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Ancestry Matters: Patrilineage Growth and Extinction

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Abstract

Patrilineality, the organization of kinship, inheritance, and other key social processes based on patrilineal male descent, has been a salient feature of social organization in China and many other societies for centuries. Because continuity or growth of the patrilineage was the central focus of reproductive strategies in such societies, we introduce the number of patrilineal male descendants generations later as a stratification outcome. By reconstructing and analyzing 20,000 patrilineages in two prospective, multi-generational population databases from 18th and 19th century China, we show that patrilineages founded by high status males had higher growth rates for the next 150 years. The elevated growth rate of these patrilineages was due more to their having a lower probability of extinction at each point in time than to surviving patrilineal male descendants having larger numbers of sons on average. As a result, patrilineal male descendants of high status males account for a disproportionately large share of the male population in later generations. In China and elsewhere, patrilineal kin network characteristics influence individuals' life chances; thus effects of a male founder's characteristics on patrilineage size many generations later represent an indirect channel of status transmission that has not been considered previously.

Keywords

descent line; population composition; extinction; multigenerational inequality

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²For the linear flow models, we set the dependent variable for extinct descent lines to zero. For extinct lines in the exponential, Poisson and negative binomial flow models, we replace the logged previous descent line size with -1 . This allows us to keep the numbers of cases the same across different estimations. We also experimented with other imputations, including $\log(N(t-1)+0.1)$ or setting $\log(N(t-1))$ to 0, and with dropping extinct descent lines. The results are consistent with those reported in Table 4. These results are available upon request.

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INTRODUCTION

We assess whether males in historical China successfully translated their high status into larger numbers of patrilineal male descendants in subsequent generations. We focus on patrilineal male descendants because family reproductive strategies in China and many other patriarchal societies focused on the growth or at least continuity of the male descent line (Cohen 1990; Freedman 1966; Harrell 1985; Lee and Wang 1999; Wolf and Huang 1980; Wolf 2001). We rely on direct, empirical analysis of multi-generational data to measure the influence of a man's status on his long-term reproductive success as reflected in the subsequent growth or extinction of his patrilineal descent line, or patrilineage. Previous demographic, sociological, and population genetic studies of long-term reproductive success and resulting changes in population composition mostly extrapolated from data on two generations, by using measured relationships between parents' and children's outcomes as inputs to analytic models or simulations (Bodmer 1965; Cavalli-Sforza and Feldman 1981; Mare 1997; Preston and Campbell 1993; Wachter, Hammel and Laslett 1978).

We conceptualize the size of a male founder's patrilineage in later generations as a stratification outcome important to demographers, sociologists, and other social scientists studying patrilineal societies such as historical China where the inheritance of status and property was largely patrilineal and patrilineages were key units of social organization. In a patriarchal society where the continuity or growth of the patriline was the overriding focus of family strategies, all of the outcomes normally considered in studies of the implications of status—including marriage, fertility, health, mortality, and the transmission of status—are simply the means to an end: representation, or overrepresentation, by patrilineal male descendants in later generations. By focusing directly on representation by male descendants in later generations instead of the various demographic and social outcomes that interact to determine it, we introduce a new perspective that emphasizes the overall implication of social and economic status in a patriarchal society, not the separate, partial implications.

To examine the influence of male founders' characteristics on the number of his patrilineal male descendants, we apply regression-based techniques to two large prospective, multi-generational demographic databases that describe populations at opposite ends of the social spectrum during the last imperial dynasty of China (Qing, 1644–1911): the Imperial Lineage, who lived largely in Beijing, and populations of farmers who lived in the northeast Chinese province of Liaoning (Lee, Campbell and Wang 1993; Lee, Campbell and Chen 2010). Since our data are prospective and the populations are closed, they are free of the survivor bias and loss to follow-up that are typical of family genealogies and other retrospective data. They allow us to follow not only the descent lines which flourished, but also the ones which became extinct. Even though the populations we study are not representative of historical Chinese populations in a formal, statistical sense, their positions at nearly opposite ends of the social spectrum make it reasonable to claim that observed similarities are indicative of basic processes common to historical Chinese populations, and perhaps other historical populations as well.

Relying on a one-sex population growth framework, we define a descent line to consist of a male founder and all his patrilineal male descendants, namely his son, his sons' sons, and so

forth. We show that the status of a descent line founder influenced his representation in later generations not only because he had more sons, but also because for several more generations, his patrilineal descendants also had more sons. Patrilineages founded by high status males eventually accounted for a disproportionately large share of the male population. While the growth rate advantages of descent lines with high status founders emerged in the initial generation, these advantages eventually dissipated. As a result, the share of the male population occupied by the patrilineal descendants of high status descent line founders increased for several generations, then stabilized. The results suggest a long-term trend of regression to the mean for the growth rates of high status descent lines.

By examining the determinants of patrilineage extinction and growth separately, we challenge a common belief that families in historical China (Hsu 1943; Wolf 1995:116–117; 2001) and elsewhere (e.g., Betzig 1986; Turke 1989; see a summary in Table 1 of Hopcroft 2006) always maximized their numbers of male births. Our results show that the social status of male founders had a greater and more enduring effect on the chances of their descent lines becoming extinct than it did on the growth rates of the lines that avoided extinction. The results imply that high-status origin descent lines achieved overrepresentation in succeeding generations of males by minimizing their extinction probabilities rather than by maximizing the number of male births in each generation. The results provide empirical evidence of short-term versus long-term and quantity-quality trade-offs in family reproductive success as suggested by life history theory (Hill and Kaplan 1999; Mace 2000).

This study enriches our understanding of multi-generational social stratification processes. Our results substantiate Mare's (2011) argument that traditional social mobility studies provide an incomplete picture of social inequality between families by focusing exclusively on surviving families or descent lines. In addition, our results imply a channel for an indirect influence of ancestor's characteristics on individuals' social attainments. Among surviving descent lines, if individuals' life chances depend on the characteristics of their kin networks (Campbell and Lee 2008a, 2011; Jæger 2012), the reproductive success of high status founders would influence the social characteristics of their descendants by shaping the size and composition of the patrilineal kin networks in which they were embedded. This would represent a novel channel by which a distant ancestor's characteristics influenced contemporary stratification outcomes.

BACKGROUND

Social Stratification, Demographic Differentials and Descent Line Dynamics

Classic approaches to the study of social stratification and mobility do little to illuminate the implications of status differentiation in one generation for long-term “processes of ‘social metabolism’” (Duncan 1966). Intergenerational social mobility studies typically examine influences of parents' social status on social success of offspring independently of mortality and fertility patterns at the population level (e.g., Blau and Duncan 1967; Erikson and Goldthorpe 1992; Featherman and Hauser 1978; Long and Ferrie 2013). Only a few studies have examined how social mobility and demographic differentials interact to shape long-term population renewal as well as growth and decline of various social groups (Lam 1986;

Maralani 2013; Mare 1997; Mare and Maralani 2006; Matras 1961, 1967; Preston 1974; Preston and Campbell 1993). Because of a lack of multi-generational data, most of these studies rely on projections or simulations from two-generation models. Their results are heavily dependent on assumptions included in the model.

Studies of stratification processes and population composition should account for potentially complex interactions between status differentials in demographic behaviors. In many preindustrial societies, high status was associated with increased reproductive fitness, in the form of larger numbers of surviving offspring (Courtiol et al. 2012; Gillespie, Russell, and Lummaa 2008; Goodman et al. 2009; Hill 1984; Huber, Bookstein, and Feider 2010; Nettle and Pollet 2008). While the positive relationship between high status and reproductive fitness should have led to long-term growth of high status descent lines, life history theory also suggests that family trade-offs between quantity and quality of children as well as between current and future reproduction may have made relationships between male social status and the number of patrilineal descendants very complex (Hill and Kaplan 1999). Parents may have fewer children than they are physiologically capable of in order to enhance the chances that offspring will survive to adulthood, find an acceptable spouse, attain high status, or have children of their own (Boone and Kessler 1999; Goodman et al. 2012; Hill 1984; Huber et al. 2010; Liu and Lummaa 2011; Liu, Rotkirch and Lummaa 2012). Families may exercise control over current number of offspring in order to preserve resources for reproduction of future generations.

