Advances in Life Course Research 53 (2022) 100481

Contents lists available at ScienceDirect

Advances in Life Course Research

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

Fading family lines- women and men without children, grandchildren and great-grandchildren in 19th, 20th and 21st Century Northern Sweden

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A R T I C L E I N F O

Keywords:
Lineages
Kinship
Demography
Childlessness
Grandparents
Sweden

A B S T R A C T

We studied to what extent family lines die out over the course of 122 years based on Swedish population-level data. Our data included demographic and socioeconomic information for four generations in the Skellefteå region of northern Sweden from 1885 to 2007. The first generation in our sample consisted of men and women born between 1885 and 1899 (N = 5850), and we observed their children, grandchildren, and great-grandchildren. We found that 48% of the first generation did not have any living descendants (great-grandchildren) by 2007. The risk of a family line dying out within the four-generational framework was highest among those who had relatively low fertility in the first generation. Mortality during reproductive years was also a leading reason why individuals in the first generation ended up with a greater risk of not leaving descendants. We identified socioeconomic differences: both the highest-status and the lowest-status occupational groups saw an increased risk of not leaving any descendants. Almost all lineages that made it to the third generation also made it to the fourth generation.

1. Introduction

A preference to see one's family lines continue can be a central reason why individuals choose to enter parenthood, why they choose to have a certain number of children and why parents invest time and resources in their children's wellbeing, health and economic opportunities - and thereby the children's potential for partnering, reproduction and survival. Continuing a family lineage and leaving descendants can be of importance for individuals (Kotre, 1984), for families, communities and even countries (Goody, 1973; Hunter and Rowles, 2005; Skirbekk, 2022). When substantial shares of the population do not leave any descendants over the course of a few generations this is likely to have social, genetic, and economic conditions ramifications. It can influence for instance economic inequality, fiscal sustainability, healthcare needs and demographic development.

Understanding trends in the descendant-less share requires an understanding of fertility and mortality across generations. These trends are differently affected by the first generation's fertility choices compared to childbearing behaviours among successive generations. Moreover, they relate to mortality differences across generations and how individual mortality risks interact with childbearing patterns. Finally, they depend on how socioeconomic and other factors influence demographic behaviours, and how childbearing behaviours are socially and genetically transmitted across generations (Axinn, Clarkberg, & Thornton, 1994b; Barber, 2001; Briley, Tropf, & Mills, 2017; Verweij et al., 2017). In effect, one needs population level multigenerational data to assess which shares of the population that fail to leave offspring in the longer term, which generations that are more important for these outcomes and the causes of these changes.

Evolutionary based theories of human behaviour are informed by the tenet that one seeks to maximize reproduction and survival of offspring and raise ones chances of leaving descendants in the longer term (Betzig, 2020; Sear, 2015). In effect, understanding to which extent some individuals do not leave descendants, and what characterizes these individuals, is of interest.

Life course theory focus on how life courses are connected across

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https://doi.org/10.1016/j.alcr.2022.100481
Received 13 July 2020; Received in revised form 14 April 2022; Accepted 21 May 2022
Available online 23 May 2022
1040-2608/

generations (Elder, 1977; Szydlik, 2012). It discusses how such links persists across generations through for example bequests connecting non-living kin (Szydlik, 2012) and the inheritance of cultural traits within families (Mare, 2011). Whether one leaves children or not will influence bequest transmissions of both wealth and culture. Understanding the effects of high shares not having children, and that parenthood relates to selection in terms of socioeconomic, biological or health will have consequences for following generations, which traits that are intergenerationally transmitted and how new generations can live their lives.

Empirically, relatively little is known on how common it is to not leave any descendants in a multigenerational perspective, and we have not identified any empirical earlier studies that went beyond using grandparenthood to empirically measure lineage extinction by separate distinct generations using individual-level data. There is an insufficient understanding of the demographic causes of family line cessation (i.e. high mortality or low fertility), for which generation family line cessation occurs, and the role played by socioeconomic factors in this phenomenon.

To investigate these research topics, we study family lines over the course of four generations from the late 19th century to the early 21st century in Sweden. This was a period in which Swedish mortality levels were among the lowest in the world (Drefahl, Ahlbom, & Modig, 2014), while the timing of the fertility transition was similar to many other high-income societies (Statistics Sweden, 1999). Moreover, the Swedish population size almost doubled through natural growth over the course of this period.

We use both historical government data derived from parish registers and recent administrative register data. Our dataset consists of men and women born between 1885 and 1899 in Skellefteå, a coastal area in northern Sweden, and their children, grandchildren and great-grandchildren. We investigate to what extent differences in lineage survival are driven by fertility, mortality, and socioeconomic characteristics for each successive generation.

Our study is organized as follows: First we give a theoretical overview of the mechanisms that affect whether family lineages die out. We begin by illustrating how demographic factors affect lineage cessation, and then review the causes of childlessness and the proximate cause of lineage cessation for each generation. Thereafter we review previous literature that empirically assesses childlessness and grandchildlessness in different times and places, with a particular focus on 19th and 20th century Europe. We then go on to present our dataset, discuss the methods we use and present our findings along with a discussion.

