; House et al., 1988; Wilson and Oswald, 2005). In a society such as historical China, where social status and acceptance depended largely on being married and having male offspring, single men were marginalized (Hudson and Den Boer, 2004). Lower mate availability for men also enhanced women's bargaining power in the marriage market. Thus, some men with high-socioeconomic status (SES) were forced to 'marry down' to low-SES women with worse health and unhealthy behaviors. Because a man's health can be affected by his wife's social status, health, and health behaviors (Bartley et al., 2004; Fletcher and Marksteiner, 2017; Jaffe et al., 2006; Monden et al., 2003), living in an environment with low mate availability may mitigate the health benefits of marriage among men through lowering marriage quality and adverse spousal health spillover effects.

Decreased perceptions of marriage chances, of course, are an even earlier stressor. Findings from animal research show that an unbalanced sex ratio leads to intense intra-sexual competition and more aggressive interactions among the supernumerary sex (Burley, 1985; Millesi et al., 1998). Stress resulting from these reproductive or mate-seeking efforts increases mortality rates among the supernumerary sex (Burley, 1985; Kuroki, 2014; Millesi et al., 1998). Analogously, men living in an environment with lower mate availability may have fewer marriage prospects and suffer from the stress of competition for, and choice of, mates (Barclay, 2013a,b; Bien et al., 2013; Kruger, 2008; Kuroki, 2014). Cumulatively, stress during the period of sexual maturity may have long-term consequences on old-age mortality. These arguments suggest that lower mate availability may adversely affect men's health regardless of their marital status, and this effect cannot be completely mitigated by marriage.

On the contrary, fierce mating competition sometimes motivates individuals to be healthier. This is evidenced in the existing literature on mate selection models, which finds four basic considerations that affect marriage decisions: a potential mate's family background, a potential mate's current SES and related behaviors, structural characteristics of the marriage market, and a potential mate's health characteristics (Fu and Goldman, 1996). In order to increase marriage chances when mate availability is low, individuals may be motivated to increase pre-marital investments, attain higher SES, and improve their health (Chiappori et al., 2009; Iyigun and Walsh, 2007; Lafortune, 2013; Wei and Zhang, 2011a,b). These pre-marital investments may have long-term beneficial consequences on health even apart from attracting a mate. Thus, lower mate availability may actually improve men's health in later life.

We propose three hypotheses of the effect of SRSM on later-life mortality:

- Male-to-female SRSM *raises* men's mortality risks later in life by reducing their marriage chances (**H1**). The consequence of sex ratio on mortality is based solely on marital status and only affects those who are not married. Under this assumption, we expect the adverse effect of SRSM to disappear after we control for marital status.
- Male-to-female SRSM *raises* men's mortality risks later in life because of the stress brought on by low marriage prospects, regardless of marriage outcomes (**H2a**). SRSM affects all individuals by increasing their stress levels, regardless of marital status. Under this assumption, we expect the adverse effect of SRSM will not disappear even after we control for marital status.
- Male-to-female SRSM *lowers* men's mortality risks later in life because fierce mate competition motivates them to be healthier (**H2b**). Like **H2a**, this hypothesis implies that SRSM affects all individuals regardless of marital status. Under this assumption, we expect to see a beneficial effect of SRSM even after we control for marital status.
- Male-to-female SRSM may mitigate the health benefits of marriage and social status because fierce mate competition may compromise the quality of marriage (**H3**). This hypothesis focuses on the effect of SRSM among advantaged populations. Under this assumption, we expect a positive coefficient of the interaction term between marital/occupational status and SRSM on mortality risk.

3. Literature review

Very little research has addressed the relationship between sex ratios and individual long-term health. Among those few studies, findings are mixed (Barclay, 2013a,b; Barclay and Scott, 2014; Bryngelson et al., 2011; Hensing and Alexanderson, 2004; Jin et al., 2010; Mastekaasa, 2005). Two studies, to our knowledge, have examined the effect of SRSM on later life mortality. Jin et al. (2010) showed that men who reached their sexual maturity in an environment with a higher male-to-female sex ratio (sex ratio 0.5–0.66 compared with sex ratio 0.44–0.48) suffered from a loss of about three months of life expectancy at age 65. Their analyses are based on data from both a representative sample of all 1957 Wisconsin high school graduates and a Medicare-based sample of elderly men with long-term mortality follow-up in the United States. Later, Barclay (2013a,b) examined the same hypothesis on cohorts born in 1941 and 1942 using the Swedish administrative register data. Although not statistically significant, the results generally showed an opposite direction of the effect of SRSM on mortality risks at later ages.

