Explorations in Economic History 97 (2025) 101678

Contents lists available at ScienceDirect

Explorations in Economic History

journal homepage: www.elsevier.com/locate/eeh

Socioeconomic differences in population growth in 19th century Liaoning, China: a decomposition

Cameron Campbell [a,b,*], James Z. Lee [a]

[a] Division of Social Science, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong S.A.R., PR China
[b] School of History and Culture, Central China Normal University, Wuhan, Hubei, PR China

ARTICLE INFO

Keywords:
Qing china
Population growth
Socioeconomic differentials
Demographic rates
Economic conditions
households

ABSTRACT

We decompose population growth in 19th century Liaoning in northeast China into the shares accounted for by different socioeconomic groups, and by time periods with different economic conditions as reflected in grain prices. This decomposition reveals who benefitted the most when social and economic conditions supported population increase. Previous studies of one region for which relevant data are available, northeast China, showed that birth and death rates varied according to community, household, and individual context, but did not investigate differences in growth rates by context, or the shares of population growth accounted for by each group. Using the same dataset, we decompose population growth by synthesizing differentials in mortality and fertility into estimates of implied growth rates of population subgroups and the shares of total population growth they account for. This decomposition framework can be applied in any setting where household registers or other sources allow for the measurement of the mortality and fertility rates of population subgroups at fixed points of time. We show that advantaged socioeconomic groups contributed disproportionately to population growth in northeast China, and that more growth took place when harvests were good, that is when grain prices were low. Even though mortality and fertility responses to grain price fluctuations varied across subgroups, there is no evidence of differential response of growth rates to these fluctuations. We conclude by discussing the implications of our findings for our understanding of population dynamics in the late Qing.

1. Introduction

China's population grew rapidly in the 18th and 19th centuries. In 1700, the population was around 160 million (Lee and Wang 1999). By 1900, it was around 450 million. This is widely attributed to the spread of new crops and cultivation of new areas (Ho 1959). At the macro-level, there was substantial regional and temporal variation. For example, during the 19th century, growth in some central regions like Jiangnan was muted and growth in previously sparsely populated frontier regions accounted for much of the population increase.

The growth rates of different socioeconomic groups also varied. Birth rate and death rates differed according to economic conditions, community and household context, and individual characteristics (e.g. Campbell and Lee 1996; Lee and Campbell 1997; 2010; Wang et al. 2010). Not only did socioeconomically advantaged males marry earlier and had more children, but so did men with

---

* Corresponding author.
E-mail addresses: camcam@ust.hk (C. Campbell), jqljzl@ust.hk (J.Z. Lee).

https://doi.org/10.1016/j.eeh.2025.101678
Received 2 March 2024; Received in revised form 5 March 2025; Accepted 6 March 2025

privileged positions in the household hierarchy, for example, household heads. Differences in mortality rates on various dimensions were substantial but patterns were complex. A small number of case studies of lineages for which multi-generational genealogical data are available show that males of high socioeconomic status had more surviving sons and that high status lineages or lineage branches grew more quickly (e.g. Harrell 1985; Hu 2023; Song et al. 2015).

Identifying the social and economic groups that contributed the most to population growth is important for understanding the implications of such growth for Qing society and economy. If socioeconomically advantaged groups had faster growth rates and contributed disproportionately to increases in population during the Qing, this may have increased the downward mobility of their offspring. The numbers of exam degrees and officials that well-off families competed for remained fixed as the population increased. Campbell and Lee (2003) already documented downward mobility for one privileged subpopulation: the sons of local officials and degree-holders. Rapid growth in their families would have made competition among their sons even more intense. Conversely, if growth was concentrated among the less well-off, it would have increased economic pressure on farmers by accelerating the fragmentation of landholdings and lowering wages.

Despite the importance of measuring growth rate differentials, the studies mentioned above all consider birth and death rates separately. A unified approach is necessary because the differences between subgroups in birth and death rates that they reported might have contradictory implications for growth not apparent in the separate analyses carried out so far. For example, in a situation like that of household heads or men with official posts in Liaoning who had higher birth and death rates (Lee and Campbell 1997), whether their growth rates were higher than those of the population at large would have depended on how fertility advantage and mortality disadvantaged netted out.

To compare the growth rates of subgroups in late imperial China and decompose population growth into the shares accounted for by each of them, we apply a regression-based framework for that combines the fertility and mortality rates of subgroups. This decomposition framework does not require multigenerational data like those used in Song et al. (2015) and Hu (2023) and can be applied wherever data exist that already allow for mortality and fertility differentials to be studied, for example, where there are data like those used by participants in the Eurasia Project in Family and Population History (Bengtsson et al. 2004; Lundh and Kurosu et al. 2014; Tsuya et al. 2010) or the Life at the Extremes Project (e.g. Chuang et al. 2006; Engelen et al. 2011).

We make use of data for males in Liaoning in northeast China from 1789 to 1909 from the publicly released China Multigenerational Panel Dataset – Liaoning (CMGPD-LN). Population growth in the region covered by the CMGDP-LN was like that observed in other regions that grew quickly during the Qing (between 1789 and 1909, the population grew by a factor of 2.6). The CMGPD-LN also has an important advantage over the genealogical data used in studies of population dynamics in China before the twentieth century (e.g. Harrell 1985; Hu 2023; Hsiue 2017; Liu 1985; Telford 1995): they provide information on household and village context. For the males in the CMGPD-LN, we regress death in the next three years and the number of boys born in the next three years on logged number of males in the household, lineage, and village, the numbers of men with official position in the household and the village, the category and region of the administrative population, logged sorghum prices over the next three years, and calendar year. We then calculate the growth rates of different subgroups by differencing their predicted birth and death rates. We use these predicted growth rates to decompose the overall population growth rate into the shares attributable to different population subgroups.

We find that in nineteenth-century Liaoning, larger households and lineages and households with high-status males grew more quickly, suggesting that they benefitted disproportionately from the conditions that led to population growth. However, it would also have increased competition among them for exam degrees and government posts, leading to more downward mobility. While growth rates overall were sensitive to economic fluctuations, as measured in sorghum prices, evidence about the differences in the responses of subgroups is mixed. Responses of administration populations may have varied according to their category and region, but there was little evidence of systematic variation in the responses of growth rates according to household, lineage, or village size, or numbers of men with position in the household or lineage.

This study makes three contributions. First, it introduces an approach for decomposing population growth into the shares contributed by different social and economic groups that could be applied in other settings. Second, it ties together previously separate findings on differentials in birth and death rates in northeast China reported in several decades' worth of studies. Third, and most importantly, identifies the groups that had the highest growth rates and contributed the most to population increase, this study offers a new view of population growth in late imperial China and possible implications for society and the economy.

The paper is organized as follows. In the next section, we review relevant literature on the determinants of population growth and social and economic differentials in birth and death rates in past times to show that even though the latter were inspired by the former, the two literatures until now have been distinct literatures. We then introduce the 19th century northeast Chinese population that we study and the data that covers them. We highlight features of the data that affect the design of our analysis and review the variables that we include in the analysis. We then introduce our regression-based approach by which we synthesizes estimates of growth rates for social and economic groups from their birth and death rates and decompose population growth into the shares attributable to different groups. We discuss the implications of findings for our understanding of population growth during the Qing and conclude with suggestions for future directions.

2. Background

Early historical studies of population dynamics studied relationships between population and the economy at the national or regional level. They made use of highly aggregated time series, including annual counts of total numbers of births and deaths, estimates of total population size, estimates of the real wage, and/or agricultural prices. Well-known studies include the ones by Ronald Lee that used time series from England, as summarized in Lee (1985), as well as studies of Sweden by Bengtsson and Ohlsson (1984) and

Bengtsson (1984), the comparative study of England and France by Weir (1984), and the comparative study of multiple European countries by Galloway (1988). More recent studies address similar questions but apply more advanced econometric methods.[1] Collectively, both classic and recent studies suggest that Malthusian homeostatic processes operated in the short- and long-term, though the details were complex, and the strength of relationships varying by time and place.

Once individual-level or other disaggregated data and the technology to analyze it became available, attention shifted to socio-economic differentials in demographic outcomes, most commonly birth and death rates, for insight into the implications of historical patterns of inequality. For example, Hammel and Galloway (2000) differentiated fertility and mortality responses to grain price fluctuations by social class in the Balkans by analysis of times series constructed from parish register data. Cinnirella et al. (2017) showed that families adjusted the timing of births in response to economic conditions and their number of children, and that effects were strongest among the least well off. The Life at the Extremes Project compared determinants of mortality, fertility, and other demographic outcomes for 19th century Netherlands and early 20th century Taiwan (e.g. Chuang et al. 2006; Engelen et al. 2011).