To account for trade-offs between maximization of total number of offspring and minimization of extinction chances, it is necessary to compare and contrast the effect of status on descent line growth rates and extinction probabilities. The influence of social status on the probability of childlessness may differ from its influence on the total number of children among couples who have at least one. For example, Fieder and Huber (2007) show that the relationship between socioeconomic status and reproductive success depends on the inclusion and exclusion of childless individuals. Most importantly, descent lines face hurdles in each generation that must be overcome to have any representation in the next generation. The most obvious of these hurdles in traditional societies is marriage (e.g., Dherbécourt 2013; Goodman and Koupil 2010). At least one man in each generation must marry and have one child for the descent line to be represented in the following generation. If the effects of social status on reproductive success in each generation differed by parity of births, high status may have had a more complex effect on descent line dynamics than a simple increase in the mean number of offspring.

Studies of descent lines confirm that extinction was common in historical populations, and that small numbers of descent lines eventually accounted for large shares of the population. Systematic efforts to study the long-term growth and extinction of descent lines date back at least to Francis Galton and H.W. Watson's (1874) application of branching theory to study aristocratic surnames. Lotka (1929, 1931, 1941) subsequently estimated family extinction probabilities for male descent lines in the United States white population in 1920. Wachter and Laslett (1978) analyzed the long-term influences of such demographic behaviors as marriage and reproduction on the extinction of British elite patrilineal lines. Empirical, theoretical, and simulation studies in population genetics go further and show that over the long-term,

the overwhelming majority of descent lines become extinct, and a small subset become dominant (Semino et al. 2000, Chang 1999; Lachance 2009; Murphy 2004; Rohde, Olson and Chang 2004).

Changes over time in the distribution of surnames in aggregated data provide additional insights into long-term processes of descent line growth and extinction (Matsen and Evans 2008). In societies that experience little immigration, surname distributions become highly concentrated and the distribution of their sizes highly skewed (e.g., Piazza et al. 1987; Yasuda et al. 1974). In China, less than 5% of the surnames in use account for 85% of the population (Du et al. 1992; Colantonio et al. 2003). Surname studies by population geneticists suggest that even if the evolution of surnames has no association with traits that are transmissible and related to reproduction, random drift will still generate inequality in descent line size that has nothing to do with founder's characteristics (Cavalli-Sforza, Menozzi and Piazza 1994).

Most studies of descent line growth and extinction focus on patrilineage male descent lines, or patrilineages. Substantive interest in the dynamics of patrilineages reflects the tendency in historical and/or patriarchal societies for important social processes such as surname transmission, inheritance of property and status, and the definition of membership kin-based groups such as lineages to be based primarily on patrilineal descent. For these reasons, records of patrilineal descent are more abundant than records of matrilineal descent. While the ideal study of patrilineage dynamics would also account for the role of assortative mating by making use of data on matrilineal kinship, relevant data are relatively rare. Indirect approaches to accounting for maternal kin is also difficult because matrilineages likely had fundamentally different dynamics, making it impossible to extrapolate to them from findings on patrilineages (Borgerhoff Mulder 2000; Hopcroft 2006; Lee and Wang 1999; Mann 2002; Turke 1989). Most importantly, variance in the number of offspring was larger for men than for women. Men not only had a longer reproductive span than women, but in societies such as China, also had more opportunities for remarriage or polygyny.

The Chinese Context

We focus on patrilineal descent lines or patrilineages because family reproductive strategies in historical China and many other societies focused heavily on their continuity. The centrality of patrilineality in Chinese social organization is well-known. Sons not only carried on the family name, but remained in the household after marriage and provided support to aging parents, and were thought to be more valuable as sources of household labor (Hsu 1943; Lee and Wang 1999; Wolf 1995, 2001; Wolf and Huang 1980). Families were less interested in daughters because they left the family and joined their husband's household once they married. One reflection of the centrality of patrilineality was that Chinese genealogies focused on recording sons, and often omitted daughters.

Understanding the social determinants of differences in patrilineage growth and extinction is important for understanding inequality in China and other societies because patrilineage membership was an important stratifying variable that conditioned life chances. In China, the patrilineage was the most important unit of social organization outside the household in historical China. Lineage organizations with membership defined by patrilineal descent from

a common male ancestor managed ancestral temples, owned property, operated schools for the children of members, represented their members in interactions with other lineages, played an important role in local politics, and compiled lineage genealogies (Cohen 1990; Freedman 1966). Inequality between patrilineages in marriage and socioeconomic attainment was more pronounced than inequality between villages (Campbell and Lee 2011). Empirical evidence suggests kin network size and composition influenced individual demographic behavior and social attainment, not only in China (Agree, Biddlecom and Valente 2005; Campbell and Lee 2008a b; Hermalin, Ofstedal, and Chi 1992) but elsewhere (Sear et al. 2002, 2003). Potentially, effects of male status in one generation on the size and composition of the patrilineal male kin group many generations later was yet another indirect channel by which status might be transmitted over multiple generations.

In China, the effects of the social status of a male founder on the subsequent growth of his patrilineage may have been complex. A variety of considerations may have led couples to have fewer sons than their social and economic circumstances might have allowed (Campbell and Lee 2010a; Mann 2002: 449; Wang et al. 1995, 2010). Even though high status males had more surviving sons than other males (Wang et al. 2010), that does not imply that they actively maximized their numbers of male births. Under plausible scenarios, forgoing male births would improve outcomes for surviving sons by reducing the dilution of family resources. For example, sex ratio imbalances in the marriage market made finding a wife for each son costly. In a partible inheritance system in which male kin divided family property at the time of household division, limiting the number of sons would slow the dissipation of landholdings and other material wealth. Under such conditions, families may have sought to maximize the chances that at least one son reached adulthood, married, and achieved high status, rather than maximizing their total number of male births. Families, in other words, may have sought to minimize the chances of extinction or downward mobility.

THEORETICAL FRAMEWORK

We begin by introducing our theoretical framework for examining effects of a male founder's social status on the subsequent growth or extinction of his patrilineage. We start by considering the classic population growth equation (Preston, Heuveline and Guillot. 2001:11):

$$N(T) = N(0)e^{\int_0^T r(t)dt} \quad (1)$$

Here, $N(0)$ and $N(T)$ refer to patrilineal descent line size (stock) at times 0 and T , respectively. The integrand $r(t)$ is the instantaneous growth rate (flow) at time t . In this one-sex model, each descent line has one male founder, and $N(0)$ is defined to be the number of that founder's male offspring through the male line. The effects of descent line founders' characteristics on the total number of descendants $N(T)$ can work through either the initial reproduction of the founders, i.e., $N(0)$, the growth rate of the descent line over time, $r(t)$, or both. We rely on this stock and flow framework to analyze the role of the mechanisms that governed descent line growth.

We specify three mechanisms—Initial Advantage, Permanent Advantage, and Advantage Dissipation — by which a male founder’s characteristics may have influenced the subsequent size and growth rate of his patrilineage (see Table 1). We also summarize potential implications of the three mechanisms for the growth trajectory of descent lines in Figure 1. We expect the actual impact of founder’s characteristics on descent line growth to have included a combination of these three mechanisms.

In Table 1, we assume that Initial Advantage affects patrilineal descent line growth entirely through the reproduction of the founders, namely, $N(0)$ in Equation 1. In the Initial Advantage scenario, represented in Figure 1 with a grey dashed line, high fertility on the part of the founder multiplies the initial size of the descent line $N(0)$ by c but has no effect on the growth rate $r(t)$ in later generations. The number of high-origin descendants will always be c times the number of low-origin descendants. At the population level, this mechanism implies that high-origin descent line’s share increases immediately in the generation after the founder, and then remains stable afterward.

Permanent Advantage and Advantage Dissipation allow for changes in the growth rate $r(t)$. In the Permanent Advantage scenario, represented as the black dashed line in Figure 1, founder’s characteristics trigger a permanent increase in $r(t)$. Because the growth rate of the descent line experiences a permanent increase, the descent line accounts for a steadily increasing share of the population. Eventually, high-origin descendants dominate the population, and the share of low-origin descendants declines to insignificance.

Advantage Dissipation, represented by the dotted line in Figure 1, is an intermediate between Initial Advantage and Permanent Advantage. It assumes that high-origin descent lines will experience a higher growth rate for some number of generations, but the advantage will decline over time and eventually disappear. The share of the population accounted for by high-origin descent lines will grow until the differences in $r(t)$ dissipate, and remain stable afterwards.