Three major questions remain on the relationship between SRSM and later-life mortality. First, the relationship between SRSM and later-life mortality in contexts other than the United States and Sweden is unclear. It is difficult to generalize the findings from these studies because skewed sex ratios are often not as severe in developed countries as they are in developing countries. If SRSM raises later-life mortality in developing countries, the consequences are likely to be much more pronounced than the consequences captured by the existing literature. Second, assuming there is a positive relationship between SRSM and later-life mortality, it is also not clear whether the effect of sex ratio is totally mediated by marriage outcomes. That is, living in a low-mate-availability setting may not affect later-life mortality if individuals manage to get married. Third, existing theoretical discussions tend to emphasize potential consequences of low-mate availability on disadvantaged groups in the marriage market. The three mechanisms (i.e., marriage outcomes, stress, and motivation) apply particularly to the disadvantaged in the marriage market. The advantaged in the marriage market are expected to worry less about marriage chances, and most of them manage to find partners regardless of low-mate availability. However, in such a setting, in order to get married, men with high social status may have to marry down. Taking a lower-status wife may have an adverse effect on the husband's health. Therefore, a high sex ratio may mitigate the health benefits of marriage and high social status.

Although measuring sex ratio is conceptually straightforward, it is difficult in practice. Particularly in modern societies, it is difficult to identify a geographically well-defined marriage market because individuals are more mobile than in the past. Migration affects marital outcomes. In this study, we attempt to partly overcome this challenge by using data from historical China. The population we examine was relatively closed with a very low level of migration (Dong and Lee, 2014). When inter-village migration did occur, it was recorded. Therefore, the data enable us to examine a stable marriage market and measure mate availability more accurately.

4. Data

Data for this study come from the China Multi-Generational Panel Dataset, Liaoning (CMGPD-LN), 1749–1909. The CMGPD-LN reports data from historical household registers in the Liaoning Province in Northeast China. A map of the regions covered by CMGPD-LN can be found in Fig. 1. Details about how the data were recorded, collected, and processed are documented in the User Guide (Lee et al., 2010).

The registry data, recorded every three years, provide extensive

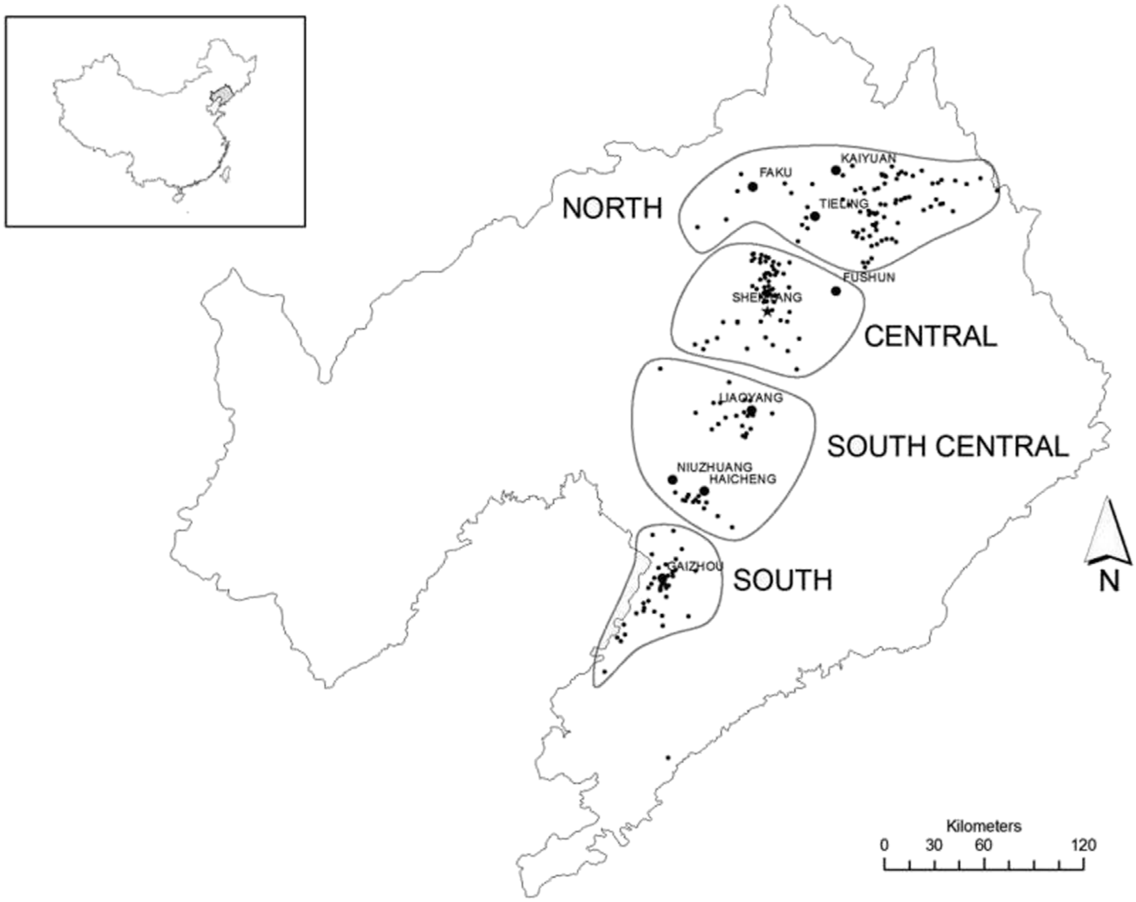

Fig. 1. Communities covered by Liaoning household register data, 1749–1909.
Source: Lee et al. (2010: 38).

details on individual-, household- and community-level characteristics. In this study, we use a subset of the original data, consisting of 285 villages. We chose these villages because we have accurate geographical information (longitude and latitude) for them, which allows us to identity fairly controlled marriage markets. A description of our sample restriction procedures is provided in Online Appendix 1.