1.1. *What causes family lineages to die out?*

The topic of our study – the proportion in the population who leave no descendants after one, two and three generations – is determined by demographic factors. In a narrow sense, the proportion of people having no great-grandchild can be viewed as a demographic process occurring over three generations, in which the descendant(s) in each generation either die before having children or live through their reproductive years without having children. The first of these mechanisms, the role of mortality, has declined in importance over time, since mortality at younger ages fell rapidly over the course of the 19th and 20th centuries. The second mechanism relates to fertility and childlessness (we hereafter mostly use childlessness as a shorthand for the combined effects of surviving throughout the reproductive part of adulthood and having no children while surviving to the age of 45 – in contemporary demography childlessness is typically defined in the second sense only). In societies characterized by low mortality, fertility is the primary pathway to understanding why an individual leaves no descendants.

Postponed and lowered fertility levels in the post-war period have decreased the number of children, which implies that the number of subsequent descendants that Europeans have also decreased. Evidence suggests that men are more likely to be childless particularly in later cohorts in several countries (Miettinen, Rotkirch, Szalma, Donno, & Tanturri, 2015). As childlessness differs by gender, grandchildlessness and great-grandchildless may also differ between men and women. Furthermore, particularly men with lower income are likely to be childless in several settings, including contemporary and historical Sweden (Kolk, 2022; Kolk and Barclay, 2021; Skirbekk, 2008).

To understand the lack of descendants across multiple generations, the number of children an individual has also plays an important role, as each additional child increases the probability that at least one child will bear grandchildren.[1] The proportion leaving no descendants over multiple generations can be viewed as a succession of probabilities for each generation to be childless. The combined effect of fertility and mortality variation affects net reproduction across generations. Before the demographic transition and the rise in life expectancy, early life mortality was the most common reason a newborn child did not leave any descendants (e.g. Low 1991). The cumulative risk that a person would die before reaching one's reproductive age was high. Moreover, extramarital fertility in Sweden was low at the same time as substantial shares married relatively late in their reproductive lives or did not marry at all. Throughout our study period, mortality fell, and life expectancy at birth rose from being in the 40s in the late 19th century to over 80 years in the early 20th century. Therefore, despite high marital fertility in the early period we study (Dribe and Scalone, 2014), population growth was moderate. The period we study was also one of increasingly effective and more affordable contraceptives combined with better sexual and reproductive education and knowledge (Kling, 2006), and average fertility declined dramatically from the 1920s. The net effect in the case of Sweden was that the number of surviving offspring was relatively stable over this period, after a rapid fertility decline in the very early parts of the 20th century (Hyrenius, 1951).

Our study period is simultaneous with the fertility transition in Sweden. The fertility transition took place a few decades later in our study region than in central Sweden (Alm Stenflo, 1994). Cohort fertility fell from an average of around five children per woman at the turn of the century until it stabilized at just below two children for most cohorts of the 20th century. In Sweden, for cohorts born between 1875 and 1960, the share of the population who died before age 45 fell from 40% to only 4% (Statistics Sweden, 1997). This increase in survival through key childbearing years suggests that mortality became a decreasingly important cause of not having descendants over time. Below we summarize reasons for having or not having children in historical and contemporary Europe, followed by a summary of previous empirical research on lineage extinction.

1.2. *Why do people not have children?*

The proportion of men and women never having children was high in most of historical north-western Europe, including Sweden compared to the rest of the world (Sobotka, 2017). In north-western Europe, a large share of the population also never married, in what has been described as a Malthusian marriage system in which the proportion marrying and the age at marriage responded to wages and economic resources (e.g. Wrigley and Schofield, 1981), which has been strongly linked to high childlessness. The majority of births occurred within marriage, and marital probabilities were strongly linked to occupation and economic status in 19th century Sweden (Low, Clarke, & Lockridge, 1991). The European marriage pattern is characterized by late marriage, high levels

[1] This pattern has been a matter of some controversy in evolutionary studies of human behaviour, as it was theorised that low fertility may have been an evolutionary strategy to maximise the quality of an individual's children, who in turn would translate their superior socio-material situation into a larger number of grandchildren (or later descendants). It is now generally agreed that this seems not to be the case in historical and contemporary Western societies (e.g. Borgerhoff Mulder, 1998, Goodman et al., 2012).

of cohabitation (especially in early adulthood), and high shares not marrying. Historically, the marriage pattern, with low levels of extra-marital births, high levels of non-marriage and late marriage (particularly in times of economic downturns) related to low and late fertility and high levels of non-parenthood.

In the first decades of the 20th century, women were more likely than men to be childless in many European countries, following high male war-related mortality and resulting in higher shares of women in reproductive ages (Cochrane, 1979; Morgan, 1991; Sobotka, 2017). However, Sweden had a neutral position during the world wars, meaning that gender differences in mortality were largely unaffected by these trends – and throughout the 20th century, men had higher levels of childlessness than women. Childlessness decreased in the early part of the 20th century and then increased in comparison from the middle of the century onwards in Sweden (Myrdal and Myrdal, 1934; Sobotka, 2017).