Initial Advantage

The sociological literature on stratification frequently invokes Initial Advantage as part of cumulative advantage theory to explain the evolution of inequality over time. In this conception, the advantage of one group over another depends on *initial* positions, and the subsequent growth of inequality is path-dependent. Initially minor and possibly random disparities may widen over time because success begets success. Empirical tests make use of evidence from a variety of areas, including academic publication records (Allison, Long and Krauze 1982; Merton 1968, 1988), cognitive development (Guo 1998), and health (Pampel and Rogers 2004). Merton (1988) describes this phenomenon as, “the ways in which initial comparative advantage of trained capacity, structural location, and available resources make for successive increments of advantage such that the gaps between the haves and the have-nots...widen” (p.606). For Merton, Initial Advantage is the essential characteristic of a cumulative advantage process. From this perspective, any exogenous events that generate an initial advantage can have long-term consequences on patterns of inequality (DiPrete and Eirich 2006).

For our outcome of interest, number of patrilineal male descendants in later generations, the Initial Advantage mechanism is analogous to ‘founder effects’ in the genetics literature (Falconer 1960). If reproductive differentials between descent lines exist only in the founder generation, the ratio of descent line sizes increases in that generation, but remains constant afterward (the grey dashed line in Figure 1). Differences in lineage size therefore reflect a path-dependent process driven solely by differences in the reproduction of the founders.

Permanent Advantage

Disparities in patrilineage size according to the socioeconomic status of founders may continue to widen after the first generation if the founder’s status affects the reproduction of members of later generations, whether directly or indirectly. We refer to this scenario as Permanent Advantage, in which ‘permanent’ refers to the possibility that high status origin descent lines continue to grow faster than other descent lines. Our inspiration is Allison et al.’s (1982) observation that cumulative advantage does not produce additional changes in patterns of inequality later in time unless the rate of accumulation continues to vary between population subgroups.

The relevance of Permanent Advantage depends on whether or not a founder transmits traits to his offspring that affect their reproduction. For example, if a high status founder not only has more sons, but also in turn transmits the high status that leads to high fertility to these sons, the share of the population accounted for by the descent lines of high status founders will expand steadily over time. The ratio of the sizes of high- and low-origin lineages would steadily increase, until the high status lineage accounts for nearly the entire population (the black dashed line in Figure 1).

Advantage Dissipation

Advantage Dissipation (the dotted line in Figure 1) addresses the reality that founder characteristics are unlikely to trigger the permanent increases in growth rates assumed in the Permanent Advantage scenario. More concretely, in the multi-generational process of descent line growth, resource dissipation and downward social mobility may serve as a ‘brake’ that attenuates fertility differentials (DiPrete and Eirich 2006). When the status and demographic behavior of descendants of high status founders finally becomes indistinguishable from the rest of the population, relative sizes of descent lines stabilize.

Previous discussion of the phenomenon of “regression to the mean” in family advantage suggests the likely importance of advantage dissipation. Becker (1991: 273) argues that “almost all earnings advantages and disadvantages of ancestors are wiped out in three generations. Poverty would not seem to be a ‘culture’ that persistent for several generations.” Similarly, centuries before Becker, a common folk expression in China was that “wealth doesn’t last for three generations.” In an empirical study based on genealogies, biographies and local histories, Ho (1964) found that even under a very relaxed standard for defining high social status, the average descent line fell into complete oblivion, or at least mediocrity, in some eight generations. All these observations are in line with Galton’s early conceptualization of “regression toward mediocrity” (Zimmerman 1992).

Our data and methods allow us to discern the relative importance of these three mechanisms. Prior sociological theory suggests that Initial Advantage, Permanent Advantage, and Advantage Dissipation alone or in combination will generate different patterns of results in empirical studies (DiPrete and Eirich 2006). Because we can measure the influence of founder's characteristics on descent line size and growth rate in each generation, we can assess the relative importance of the three processes. Our approach therefore advances on the indirect one based on surname studies.

ANALYTIC APPROACH

Modeling Stock and Flow

To distinguish the roles of Initial Advantage, Permanent Advantage, and Advantage Dissipation in explaining the effect of a male founder's status on subsequent patrilineage growth, we apply a stock-flow analytic framework. Equation 1 shows a continuous time model of descent line growth. In the discrete-time model that we adopt for our empirical analysis, we redefine *stock* as the number of members of the descent line alive at time t and flow to refer to growth from time $t-1$ to t . We assess the relative importance of the three proposed mechanisms by estimation of regression models from four different families: linear, exponential, Poisson, and negative binomial. Each makes different assumptions about the relationships of stocks and flows to the right-hand side variables. The linear stock and flow models shown below assume that the number of descendants at time t and the changing number of patrilineage male descendants from time $t-1$ to t are linear in male founder's characteristics $\mathbf{X}$.

$$\begin{aligned} N_i(t) &= \mathbf{X}_i\beta + \varepsilon_i \\ N_i(t) - N_i(t-1) &= \mathbf{X}_i\beta + \varepsilon_i \end{aligned}$$

The exponential stock and flow models assume an exponential relationship of founder's characteristics $\mathbf{X}$ to the number of descendants at time t and the change in the number of descendants from time $t-1$ to t :

$$\begin{aligned} \log(N_i(t)) &= \mathbf{X}_i\beta + \varepsilon_i \\ \log(N_i(t)) - \log(N_i(t-1)) &= \mathbf{X}_i\beta + \varepsilon_i \end{aligned}$$

To keep the extinct descent lines in the analyses, we replace $\log(N_i)$ with -1 when N_i is zero.¹

In an early model of descent line growth, Fisher (1922) applied the Poisson distribution and assumed that the probability of extinction is determined by the average number of offspring per individual. Following this tradition, our third set of models assumes that the number of descendants at time t for the i th descent line, $N_i(t)$, follows a Poisson distribution with parameter $\mu > 0$.

¹We also experimented with other values, such as 0, -0.5 , and -2 , and none of the conclusions changed.

$$P(N_i(t)|\mu_{it}) = \frac{\exp(-\mu_{it})\mu_{it}^{N_i(t)}}{N_i(t)!} \quad (2)$$

In Equation 2, μ_{it} is the expected number of descendants at time t . The assumption of the Poisson distribution also requires that the expected number of descendants equals the variance of the number of descendants, $\forall i: E(N_i(t)) = \text{Var}(N_i(t))$.

The Poisson stock model assumes that the conditional mean of the number of descendants at time t is a function of independent variables $\mathbf{X}$'s that describe time-invariant founder's characteristics:

$$\mu_{it} = E(N_i(t)|\mathbf{X}_i) = \exp(\mathbf{X}_i\beta) \quad (3)$$

The Poisson flow model represented in Equation 4 is similar except that it introduces a control for the count of descendants at time $t-1$.

$$\mu_{it} = E(N_i(t)|\mathbf{X}_i, N_i(t-1)) = \exp(\log(N_i(t-1)) + \mathbf{X}_i\gamma)^2 \quad (4)$$

Equivalently,

$$E\left(\frac{N_i(t)}{N_i(t-1)}|\mathbf{X}_i, N_i(t-1)\right) = \exp(\mathbf{X}_i\gamma) \quad (5)$$

We also estimate a fourth set of models, negative binomial regression models, to account for the possibility that the Poisson model's assumption of equality of the variance and mean of the number of descendants is violated because of over-dispersion. In that situation, the relationship between founder's characteristics and the expected number of descendants still follow Equations 3 and 4. However, the variance in the number of descendants is assumed to follow a gamma distribution with a parameter that is estimated separately.

We use 'stock effect' to refer to the ratio of expected mean number of descendants of high-status founders to that of low-status founders. We use 'flow effect' to refer to the ratio of the expected growth rate of descent lines with high-status founders to that with low-status founders. In either case, if the ratio is 1, the founder's characteristics do not influence descent line size (stock) or growth rate (flow).

Initial Advantage, Permanent Advantage, and Advantage Dissipation predict different patterns of effects of founder's characteristics on stock and flow. If Initial Advantage is present, we expect to observe an effect on stock in every generation. However, we only expect to see an effect on flow in the first generation. This is because the growth rate of the descent line is elevated only in the founding generation, and then reverts to be the same as other descent lines in later generations. If Permanent Advantage is present, both the stock effect and the flow effect should be apparent in every generation, because high status not only increases the total number of the descendants but also their growth rate. If Advantage

Dissipation is present, the stock effect may keep increasing until the flow effect disappears, because founder's effect on growth rate fades away with time.