The data have three features that make it especially suitable for our analysis. First, the CMGPD-LN data allow longitudinal linkage of the records of individuals across the life course, so they are especially suitable for analyzing long-term consequences of early-life conditions. Second, one of the unique features of the CMGPD-LN compared to other historical Chinese data is that mortality is recorded thoroughly through age 75. Third, problems with selectivity bias and errors caused by immigration and emigration are minimal, which allows us to calculate the sex ratio with great precision. Inter-village migration was well recorded in the data. In our final sample, there were about 20 men who migrated between villages during their sexually mature period.

One major limitation of the data is the underreporting of unmarried women. Similar with poor records of young females in many other Chinese datasets, unmarried daughters' records are omitted to a large extent in the CMGPD-LN (Lee et al., 2010). Further, the full names of women were not recorded, so we were unable to link married women with their natal families. If we calculate SRSM using raw data of unmarried women, the measure will be largely biased. Fortunately, all the records of married and widowed women are complete. Within a geographically well-defined marriage market, we would expect that married and widowed women were formerly unmarried women in the same market. Therefore, we can impute the marital histories of these women based on the record of their first-time appearance in the registers, and calculate the number of unmarried women for a certain year and age in this market.

This way of dealing with the underreporting of unmarried women works well given four important assumptions. The first assumption is that the marriage market is well-defined geographically. That is, almost all marriage activities happen within the defined marriage market. In this study, we make use of the longitude and latitude information for each village to identify a geographically well-defined marriage market for each village. Second, we assume the populations that are not included in our sample are homogeneous to the populations included in our sample within the same marriage market. Within a marriage market, it is possible that some villages are not included in our sample because their longitude and latitude information is not available. Our calculated SRSM will reflect the true SRSM in the corresponding marriage market only if SRSM for populations not included in our sample are similar to that for populations included in our sample in the same marriage markets for a given year. It is impossible to verify this assumption directly. However, the availability of the geographic information among villages in the CMGPD-LN is plausibly random, and the proportions of ever-married women among the population included in our sample and the entire population in the CMGPD-LN are similar in a given year (see Online Appendix Figure A2). Therefore, there is no strong reason to suspect SRSM for populations not included in our sample is systematically different from that for populations included within the same marriage market in a given year. Third, the mortality rate among unmarried females cannot be substantially higher than the male mortality rate during the sexually mature period. During the sexually mature period, female mortality is only slightly higher than male mortality (see Online Appendix Figure A1). Fourth, women who are married are not a selected group of individuals that excludes a number of unmarried women. Fortunately, marriage in northeast Qing