Longer education has historically been related to a later onset of childbearing and lower fertility outcomes (Cochrane, 1979). At least since the late 19th century Sweden has had high levels of education relative to other countries (Cochrane, 1979). Yet, educational differences in fertility and childlessness have over time decreased and are nowadays low in Sweden (Jalovaara et al., 2019). Fertility differences based on income, however, are substantial in contemporary Sweden: Higher-income men and women are both much more likely to have children (Kolk, 2022).

In contemporary societies, people may end up without offspring for a variety of reasons, including the lack of a partner, a feeling of financial insecurity or the pursuit of activities and lifestyles that are difficult to combine with having children (De Jong and Sell, 1977; Lesthaeghe, 1983; Van de Kaa, 1987), whereas mortality is a less important as the demographic transition progress (Lee 2003). Childbearing entails high costs and time use which can lead some to forego having children (Balbo, Billari, & Mills, 2013; Tanturri, 2013). A variety of often unforeseen life events can mean many will not be able to realize their fertility preferences. Some become childless because they postpone childbearing for too long and are unable to conceive due to biological reasons. Childlessness is relatively often caused by postponing childbearing to ages when fecundity is markedly lower, leading many to involuntary childlessness (Kreyenfeld and Konietzka, 2017; Saarela and Skirbekk, 2020).

Childlessness can be both voluntary and involuntary. Relatively few individuals state that they prefer not to have children. Population-level surveys in contemporary high-income countries suggest that most people prefer to have children; very low percentages indicate that they would not like to have any children (Miettinen and Szalma, 2014). Among those aged 18–40, only 5% of women and 7% of men across the EU in 2011 stated that they see childlessness as ideal, and the percentage is still lower in Sweden, where only 2% of women and 4% of men have a stated preference for childlessness (Miettinen and Szalma, 2014).

While family sociologists have extensively examined reasons for having or not having children, less is known about desires for leaving descendants in subsequent generations. Life course theory offers insights into how and why generations are connected to each other (Szydlik, 2012). Passing on knowledge, culture and beliefs is central for many individuals (Hunter and Rowles, 2005). Lineage continuity can also be an important reason why many parents aim to raise their children with family and pronatal values, which may raise the likelihood that their children will choose to have children on their own (Bengtson, Copen, Putney, & Silverstein, 2009). It is common for individuals with adult children to wish for grandchildren. Transferring one's culture, knowledge, social views and customs to the next generation can become an important aim for many and can lead some to encourage their children to have grandchildren (Axinn, Clarkberg, & Thornton, 1994a). Many parents of adult children encourage their children to enter parenthood – some argue for the benefits of having children and offer resources and support for potential grandchildren, including financial cash transfers and housing support (Lee and Mason, 2011; Margolis and Wright, 2017; Pink, 2018). One such related important dimensions in which multi-generational ties structure contemporary lives are through bequests connecting non-living kin (Szydlik, 2012).

Less is known about desires and preferences for leaving a legacy or having descendants over a longer timeframe. Anthropological studies have documented that having descendants plays a prominent role in cultures and belief systems around the world (e.g. Lévi-Strauss, 2013; Palmer and Steadman, 1997). For example, Confucian patrilineal societies place a great cultural value on having male descendants and survival of your lineage (Song, Campbell, & Lee, 2015; Wolf and Huang, 1980). Researchers have also documented that leaving a legacy for future descendants remains an important life goal for many individuals (Hunter and Rowles, 2005). Also in contemporary societies many place value on procreation and a genetic legacy as such, even if they will not meet any of their descendants (Riggs and Russell, 2010). On a grander level, many people also place value on the survival and continuation of their sociocultural group – or even humanity at large (Hunter and Rowles, 2005; Lenman, 2002).

1.3. Empirical estimates on descendants in a multigenerational perspective

As shown above, a large literature has documented patterns of childlessness in historical and contemporary populations. Less research has taken a multigenerational perspective. A recent and rapidly increasing trend in the literature has been examining the prevalence and timing of grandparenthood over the life course (Chapman, Pettay, Lahdenperä, & Virpi, 2018; Leopold and Skopek, 2015; Margolis, 2016; Skopek and Leopold, 2017). A cross-country comparison of contemporary grandparenthood in the United States and 24 European countries has been provided by Leopold and Skopek (2015). They found that compared to the United States (where, on average, grandparenthood occurred at the age of 49 among women and 52 among men), grandparenthood in Eastern Europe occurred up to three years earlier in life; while in Western Europe, it occurred up to eight years later. They also found that the estimated shared life expectancy of grandparents with grandchildren was highest (35 years) among grandmothers in East Germany and the United States; the shortest (21 years) was among grandfathers in West Germany and Spain. Over time, following increases in life expectancy, the duration of coexistence between grandparents and grandchildren has changed, whereas postponed fertility has decreased it (Chapman, Lahdenperä, Pettay, & Lummaa, 2017). Among West German women, lower fertility among highly educated mothers has had a strong effect – lower-educated women's chances of becoming a grandmother were similar to higher-educated women's chances of becoming a mother (Skopek and Leopold, 2017). The share of 55-year--old Swedes who did not have grandchildren rose from 30% to 65% between 1990 and 2005, although a sizeable proportion of this group will have grandchildren later (Lundholm and Malmberg, 2009).