Along these lines, the Eurasia Project in Population and Family History conducted comparative studies of the interactions between economic conditions and community, household, and individual characteristics in shaping demographic outcomes that revealed who was most or least affected when times were bad. The underlying intuition is that groups with the least resources should be most sensitive to price or other fluctuations (Bengtsson 2004; Campbell et al. 2004). Analyses relied on household and individual microdata that situated individuals within their community and household context, and looked separately at mortality (Bengtsson et al. 2004), fertility (Tsuya et al. 2010), and marriage (Lundh and Kurosu 2014) responses to economic stress. Other studies by project participants examined more specific topics within the larger framework of the project. Most relevant to the emphasis on multiple outcomes in this study are the analyses of mortality and migration in Belgium by George Alter, Michel Oris, and collaborators (Alter et al. 1999; Oris and Alter, 2001 and 2003), and the study of mortality and migration in Japan by Noriko Tsuya and Satomi Kurosu (Tsuya and Kurosu 2010).

For northeast China, the region covered in this study, studies have investigated differentials in birth and death rates (Campbell and Lee 1996, 2004; Lee and Campbell 1997; Wang et al. 2010; Wei 2025).[2] Fertility differentials were mostly as expected. Fertility fell when grain prices rose. Men who had higher socioeconomic status in the form of an examination degree or official position, who occupied privileged positions in the household hierarchy such as household head, or who were members of larger households all had higher fertility. Part of this was attributable to their earlier marriage. If widowed, it reflected their higher likelihood of remarriage. These patterns held regardless of whether fertility was measured as the occurrence of a birth in an event-history analysis, or a count of the total number of sons born, or total number of surviving sons (Wei 2025). They also held regardless of whether fertility was measured for fathers or mothers.

Mortality, however, was more complex (Campbell and Lee 1996, 2004). Some results for Liaoning were as expected. Mortality rose when grain prices increased. Widowers and orphans experienced elevated mortality. Other results were counterintuitive. Some high-status males, including household heads and men who had salaried official positions, had elevated death rates. Lee and Campbell (1997) referred to this as the ‘price of privilege.’ Such unexpected results on differentials in mortality were common enough in China and in the other settings considered by the Eurasia Project to preclude relying on birth rate differentials alone to make claims about the growth rates of subgroups, let alone their contributions to overall growth.

The implications of differentials in birth and death rates for the growth rates of population subgroups remains understudied, at least for China. Studies that showed higher status lineages grew more quickly (e.g. Harrell 1985; Hu 2023; Song et al. 2015) did not examine their contribution to population growth overall. Mare and Song (2023) applied a model-based approach to study social mobility over multiple generations in Liaoning and the Imperial lineage, but did not investigate population growth. Contemporary studies like Mare and Maralani (2006), Mare (1997) and Preston and Campbell (1993) investigate how demographic differentials shaped population composition and patterns of social mobility, but not their implications for net population growth or decline.

By combining the study of differentials in birth and death rates with the study of population growth, this study paves for the study of population growth and decline that goes beyond the analysis of national-or regional-level time series in classic studies like Lee (1985) to consider the role of population subgroups. It addresses a critique of Campbell and Lee (2004) and related work on differentials by the participants in the Eurasia Project by Lee and Steckel (2006). They pointed out that one of the limitations of the Eurasia Project and related projects was that even though they were inspired by earlier classic studies of population dynamics like Lee (1985), they did not assess the implications of the patterns of differentials they reported based on micro-level data for macro-level population dynamics, including population growth and decline, and other aggregate phenomena.

---

[1] Klemp (2012) found a positive association between agricultural wages and fertility in preindustrial England. Nicolini (2007) found that in England escaped from a Malthusian regime earlier than previously thought: the relationship of population and real wages was Malthusian until the seventeenth century, at which point the positive check disappeared, followed by the preventive check. Møller and Sharp (2014) reached a similar conclusion, suggesting that England transitioned to a post-Malthusian regime earlier than previously thought. Weisdorf and Sharp (2009) examined the relationship between prices and nuptiality in England and showed that before the 19th century, the relationship was negative, but that during the 19th century, it became positive.

[2] Campbell and Lee (1996) showed that mortality risks differed according to socioeconomic status household context, including location in the household hierarchy. Lee and Campbell (1997) followed up with studies of fertility, mortality, and marriage. Campbell and Lee (2004) revisited mortality using a larger dataset and examined differentials in the mortality response to economic stress, as measured with grain prices. Wang, Campbell, and Lee (2010) examined fertility, again with a larger dataset, and also examining differentials in the response to economic stress.

3. Setting

Our study population consists of descendants of Han settlers who migrated from Shandong and elsewhere in the seventeenth and eighteenth century to what is now Liaoning province in northeast China. They became hereditary tenants akin to crown peasants living on frontier land owned by the Qing (1644–1911) state and administered through the Eight Banners, a civil and military administration. The history of the settlement and the social, economic, and institution contexts of the settlers and their descendants are described in detail in Lee and Campbell (1997) and Ding et al. (2003).[3] The population of this region grew quickly: the population growth rate implied by the combination of birth and death rates was 0.8 % (Table 1), with an implied doubling time for the population of 86.6 years. Accordingly, the population should have increased by a factor of 2.6 between 1789 and 1909.

These tenants were divided into categories according to their institutional affiliation. The first, who we refer to as regular, were farmers who grew grain, and who paid their rents in kind and were free to consume or sell whatever remained on the market. They accounted for over 80 percent of the study population (Table 1). The second category, accounting for 11 percent of the population, engaged in specialized production for the Imperial Household Agency. Their products included furs, silver, honey and fish. The third category, which we refer to as low status, farmed land on estates linked to disgraced officials. Whereas the first two categories were eligible for privileges like appointments to office, those in the low status category were not.

The population was distributed among >500 villages in Liaoning across an area similar in size to New Jersey or The Netherlands. For the analysis, we divide the area into four regions: North, Central, South Central, and South. South and South Central were the most prosperous regions. South consisted of the coastal area around Gaizhou that was the hinterland of what became a treaty port, Yingkou. South Central was a prosperous agricultural plain surrounding two major towns, Haicheng and Niuzhuang. Central refers to the hinterland around the city that is now the provincial capital, Shenyang, and which during the Qing was Shengjing, a secondary national capital. The Central region was densely settled and Lee and Campbell (1997) suggested that by the middle of the 19th century, it was close to its capacity. North refers to the remote and hilly area around Kaiyuan and Tieling in the northeast of the province.

While the social, economic, and institutional context of these populations was distinctive, there was enough similarity between them and those elsewhere in China for their experience to inform our understanding of other parts of China. Reflecting the settler population's origin in Shandong and neighboring provinces, patterns of household and lineage organization were broadly similar to those elsewhere in China, especially north China (Lee and Campbell 1997). The regular and specialized populations were eligible to compete for the same degrees and offices as people living elsewhere in China. They interacted with the market like farmers elsewhere in China, especially tenant farmers.

4. Data

The data used in the analysis, the China Multigenerational Panel Dataset-Qing (CGED-Q), was created by transcribing the triennial household registers that the state used to track the tenants on its land (Lee and Campbell 2016).[4] Tenants on Eight Banner land were eligible for privileges because of their affiliation with the state, and they had little incentive to evade registration that documented their status. We have already described the origins of the registers as well as our procedures for data entry, cleaning and linkage in Lee and Campbell (1997, 223–237). The CMGPD-LN already have been used extensively in published analyses of mortality (Campbell and Lee 2004; Lee and Campbell 1997; Zang and Campbell 2018) and fertility (Lee and Campbell 1997; Wang et al. 2010). These and other studies describe the strengths and limitations of the CMGPD-LN relevant to the study of mortality and fertility, thus here we only summarize some features of the dataset of particular importance for the analysis.

The CMGPD-LN contains approximately 1.5 million triennial records of 260,000 people who lived in nearly 700 communities in what is now Liaoning between 1749 and 1909 (Lee et al. 2010). These records were from household registers that resembled censuses and were compiled every three years. The original registers were organized into 29 series, each corresponding to an administrative population in one of the three categories described earlier. We restrict the analysis to the records from 1789 to 1909 which distinguished residential households. We also restrict the analysis to men because even though the registration of married women was nearly complete, the recording of daughters and their births and marriages is incomplete.[5] After excluding records of males whose village of residence could not be determined, who appeared to be already deceased or departed from the population, or who were listed in registers for which the immediately succeeding triennial register was not available, we are left with 494,647 records of males that we use in the analysis.