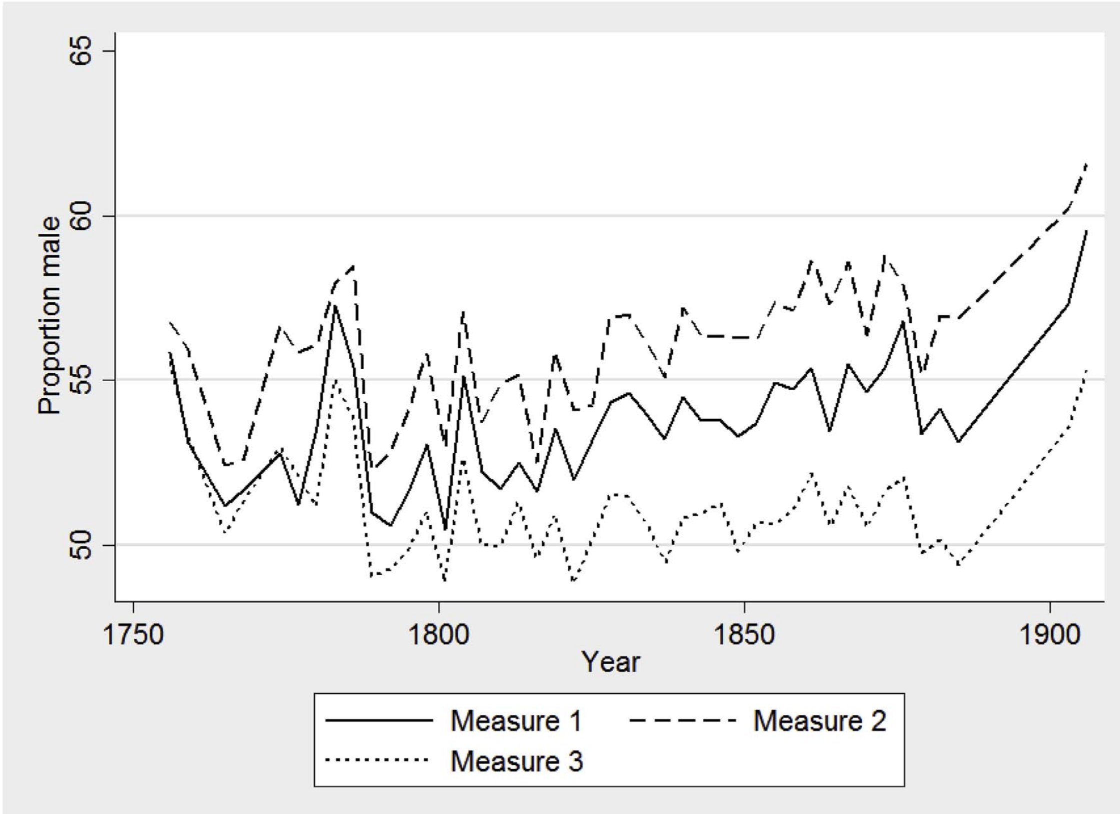

Fig. 2. Sex ratio at sexual maturity, CMGPD-LN, 1749–1909.

China was almost universal for females (Lee et al., 2010) due to cultural norms. For example, in one of the largest villages in our sample, *Daoyi*, only 1 percent of women remained unmarried at 35 *sui* (Lee and Campbell, 1997).

5. Measures

5.1. Sex ratio at sexual maturity

In order to make SRSM a valid measure for mate availability, we need to discuss two concepts: marriage markets and sexual maturity. Existing literature on geographical heterogamy shows that marriage markets worldwide were local before the 20th century (Ermisch, 1981; Westoff and Goldman, 1984). Particularly in pre-industrial China, due to poor transportation infrastructure, patriarchal lineage, and a strong desire for kinship networks, families in rural China mostly sought spouses in the same village or nearby villages (Fan and Huang, 1998). Even in the late 1980s, most rural marriages in China matched individuals who lived within a 25-km radius (Fan and Huang, 1998). Although we cannot find direct evidence on the geographic range of the marriage market in rural Qing China, it is very unlikely that individuals 200 years ago would find spouses outside of a 25-km radius. Therefore, we believe the 25-km radius around a focal village is a well-defined marriage market. Using the accurate longitude and latitude of each village, we identified all the villages within the 25-km radius of each focal village in our dataset.

Defining the term "marriage market" is key to our sex ratio measurement. In this study, we define it as eligible individuals living within a 25-km radius of a focal village. Eligibility is based on ages of sexual maturity. For females, the onset of sexual maturity is usually defined as the onset of menarche (Ljung et al., 1974). The average age for the onset of menarche for females in historical China was around age 13 *sui* (Wang, 2000). According to marriage law in the Qing Dynasty (1636–1912), the earliest age that a female was allowed to marry was age 14 *sui* (Zhang, 2013). For males, one way of defining the onset of sexual maturity is to look at cohort-specific mortality curves and identify the point at which the "accident hump" among males is at its peak (Goldstein, 2011). The "accident hump" in early adult mortality among males reflects an increase in deaths attributable to accidents, violence, and disease; there is evidence that these events coincide with the peak of male hormone production (Parkes, 1976). The peak of this "accident hump" occurred at approximately the age of 16 *sui* in our data. We use a 10-year age band to approximate the duration of sexual maturity for both men and women. Therefore, we define sexual maturity as males ages 16–25 *sui* and females ages 14–23 *sui*.

We compare three measures of sex ratio that fluctuate due to changes in fertility rates over time. These measures are also calculated to reflect common patterns of age difference in marriage partners observed in northeast China during the Qing Dynasty. We consider both married and unmarried males as competitors because polygyny existed in the populations covered by the registers.

For Measure 1, we first calculated SRSM for each year in each marriage market. That is, for each marriage market each year, we divided the number of males ages 16–25 *sui* by the sum of males ages 16–25 *sui* and unmarried females ages 14–23 *sui*. We assigned to each individual the market-specific sex ratios in the year during which they turned 19 *sui* (age 17.5 in standard ages). This measure allows us to study early adult mortality and compare our results with those using the Medicare sample in Jin et al. (2010).

For Measure 2, we first calculated 10 observations of the market-year-specific sex ratio based on a narrowly defined sex ratio age band. This more narrowly defined sex ratio reflects a two-year mean age difference between males and females as shown in our data. For example, for a male, the first measure at age 16 would be the sex ratio of 14- through 18-year-old males to 12- through 16-year-old unmarried females. At age 25, it would be males ages 23–27 and unmarried females ages 21–25. Then we took the mean of these 10 observations of the sex ratio for each individual. Forty-five percent of the observations in our sample have a marital age gap of less than two years.