Studies focused on the proportions of people who will ever leave descendants over a longer timeframe have primarily relied on data sources other than censuses or survey data. Studies on family extinction have a long history in the sciences, as examined by Watson and Galton (1875), on the basis of surnames and "one-sex population" models. Lotka (1931) revisited the question in 1931. Lineage extinction is likely to have been very common in evolutionary history. This has resulted in genetic bottlenecks in which the genetic information of only a few individuals has been transferred to the next generations (Raup, 1994). Models in ecology exist to assess the frequency of a local group eventually ending up extinct (Colantonio, Lasker, Kaplan, & Fuster, 2003; Fox and Lasker, 1983; Hamza, Jagers, and Klebaner, 2016; Raup, 1994). Some such studies have examined humans, and surnames in historical populations to model propensities of lineage extinctions (Fox and Lasker, 1983; Yasuda, Cavalli-Sforza, Skolnick, & Moroni, 1974). Yasuda and colleagues found that 58% of the medieval surnames in a sample from the upper Parma Valley (an area in Northern Italy) no longer existed by the second half of the 20th century – most family names have disappeared, and the frequency of disappearance was greater the fewer original bearers there were.

A small number of studies have examined lineages from a demographic perspective using empirical data. Song et al. (2015) examined the growth rate of patrilines using historical Chinese records, treating the survival in years of (all members of) a patrilineage as their unit of analysis, but basing their data on micro-level records. They found that high-status patrilineages had a lower probability of extinction at each point in time, but did not find that successful patrilines had a larger number of sons on average. Wachter, Hammel, and Laslett (1978) studied the extinction of elite English patrilines over multiple generations using analytical models.

East Asian data has been used to study lineages, partly because of a long history of lineage genealogies (Song and Campbell, 2017), which is related to the high value placed upon lineage continuity in the Chinese cultural sphere. Genealogies also tend to over-record "sociocultural" reproduction, under-recording less successful individuals. Researchers have also used microsimulations to extend multigenerational genealogical data (Zhao, 1996, 2000), although there has also been more focus on multigenerational household structure than lineage continuity. Murphy (2004) used microsimulations to study lineage continuity over very long periods (over 10 generations and 500 or more years).

Higher social status has been found to be associated with a lower risk of lineage extinction in China (Song et al., 2015). Prior to the demographic transition, higher-status individuals were likely to marry younger and to have higher fertility. Higher-status individuals had a greater number of descendants in periods of low population growth, which implies lower lineage extinction risks (Low, 1990; Skirbekk, 2008). In contemporary societies, given decreased mortality among all social groups and high social status increasingly being related to low and postponed fertility, high social status may have ceased to represent the same advantage to ensuring lineage survivorship (Goodman, Koupil, and Lawson, 2012).

Two Swedish studies have focused on the number of surviving descendants over three and four generations. Goodman et al. (2012) estimated the number of grandchildren of men and women born from 1915 to 1929 in Sweden. Kolk and Hällsten (2017) used data from northern Sweden and examined both educational and reproductive outcomes over four generations. Both studies were prospective, and had a main focus on the average number of descendants. However, both studies had to make assumptions to either select a population of reproducing and geographically immobile initial generations (Kolk and Hällsten, 2017) or rely on cohorts where some descendants had not completed their childbearing (Goodman et al., 2012); basing the studies on the focal cohort, they primarily examined grandparenthood. Both studies also did not examine proportions of people without any descendants directly, and neither study could provide answers to the question of the proportion of individuals without great-grandchildren. To our knowledge, the phenomenon of family line cessation over four generations has not ever been tested empirically using representative (and largely un-truncated) data for any population including both grandchildren and great-grandchildren.

1.4. Our approach and contribution

Our approach differs from most recent research on grandparenthood in that we are not conditioning our focus on the survival of our index persons. Other research has focused on the personal experience of having a grandchild, whereas we are interested in the probability that a person surviving to adulthood would ever have grandchildren or great-grandchildren (regardless of whether they survive to experience it). As such, our research is more relevant for understanding long-term multigenerational processes and for examining the proportions of people who will eventually leave social or genetic descendants, in contrast to researcher designs that relate the subjective experiences of having descendants (while alive).

To understand the processes relating to the likelihood of not having children, grandchildren and great-grandchildren, it is important to understand the demographic pathways: did individuals die before reaching their reproductive years, or did they survive into adulthood but bear no children? Did individuals have children, but no grandchildren or great-grandchildren? How do occupation and fertility affect the probability of having no descendants after the first, second and third generations? These are the topics that we address using longitudinal data over four generations spanning three centuries. Studying proportions of people who fail to reproduce in the later stages of the demographic transition, as is done in the current study, can be of particular interest for understanding the natural selection processes that take place in contemporary populations (Rowland, 2007).

2. Data and methods

2.1. Data description

Our data is based on a combination of parish records and modern administrative registers from the Swedish government. In the late 19th century, Skellefteå was predominantly a farming region with a large share of farmers who owned their own land. The area underwent rapid industrialization at the beginning of the 20th century, when the mining industry played an important role. At the beginning of the 20th century, among our index cohorts, around 63% worked in farming. The fertility transition took place at the beginning of the 20th century, and the fertility behavior of our index cohort was accordingly highly variable. These data sources allow us to follow the fertility of our starting generation, their children and their grandchildren, and to estimate proportions of people without descendants at varying numbers of generations. Our historical data include a number of adjacent parishes in the Skellefteå region, located in northern Sweden on the coast of the Baltic Sea, where our data include the complete population of the region. These data are linked with contemporary digitized Swedish population registers that include the complete population of Sweden (see supplemental text 1 for further discussion on linkage).