The left-hand side variables in our regressions are an indicator of whether a man died in the next three years and a count of how many sons they fathered in the same period. Table 1 presents the proportion of men dying in the next three years and the mean number

---

[3] Originally the Eight Banners were the army, primarily Manchus from northeast China, who conquered China to form the Qing. Eventually the Eight Banners acquired bureaucratic and administrative roles as well, including the management of state land.

[4] All the CMGPD-LN data and accompanying documentation are available for download at the Interuniversity Consortium for Political and Social Research: https://doi.org/10.3886/ICPSR27063.v10

[5] While it would be desirable if the data would allow for the inclusion of females in the analysis, results that rely solely on records of males should nevertheless yield useful insights into population dynamics. Previous studies of differentials in fertility in Liaoning yield similar findings on patterns according to socioeconomic status and other characteristics regardless of whether we consider births to men or their wives (Lee and Campbell 1997; Wang, Campbell and Lee 2010; Wei 2025). This reflects that female marriage was early and universal, and that aside from a small number of remarried widowers whose spouses were younger than they were, men and women tended to be similar in age.

Table 1
Summary statistics, CMGPD-LN, 1789–1909.

	Mean	S.D.	Minimum	Maximum
Left-Hand Side Variables				
Male births in next 3 years	0.077	0.28	0	4
Male death in next 3 years	0.053	0.22	0	1
Annual Male Population Growth Rate	0.8 %			
Right-hand Side Variables				
Males with position in the household	0.098	0.40	0	9
Males with position in the lineage	1.192	2.66	0	32
Number of males in the household	8.077	7.54	1	76
Number of males in the lineage	142.847	146.66	1	988
1789–1799	4.70			
1800–1824	5.67			
1825–1849	6.18			
1850–1874	7.63			
1875–1899	9.45			
1900–1911	13.48			
Number of males in the village	248.346	312.45	1	1676
Administrative Category				
Regular	0.824	0.38	0	1
Specialized	0.113	0.32	0	1
Low status	0.063	0.24	0	1
Region				
North	0.379	0.49	0	1
Central	0.287	0.45	0	1
South Central	0.205	0.40	0	1
South	0.128	0.33	0	1
Records	494,697			

of male births linked to men in the next three years. The indicator for death in the next three years was based on the presence of an annotation in the next available triennial register indicating that the individual had died. We inferred the number of sons fathered by a man in the next three years from the computed birthyears of sons recorded in later registers who we linked to them. Boys who died in infancy or early childhood tended to be omitted from the registers, so our analysis only considers boys who survived long enough to be recorded in a register. Since we are interested in net population growth, this is not an issue. However, because boys whose birth is inferred to be in the three-year period between two registers may not appear in our records until a later register, our denominator for the total number of males may be slightly underestimated. Again, this should not affect estimates of net growth rates.

Table 1 also presents the right-hand side variables. Because our interest is in the birth and death rates for the whole male population, both analyses use all males regardless of age. We do not include age or any individual-level covariate that is intrinsically associated with age and therefore the risk of fathering a child or dying. We control the geographic region and administrative category of the population as defined above. We include counts of the number of men with an official position in the household and lineage as a measure of their social and economic status. By position, we refer to any salaried official position or status with the government, along with some exam or purchase degrees or honorary titles that would have been indicative of wealth or high standing. The salaries for official positions were large enough to support a large household (Lee and Campbell 1997). Holders of official positions represented the local elite. According to Table 1, the average number of positions in the household was 0.098, and some men lived in households with as many as 9 positions. Overall, 8 percent of men lived in a household were someone held a position.

The number of men in the household is intended as a measure of the household's labor capacity. Previous studies also suggest that in the Liaoning farming populations covered by the CMGPD-LN, larger households were wealthier (Campbell and Lee 1999; Lee and Campbell 1997, 1998). In a recently settled frontier region like Liaoning where many areas remained sparsely population well into the 19th century and labor was at a premium, large households may have enjoyed returns to scale in agricultural production or the provision of public goods to household members. While diminishing returns would have been inevitable for households that grew beyond a certain point, or in other parts of China where land was scarce, Liaoning does not appear to have faced such constraints. According to Table 1, males on average lived in households in which there were a total of eight males, including themselves. The largest household had 76 males. These figures are consistent with previous examinations of the data which confirmed that people tended to live in large households with multiple families (Lee and Campbell 1997). While the other right-hand side variables were mostly stable over time, the average size of the households in which men lived increased over time. At the beginning of the period, the average man lived in a household consisting of 4.7 males. By 1900–1911, the figure was 13.48. Below we will investigate whether the effects of household size varied by time.

Number of men in the lineage reflects the larger kin network in which households were embedded. The lineage was an important unit of social and in some cases economic organization in late imperial China (Campbell and Lee 2008, 2011). We reconstructed lineages through record linkage. We defined a lineage as consisting of men who were descended from the same household group in the earliest available population register for their series. There were 880 such lineages in the data. On average, men were part of lineages that had 143 male members. Based on fieldwork, these tended to correspond to the lineages recognized by the inhabitants of villages. In the estimations below, we transform the numbers of men in the household, lineage, and village by logging and dividing by the log of

1.1, so that estimated coefficients reflect the effect of a 10 % increase in the count.

To measure economic conditions for the farmers who accounted for most of the population, we use a logged, detrended low sorghum price series measured at the level of the prefecture (Campbell and Lee 2004). Again, we divide the logged prices by the log 1.1 so that estimated coefficients reflect the effect of a 10 % increase in prices. During the Qing, the high and low prices of five key grains in each prefecture were reported to the central government every month.[6] For each of the five grains, the high price series reflected the ones paid by consumers in larger cities, whereas the low-price series reflected producer prices. In Liaoning, sorghum was the most important of the five grains. Previous studies have shown that the low sorghum price series closely reflected harvest outcomes and had the strongest association with the demographic outcomes of the farmers covered in the dataset (Campbell and Lee 2004; Lee and Campbell 1997, 2005; Lee et al. 1992). Elevated prices in the low sorghum price series were indicative of poor harvests.. While higher prices may have benefited large landowners who still had a surplus to sell when harvests were reduced, they left tenant farmers like the ones covered by the CMGPD-LN with less to consume or sell because they had to cover fixed, in-kind rents (Lee and Campbell 1997). We have no evidence that the Liaoning farmers were able to store grain or other food from one year to the next, thus in an extremely bad year, they would not have had enough left after paying their rents to maintain their usual consumption. They would have had to cut back on food consumption or cut back on other consumption or sell assets to purchase food on the market at higher than normal prices(Campbell et al. 2004).

5. Methods

To map the growth rates of population subgroups implied by their birth and death rates and measure the contributions of these population subgroups to population growth, we apply a regression-based decomposition that we will describe in detail below. To summarize, we regress birth and death in the whole population on membership in population categories as well as quantitative measures of household, community, and village context. Differencing the predicted death and birth rates for each subgroup yields their predicted growth rates. The decomposition method can be applied to longitudinal, individual-level demographic data like that in the Eurasia Project and doesn't require that the membership of the subgroups to be fixed. Because population composition was in constant flux, with people moving from one subgroup to another, the resulting predicted growth rate is best thought of as force operating at a specific point in time. We use predicted growth rates to decompose population growth into the shares attributable to specific subgroups.

Decomposition based on the coefficients estimated in linear regressions are widely used to identify the sources of differences in rates across time and between populations. Our own inspiration was the decomposition of mortality change into the shares attributable to different causes of death in Preston (1976), which regressed overall mortality rates at the national level on cause-specific mortality rates.[7] Other examples include Preston's (1975) study of the role of economic growth in increases in life expectancy around the world after the Second World War, the decomposition of income and other differentials in mortality in the United States by Kitagawa and Hauser (1973) and the decomposition of wage differentials by Blinder (1973) and Oaxaca (1973).

We first estimate linear probability models for the chance of dying y_d in the next three years (Eq. (1)), and linear regressions of the numbers of sons y_b fathered in the next three years (Eq. (2)). The right-hand side variables may be continuous, as in the case of household or village size, or discrete, as in the case of administrative category and region. Estimated b_{di} and b_{bi} reflect the effect on the death or birth rate of a one-unit change in a continuous variable. In the case of a categorical variable, they reflect differences between the birth or death rate of the specified category and the baseline category.