For Measure 3, we adopted a narrower five-year age band to define sexual maturity. For each market each year, we calculated the sex ratio among males ages 16–20 and unmarried females ages 14–18. Then for each individual, we took the mean of the five measures of sex ratio at ages 16–20 for males to 14–18 for women. Measure 3 allows us to compare our findings with the results in Barclay (2013a,b).

In all the three measures, SRSM is a time-constant continuous variable for each individual. SRSM is entered as a linear term in our models because the relationship between SRSM and mortality does not exhibit an obvious non-linear pattern (see Online Appendix 2). Fig. 2 shows the means of each measure by year. Measure 2 gives the highest proportion of males, followed by Measure 1 and Measure 3. In most years, the proportion of males is within the range of 50–60 percent. According to existing historical literature on the Qing Dynasty, the proportion of males is roughly 52–57 percent among adults in the northeast and nearby areas (Jiang, 1997; Lee et al., 1994). Our numbers are consistent with these numbers, and patterns of all three measures are highly consistent over time. In general, the means of sex ratio increase gradually over time. This suggests that there might be some secular trend of sex ratios during this period. Therefore, we include year dummies in our mortality analyses.

5.2. Mortality

The key outcome variable is mortality status. Although the occurrence of death events is recorded, the CMGPD-LN does not record an exact date of death. We only know in which registers individuals were last recorded as alive. Therefore, an individual's mortality risk is measured as whether a death occurred in the past three years. Our analysis is conditional on survival to 20 *sui* (see Online Appendix 1 for the validity of our sample restrictions). The mean of the ages of dying in the past three years for males is around 52.08 *sui* with a standard deviation of 12.3.

5.3. Control variables

Controls include basic demographic characteristics such as age, year, and current region. Age in *sui* was entered as both linear and quadratic polynomial terms. Year was entered as a series of dummy variables. Region was entered as a set of dichotomous indicators indicating north, central, south central, and south Liaoning.

We capture social status in adulthood and old age by creating dummy variables for whether the individual held a position and whether he was married. Both of these variables are time-varying. Having a salaried official position is a sign of being a member of the local elite. A previous exploration of CMGPD-LN showed that males from families with relatively high SES were more likely to marry early (Lee et al., 2010).

We control for features of household context that previous studies have shown to be associated with mortality in historical China (Campbell and Lee, 2009). These are birth order among siblings, number of present brothers, and short birth intervals. Except for number of present brothers, others are all time-constant variables. Number of present brothers was input as the number of brothers who shared the same father in each year. A short preceding birth interval is defined as a maternal birth interval from zero to two years. A count of the siblings previously born to the same father is included as a measure of birth order.

We further control for village-level SES, which may affect both the sex ratio at sexual maturity and individual mortality risks later on. More resources may be linked to a lower male-to-female sex ratio and at the same time lower mortality. The preference for sons is a long-standing tradition in China (Banister, 1991; Edlund, 1999). Female infanticide as a birth control technique was widely used in historical Chinese households (Lee and Campbell, 1997). Poor villages may have a stronger son preference than wealthier villages because poor villages were often not able to afford daughters. Previous studies using the same data show that poor households reported a lower female birth rate than wealthy households (Lee and Campbell, 1997). Therefore, wealthy villages could have a lower sex ratio at sexual maturity because of a weaker son preference, and at the same time a lower mortality than poor villages.

We create four measures of village-level characteristics. The first measure is the proportion of married men under age 30 *sui* in each village for each year (Dong and Lee, 2014) because being married at a younger age is a strong indicator of SES (Chen et al., 2014). The second measure is the proportion of men having official positions within each village for each year. The third measure is logged village population. All three measures are time-varying and generated to capture village-level SES.

Son preference, which was particularly common in historical China (Banister, 1991; Edlund, 1999), may affect sex ratios and male mortality simultaneously. We use the difference between the proportion male calculated using raw data without imputation and the proportion male calculated after the imputation as a proxy of son preference. The idea is that if we consider the proportion male after imputation as the true proportion male, the difference between it and the value without imputation should capture the extent of female underreporting. Our assumption here is that the extent of female underreporting is positively correlated with son preference. Therefore, the larger the difference between these two sex ratio measures, the stronger the son preference in the village. Table 1 summarizes all the variables in our analysis.

6. Methods

We first examine whether there is an association between SRSM and later-life male mortality (**H2**), and whether this association operates

Table 1
Summary statistics.