Modeling Extinction and Growth

The models above assume that the probability of extinction is a byproduct of the distribution of the number of offspring. For example, the Poisson model introduced above requires that the proportion of observed zeroes (extinctions) in the empirical data matches the proportion of zeroes predicted by the Poisson distribution. This implies an assumption that the same underlying process accounts for the influence of founder's status on the probability of extinction, and conditional on avoiding extinction, the probabilities of having different numbers of descendants.

To allow founder's characteristics to have separate effects on patrilineage extinction probabilities, and conditional on avoiding extinction, the growth rate of the patrilineage, we introduce a mixture negative binomial distribution that models processes of extinction and growth jointly (Johnson, Kemp and Kotz 2005). Suppose that π and $1-\pi$ are the probabilities of failure and success for overcoming a 'hurdle' that conditions success at reproduction, and thereby avoiding extinction. For example, π might be the probability that no sons survived to adulthood and married, and $1-\pi$ the probability that at least one son survived and married. Again, the assumption is that these are independent of the distribution assumed for the number of offspring for those who did marry. Let the probability of having j descendants in a truncated distribution be written as p_j . Then we have

$$\begin{aligned} P[N_i(t)=0|Z_i] &= \pi, \\ P[N_i(t)=j|X_i, N_i(t)>0] &= \frac{(1-\pi)p_j}{1-p_0}, \end{aligned} \quad (6)$$

where $P[N_i(t)=j]$ is the probability that the number of descendants for the i th descent line at time t is j . Z is the set of covariates to explain extinction and X is the set of covariates to explain descent line growth.³

For the sake of simplicity, we use a logistic model to predict $P[N_i(t)=0]$ and assume the truncated part $P[N_i(t)=j | [N_i(t) > 0]]$ still follows a negative binomial distribution. Then

$$\begin{aligned} P[N_i(t)=0|Z_i] &= \frac{1}{1+\exp(Z_i\gamma)} \\ P[N_i(t)=j|X_i, N_i(t)>0] &= \frac{1-P[N_i(t)=0|Z_i]}{1-\frac{\theta_{it}}{(\mu_{it}+\theta_{it})^{\theta_{it}}}} \cdot \frac{\Gamma(N_i(t)+\theta_{it})}{\Gamma(\theta_{it})\Gamma(N_i(t)+1)} \cdot \frac{\mu_{it}^{N_i(t)}\theta_{it}^{\theta_{it}}}{(\mu_{it}+\theta_{it})^{N_i(t)+\theta_{it}}} \end{aligned} \quad (7)$$

³We test the differences between negative binomial models, mixture negative binomial models and mixture Poisson models based on the Bayesian Information Criterion (BIC), as the models are not nested. The results suggest that the mixture negative binomial models significantly improve the goodness-of-fit of the model compared to the regular negative binomial models and mixture Poisson models (test results are available upon request).

DATA AND MEASURES

Data

Our data are derived from the China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL) and the China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN). Published studies of demographic behavior have already established the suitability of these two sources for the analysis here (Campbell and Lee 2008a b, 2010a, 2011; Lee and Campbell 1997). The CMGPD-IL records 83,256 males in the Aisin Gioro imperial lineage from 1652 to 1936. The lineage originated in northeast China and founded the Qing dynasty (1644–1911). Specifically, the CMGPD-IL records the grandfather of the Qing founder, his four brothers, and their male and female patrilineal descendants from approximately 1550 to 1936 (Lee et al. 1993). At the beginning of the Qing Dynasty, the imperial lineage was a small, elite group. Many but not all members held official positions or noble titles. As the lineage grew, steadily larger proportions of men were distant relatives of the emperors and held neither official position nor noble title. The genealogy from which the CMGPD-IL was constructed was maintained by the Qing Office of the Imperial Lineage. Because the genealogy was prospective, maintained by an elaborate bureaucracy, and used for administration, it has minimal loss to follow up. In contrast with traditional, privately compiled family genealogies, it records low status, never-married, and childless males. The CMGPD-IL only allows for the reconstruction of patrilineal pedigrees: because even though in contrast with almost all other Chinese genealogies it recorded nearly all daughters, even those who died on their first day of life, it only followed them up to the time they married out and joined their husband's family (Lee et al. 1993).

The China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN) is derived from triennial household registers of farming populations who produced for the Qing Imperial Household Office (Lee et al. 2010). The complete dataset and documentation are now public and available for download at the Interuniversity Consortium for Political and Social Research.⁴ Whereas the imperial lineage is an elite urban population concentrated in Beijing and Shenyang, the CMGPD-LN covers a large, rural population spread over a very large area in what is now Liaoning province in northeast China. The farmers covered by the CMGPD-LN were descended from Han-Chinese immigrants who migrated from Shandong and other locations into Liaoning in the late 17th and early 18th century. The data consist of 29 sets of triennial household registers with 1.5 million observations of more than 260,000 unique individuals between 1749 and 1909.

The Liaoning household registers provide far more comprehensive and accurate demographic and sociological data than other available household registers for China before the twentieth century (Lee and Campbell 1997: 223–237; Lee et al. 2010: 149–158). The format and organization of the data closely resemble a linked triennial census. Entries in each register were grouped first by village, then by household group and then by household. The population is closed, in the sense that the registers follow families that moved from one village to another within the region, thus the registers are uniquely suited to the

⁴See <http://www.icpsr.umich.edu/icpsrweb/CMGPD/> for CMGPD-LN data and documentation.

reconstruction of descent lines through intergenerational record linkage, and study of the predictors of descent line growth, decline, and extinction (Campbell and Lee 2010b). Once again reflecting the emphasis on patrilineal descent in historical China, the data only allow for construction of male pedigrees. While the data record the characteristics of married women and widows in considerable detail, it does not allow them to be traced back to their records as daughters in their natal household and then linked to their mothers.

These data are especially well-suited to this analysis because they are prospective and the populations are closed, with minimal loss to follow-up. The CMGPD-LN followed families when they moved within the region, and explicitly annotated the small number of men who left the region entirely and were therefore lost to follow-up (Campbell and Lee 2001). Such men accounted for less than 1 percent of the recorded population. The members of the Imperial Lineage recorded in the CMGPD-IL were required to live in either Beijing or what is now Shenyang, Liaoning, which during the Qing was a secondary capital. Again, follow-up was nearly complete. The results here are from an analysis that excludes the lineage members who lived in Shenyang because of concerns about the quality of certain features of their data such as the completeness of the recording of dates of death (Lee et al. 1993), but results from analyses which include them are similar.

Measures

In both the CMGPD-IL and the CMGPD-LN, we specify an analytic definition for male descent line founders, and then reconstruct their patrilineal descent lines through automated record linkage. Our analytic definitions of male founders and patrilineal descent lines reflect a balance between having enough descent lines to make meaningful comparisons, and having enough generational depth to examine processes over the long term. The Imperial Lineage grew very rapidly in the 17th century, thus choosing men born earlier would dramatically reduce the numbers of descent lines. Because the members of the Lineage were nearly all of very high status until the middle of the 17th century, it would also reduce variation in the characteristics of the founders. In the population recorded in the CMGPD-LN, the actual founders were mostly settlers whose arrival predated the registration system, and about whom we have almost no data.

To create an analytic sample of patrilineal descent lines in the CMGPD-IL, we define *descent line founders* as all men born between 1675 and 1725 who survived at least to age 25. The definition we apply yields 3,314 founders whose patrilineal descent lines could be traced for the next 150 years, or about six generations. Similarly, in the CMGPD-LN we define descent line founders to be all men born between 1715 and 1765.⁵ We treat the year of the founder's birth as the founding year of the descent line, and track each descent line for 125 years, or about five generations. In both cases, we experimented with alternative definitions for descent line founders and the results are consistent with the ones reported here.

⁵We did not restrict the sample to founders who survived to age 25 or above, because in rare cases age at death are not available (Lee et al. 2010: 19–20). Instead, we restrict the sample to adult founders who have a social status recorded. In our final sample, roughly 94% of the founders survived at least to age 16 *sui*, and 90% survived at least to age 25 *sui*.

For our basic outcome variable, number of living males in the patrilineal descent line, we count the numbers of living patrilineal male biological and adopted descendants of each founder every 25 years.⁶ To do this in the CMGPD-IL, we transform it from a person file in which each record represented the life history of one male into a person-year file in which each record described a male in a specific calendar year. For the CMGPD-LN, we first transform the original triennial observations into a person file like the CMGPD-IL in which each record is the life history of one male. We then use that entry to produce person-year files like the one for the CMGPD-IL. In both datasets, we attach founder identifiers to the person-year records, and then count up the numbers of male descendants at 25-year intervals. At time zero, defined as the founder's year of birth, the number of male descendants is zero. 25 years later, it includes any surviving sons of the founder. The descent line size could be still zero if the founder had not yet had any sons. 50 years later, the count would include any living sons and grandsons. Again, the focus on numbers of male descendants reflects the data limitations described earlier.