Because we estimate linear regressions, for each continuous right-hand side variable x_i, we can estimate the effect of a one-unit increase in its value on the implied annual growth rate $\Delta \mathrm{r}_\mathrm{i}$ by differencing the associated estimated coefficients b_{di} and b_{bi} produced by the birth and death rate regressions and dividing by three (Eq. (3)).[8] Similarly, where x_i is categorical variable, the difference $\Delta \mathrm{r}_{\mathrm{i}|\mathrm{c}}$ between the growth rate of category defined by $x_i = c$ and the growth rate of the baseline category is given by the difference between the birth and death rate regression coefficients for category *c:* $b_{bi|c}$ and $b_{di|c}$ (Eq. (4)). In both cases we divide by three because the original coefficients reflect changes over three years.

$$y_d = a_d + \boldsymbol{B_d X} \tag{1}$$

---

[6] The five grains were rice, millet, sorghum, wheat, and soybean. According to Lee and Campbell (1997) and Lee, Campbell and Tan (1992), these series were highly correlated with each other, and with demographic outcomes. We chose sorghum based on its importance in the Liaoning economy and because the low sorghum series had the strongest correlation with demographic rates.

[7] Because mortality change over time had to exactly equal the sum of the changes associated with each cause, the coefficients for the cause-specific rates had to sum to one and could be interpreted as the share of overall decline attributable to changes in that cause of death.

[8] We use a linear regression instead of logistic regression for death and Poisson regression for births specifically because the coefficients from a linear regression can be added together to infer implied net effects on growth rates of a one-unit change in a right-hand side variable of interest. These net effects will be the same regardless of the values of the other right-hand side variables. Working out implied net effects on growth rates using coefficients from logistic or Poisson models would require simulations because coefficients reflect proportional changes in the odds of an event (logistic regression) or the count of occurrences of an event (Poisson regression). The implied effect on the probability of the event of a one-unit change in the right-hand side variable will vary depending on the value not only of the right-hand side variable of interesting, but of the other right-hand side variables. Combining estimates death and birth would require sweeps over the distributions of the right-hand side variables. We are grateful to Dong Hao for his reminder about the non-linear aspects of predictions based on the results of logistic and Poisson regression.

$$y_b = a_b + \boldsymbol{B_b X} \tag{2}$$

$$\Delta r_i = (b_{bi} - b_{di})/3 \tag{3}$$

$$\Delta r_{i|c} = \left(b_{bi|c} - b_{di|c}\right)/3 \tag{4}$$

$$\widehat{y}_{d|x_i=c} = a_d + b_{di}c + \boldsymbol{B}_{\boldsymbol{d\bar{i}}}\boldsymbol{X}_{\boldsymbol{d\bar{i}}} \tag{5}$$

$$\widehat{y}_{b|x_i=c} = a_b + b_{bi}c + \boldsymbol{B}_{\boldsymbol{b\bar{i}}}\boldsymbol{X}_{\boldsymbol{b\bar{i}}} \tag{6}$$

$$\widehat{r}_{x_i=c} = ln\left(1 + \widehat{y}_{b|x_i=c} - \widehat{y}_{d|x_i=c}\right)\Big/3 \tag{7}$$

For each population subgroup defined by a value c for the right-hand side variable x_i, we use the estimated coefficients $\mathbf{B_d}$ and $\mathbf{B_b}$ to calculate a predicted growth rate (Eq. 7) from the death rate $\widehat{y}_{d|x_i=c}$ (Eq. 5) and birth rate $\widehat{y}_{b|x_i=c}$ (Eq. 6). In Eq. 7, because the difference in the birth and death rates is for three years, we add one to turn it into the proportion change in population over three years, log that, and then divide by 3 to get an annualized growth rate. When we carry out predictions, x_i is equal to c,. Variables for number of men in the household, lineage, and/or village are set to their mean, counts of officials positions for household and lineage are set to zero, low sorghum prices are set to their mean, the year is set to 1840, and region and administrative category are set to regular bannermen in north Liaoning.

The predicted growth rates reflect a force or pressure acting on population composition at a moment in time. It is the instantaneous growth rate that would be observed in a hypothetical population of individuals that had the birth and death rates of the regular bannermen in North Liaoning for whom x_i is equal to c and remaining continuous variables are set to their means. A high growth rate for a subgroup indicates that at each moment in time, the individuals who happen to be part of that subgroup are contributing more to population growth. Household size and other measures changed constantly, so the synthetic growth rate does not reflect the long-term experience of a specific subgroup within the population. Similarly, the number of official positions and degrees was roughly fixed, making it impossible for the actual share of the men living with someone with a degree or position to change much over time. If such men contributed disproportionately to population growth because their fertility rates were high, their actual share of the population would have been stable or even declining because their sons would have experienced downward mobility and would have ended up in households where no one had a position. Only region and administrative context were fixed, with little movement between them. For them, the predicted growth rate corresponds to the actual growth rate observed during the study period.

The predicted growth rates refer to hypothetical subpopulations in which only births and deaths occur, and there is no in- or out-migration. Our approach in effect closes the population to in- and out-migration by excluding records of individuals who were annotated in the next available register as having left and treating newly appeared individuals the same way as those who appeared in previous registers. In- and out-migration could be included in the model by regressing the chances of having arrived in the last three years or leaving in the next three years, predicting in- and out-migration rates, and then adding them to the calculated growth rates.

To decompose population growth into the portions accounted for subgroups defined by the values of right-hand side variable x_i, we produce Lorenz curves that represent the cumulative contribution to population growth of subgroups x_i arranged according to their percentile in the distribution. This allows us to read out the share of growth accounted for by the top or bottom 10 or 20 or 50 percent of the population in terms of the variable of interest x_i. To produce these, we estimate population growth rates for each percentile of a variable of interest, compute the cumulative sum at each percentile, and divide by the total growth rate. This works because the total population growth rate at any point in time has to the sum of the growth rates of the subpopulations weighted by their share of the

Table 2

Regression of birth and death rates, and implied coefficients for growth rates, CMGPD-LN, 1789–1909.

	Birth in 3 Years (1)			Death in 3 Years (2)			
	Coef.	S.E.	p	Coef.	S.E.	p	Δr
Men in the household with official positions	0.0128	0.0011	0.00	0.0010	0.0008	0.23	0.0039
Men in lineage with official positions	−0.0004	0.0002	0.01	−0.0002	0.0001	0.16	−0.0001
Number of males in household - 10 % increase	0.0004	0.0001	0.00	−0.0004	0.0000	0.00	0.0003
Number of males in lineage - 10 % increase	0.0002	0.0000	0.00	0.0000	0.0000	0.45	0.0001
Number of males in village - 10 % increase	0.0002	0.0000	0.00	0.0001	0.0000	0.00	0.0000
Population Category (Reference: Regular)							
Specialized population	−0.0001	0.0014	0.96	0.0026	0.0011	0.02	−0.0009
Low status population	−0.0096	0.0017	0.00	0.0001	0.0014	0.94	−0.0032
Region (Reference: North Liaoning)							
Central Liaoning	−0.0039	0.0010	0.00	−0.0002	0.0008	0.85	−0.0012
South Central Liaoning	0.0045	0.0011	0.00	−0.0053	0.0009	0.00	0.0033
South Liaoning	0.0038	0.0014	0.01	−0.0093	0.0011	0.00	0.0044
Logged (base 1.1) low sorghum price, detrended	−0.0019	0.0002	0.00	0.0007	0.0001	0.00	−0.0009
Year	−0.0001	0.0000	0.00	−0.0001	0.0000	0.00	0.0000
Intercept	0.0584	0.0021	0.00	0.0651	0.0016	0.00	−0.0023
Records	494,647			494,647			

population.

6. Results

Growth rates differed across population subgroups. Table 2 presents the results from the regressions of birth and death rates on household, lineage, and village characteristics, along with the implied 'coefficients' for their net effects on growth rates. According to Table 2, every male in the household who had a position increased the growth rate by 0.39 %. Every 10 % increase in the number of males in the household increased the growth rate by 0.03 %, and every 10 % increase in the number of males in the linage increased growth rates by 0.01 %. Even though according to Table 1 the average number of males in the household increased over time, according to separate calculations not shown here, the effect of a 10 % increase in the number of males fluctuated but did not exhibit a trend.[9] Village size had positive effects on birth rates and death rates, but no net effect on growth rates. Findings for region and administrative category are consistent with those reported for birth and death rates in Lee and Campbell (2005). Specialized populations grew more slowly because their death rates were higher.[10] Low status populations grew more slowly than regular populations. According to the coefficients, specialized populations had elevated death rates. Central Liaoning, which included administrative populations residing in the secondary capital of the Qing, Shengjing (the city that is now Shenyang) had a lower growth rate than the more sparsely settled north and the more prosperous south and south-central regions.