Fig. 1 shows life expectancy and fertility for the region from the 1860s onwards, and Supplemental Fig. 1 includes a map of the area under study. During the 19th century, northern Sweden was characterized by high fertility and high rates of childlessness (Alm Stenflo, 1994; Kolk, 2011). During the 20th century, fertility rapidly fell to replacement levels in Sweden with still quite high levels of childlessness for both men and women (Alm Stenflo, 1994). Mortality consistently fell throughout the period of our study, which was marked by declines in infant and child mortality (Statistics Sweden, 1997).

2.2. Study population

Our study population is defined as all men and women born between 1885 and 1899 (N = 5850) in the Skellefteå region who were still alive at age 15. Our data go back considerably further than that, but in order to ensure that migration does not significantly impact our results in the pre-1947 period, these are the most suitable cohorts for studying family dynasties. They are also conditioned on either presence in the Skellefteå parishes until age 45 or an observed death before age 45. The reasons we choose age 45 are that it is common in the literature and most female and male births have occurred by this age. However, we do not constrain reproduction to age 45, and children and their descendants born after the age of 45 are also included in our study.

Our index cohorts consist of individuals born between 1885 and 1899 (which we refer to as G1), as these cohorts are suitable for assessing the number of children (G2), grandchildren (G3) and great-grandchildren (G4) while also minimising loss due to outmigration in the historical parishes. We have chosen our cohorts in order to minimise the impact of internal migration. We discuss how local migration implies

Fig. 1. Period life expectancy and fertility in Sweden and Västerbotten county (where Skellefteå is located).
Sources: see supplemental text 1.

that we overestimate childlessness by a couple of percentage points, and how we reached this conclusion is described in Supplemental text 2.

Individuals of our first generation who migrated out of the area before age 45 are excluded from our analysis completely; thus, our data are not representative of everyone born in our sample, but of a population of "stayers" (no such conditioning is applied to any descendants). We also conduct our analyses without and with conditioning the index generation (G1) on survival to age 45 (including/excluding individuals who died between the ages of 15 and 45) to examine to what degree childlessness is due to death during reproductive ages. We link our index population to their children, grandchildren and great-grandchildren. This means that childlessness refers to members of G1 who had no children. Similarly, "grandchildren" refers to the children of G2, and "great-grandchildren" refers to the children of G3. The linkage across generations is done using birth certificates and baptism certificates in the historical records and by means of official government birth records after 1947. Linkage rates are typically very high in both the historical and contemporary registers (above 95% have information on both parents), but in a few cases, we will underestimate the fertility of men, due to missing information on fatherhood in the registers. In both historical and contemporary cases, parenthood refers to biological parenthood as registered by the relevant authorities. Our selections of cohorts allow us to capture the complete reproductive careers of three generations. As some individuals will have children very late in life, we will miss a few cases of childbearing in the final generation. In Supplemental Fig. 2, we show the birth years of members of G1, G2 and G3. Over 90% of G3 were born before 1967 and 96% were born before 1972. As eventual childbearing (and first childbearing in particular) is virtually complete by age 40 (and higher-order childbearing is irrelevant for measures of childlessness), this means that we will underestimate the proportion of individuals where no member of G3 had a child, but for all members of G3, this will be less than 1%. None of our fertility measures are conditioned on civil status, but are strictly related to registered parenthood. In our first cohort, marriage and fertility are very strongly linked, whereas for our last cohorts, unmarried cohabitation is common enough to make a focus on non-marital childbearing very hard to interpret.

The older part of our data consists of regional parish registers collected by the Swedish state church from the 18th century to 1955 (some further overview is given in Supplemental text 1). These records include vital events, occupations and information on all migrations into or out of the area (Alm Stenflo, 1994; Breen and Jonsson, 2005). As such, they resemble contemporary administrative data that can be used for prospective analyses where the population at risk can be identified. Following the introduction of personal identity numbers in Sweden in 1947, these records are linked to contemporary administrative registers of the complete population, for which digitised information is available from 1960 and fertility information as early as 1932. As a consequence, we have accurate demographic information, including migration, for the entire period, yet our historical data are limited to a specific region of Sweden from 1885 to 1955. The availability of registry data and complete population coverage decreases the risk of errors and bias in the data, particularly given the rigorous paternity investigations and low proportions of missing fathers (less than 1%) in Swedish registers (Statistics Sweden, 2017).

Although our study region saw relatively little of Sweden's large outbound migrations to North America (which was mostly before our first generation reach age 15 in 1900–1914), there were non-trivial amounts of domestic migration in the 20th century. As we cannot observe demographic events outside Skellefteå until 1947, this implies that some individuals who migrate outside of the region could incorrectly be categorised as childless. Fortunately, we have access to outmigration records for these individuals, and can therefore assess the impact of such migration. We describe the generally modest impact of such migration (changing our estimates by at most 3 percentage points) on our results in our Supplemental text 2.