We construct dichotomous variables for the socioeconomic status of the male descent line founder. For the CMGPD-IL, we define high-status origin descent lines to consist of the ones founded by men who worked in the Qing bureaucracy (e.g., ministers, military generals) or held bestowed or inherited noble titles (e.g., princes and dukes). We define the remaining descent lines as low-status origin. For the CMGPD-LN, we defined the high-status origin lines to consist of ones founded by men who held salaried official positions, examination titles, purchased and honorary titles, or served as unsalaried heads of household groups. These constituted the local elite (Campbell and Lee 2010b). The positions held by high-status founders in the CMGPD-LN were much more mundane than the ones held by their counterparts in the CMGPD-IL. The most common were soldier, scribe, or artisan. We include men who held honorary and purchased titles because they indicate substantial personal or family resources. Though heads of household groups held the lowest rank position in the administrative hierarchy and were unsalaried, they were supposed to be selected by household group members on the basis of ability.

We also include control variables to distinguish the lines according to their administrative status. For the CMGPD-IL, we distinguish between the members of the Main Line and Collateral Line. Men descended from the grandfather of the Qing founder are the *Zongshi* or Main Line. Men descended from his brothers are the *Jueluo*, or Collateral Line. We control for membership in the Main or Collateral Lines because men in the former were accorded more privileges than men in the latter. Similarly, we include a control variable to divide the lines in the CMGPD-LN into two status groups according to their type of administrative population. Most members of regular administrative populations were hereditary tenants who farmed state-owned land. Members of specialized populations provided services to the state such as collecting honey, raising bees, fishing, picking cotton, and tanning and dyeing. These specialized populations had a lower status than the regular populations (Lee et al. 2010).

⁶Because the CMGPD-IL specifies the identities of biological and adoptive fathers for each boy who was adopted between families, we calculated numbers of descendants separately based on biological descent and on social descent. The results were similar, as most adoption was between closely related male kin, and had little or no net effect on a descent line founder's total number of descendants.

We include seniority among siblings and total number of male siblings as additional controls in the regression analysis of effects of founder's status on stock and flow. Founder's total number of siblings is intended to account for the tendency in historical China for men with more male siblings to have higher chances of both marriage and attainment (Campbell and Lee 2008b). With this control, we hope to account for the possibility that unmeasured characteristics simultaneously affected a male founder's chances of attaining high status, and his chances of having more offspring. The control for whether or not a founder was an eldest brother is intended to account for advantages that first sons had in terms of attainment and marriage.

RESULTS

Descriptive Statistics

According to basic descriptive results, high-status origin patrilineal descent lines increased in size over time, but low-status origin patrilineal descent lines stagnated. Figure 2 presents the numbers of men in the CMGPD-IL according to whether their patrilineal descent lines had high- or low-status founders. From 1725 to 1875, the patrilineal descent lines with high-status male founders experienced rapid growth. By contrast, growth in the numbers of males in low-status descent lines was negligible. As a result of this disparity, even though men in high-status lines originally accounted for less than one-third of the population, by the end of the period they accounted for more than one-half of the population. This trend is consistent with the Initial Advantage and Advantage Dissipation mechanisms summarized in Table 1 and Figure 1. According to Figure 3, there were also differences in the cumulative probability of extinction. After 150 years, only half of high-status origin descent lines were extinct, in contrast with nearly three-quarters of low-status origin descent lines.

Table 2 contrasts key features of the high- and low-status origin patrilineal descent lines. Of the 3,314 descent lines in the CMGPD-IL, 1,082 are of high-status origin and 2,232 are of low-status origin. High-status founders are more likely to come from larger families and to be affiliated with the Main Line (*zongshi*).⁷ In the CMGPD-LN sample, founders tend to be more similar on the distributions of the control variables. Descent lines in the CMGPD-LN were in general smaller than in the CMGPD-IL, reflecting its overall lower growth rate. Higher proportions of males married later, or not at all, and therefore had more limited opportunities for reproduction. We also calculate the generation length—defined as the difference between the birth year of a father and that of his first son—for both populations. Overall the generation length for the two populations was between 25 to 30 years. High-status descent lines had shorter generation length than low-status descent lines. As a result, for both populations the analytic samples represent the experience of roughly five to six generations.

⁷When calculating the number of founder's male siblings, we include all the males born to the descent line founders' father, regardless of how long they lived.

Determinants of Stock and Flow

We begin our presentation of results by examining the influence of male founder's characteristics on patrilineal descent line size (*stock*) and growth rates (*flow*) at 25-year intervals. Based on the results, we assess the relative importance of Initial Advantage, Permanent Advantage and Advantage Dissipation in accounting for differences in the dynamics of the high- and low-origin descent lines. As a robustness check, we not only estimate the model described in Equation 2 that assumes that numbers of descendants follow a Poisson distribution, but we also estimate linear, exponential, and negative binomial models that incorporate different assumptions about the distribution of numbers of descendants. In all cases, we assume that the process determining descent line size and growth also accounts for extinction probabilities.

Results for stock models summarized in Table 3 demonstrate that in both the CMGPD-IL and the CMGPD-LN, the influences of male founder's social status on the total number of male descendants increase over time. They hold regardless of the assumptions about the appropriate distribution for the total number of descendants. Alpha parameter tests in Appendix A suggest that in general, the negative binomial models provide better estimates than the Poisson models.⁸ Results from the two datasets are broadly similar: the gap in the sizes of the high- and low-origin descent lines widens with time.

Results for flow models summarized in Table 4 reveal that male founder's status has long-term effects on the growth rate of patrilineal descent lines. More than one century later, differences in the growth rates of high- and low-origin descent lines remain statistically significant. Results for the CMGPD-IL from the negative binomial model show that the ratio of growth rates between the high- and low-origin descent lines after 25 years is 1.54(= $e^{0.432}$). For the CMGPD-LN, the corresponding ratio is 1.73(= $e^{0.548}$). After 125 years, the ratio is 1.17 (= $e^{0.159}$) and 1.19 (= $e^{0.172}$) for the two populations. These differences are not an artifact of the founder's success at transmitting high status to his sons, grandsons, or later descendants, and their resulting higher fertility: they persist after the introduction of controls for the number of descendants in later generations who were themselves of high status.⁹

Figures 4 and 5 plot size and growth rate ratios from Tables 3 and 4 for high- and low-origin patrilineal descent lines in the CMGPD-IL and CMGPD-LN. In both figures, the horizontal line at 1 corresponds to a hypothetical null founder effect, in which the descent line size or growth rates of the high- and low-origin descent lines are equal. The solid black lines represent the stock effect estimated from the negative binomial models. Overall, the time trends in stock effects show that the larger size of the high-origin descent lines is apparent as early as 25 years after the founding of the line. Moreover, descent line founders who have more offspring in the first 25 years also have more descendants in the long run. This is consistent with the Initial Advantage mechanism.

⁸We plot the actual growth from the empirical data and the predicted growth of descent lines based on different models in Figure A1 and A2. To compare the models across time, we fixed all the other independent variables at their means. The results suggest that the Poisson and the negative binomial model provide the best estimates for descent line growth trajectories, though they may yield biased estimates for the mean number of descendants toward the end of the period, perhaps because the models do not account for excess zeroes (i.e., extinction) in later years.

⁹Results not shown here, but available from the authors upon request.

Flow effects, represented as solid gray lines in Figures 4 and 5, were more consistent with Advantage Dissipation than Permanent Advantage. In both populations, the magnitude of effects of founder's status on patrilineal descent line growth rates declines steadily over time. Though in both the CMGPD-LN and CMGPD-IL an effect of founder's status on growth rates is still discernible and statistically significant at the end of the observation period, it is much smaller than in the earlier periods. Extrapolation from the trends in the figures suggests that within another generation or two, the growth rates of the high- and low-origin descent lines would be equal. Afterward, the ratio of the sizes of the descent lines would be constant.