Variable	Number of observations	Mean/Proportion	
		Total	SD
Sex ratio at sexual maturity (proportion male)			
Measure 1	62462	53.988	5.975
Measure 2	62424	56.959	7.886
Measure 3	62462	51.187	6.046
Mortality			
Dying in the next three years	68200	0.061	0.239
Demographic variables			
Year	68200	1856.943	35.568
Age	68200	40.075	14.193
Region (Ref = Northern Liaoning)			
Central Liaoning	68200	0.054	0.226
Southern Liaoning	68200	0.172	0.377
Southern Central Liaoning	68200	0.316	0.465
Socioeconomic status			
Married	68200	0.677	0.467
Had position	68200	0.008	0.092
Household context			
Short birth interval	68200	0.088	0.284
Birth order among brothers	68200	2.031	1.478
No. of survive brothers	68200	1.160	1.377
Village socioeconomic status			
Son preference (measure 1)	62448	40.193	8.530
Son preference (measure 2)	62079	37.625	8.865
Son preference (measure 3)	62408	41.438	9.106
Logged village population	68200	5.313	1.224
Proportion of married men under 30 *sui*	68200	0.676	0.171
Proportion of men having positions	68200	0.006	0.015

solely through marriage outcomes (**H1**). For each of the three measures of SRSM, we have two sets of analyses. We begin with discrete-time event-history analysis via logistic regression, which is an appropriate method in light of the structure of the data. Previous studies on mortality in the CMGPD-LN have all used discrete-time event history analysis because the data only specify the three-year interval in which a death occurred, not the actual date of death (Campbell and Lee, 2009; Dong and Lee, 2014). Discrete-time event-history analysis is specifically designed for such data, in which only the interval is known, instead of the actual date (Allison, 1984).

Adult male mortality can be associated with unobserved household characteristics that are also correlated with SRSM. For example, poor households with strong son preference may choose to live in a community that supports this preference. Such communities are likely to have a higher SRSM. At the same time, poor households with a strong son preference may have higher male mortality risks. To control for unobserved household characteristics that simultaneously influence SRSM and mortality later in life, we introduce a father fixed-effects model. Comparisons among brothers allow us to control for the common household environment, household wealth, and some genetic factors. This father fixed-effects model can also mitigate unmeasured village-level characteristics to some extent.

We then look at whether high SRSM may mitigate the health benefits of marriage and high social statuses (**H3**). For each measure of the sex ratio, we analyze two similar sets of models and add interaction terms between SRSM and being married/having an official position. A significantly positive effect of the interaction term would suggest low mate availability mitigates the health benefits of marriage and high social status among males because they might have to choose a relatively low-status partner.

7. Results

SRSM is positively associated with later-life male mortality risks (**H2a**). No supporting evidence for **H1** and **H2b** are found. Models 1, 3, and 5 in Table 2 present relevant results from the event-history analyses via logistic regression using three measures of the sex ratio. For every 1 percentage point increase in the proportion of males, men's odds of dying are raised by 1.2 percent ($e^{0.0116} = 1.012$) for Measure 1, 0.5 percent ($e^{0.00457} = 1.005$) for Measure 2, and 0.8 percent ($e^{0.00791} = 1.008$) for Measure 3. The coefficient is only statistically significant for Measure 1 and Measure 3. After introducing a father fixed-effects model in models 2, 4, and 6, the positive association between SRSM and adult mortality still holds. For every 1 percentage point increase in the proportion of males, men's odds of dying are raised by 0.7 percent ($e^{0.00745} = 1.007$) for Measure 1, 1.9 percent ($e^{0.0189} = 1.019$) for Measure 2, and 1.8 percent ($e^{0.0178} = 1.018$) for Measure 3. The coefficient is statistically significant for Measure 2 and Measure 3. The differences in the results from models with and without fixed effects are not driven by sample selection caused by the loss of observations in the fixed-effects models (see Online Appendix 3). For Measure 2, we also calculated a similar sex ratio using a four-year age gap as a robustness check. About 69 percent of the marriages in our sample fall within this four-year age gap. Results are highly consistent and are shown in Online Appendix Table A2.

Taken together, a 1 percentage point increase in the proportion of males at sexual maturity predicts a less than 2 percent increase in the odds of dying. This positive association is robust to various features of demographic characteristics, individual SES, household context, and village-level characteristics, as well as unobserved time-invariant household environments. These results suggest that SRSM is positively associated with male mortality in later life, regardless of marital status.

Results across the three measures of sex ratio differ in terms of statistical significance. But all coefficients are positive across all models. This suggests that the significance of the relationship can be sensitive to how the sex ratio is constructed. Findings in previous studies using only a single measure of sex ratio should be taken with caution. Among the three measures, results using Measure 1 are generally the least statistically significant. It is likely that the 10-year age band used to calculate Measure 1 cannot capture the real marriage market in historical northeast China, considering almost 70 percent of the couples in our sample had an age gap of less than 4 years.

In order to test **H3**, we look at the interaction between SRSM and marital/occupational status. Results are presented in Tables 3 and 4. In general, we find the health benefit of marriage is compromised in a low-mate-availability setting, although only the coefficient for Measure 2 is statistically significant. Based on the estimates in Model 4 of Table 3, compared to a married male who lived in a marriage market with a sex ratio of 1:1 at sexual maturity ($e^{(-1.023+50*(0.008+0.0165))} = 1.224$), the odds of dying in the next three years for a married male who lived in a marriage market in which 55% of the population are males are 13 percent higher ($e^{(-1.023+55*(0.008+0.0165))} = 1.383$, $\frac{1.383-1.224}{1.224} = 0.13$). This is consistent with the hypothesis that low mate availability raises the mortality risks for married men because those who live in unfavorable marriage markets are forced to choose mates of lower quality.