2.3. Methods

For most of our analysis, we present the proportion of G1 that have any children, any grandchildren and any great-grandchildren. The measures of no great-grandchildren are strictly higher than or equal to the proportion of people having no children and no grandchildren, as not all people having children will have future descendants. We present results where we further examine if this proportion differs by sub-group, such as sex, and with conditioning for G1 on survival to at least age 15 or survival to the end of reproductive ages at age 45 (Fig. 2). We also present further analyses where we show the bivariate relationship between lineage survival and both fertility outcomes in G1 Fig. 3) and occupation (Fig. 4). In some analyses, we only examine descendants of a single sex, ignoring any children or descendants of the opposite sex. As such, a measure of the proportion of men with no great-grandchild in our single-sex models reflects the number of men who had any son, who had any son, who had any son. This, for example, corresponds to the survival of the surname for men (given a patrilineal naming tradition). We do this both to make our findings comparable to some previous methodological approaches in the literature relying on (patrilineally inherited) surnames, as it is relevant for some forms of genetic inheritance (e.g. Mitchondrial DNA, and Y-chromosme DNA), and as it is

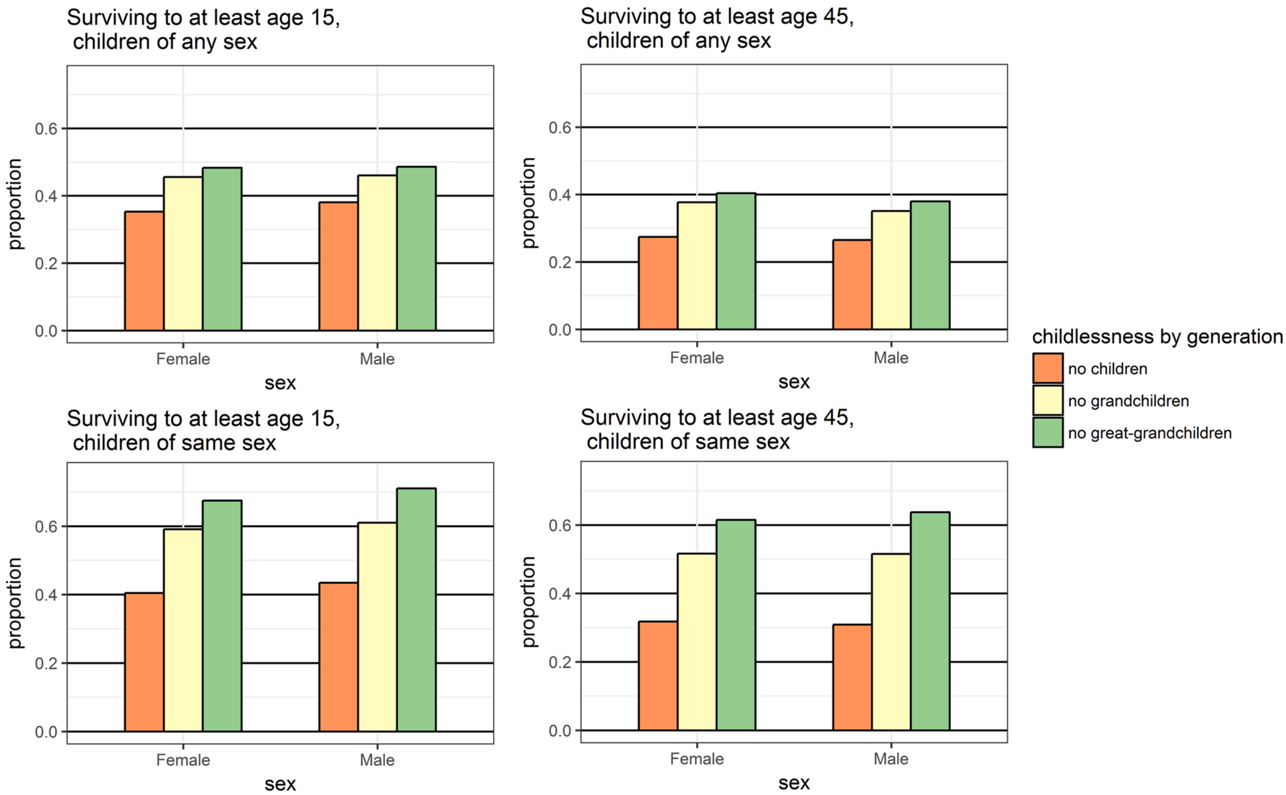

Fig. 2. Proportions of men and women born in Skellefteå from 1885 to 1899 without descendants in the following generations, organised by sex, bilateral (upper panels) vs matrilineal/patrilineal decent (lower panels), and for a population of G1 conditional on survival to age 15 (left panels) and conditional on survival to age 45 (right panels).
Upper left (2a): Descendants in each generation, for all G1 at age 15. Upper right (2b): Descendants in each generation, for all G1 at age 45. Lower left (2c): Descendants of the same sex in each generation, for all G1 at age 15. Lower right (2d): Descendants of the same sex in each generation, for all G1 at age 45.

historically and sociologically interesting.