Extinction and Growth as Separate Processes

We next examine whether the mechanisms that govern patrilineal descent line growth differ from the ones that govern extinction. Results from models based on Equation 6 allow for the determinants of extinction probabilities to differ from the determinants of descent line size or growth. Specifically, we apply a mixture negative binomial model to fit the extinction probability and the size of growth rate simultaneously.¹⁰ The stock models treat extinction as a cumulative process, so after a descent line is extinct it is still included in the analyses for later periods, during which it continues to be recorded as extinct. The flow models include controls for descent line size twenty-five years previously, and exclude descent lines that are already extinct, and thus account for the possibility that higher extinction probabilities now might be an artifact of a smaller descent line size twenty five years earlier.

Table 5 presents the relevant results. Coefficients from the logistic regression represent effects on the probability of the patrilineal descent line not being extinct, that is, its size being non-zero. Positive coefficients imply higher odds of descent line survival. Coefficients from the truncated negative binomial regression represent effects on descent line size or growth rate, conditional on the descent line not being extinct. To help clarify implications of the results from the mixture negative binomial regressions and facilitate comparisons with results in Tables 3 and 4, dashed lines in Figures 4 and 5 present stock effects and flow effects for surviving descent lines.

Results from the stock models reveal that in both populations, high-origin patrilineages were much more likely to avoid extinction, and that differential extinction probabilities account for much of the differences in mean descent line size in Table 3. The truncated negative binomial portion of the stock models suggests that in the CMGPD-IL, surviving high-origin descent lines are about 1.76 times ($= e^{0.568}$) the size of surviving low-origin descent lines 150 years after founding. By contrast, in the stock results in Table 3 that include extinct descent lines, high-origin descent lines were on average 2.43 times ($= e^{0.888}$) the size of low-origin descent lines. Extinction processes were perhaps even more important in the CMGPD-LN. Whereas in Table 3, high-origin descent lines in the CMGPD-LN were 2.02 ($= e^{0.703}$) times the size of low-origin descent sizes overall after 125 years, according to

¹⁰To compare the mixture negative binomial model to the regular negative binomial model, Appendix C provides Vuong likelihood ratio tests (Vuong 1989) comparing all models in the same year. Failure of the likelihood ratio test for $\alpha=0$ indicates zeroes are generated by the same process as non-zero counts. Substantively, this implies that founder's socioeconomic status has the same effects on the extinction and growth processes. Overall, the Vuong likelihood ratio tests prefer the mixture negative binomial over the regular negative binomial models. For both the stock and flow models at most of the years, test statistics show a p-value < 0.001 .

Table 5, non-extinct high-origin descent lines were only 1.18 ($= e^{0.168}$) times the size of non-extinct low-origin descent lines.

Results for extinction in the flow models in Table 5 reveal that at each point in time, extant high-origin patrilineages were more likely to survive to the next time period than low-origin descent lines of the same size. In the CMGPD-IL, comparison of same-sized high- and low-origin descent lines 125 years after founding reveals that the high-origin descent lines had 1.70 ($= e^{0.533}$) times the odds of surviving to year 150. In the CMGPD-LN, a high-origin descent line 100 years after founding has about 1.24 ($= e^{0.219}$) times the odds of surviving another 25 years.

The processes that governed growth among surviving patrilineages were very different. According to the flow results for descent line size in Table 5, the effects of founder's status on descent line growth declined over time. For both the CMGPD-LN and CMGPD-IL, the growth rates of surviving high- and low-origin descent lines were indistinguishable by the end of the period of observation. The coefficients were small and statistically insignificant. The contrast with the comparatively stable effects of founder's original status on extinction probabilities suggests that toward the end of the period for which data are available, most if not all of the small but persistent and statistically significant effect of founder's characteristics on descent line growth rates in Table 4 was due to effects on extinction chances.

One plausible interpretation of these results is that later generations minimized the chances of having no offspring who survived to adulthood and married, rather than maximizing the total number of births. This is most apparent in the contrast between the trends in the effects on founder's status on extinction probabilities and descent line growth in the flow models in Table 5. Figure 6 converts the coefficients in the flow results into probability of extinction for surviving lines in next 25 years. Trends in both populations suggest that the probability of extinction first declined in the first 50 to 75 years because founders and their sons had not yet finished reproducing, then grew afterward. Toward the end of the period under observation, high status continues to reduce the probability of extinction by the next time period, even though its effect on the number of descendants among the descent lines that persist to the next time period has disappeared.

At this point, we can only speculate as to how patrilineages minimized chances of extinction, and whether their behavior was deliberate. It may be that the lines with high status founders tended to be families that made a trade-off between quantity and quality of sons, such that they invested more in each son, and raised the chances that at least one of them would survive to adulthood, marry, and have offspring. Such behavior may have reflected a desire to avoid downward mobility, or a specific desire to avoid extinction. Having a high-status founder may simply have been an observable proxy for the existence of such a strategy, or the high-status founder may have introduced such a strategy, which persisted in later generations.

DISCUSSION

Using empirical evidence from two Chinese multi-generational population databases, each of which spans 125 to 150 years, we have shown that male social status in one generation has long-term implications not only for their total number of patrilineal male descendants, but for the reproductive success of those descendants. First, men of high status are especially successful in the competition for representation by patrilineal male descendants in later generations, and these male descendants also are especially successful at reproduction. The effect of male founder's social status on the growth rates of patrilineages lasts for several generations, and is large enough to affect the composition of the male population in later generations. Nevertheless, the patrilineal male descendants of high status males in one generation never come to completely dominate the male population, since their share of the population stabilizes when their growth rate advantage dissipates. In our samples, the share of the population accounted for by the patrilineal descendants of high-status males in one generation stabilized after 150 years, or roughly six generations.

Second, the key long-term effect of male high status on the reproductive behavior of patrilineal descendants was that it reduced their chances of having no surviving male offspring, rather than increasing the average number of offspring among those who survived. In other words, high social status among descent line founders had more enduring effects on the chances of descent line extinction than it did on the growth rates of descent lines which survived. While the effect of male founder's social status on the growth rate of surviving patrilineages becomes negligible after 150 years, effects on the chances of extinction are still apparent.

The evident influence of male founder's social status on the reproductive success of patrilineal descendants and eventual overrepresentation in the male population may reflect transmission of other forms of socioeconomic status, or determinants of status, that are not recorded in our data. This may have been property and other forms of material wealth that were accumulated rapidly in one generation and dissipated slowly by descendants. Attainment of socioeconomic status may also have been influenced by knowledge, attitudes, aspirations, and other forms of intangible social, economic, or cultural capital that were transmitted within families across multiple generations (Borgerhoff Mulder et al. 2009; Campbell and Lee 2011; Cavalli-Sforza and Feldman 1981).

While genetic transmission of traits that directly or indirectly influence reproductive success is one possible mechanism, the role of any such processes is difficult to assess. Existing findings on the direct role of genetic transmission on reproductive success is mixed: some studies suggest a strong genetic effect through a single gene or a suite of genes that either control individuals' latent fixed traits (Cam et al. 2002; Saifl and Chandra 1999), or influence behaviors related to reproduction, such as mating, cooperation, parenting, and aggression (Robinson, Fernald and Clayton 2008; Brown et al. 2011), whereas others suggest that genotype and maternal environment contribute to a very small portion of reproductive variability compared to the roles of phenotype and stochastic environment factors (Gustafsson 1986; Tuljapurkar et al. 2009). As for suggestions that genetic transmission of traits conducive to the attainment of status had indirect effects on

reproductive success and could lead to the diffusion of these traits through the population (Clark 2007; Unz 2013), we are skeptical. Estimates of the heritability of cognitive ability and other relevant traits generally suggest mild associations. Analysis of two-sex models suggests that in the absence of completely assortative mating, heritability of traits conducive to the attainment of status and which indirectly affected reproduction would not lead those traits to become universal (Preston and Campbell 1993).

We can rule out some other explanations. Indirect effects on patrilineage growth rates in later generations via intergenerational transmission of the forms of male status recorded in our data are unlikely to account for the results shown here. The same results are apparent in calculations not shown here that control for the social status of men in later generations. Tentatively, we can also rule out polygyny as a key mechanism in accounting for differential growth rates, since it was extremely rare in the largely rural CMGPD-LN population, and became uncommon in the CMGPD-IL. Adoption of sons was also unlikely to have played a role because in historical China, it was usually between closely related male kin who belonged to the same patrilineage (Lee and Wang 1999), and would have had little net effect on the total number of male descendants. The CMGPD-IL has detailed records of adoption, and in calculations not shown here we found little or no difference in the total number of male descendants according to whether we applied a biological or social definition of ancestry when constructing patrilineal pedigrees.