While the effect on growth rates of being in a household with a male who held a position may seem small, the implication is that over ten years, such households would grow by 4 % more than other households. Men whose fathers held position were more likely to have positions themselves (Campbell and Lee 2003) so such differentials may have persisted across multiple generations, leading eventually to overrepresentation in the current population of the descendants of men who held position in previous generations (Hu 2023; Song et al. 2015). Of course, in an environment where the number of positions and degrees was fixed, such tendencies would be countered by downward mobility.

To clarify the substantive implications of the results for sorghum prices and the sizes of household, lineage, and village, Fig. 1 presents predicted growth rates for households, lineages, and villages at different percentiles of size, and for years at different percentiles of the low sorghum price. The predictions are based on the regression results in Table 2. We focus on sorghum prices and household size, where differences in growth rates are the most apparent.

According to Fig. 1, the largest households grew more quickly. The top ten percent of men in terms of household size had annual growth rates of 1.4 % or higher, and the bottom ten percent of men in terms of household size had annual growth rates of around 0.2 %. The findings on the association of household size with growth prospects are consistent with previous claims that in Liaoning, a frontier region where labor was at a premium, larger households were more prosperous and had higher birth rates (Lee and Campbell 1997). Similarly, Wang et al. (2010) reported that married women in multiple-family households had higher birth rates than married women in single-family households. Chen et al. (2014) reported that men in larger households married earlier. Findings on the effects of household size on mortality rates were inconsistent.

We also calculated growth rates for households according to the number of men with positions. Since only 8 percent of men lived in households where at least one man had a position, we summarize the growth rates here in the text. The results are consistent with expectations based on earlier findings that having an official position or being related to someone with an official position was associated with earlier marriage and higher fertility (Campbell and Lee 2008; Chen et al. 2014; Wang et al. 2010). According to our calculations, the 92 percent of men who lived in households where no male had positions had an annual growth rate of 0.7 %, the 6 percent of men in households where one male had a position had an annual growth rate of 1 %, the 1 percent of men in households where there were 2 to 9 men with positions had a growth rate of 1.5 %. The remaining 1 percent of men who lived in households with 9 or more men with position had a growth rate of 4.0 %, corresponding to a doubling time of 17.5 years.

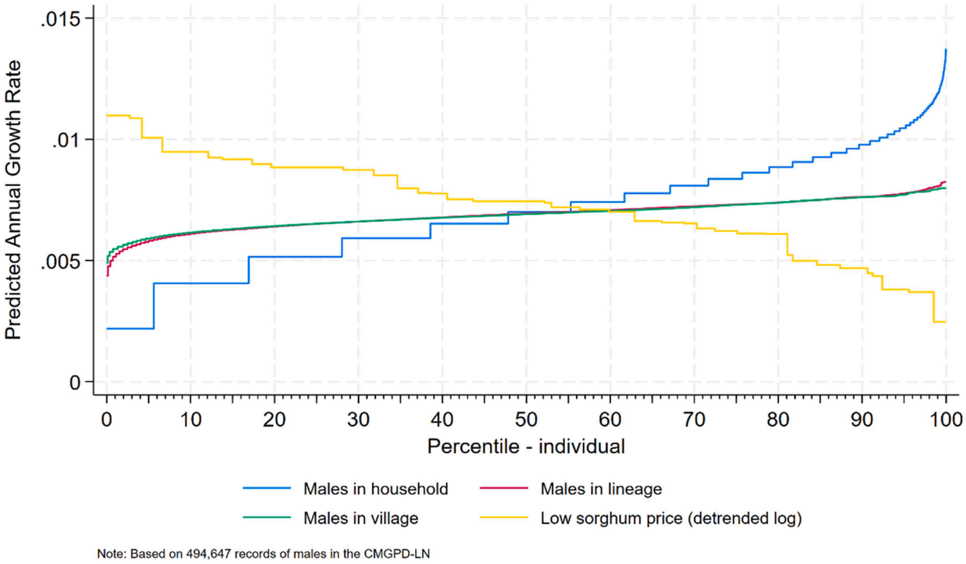
Fig. 2 decomposes population growth into the shares attributable to households with different numbers of males. It plots the cumulative share of population growth accounted for by men in households at different percentiles in terms of size. In a regular administrative category population in north Liaoning where continuous variables are all set to their mean, the 20 % of men in the smallest households contribute about 10 % of population growth, while the 20 % of men in the largest households contribute about 30 % of population growth. The 10 % of men in the largest households contributed about 20 % of population growth. For reference, we also plot the number of males in the household for each percentile, with the scale on the right-hand side y-axis. The men in the top 20 percent in terms of the number of males in the household lived in households with at least 12 men, and the men in the top 10 percent in terms of number of males in the household lived in households with at least 16 men. Such processes would have increased the fragmentation of landholding because when these households finally divided, they would divide among more men.

We also decomposed growth into the shares attributable to the households with different numbers of men with position. Again, since 92 percent of men lived in households where no one held a position, we summarize the results here rather than provide a plot. The most striking finding was that the top 8 percent of men in terms of the number of men in the household with official positions accounted for 15.7 percent of population growth, while the remaining 92 percent of men who lived in households where no one held a position accounted for 84 percent of growth. Again, since the numbers of degrees and positions was largely stable during the period under consideration, this would have contributed to the downward mobility among these groups reported in Campbell and Lee (2003).

---

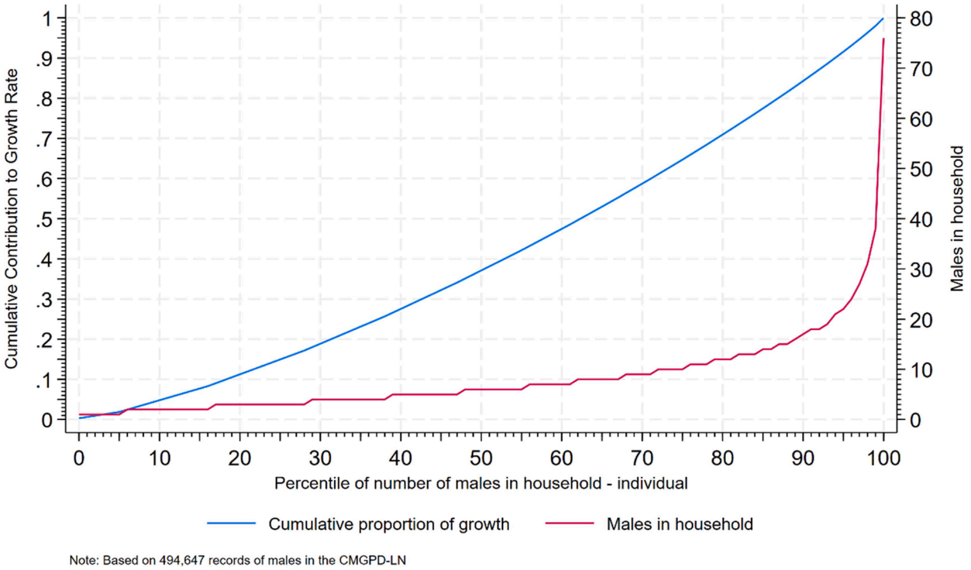
[9] 1789-1799: 0.01%, 1800-1824: 0.03%, 1825-1849: 0.02%, 1850-1874: 0.03%, 1875-1899: 0.04%, 1900-1911: 0.03%.

[10] The elevated mortality of populations engaged in specialized production is consistent with findings in Campbell and Lee (2004), which speculated that they reflected the tendency for these populations to be located in remote areas and depend on non-agricultural production.



Note: Based on 494,647 records of males in the CMGPD-LN

Fig. 1. Predicted growth rates according to household, lineage, and village size, and low sorghum price, CMGPD-LN, 1789–1909.



Note: Based on 494,647 records of males in the CMGPD-LN

Fig. 2. Cumulative share of population growth accounted for by men in households according to size, CMGPD-LN, 1789–1909.

There were differences in growth rates between years of high and low prices. According to Fig. 1, when prices were at their lowest, growth rates were around 3 percent, but when they were at their highest, they fell to 1 percent. Fig. 3 decomposes population growth according to percentiles of annual sorghum prices. According to the results, the years that were in the bottom half in terms of current low sorghum prices accounted for sixty percent of growth, while the years that were in the top half in terms of current low sorghum prices accounted for forty percent of population growth. This assumes linear effects of logged, detrended low sorghum prices on birth and death rates.

The growth rates of population subgroups did not vary in terms of their sensitivity to price fluctuations. Table 3 presents the relevant results. There was some indication that when sorghum prices were high, specialized populations had slightly higher or at least slightly less negative growth rates (by 0.1 %). Such a pattern was also apparent for south Liaoning. In some cases, population subgroups had responses to price fluctuations with opposing implications, leading to no net effect. For example, low status populations had a lower reduction in fertility when prices were high, but a higher increase in mortality, and the net effects on growth rates were negligible.