Our measure of occupation is based on the highest occupation over a life course (combining notations from a variety of different registers), and may, for married individuals, be assigned from the spouse (typically the husband) instead of G1 themselves. For these reasons, we only present results on occupational status for both sexes combined. We use four categories for our occupational status measure that are based on the HISCO system to measure occupational class (Breen and Jonsson, 2005). These four measures capture the two essential dimensions of occupational status, people working in agricultural and non-agricultural sectors, and a division into high and low social status. The number of individuals in the non-agricultural occupations is very small, so a more fine-grained division is not meaningful. The measure is calculated from the highest observed HISCO occupation during the life course, and can thus be measured at different ages for different individuals. The categories include farmers (typically owning their own land), high-status occupations, non-agricultural workers and agricultural workers (typically not owning their own land). Land-owning farmers account for 30% of our sample. High-status occupations include a broad range of high-status and middle-status administrative occupations as well as various occupations related to teaching and religious organisations (5.4%). Non-agricultural workers include a diverse group of lower-status occupations not related to agriculture (33%). Our final category includes agricultural workers who are involved in agricultural production but do not own any land and thus have fewer resources than agricultural landowners (11%). The high share of farmers with ownership of their own land reflects a long historical pattern of freeholders in northern Sweden. Some of the non-tenured landowners can most likely be characterised as life-cycle servants. Around 20% have no known occupation, in many cases because they died relatively young, before any occupation was recorded. We present descriptive statistics in Supplemental Table 1 for all our variables of interest. All input data for our graphs are available in Supplemental File 1.

We also run a number of regression analyses, which are multivariate ordinary least square regressions with robust standard errors (linear probability models), where the dependent variables are any children, any grandchildren and any great-grandchildren, respectively. We choose linear probability models to make our output easily interpreted in the same manner as our descriptive tables, as well as that they are suitable for comparison across different models with different analysis populations (Mood, 2010). Regression coefficients are interpreted as an increase in the probability of being childless in each category (where 0.25 is equivalent to a 25% difference). These results are presented in Supplemental Table 2, and described at the end of the result section.

3. Results

The results are based on men and women born between 1885 and 1899. We show the percentage of both men and women from the original generation who, by the end of 2007, had i) no children, ii) no grandchildren or iii) no great-grandchildren.

Our overall main results are presented in Fig. 2a and 2b. We find that among those who survived to age 45, 26% of women and 27% of men do not have any children (2b). This number increases to 38% (women) and 35% (men) for no grandchildren and to 40% and 38% for no great-grandchildren, and is the same for men and women. The proportions without decendants are even higher when our anlysis population consists of everyone in G1 surviving to age 15 (and thus pre-reproductive mortality between 15 and 45 also contributes to our estimates), where 36% of women and 38% of men do not have any children (2a). This number increases to 46% for no grandchildren and to 48% for no great-grandchildren, and is the same for men and women. Our results show