These findings are subject to caveats. First, even though the populations analyzed here are from nearly opposite ends of the social spectrum in late Imperial China, the possibility remains that their experience is atypical of historical Chinese populations, and that populations located elsewhere on the social spectrum were characterized by other dynamics. It is also possible that the processes reported here are limited to China, or patriarchal societies like China in which family strategies focus on the perpetuation of the male descent line, and do not generalize to other human populations. The findings may also be less germane to contemporary populations, where variances in reproduction may be smaller than those in the past, and where the chances of not having any sons at all may be less tied to social status.

Second, the results are only for patrilineal descent lines, not matrilineal ones. The data do not allow for women to be linked to their mothers and do not provide measures of social status for women, and as noted earlier, it is not possible to extrapolate from results for patrilineages to matrilineages. Effects of founder's characteristics on the total number of patrilineal and matrilineal descendants might differ considerably from the ones here. Thus while the results here provide insight into the dynamics of the patrilineal descent lines that were an important unit of social organization in historical China, they do not illuminate other substantively important processes that also involve matrilineal kin networks.

Future studies will need to parcel out the roles of differentials in component demographic behaviors such as fertility, mortality, marriage, remarriage, polygyny, and adoption in accounting for these patterns. The most important next steps are to produce an accounting of the specific demographic components of the link between male founder's status and subsequent patrilineage, locate and analyze more encompassing measures of status than the

official titles and positions used here, and identify the traits that affect reproductive success and are transmitted within families. A very basic question is whether the advantage of the high-origin lines in avoiding extinction reflected higher marriage chances of descendants. Alternatively, it may be that married men in high-origin lines were more successful at ensuring that at least one of their sons survived to adulthood. A refined analysis would examine effects of high status in one generation on the fertility, mortality and marriage of descendants many generations later.

These analyses should also be replicated using other multi-generational databases that also record matrilineal descent lines. These include the Quebec genealogical databases PRDH and BALSAC (Tremblay et al. 2008), the Uppsala Multi-generational Birth Cohort Study (UBCoS) (Goodman et al. 2012; Goodman and Koupil 2009) and the Utah Population Database (Bean et al. 1990). None of these societies was as explicitly focused on the continuity of the patrilineal descent line as historical China, thus comparison would help clarify the extent to which the results here are specific to explicitly patrilineal societies such as China, or perhaps characteristics of historical societies more broadly. Results from analyses of these databases would also illuminate the role of marital endogamy and other processes in accounting for features of patrilineage dynamics like the ones reported here, and would allow for comparison between the dynamics of patrilineal and matrilineal descent lines.

CONCLUSION

The results here underscore the importance of Mare's (2011) call for stratification studies to take a multi-generational approach that accounts for not only the influence of distant ancestors and kin, but also for the interaction between status transmission and demographic behavior in shaping population composition. We show that male social differentiation in one generation alters the composition of the male population in future generations. Also, male social status in one generation has a longer term influence on the reproductive success of patrilineages than is commonly assumed in "two-generation" studies. The influence, however, dissipated over time, so that the reproductive behavior of patrilineal male descendants of high-status founders eventually becomes indistinguishable from the rest of the population.

The most important implication of these results is that future studies need to reevaluate many of the explicit or implicit assumptions made in studies of kin network influences on individual outcomes. In particular, characteristics of kin networks which are assumed to be exogenous to individual characteristics may in fact be endogenous. According to the results here, the size, composition, and other characteristics of the patrilineages in which individuals in patrilineal societies are embedded are themselves shaped by the characteristics of male ancestors who lived many generations ago. This represents a novel form of indirect transmission of status. Studies of kin networks cannot simply equate regression coefficients estimated for characteristics of kin networks with effects of these kin. The results are subject to a subtle form of omitted variable bias associated with absence of data on the distant ancestor from whom everyone in the observed kin network is descended, and whose status influenced the observed characteristics of the kin network. Without recognizing this

problem, studies may yield biased estimates of the influence of kin networks on individuals' demographic and socioeconomic outcomes.

Our results also suggest that analyses of relationships between social status and patrilineage growth in human populations need to account separately for extinction and, conditional on avoidance of extinction, numbers of sons. Male status influenced the number of patrilineal male descendants many generations later, and did so in large part by reducing the chances that males in one generation would have no sons at all in next generation. If a male founder's characteristics have a more important effect on the probability of the patrilineage avoiding extinction than on the growth rate of the patrilineage, studies based on retrospective surveys or the genealogies of surviving patrilineages may underestimate the importance of founder effects. If the more complex strategies for patrilineage descent line continuity suggested by the results were typical of patrilineal societies, future simulation studies of population dynamics and kinship networks over the long term (e.g., Lavelly and Wong 1998; Murphy 2004; Bongaarts, Burch and Wachter 1987) will need to reconsider many of their assumptions.

Our findings from two large, multi-generational population databases in 18th and 19th century China suggest that in patrilineal societies, socioeconomic differentials in male demographic behavior in the distant past have long-term implications for the size and composition of networks of patrilineal kin many generations later. New, very different socio-demographic patterns have emerged in the last two centuries, and will shape the world that our descendants experience. We eagerly await the results of empirical analyses that use large, contemporary, multi-generational population databases to ascertain the saliency and relevance of these historic patterns in contemporary settings.

Data

Lee, James Z., and Cameron D. Campbell. China Multi-Generational Panel Dataset, Liaoning (CMGPD-LN), 1749–1909 [Computer file]. ICPSR27063-v6. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2011-09-02. doi: 10.3886/ICPSR27063.v6

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Figure 1.
Three Mechanisms for Effects of Founder's Characteristics on Patrilineal Descent Line Growth

Note: For the low-origin descent line, we assume its growth function is $N(T) = N(0)e^{\int_0^T r(t)dt}$. Under the assumption of initial advantage, the growth function of the high-origin descent line becomes $N(T) = c \cdot N(0)e^{\int_0^T r(t)dt}$, where c is constant multiplier to $N(0)$. Under the assumption of permanent advantage, the growth function of the high-origin descent line becomes $N(T) = N(0)e^{\int_0^T c \cdot r(t)dt}$, where c is constant multiplier to $r(t)$ for high-origin descent lines. Under the assumption of advantage dissipation, the growth function of the high-origin descent line becomes $N(T) = N(0)e^{\int_0^T \left(c \cdot r(t) - \int_0^T a(t)dt \right) dt}$, where $\int_0^T a(t)dt$ accumulates over time and counteracts the effect of c for a high-origin descent line.

Figure 2.
Patrilineal Descent Line Size over Time, by Male Founder's Status (CMGPD-IL)

Figure 3.
Patrilineal Descent Line Extinction by Male Founder's Social Status: CMGPD-IL

Figure 4.
The Effect of Male Founder's Status on Relative Patrilineal Descent Line Sizes and Growth Rates over Time: CMGPD-IL

Figure 5.
The Effect of Male Founder's Status on Relative Patrilineal Descent Line Sizes and Growth Rates over Time: CMGPD-LN

Figure 6.
Probability of Extinction in the Next 25 Years for High-origin and Low-origin Patrilineal Descent Lines: CMGPD-IL & CMGPD-LN

Table 1

Implications of Changes in Growth Equation Components for a Patrilineal Descent Line's Share of the Population

		Increase in Growth Rate $r(t)$		
		No	Yes	
			Permanent	Transitory
Founder's Reproduction $N(0)$ Is Above Average	No	No change in the descent line's share of population	<i>Permanent advantage:</i> descent line's share of population increases steadily	<i>Advantage dissipation:</i> descent line's share of the population increases for several generations, then stabilizes
	Yes	<i>Initial advantage:</i> descent line's share of population increases in next generation, then remains stable	<i>Initial advantage + permanent advantage</i>	<i>Initial advantage + advantage dissipation</i>

Note: Permanent means that the acceleration of growth rate is constant or positive. This implies that the growth rate of high-origin descent lines is always higher than the low-origin descent lines. Transitory means that the acceleration of growth rate is negative, though the growth rate itself is positive. This implies that the growth rate of high-origin descent lines will eventually drop down to the same level as that of the low-origin descent lines.