Similarly, males having official positions in a low-mate-availability setting face a higher mortality rate, although the coefficients are only statistically significant for Measure 3. While in contemporary society higher social status is associated with better health, in the Qing Dynasty we find that men with official positions in northeast China had higher odds of dying. This adverse consequence of having an official position is consistent across almost all studies using CMGPD-LN (Campbell and Lee, 1996, 2009). One explanation is the existence of the 'price of privilege' in historical China (Lee and Campbell, 1997). In Qing China, the Civil Service Examination system was the primary channel for recruiting government officials. This exam system helped a large number of individuals achieve upward mobility (Bai and Jia, 2016; Chang, 1955; Edmunds, 1906; Rawski, 1979). In order to obtain salaried positions, an individual had to invest a tremendous amount of time in reading and writing. Long hours studying, a limited amount of physical exercise and high stress may have led to a higher mortality for these individuals than peasants, who spent most of their time in physical labor. Based on the estimates in Model 6 of Table 4, compared to a male with an official position who lived in a marriage market with a sex ratio 1:1 at sexual maturity ($e^{(-1.884+50*(0.0164+0.0525))} = 4.764$), the odds of dying in the next three years for a male with an official position who lived in a marriage market in which 55% of the population are males are 41 percent higher ($e^{(-1.884+55*(0.0164+0.0525))} = 6.723$, $\frac{6.723-4.764}{4.764} = 0.41$). These results are consistent with the hypothesis that low-mate availability raises mortality risks for men with high social status because of reduced quality in available mates.

8. Conclusions

The relationship between mate availability and long-term health is theoretically well speculated but empirically less examined. In this study, we examine the relationship between SRSM and later-life mortality risks in the historical context of northeast China. We find a higher proportion of males at sexual maturity increases later-life mortality risks (**H2a**). This pattern is robust across three measures of sex ratio. The magnitude of the effect is generally less than 2 percent.

Further, we find that a higher SRSM mitigates the health benefits of marriage and exacerbates the disadvantage of having an official position **(H3)**. This is consistent with the argument that low mate availability reduces matching quality among the advantaged in the marriage market, and low matching quality together with adverse spousal health spillover effects leads to worse health outcomes. In historical China, social status and acceptance depended largely on marriage and male descendants (Hudson and Den Boer, 2002). For this reason, it was rare for men to remain unmarried if they could. Because of this universal pattern of marriage among men with high social positions, the adverse effect of low mate availability among married men and men with high

Table 2
Sex Ratio at Sexual Maturity and Adult Male (20–75 sui) Mortality.

	Measure 1		Measure 2		Measure 3	
	Logistic regression	Logistic regression with fixed effect of father	Logistic regression	Logistic regression with fixed effect of father	Logistic regression	Logistic regression with fixed effect of father
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Sex ratio at sexual maturity						
Proportion male	0.0116**	0.00745	0.00457	0.0189**	0.00791**	0.0178**
	(0.00460)	(0.00995)	(0.00391)	(0.00765)	(0.00381)	(0.00794)
Socioeconomic status						
Married	−0.101***	−0.0842	−0.102***	−0.0796	−0.102***	−0.0823
	(0.0374)	(0.0661)	(0.0376)	(0.0667)	(0.0374)	(0.0662)
Had position	0.405**	0.807***	0.383**	0.765**	0.412**	0.827***
	(0.175)	(0.309)	(0.176)	(0.314)	(0.174)	(0.309)
Village socioeconomic status						
Son preference	0.00691**	0.00209	0.00684**	0.0180***	0.00520*	0.0111*
	(0.00336)	(0.00745)	(0.00333)	(0.00659)	(0.00293)	(0.00614)
Logged village population	0.0649***	0.0668	0.0667***	0.0734	0.0653***	0.0685
	(0.0168)	(0.0948)	(0.0168)	(0.0960)	(0.0168)	(0.0952)
Proportion of married men under 30 *sui*	0.192*	−0.656**	0.183	−0.654**	0.191*	−0.659**
	(0.113)	(0.267)	(0.113)	(0.269)	(0.113)	(0.267)
Proportion of men having positions	1.034	3.687	1.111	3.921	0.967	3.716
	(1.324)	(3.254)	(1.327)	(3.262)	(1.325)	(3.252)
Household context						
Short birth interval	−0.0561	−0.0337	−0.0580	−0.0561	−0.0562	−0.0332
	(0.0652)	(0.0992)	(0.0655)	(0.0998)	(0.0652)	(0.0993)
Birth order among siblings	0.0304**	0.141***	0.0316**	0.154***	0.0310**	0.140***
	(0.0128)	(0.0422)	(0.0128)	(0.0425)	(0.0128)	(0.0423)
No. of present brothers	−0.0416***	1.141***	−0.0456***	1.141***	−0.0437***	1.139***
	(0.0154)	(0.0537)	(0.0155)	(0.0541)	(0.0154)	(0.0537)
N	62,448	26,288	62,079	26,008	62,408	26,234
Group		2787		2771		2784

Standard errors in parentheses, *p < 0.1, **p < 0.05, ***p < 0.01. To save space, coefficients of age, year, and region are not included. Age in sui was entered as a polynomial. Year was entered as a set of dummies. Region was entered as a set of dichotomous indicators, distinguishing between north, central, south central, and south Liaoning.