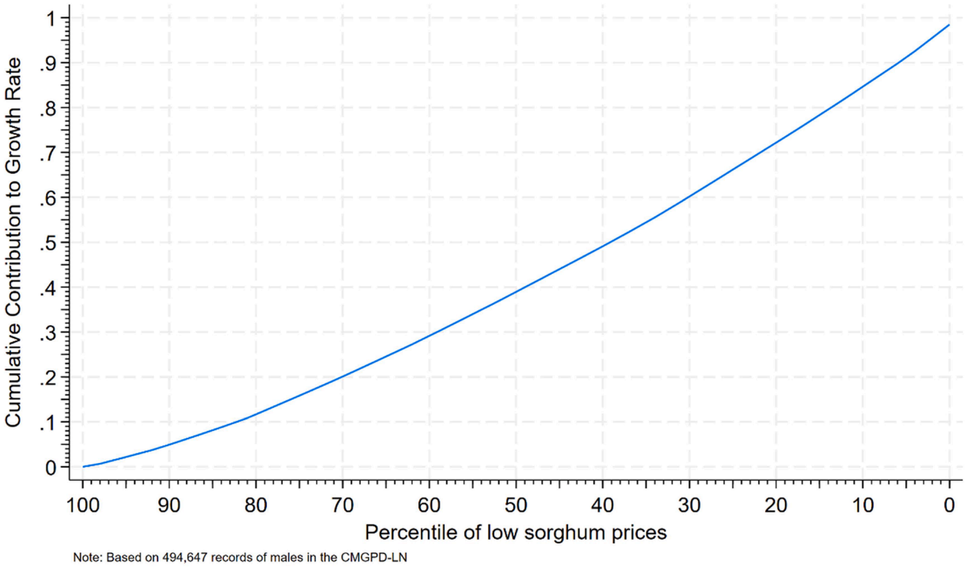


Fig. 3. Cumulative share of population growth accounted for by men according to the low sorghum price, CMGPD-LN, 1789–1909.

7. Discussion

While it was already well-known that there was regional and temporal variation in population increase in Qing China, the results here confirm that variation in the growth rates of social and economic groups within regions and time periods was also substantial. At any given point in time, larger households and linages and households with more men who held official positions contributed disproportionately to population growth. While the Liaoning context that we study here is distinctive, but family and household organization and the underlying dynamics of the agricultural economy were similar enough to other locations in China that the association between socioeconomic advantage and contributions to population growth observed here are likely to have characterized other parts of China.

The association between sorghum prices and growth rates suggests a possible role in late imperial China for the homeostatic processes that were the focused of early studies like Lee (1985). Confirming expectations based on results from separate analyses of birth and death rates, growth rates were slower when grain prices were high, and higher when grain prices were low. As discussed above, high grain prices were indicative of poor harvests, which adversely affected farmers because any benefits of being able to sell at a higher price were offset by having less to sell, or possibly having to buy grain on the market. If high grain prices became more common over time resulting from rising population pressure, years of low growth should also have become more common, leading to reduced growth rates.

The concentration of population growth among the relatively well-off, that is the members of households where one or more men held an official position, may have intensified the tendency towards downward mobility among local elites. Since such households tended to be the ones most likely to have the wherewithal to educate their sons to prepare for the exams, it would have heightened the competition for official positions more than if population growth was evenly distributed among social and economic classes. The numbers of official positions were relatively stable in the 18th and 19th centuries even though the population was increasing. To the extent that it was the relatively well-off families who sought these positions for their sons who accounted for most of the population growth, they would have been competing with larger numbers of candidates from similar socioeconomic backgrounds than if growth was more evenly distributed. As it was, Campbell and Lee (2003) showed that downward mobility was common for men who held positions. The positive association between the number of men in the household with position and the growth rate may have contributed to such downward mobility by making it even harder for such families to sustain their position and further increasing the chances that the offspring of men with no position would not have positions of their own.

More speculatively, the relationship between household size and population growth rates may have helped regulate population growth over the long term. To the extent that the higher growth rates of larger households led them to account for a disproportionate share of population growth, in the long term it would have accelerated the fragmentation of landholding among the largest and best-off households when they divided, increasing the chances of downward mobility among their descendants. Even though average household size increased over time (Table 1), at any given time the large households in which distantly related kin lived together were the most vulnerable to the death of key kin triggering a division, and they were accordingly more fragile (Campbell and Lee 1999; Lee and Campbell 1997). Among households that did not divide, in the absence of acquisition of more land, as their members increased beyond the numbers required to work the land they held, they presumably would have begun to experience diminishing returns.

The association between lineage size and growth rates may have facilitated the homogenization of surnames in rural communities. China is well-known for having many rural communities where everyone has the same surname, or there are only a small number of

Table 3
Regression of birth and death rates, with interactions with sorghum prices and year, CMGPD-LN, 1789–1909.

	Birth in 3 Years (1)			Death in 3 Years (2)			
	Coef.	S.E.	p	Coef.		p	Δ*r*
Men in household with official positions	0.01720	0.00257	0.00	0.00026	0.00204	0.90	0.00565
Men in lineage with official positions	−0.00053	0.00043	0.21	0.00065	0.00034	0.06	−0.00039
Number of males in household - 10 % increase	0.00025	0.00012	0.03	−0.00066	0.00010	0.00	0.0003
Number of males in lineage - 10 % increase	0.00033	0.00010	0.00	−0.00036	0.00008	0.00	0.00023
Number of males in village - 10 % increase	0.00075	0.00007	0.00	−0.00006	0.00006	0.30	0.00027
Administrative Category (Reference: Regular population)							
Specialized population	0.01415	0.00327	0.00	0.01569	0.00260	0.00	−0.00051
Low status population	0.00600	0.00402	0.14	0.01302	0.00319	0.00	−0.00234
Region (Reference: North Liaoning)							
Central Liaoning	−0.00752	0.00234	0.00	0.00707	0.00186	0.00	−0.00486
South Central Liaoning	0.00372	0.00256	0.15	−0.01130	0.00203	0.00	0.00501
South Liaoning	0.00929	0.00339	0.01	−0.01057	0.00269	0.00	0.00662
Logged (base 1.1) low sorghum price, detrended	−0.00306	0.00095	0.00	−0.00034	0.00076	0.66	−0.00091
* Men in household with official positions	0.00035	0.00047	0.45	0.00022	0.00037	0.54	0.00004
* Men in lineage with official positions	0.00008	0.00008	0.27	−0.00010	0.00006	0.11	0.00006
* Number of males in household - 10 % increase	−0.00002	0.00002	0.31	0.00001	0.00002	0.75	−0.00001
* Number of males in lineage - 10 % increase	0.00005	0.00002	0.02	0.00003	0.00002	0.09	0.00001
* Number of males in village - 10 % increase	−0.00004	0.00001	0.02	0.00001	0.00001	0.46	−0.00001
* Population Category (Reference: Regular population)							
Specialized population	0.00176	0.00068	0.01	−0.00144	0.00054	0.01	0.00107
Low status population	0.00170	0.00087	0.05	0.00189	0.00069	0.01	−0.00006
* Region (Reference: North Liaoning)							
Central Liaoning	0.00063	0.00046	0.18	−0.00068	0.00037	0.06	0.00044
South Central Liaoning	0.00174	0.00051	0.00	−0.00038	0.00041	0.35	0.00071
South Liaoning	0.00278	0.00068	0.00	−0.00072	0.00054	0.18	0.00117
Year	0.00030	0.00006	0.00	−0.00051	0.00005	0.00	0.00027
* Men in household with official positions	−0.00006	0.00004	0.08	0.00001	0.00003	0.63	−0.00003
* Men in lineage with official positions	0.00000	0.00001	0.82	−0.00001	0.00000	0.01	0
* Number of males in household - 10 % increase	0.00000	0.00000	0.18	0.00000	0.00000	0.01	0
* Number of males in lineage - 10 % increase	0.00000	0.00000	0.52	0.00001	0.00000	0.00	0
* Number of males in village - 10 % increase	−0.00001	0.00000	0.00	0.00000	0.00000	0.01	0
* Population Category (Reference: Regular population)							
Specialized population	−0.00018	0.00004	0.00	−0.00021	0.00003	0.00	0.00001
Low status population	−0.00021	0.00006	0.00	−0.00020	0.00004	0.00	0
* Region (Reference: North Liaoning)							
Central Liaoning	0.00005	0.00003	0.10	−0.00011	0.00003	0.00	0.00006
South Central Liaoning	0.00002	0.00003	0.50	0.00007	0.00003	0.01	−0.00002
South Liaoning	−0.00005	0.00004	0.22	0.00000	0.00003	0.99	−0.00002
Intercept	0.02644	0.00471	0.00	0.09069	0.00374	0.00	−0.02142

surnames. This could arise naturally because of randomly occurring variations in the growth rates of lineages. The results here, however, suggest that the process of surname homogenization in communities may have been accelerated by a tendency for the largest lineages to grow even more quickly. If larger lineages were by virtue of their size more likely to grow more quickly, they would overwhelm smaller lineages in the same community more quickly, leading to homogenization more quickly than if lineage extinction were purely random.