Table 2

Descriptive Statistics for Patrilineal Descent Line Characteristics

	CMGPD-Imperial Lineage			CMGPD-Liaoning		
	All	High-Origin Descent Line	Low-Origin Descent Line	AI	High-Origin Descent Line	Low-Origin Descent Line
Founder's Characteristics						
Eldest brother in the family (%)	26.07	24.77	26.70	73.99	75.46	73.63
Number of male siblings	5.84 (4.96)	6.91 (5.99)	5.32 (4.28)	1.26 (1.37)	1.26 (1.37)	1.27 (1.37)
Imperial lineage main line (%)	48.40	59.89	42.83			
Regular status population (%)				82.14	82.90	81.95
Generation length	25.56 (7.39)	24.41 (6.92)	26.21 (7.56)	29.77 (8.48)	29.25 (8.41)	29.96 (8.50)
Average Number of Descendants						
After 25 years	.62 (.88)	.84 (1.02)	.51 (.77)	.25 (.54)	.38 (.66)	.22 (.51)
After 50 years	1.81 (2.06)	2.61 (2.62)	1.42 (1.57)	1.07 (1.43)	1.70 (1.68)	.92 (1.31)
After 75 years	2.65 (3.49)	4.15 (4.67)	1.93 (2.44)	1.66 (2.58)	2.73 (3.20)	1.40 (2.32)
After 100 years	3.07 (5.00)	5.15 (6.96)	2.05 (3.25)	1.95 (3.65)	3.27 (4.61)	1.62 (3.28)
After 125 years	3.20 (6.32)	5.75 (9.15)	1.97 (3.75)	2.20 (4.93)	3.70 (6.29)	1.83 (4.45)
After 150 years	3.22 (7.08)	5.93 (10.44)	1.91 (4.05)			
Observations	3,314	1,082	2,232	18,997	3,761	15,236

Sources: China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL), China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN).

Note: Figures in parentheses are standard deviations.

Table 3

Regressions of Patrilineal Descent Line Sizes (Stocks)

Stock Model	Years					
	<i>t</i> = 25	<i>t</i> = 50	<i>t</i> = 75	<i>t</i> = 100	<i>t</i> = 125	<i>t</i> = 150
CMGPD-IL						
Linear						
High status founder	.286*** (.032)	1.057*** (.074)	1.927*** (.124)	2.607*** (.176)	3.098*** (.222)	3.248*** (.250)
Exponential						
High status founder	.224*** (.025)	.500*** (.034)	.655*** (.040)	.734*** (.044)	.747*** (.047)	.739*** (.048)
Poisson						
High status founder	.432*** (.046)	.538*** (.027)	.663*** (.022)	.769*** (.020)	.871*** (.020)	.909*** (.020)
Negative Binomial						
High status founder	.432*** (.050)	.536*** (.037)	.658*** (.043)	.766*** (.051)	.864*** (.061)	.888*** (.070)
<i>N</i>	3,314	3,314	3,314	3,314	3,314	3,314
CMGPD-LN						
Linear						
High status founder	.160*** (.010)	.779*** (.025)	1.321*** (.046)	1.641*** (.065)	1.862*** (.089)	
Exponential						
High status founder	.144*** (.009)	.504*** (.015)	.627*** (.020)	.646*** (.021)	.613*** (.023)	
Poisson						
High status founder	.548*** (.032)	.612*** (.015)	.663*** (.012)	.698*** (.011)	.701*** (.010)	
Negative Binomial						
High status founder	.548*** (.035)	.612*** (.022)	.664*** (.029)	.700*** (.036)	.703*** (.045)	
<i>N</i>	18,997	18,997	18,997	18,997	18,997	

Sources: China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL), China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN).

Note: Figures in the table are excerpted from Appendix A. Standard errors of the coefficients are in parentheses.

* $p < .05$;

** $p < .01$,

*** $p < .001$ (two-tailed tests).

Table 4

Regressions of Patrilineal Descent Line Growth Rates (Flows)

Flow Model	Years					
	<i>t</i> = 25	<i>t</i> = 50	<i>t</i> = 75	<i>t</i> = 100	<i>t</i> = 125	<i>t</i> = 150
CMGPD-IL						
Linear						
High status founder	.286*** (.032)	.771*** (.063)	.870*** (.077)	.679*** (.084)	.491*** (.092)	.150 (.087)
Exponential						
High status founder	.224*** (.025)	.276*** (.031)	.155*** (.024)	.079*** (.022)	.013 (.022)	-.008 (.021)
Poisson						
High status founder	.432*** (.046)	.267*** (.027)	.179*** (.022)	.149*** (.021)	.153*** (.020)	.098*** (.020)
Negative Binomial						
High status founder	.432*** (.050)	.315*** (.035)	.194*** (.025)	.153*** (.023)	.159*** (.025)	.110*** (.025)
<i>N</i>	3,314	3,314	3,314	3,314	3,314	3,314
CMGPD-LN						
Linear						
High status founder	.160*** (.010)	.619*** (.022)	.542*** (.028)	.320*** (.033)	.221*** (.043)	
Exponential						
High status founder	.144*** (.009)	.359*** (.013)	.123*** (.010)	.019* (.009)	-.033*** (.010)	
Poisson						
High status founder	.548*** (.032)	.410*** (.015)	.186*** (.012)	.135*** (.011)	.096*** (.010)	
Negative Binomial						
High status founder	.548*** (.035)	.459*** (.018)	.203*** (.014)	.172*** (.014)	.172*** (.016)	
<i>N</i>	18,997	18,997	18,997	18,997	18,997	18,997

Sources: China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL), China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN).

Note: Figures in the table are excerpted from Appendix B. Standard errors of the coefficients are in parentheses.

* $p < .05$;

** $p < .01$,

*** $p < .001$ (two-tailed tests).

Table 5
Mixture Negative Binomial Regressions of Patrilineal Descendants Growth and Extinction

	Years				
	$t = 25$	$t = 50$	$t = 75$	$t = 100$	$t = 150$
CMGPD-IL					
<i>Stock Model: $P(N(t))$</i>					
Logistic model: $N(t) > 0$					
High status founder	.575*** (.077)	1.126*** (.101)	1.185*** (.099)	1.116*** (.089)	.981*** (.082)
N	3,314	3,314	3,314	3,314	3,314
Truncated negative binomial: $N(t) N(t) > 0$					
High status founder	.352*** (.090)	.431*** (.049)	.484*** (.048)	.543*** (.055)	.606*** (.062)
N	1,419	2,374	2,306	2,088	1,801
<i>Flow Model: $P(N(t) N(t-1) > 0)$</i>					
Logistic model: $N(t) > 0$					
High status founder	.575*** (.077)	.728*** (.201)	.632*** (.171)	.585*** (.151)	.381*** (.135)
N	3,314	1,419	2,374	2,306	2,088
Truncated negative binomial: $N(t) N(t) > 0, N(t-1) > 0$					
High status founder	.352*** (.090)	.252*** (.050)	.145*** (.029)	.102*** (.025)	.037 (.026)
N	1,419	1,261	2,306	2,088	1,801
CMGPD-LN					
<i>Stock Model: $P(N(t))$</i>					
Logistic model: $N(t) > 0$					
High status founder	.659*** (.051)	1.153*** (.041)	1.123*** (.039)	1.058*** (.038)	.974*** (.037)
N	18,997	18,997	18,997	18,997	18,997
Truncated negative binomial: $N(t) N(t) > 0$					
High status founder	.254*** (.079)	.307*** (.027)	.243*** (.023)	.211*** (.027)	.168*** (.033)
N	3,975	10,247	9,423	8,111	6,820
<i>Flow Model: $P(N(t))$</i>					
Logistic model: $N(t) > 0 N(t-1) > 0$					
High status founder	.659*** (.041)	.702*** (.140)	.411*** (.081)	.401*** (.072)	.219*** (.069)

	Years				
	<i>t</i> = 25	<i>t</i> = 50	<i>t</i> = 75	<i>t</i> = 100	<i>t</i> = 125
<i>N</i>	18,997	3,975	10,247	9,423	8,111
Truncated negative binomial: $N(t) N(t) > 0, N(t - 1) > 0$					
High status founder	.254** (.079)	.195*** (.027)	.056*** (.014)	.031* (.013)	.001 (.013)
<i>N</i>	3,975	3,584	9,423	8,111	6,820

Sources: China Multi-Generational Panel Dataset-Imperial Lineage (CMGPD-IL), China Multi-Generational Panel Dataset-Liaoning (CMGPD-LN).

Note: Figures in the table are excerpted from Appendix C. Standard errors of the coefficients are in parentheses.

* $p < .05$;
** $p < .01$,
*** $p < .001$ (two-tailed tests).