Table 3
Sex Ratio at Sexual Maturity, Marital Status, and Adult Male (20–75 sui) Mortality.

	Measure 1		Measure 2		Measure 3	
	Logistic regression	Logistic regression with fixed effect of father	Logistic regression	Logistic regression with fixed effect of father	Logistic regression	Logistic regression with fixed effect of father
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Male-to-female sex ratio at sexual maturity						
Proportion male	0.00907	−0.00131	0.000766	0.00800	0.00442	0.00930
	(0.00595)	(0.0118)	(0.00505)	(0.00932)	(0.00522)	(0.00978)
Socioeconomic status						
Married	−0.323	−0.808	−0.442	−1.023**	−0.393	−0.793*
	(0.330)	(0.526)	(0.287)	(0.474)	(0.299)	(0.481)
Had position	0.407**	0.805***	0.382**	0.753**	0.411**	0.806***
	(0.175)	(0.309)	(0.176)	(0.314)	(0.175)	(0.309)
SR*Married	0.00410	0.0134	0.00598	0.0165**	0.00566	0.0138
	(0.00606)	(0.00962)	(0.00501)	(0.00820)	(0.00578)	(0.00927)
N	62,448	26,288	62,079	26,008	62,408	26,234
Group		2787		2771		2784

Standard errors in parentheses, *p < 0.1, **p < 0.05, ***p < 0.01. To save space, coefficients for controls for household characteristics, village characteristics, age, year, and region are not shown.

social status may be more salient than that estimated in studies of Western countries.

This study has several limitations. First, the CMGPD-LN only allows study of early-life contextual influences on later-life mortality for males because it is impossible to follow females over the life course. Second, the actual effect of SRSM might be larger than that found in our analysis. The data only allow us to measure whether a death occurred in a three-year interval, which may not fully capture the effect. Together with possible measurement errors of SRSM under the assumption that patterns of female underreporting are random conditional on village SES and son preference, the magnitude of the effect is likely biased downward (Hausman, 2001). Finally, it is still possible that our fixed-effects models do not account for all confounders in the relationship between SRSM and later life mortality. Future research using experimental designs can better examine a causal relationship between SRSM and later life mortality.

Despite these limitations, we believe this study advances the literature on later-life consequences of early-life exposures and the literature on the consequences of unbalanced sex ratios. Our findings also have important policy implications. Compared to historical causes of death in China, major causes of deaths in the recent stage of epidemiological transition are degenerative and manmade (e.g., heart

Table 4
Sex Ratio at Sexual Maturity, Salaried Positions, and Adult Male (20–75 sui) Mortality.

	Measure 1		Measure 2		Measure 3	
	Logistic regression	Logistic regression with fixed effect of father	Logistic regression	Logistic regression with fixed effect of father	Logistic regression	Logistic regression with fixed effect of father
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Male-to-female sex ratio at sexual maturity						
Proportion male	0.0113**	0.00767	0.00428	0.0189**	0.00721*	0.0164**
	(0.00461)	(0.00999)	(0.00391)	(0.00766)	(0.00382)	(0.00797)
Socioeconomic status						
Married	−0.101***	−0.0845	−0.102***	−0.0796	−0.102***	−0.0840
	(0.0374)	(0.0661)	(0.0376)	(0.0667)	(0.0374)	(0.0662)
Had position	−1.061	1.288	−1.110	0.573	−2.016*	−1.884
	(1.524)	(1.865)	(1.249)	(2.232)	(1.051)	(1.511)
SR*Position	0.0275	−0.00898	0.0266	0.00340	0.0476**	0.0525*
	(0.0282)	(0.0344)	(0.0218)	(0.0391)	(0.0199)	(0.0284)
N	62,448	26,288	62,079	26,008	62,408	26,234
Group		2787		2771		2784

Standard errors in parentheses, *p < 0.1, **p < 0.05, ***p < 0.01. To save space, coefficients for controls for household characteristics, village characteristics, age, year, and region are not shown.

diseases, cancer and stroke). These causes are more stress related than most causes of death in historical China. Therefore, a skewed SRSM may have an even more severe consequence on later-life health and mortality now than in centuries past. Future research is needed to validate this study in different historical, social, and epidemiological contexts.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.socscimed.2018.02.024.

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