8. Conclusion

By moving beyond the separate study of differentials in birth and death rates to differentials in growth rates, this analysis provides insights into population dynamics in northeast China during the late Qing. Unsurprisingly, population growth was slower when grain prices were high. This is as expected, since birth rates declined, and death rates rose when grain prices were high. Even though Campbell and Lee (2004) and Wang et al. (2010) reported differences in the responses of birth and death rates to fluctuations in grain prices, there was little evidence of overall differences in the impacts of prices on the growth rates of subgroups, however. Similarly, growth was lowest in central Liaoning, a densely settled region surrounding the major city that is now Shenyang. Population growth was highest in southern and south-central Liaoning, which during the late Qing were the most prosperous regions in the province. Such results are not surprising, since previous studies had shown that birth rates were higher, and death rates lower in the south. Finally, the well-off had higher growth rates. Larger households and lineages, and household with more men with official positions, grew faster.

This study marks a conclusion to a long line of work studying social, economic and household differentials in birth, death and other rates in northeast China. In the last three decades, we and our collaborators have published dozens of studies of how community, household, and individual characteristics shaped the birth, death, marriage, and migration chances of individuals. Though decades ago we and many others in the Eurasia Project originally were inspired to study differences between social and economic groups in the relationship between economic conditions and demographic behavior in past times by classic studies of population-level processes like

Lee (1985) and Weir (1984), this is the first time we have come full circle and assessed the implications of differentials by social and economic status for macro-level population dynamics.

We hope that the framework we present here inspires additional studies of the contributions of different population subgroups to overall population growth and decline. Specifically, we hope that others are inspired to apply our approach in other settings where relevant data are available to examine the implications of the differentials that they have been studying separately for population-level processes. By allowing for the disaggregation of the population dynamics into the shares contributed by subgroups, our decomposition approach allows us to move past the separate consideration of birth, death, and other rates characteristic of the Eurasia Project in Population and Family History (Bengtsson et al. 2004; Lundh and Kurosu et al. 2014; Tsuya et al. 2010) and examine how they combine to shape population growth or decline. It can help identify the contributions of different population groups to overall growth, and their contributions to the response to fluctuations or long-term trends.

We further hope that the results from such studies are integrated into studies of the implications of socioeconomic differentials in demographic behavior for social mobility. A long line of work at the intersection of demographic and social mobility has examined the implications of demographic differentials and intergenerational associations in status for the socioeconomic composition of the population (Preston and Campbell 1993; Mare 1997; Mare and Maralani 2006). The model-based simulations used in such studies are more demanding in terms of data than the one presented here. While the approach here may not yield the same level of detail in terms of insights into implications for population composition as these studies, it does offer insight into the pressures promoting upward or downward mobility for different population subgroups in historical societies for which data like those used in these studies are not available.

CRediT authorship contribution statement

Cameron Campbell: Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **James Z. Lee:** Project administration, Funding acquisition, Data curation, Conceptualization.

Acknowledgments

This manuscript has been presented at: the University of Hong Kong Faculty of Social Sciences Population and Health Seminar Series, 30 January 2024; the session Inequality, Economic Stress and Demographic Behavior over Recent Centuries: Eurasia and Beyond, XIX World Economic History Congress, Paris, France. July 27, 2022; the session Inequality, Economic Stress, and Demographic Behavior over Recent Centuries: Integrated views. European Society for Historical Demography. Madrid, Spain. March 2, 2022; and the session Inequality, Economic Stress, and Demographic Behavior Sub-Session 2: Fertility and Mortality Responses to Economic Stress in the Modernizing World. Social Science History Association Annual Meeting. Philadelphia, November 13, 2021. We are grateful to the discussants and audience members for their comments and suggestions. We are also grateful to Dong Hao and other members of the Lee-Campbell Group as well as Stuart Gietel-Basten for their comments and suggestions. We are also grateful to anonymous reviewers at *Explorations in Economic History* for their suggestions. This research was supported by HK RGC General Research Fund 16602621 (Campbell PI) and HK RGC Areas of Excellence AoE/B-704/22-R (Chen Zhiwu PI). For a portion of the time during which Campbell worked on the manuscript, he was a 2022–23 Fellow at the Stanford Center for Advanced Study in the Behavioral Sciences.

Data availability

All of the data may be downloaded from ICPSR via a link provided in the paper.

References

Alter, George, Bourdelais, Patrice, Demonet, Michel, Oris, Michel, 1999. Mortalité et Migration dans les Villes Industrielles au XIXe Siècle: exemples Belges et Français. Annales de Démographie Historique 2, 31–62.

Bengtsson, Tommy, Cameron Campbell, James Lee et al. 2004b. *Life Under Pressure: Mortality and Living Standards in Europe and Asia, 1700-1900*. Cambridge: MIT Press.

Bengtsson, Tommy, Ohlsson, Rolf, 1984. Population and economic fluctuations in Sweden 1749-1914. In: Bengtsson, Tommy, Fridlizius, Gunnar, Ohlsson, Rolf (Eds.), Pre-Industrial Population Change. Almquist and Wiksell International, pp. 277–298.

Bengtsson, Tommy. 2004a. Living standards and eocnomic stress. Chapter 2 in Bengtsson, Tommy, Cameron Campbell, James Lee et al. 2004. *Life Under Pressure: Mortality and Living Standards in Europe and Asia,* 1700-1900. Cambridge: MIT Press, 27–60.

Bengtsson, Tommy, 1984. Harvest fluctuations in demographic response: southern Sweden 1751-1858. In: Tommy, Bengtsson, Fridlizius, Gunnar, Ohlsson, Rolf (Eds.), Pre-Industrial Population Change. Almquist and Wiksell International, pp. 329–356.

Blinder, Alan, S., 1973. Wage discrimination: reduced form and structural estimates. J.Hum. Sourc. 8 (4), 436–455.

Campbell, Cameron, Lee, James Z., 1996. A death in the family: household structure and mortality in rural Liaoning, life-event and time-series analysis, 1792-1867. Int. Quart. 1 (3), 297–328.

Campbell, Cameron, Lee, James Z., 2003. Social mobility from a kinship perspective: rural Liaoning, 1789-1909. Int. Rev. Soc. Hist. 48 (1), 1–26.

Campbell, Cameron, Lee, James Z., 2011. Kinship and the long-term persistence of inequality in Liaoning, China, 1749-2005. Chin. Sociol. Rev. 44 (1), 71–104.

Campbell, Cameron, James Z. Lee, and Tommy Bengtsson. 2004. Economic stress and mortality. Chapter 3 in Bengtsson, Tommy, Cameron Campbell, James Lee et al. 2004. *Life Under Pressure: Mortality and Living Standards in Europe and Asia,* 1700-1900. Cambridge: MIT Press, 61–84.

Campbell, Cameron and James Z. Lee. 2004. Mortality and household in seven Liaodong populations, 1749–1909. Chapter 10 in Bengtsson, Tommy, Cameron Campbell, James Lee et al. 2004. *Life Under Pressure: Mortality and Living Standards in Europe and Asia,* 1700-1900. Cambridge: MIT Press, 293–324.

Campbell, Cameron, Lee, James Z., 1999. Causes and consequences of household division in northeast China, 1789-1909. In: 李中清, Lee, James, 郭松义, Songyi, Guo, 定宜庄, Yizhuang, Ding (Eds.), *婚姻,家庭与人口行为:东西比较史 (Marriage and family, East-West comparative methods)* 北京:北京大学出版社. Peking University Press, Beijing, pp. 1–32.

Campbell, Cameron, Lee, James, 2008. Villages, descent groups, households and individual outcomes in rural liaoning, 1789-1909. In: Bengtsson, Tommy, Mineau, Geri (Eds.), Kinship and Demographic Behavior in the Past. Springer, pp. 73–104.

Chen Shuang, Cameron Campbell, and James Z. Lee. 2014. Categorical Inequality and gender difference: marriage and remarriage in Northeast China, 1749-1913. Chapter 11 in Lundh, Christer, Satomi Kurosu, et al. *Similarity in Difference: Marriage in Europe and Asia,* 1700-1900. MIT Press, 393–438.

Chen, Shuang, Lee, James Z., Campbell, Cameron, 2010. Wealth stratification and reproduction in Northeast China, 1866-1907. Hist. Fam. 15 (4), 386–412.

Chuang, Ying-chang, Engelen, Theo, Wolf, Arthur, 2006. Positive Or Preventive? Reproduction in Taiwan and The Netherlands, 1850-1940. Amsterdam University Press.

Cinnirella, Francesco, Klemp, Marc, Weisdorf, Jacob, 2017. Malthus in the bedroom: birth spacing as birth control in pre-transition England. Demography 54 (2), 413–436.

Engelen, Theo, Shepherd, John R., Yang, Wen-shan, 2011. Death At the Opposite Ends of the Eurasian Continent. Amsterdam University Press.

Galloway, Patrick R., 1988. Basic patterns in annual variations in fertility, nuptiality, mortality, and prices in pre-industrial Europe. Popul. Stud. 42, 275–402.

Hammel, Eugene A., Galloway, Patrick, 2000. Structural and behavioural changes in the short-term preventive check in the Northwest Balkans in the 18th and19th centuries. Europ. J. Popul. 16, 67–108.

Harrell, Stevan., 1985. The rich get children: segmentation, stratification, and population in three Zhejiang lineages. In: Hanley, Susan B., Wolfs, Arthur P. (Eds.), Family and Population in East Asian History. Stanford University Press, pp. 81–109.

Ho, Ping-ti, 1959. Studies On the Population of China. Harvard University Press, pp. 1368–1953.

Hsiue, Carol, 2017. Human capital and fertility in Chinese clans before modern growth. J. Econ. Growth 22, 351–396.

Hu, Sijie., 2023. Survival of the literati: social status and reproduction in Ming–Qing China. J. Popul. Econ. 36 (4), 2025–2070.

Kitagawa, Evelyn M., Hauser, Philip M., 1973. Differential Mortality in the United States: A Study in Socioeconomic Epidemiology. Harvard University Press.

Klemp, Marc., 2012. Prices, wages and fertility in pre-industrial England. Cliometrica. J. Historic. Econ. Econ. Hist. 6 (1), 63–77.

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

Lee, James Z., Campbell, Cameron D., 2016. China multi-generational panel dataset, Liaoning (CMGPD-LN), 1749-1909. Inter-Univ. Consor. Politic. Soc. Res. https://doi.org/10.3886/ICPSR27063.v10, 2016-09-06.

Lee, James Z., Campbell, Cameron, 1998. Headship succession and household division in three Chinese banner serf populations, 1789-1909. Contin. Chang. 13 (1), 117–141.

Lee, James Z., Campbell, Cameron, 2005. Living standards in Liaoning, 1749-1909: evidence from demographic outcomes. In: Allen, Robert, Bengtsson, Tommy, Dribe eds, Martin (Eds.), Living Standards in the Past. New Perspectives On Well-Being in Europe and Asia. Oxford University Press, Oxford, pp. 403–426.

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

Lee, James, Campbell, Cameron, Guofu, Tan, 1992. Infanticide and family planning in rural Liaoning, 1774-1873. In: Li, Lillian, Rawski, Thomas (Eds.), Chinese History in Economic Perspective. University of California Press, Berkeley, pp. 149–176.

Lee, Ronald., 1985. Population homeostasis and english demographic history. J. Interdisciplin. History 15 (4), 635–660.

Lee, Ronald, Steckel, Richard H., 2006. Life under pressure: an appreciation and an appraisal. Hist. Methods 39 (4), 171–176.

Liu, Ts'ui-jung, 1985. Historical demography of South China lineages. In: Harrell, Stevan (Ed.), Chinese Historical Microdemography. University of California Press, Berkeley, pp. 94–120.

Lundh, Christer, Kurosu, Satomi, et al., 2014. Similarity in Difference: Marriage in Europe and Asia, 1700-1900. MIT Press, Cambridge.

Mare, Robert D., 1997. Differential fertility, intergenerational educational mobility, and racial inequality. Soc. Sci. Res. 26 (3), 263–291.

Mare, Robert D., Maralani, Vida, 2006. The intergenerational effects of changes in women's educational attainments. Am. Sociol. Rev. 71 (4), 542–564.

Mare, Robert D., Song, Xi, 2023. Social mobility in multiple generations. Res. Soc. Stratif. Mobil. 88, 100806.

Møller, Framroze, Niels, Sharp, Paul, 2014. Malthus in cointegration space: evidence of a post-Malthusian pre-industrial England. J. Econ. Growth 19, 105–140.

Nicolini, Esteban A., 2007. Was Malthus right? A VAR analysis of economic and demographic interactions in pre-industrial England. Eur. Rev. Econ. Hist. 11, 99–121.

Oaxaca, Ronald., 1973. Male-female wage differentials in urban labor markets. Int. Econ. Rev. 14 (3), 693–709.

Ding, Yizhuang, Songyi, Guo, Lee, James, Campbell, Cameron, 2003. Liaodong Baqi Yimin Shehui (Liaodong Banner Immigration and Rural Society). Shanghai Shehui Kexue Chubanshe, Shanghai.

Oris, Michel, and George Alter. 2003. Venir mourir en ville? Mortalité et migration dans l'est de la Belgique durant la Révolution industrielle. In Philippe Guignet, ed., Vol. 2, *Le Peuple des Villes dans L'europe Du Nord-Ouest (pp.* 383–402*)*. Lille: Centre de Recherche sur l'Histoire de l'Europe Nord-Ouest, Université Charles-de-Gaulle - Lille 3.

Oris, Michel, and George Alter. 2001. Paths to the city and roads to death. Mortality and imigration in East Belgium during the industrial revolution. In Isabelle Devos and Muriel Neven, eds., Recent Work in Belgian Historical Demography. *Belgisch Tijdschrift Voor Nieuwste Geschiedenis - Revue belge D'histoire Contemporaire*, XXXI (3–4): 453–495.

Preston, Samuel, H., 1976. Mortality Patterns in National Populations: With Special Reference to the Recorded Causes of Death. Academic Press, New York.

Preston, Samuel H., 1975. The changing relation between mortality and level of economic development. Popul. Stud. 29 (2), 231–248.

Preston, Samuel, Campbell, Cameron, 1993. Differential fertility and inheritance of traits: the case of IQ. Am. J. Sociol. 98 (5), 997–1019.

Song, Xi, Campbell, Cameron, Lee, James Z., 2015. Ancestry matters: patrilineage growth and extinction. Am. Sociol. Rev. 80 (3), 574–602.

Telford, Ted., 1995. Fertility and population growth in the lineages of Tongcheng County, 1520-1661. In: Harrell, Stevan (Ed.), Chinese Historical Microdemography. University of California Press, Berkeley, pp. 48–93.

Tsuya, Noriko, Kurosu, Satomi, 2010. To die or to leave: demographic responses to famines in rural northeastern Japan, 1716-1870. In: Kurosu, Satomi, Bengtsson, Tommy, Campbell, Cameron (Eds.), Demographic Responses to Economic and Environmental Crises. Reitaku University, Kashiwa, pp. 79–106.

Tsuya, Noriko, Wang, Feng, Alter, George, Lee, James Z., et al., 2010. Prudence and Pressure: Reproduction and Human Agency in Europe and Asia. MIT Press, Cambridge, pp. 1700–1900.

Chapter 11 in Wang, Feng, Campbell, Cameron, Lee, James Z., et al., 2010. Agency, hierarchies, and reproduction in Northeastern China, 1789 to 1840. In: Tsuya, Noriko, Feng, Wang, Alter, George, Lee, James Z., et al. (Eds.), Prudence and Pressure: Reproduction and Human Agency in Europe and Asia, 1700-1900. MIT Press, pp. 287–316.

Wei, Shengbin., 2025. Institutional, social, and household determinants of reproduction in Northeast China. The History of the Family. Forthcoming, pp. 1789–1906.

Weir, David R., 1984. Life under pressure: france and England, 1670-1870. J. Econ. Hist. 44 (1), 27–47.

Weisdorf, Jacob, Sharp, Paul, 2009. From preventive to permissive checks: the changing nature of the Malthusian relationship between nuptiality and the price of provisions in the nineteenth century. Cliometr. J. Historic. Econ. Econ. Hist. 3 (1), 55–70.

Zang, Emma, Campbell, Cameron, 2018. Later life mortality consequences of male Co-residence with paternal grandparents: evidence from Northeast China, 1789-1909. Demography 55 (2), 435–457.