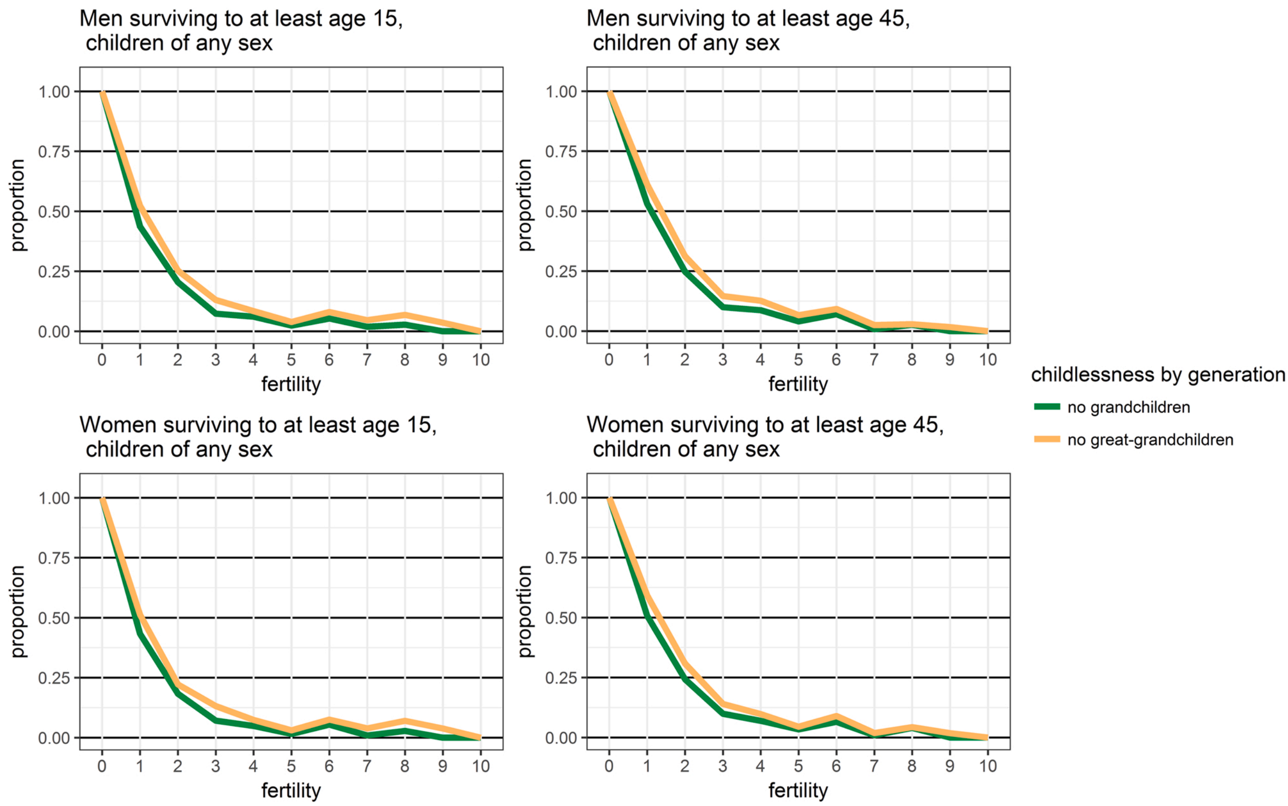

Fig. 3. Proportion of men and women born in Skellefteå from 1885 to 1899 not having descendants in the following generations, organised by fertility in G1, sex and survival status.

Fig. 4. Proportion of men and women (pooled) born in Skellefteå from 1885 to 1899 not having descendants in the following generations, organised by occupation in G1 and survival status.

that mortality between the ages of 15 and 45 contributes an additional 12% to the probability of having no descendants (in each generation) for men and 8% for women. Mortality during primary reproductive years is associated with sex differences in the proportions of people without descendants, with men surviving to age 45 having a lower risk of no descendants than women. Overall, our results suggest that an important path to having no descendants at the beginning of the 20th century in Sweden was related to premature death in adulthood for both men and women. Survival to age 15 was around 83% for the 1891 cohort in Skellefteå, so the proportion of newborns not going on to have descendants is approximately 17% higher than the proportions not having descendants among those surviving to age 15.

A major finding is that there are few differences between proportions of people with grandchildren and great-grandchildren. This may seem counter-intuitive, but it is reflective of the fact that the typical number of grandchildren is high in our cohorts, and that even with childlessness at 15% (typical for the period), the probability that five or more grandchildren will all be childless is very low.[2] In practice, it is only common for individuals with just one or two grandchildren to not have any great-grandchildren. Predictably, we find much larger differences between grandchildlessness and great-grandchildlessness among men and women with only a single child and correspondingly fewer

[2] With 10 grandchildren with a 10% probability of being childless, a person only has a 1% probability of having no descendants, although this assumes independence of empirical rates (Ruggles, 1993). We know fertility rates are correlated across generations (Kolk, 2014, Murphy & Wang, 2001), but the total influence of this is modest (e.g. a parent–child correlation of r = 0.1 means that around 1% of variance is explained by observed parental fertility).

grandchildren (Supplemental Table 2 and Fig. 3). For cohorts with lower initial fertility and a correspondingly lower number of grandchildren (such as individuals born in the 21st century), the difference across generations will likely be higher.

In Figs. 2c and 2d, we show the proportion of the population that have descendants of the same sex (exclusive matrilineal or patrilineal descent; for example, sons, the grandsons of sons, and their great-grandsons). Patrilineal decent corresponds to the survival of surnames (which are passed on from fathers to sons in many societies), an approach that has been used in much previous research. In countries with unequal inheritance rights in terms of bequests, occupations, titles or land (Swedish law stipulated equal inheritance for sons and daughters, but there were exceptions in practice), this could have important social consequences. The absence of any descendants along a same-sex lineage is predictably much higher than for offspring of any sex. For men, 71% have no great-grandsons (through the male lineage), and 67% of women have no great-granddaughters. The proportion of men and women having no grandson or granddaughter is 61% and 59%, respectively. Mortality has a fairly similar effect on same-sex lineage survival as on both-sex overall survival.

Having observed the overall extent of lineage extinction, we want to quantify the extent to which this is determined by the behavior of G1. We start examinging this by analysing how the number of children in the first generation (G1) relates to the probability of lineage cessation. Our findings suggest that high fertility in this generation is unsurprisingly strongly related to long-term lineage survival. We study this by examining the degree to which fertility in G1 is related to long-term lineage survival (Fig. 3). Lineage cessation is strongly concentrated in families with only one or two children. In families with one child surviving to age 45, 51% of women and 43% of men had no grandchildren, and 59% of women and 51% of men had no great-grandchildren. Among individuals with two children surviving to age 45, 24% of women and 18% of men had no grandchildren, whereas 30% of women and 22% of men had no great-grandchildren. On the other hand, for individuals with three or more children, the proportion that did not have great-grandchildren is very small, and for very high fertility, it is only a few percentage points.

Upper Left (3a): Men surviving to at least age 15. Upper Right (3b): Men surviving to at least age 45. Lower Left (3c): Women surviving to at least age 15. Lower Right (3d): Women surviving to at least age 45.

Finally, we examine childlessness by the occupation of the first generation using household occupational status (Fig. 4), to see if different socioeconomic groups in G1 differ in their probability to leave a decendant. Overall, we find the highest eventual lineage cessation among those who had higher occupational statuses (57% had no great-grandchildren) and the lowest lineage cessation among the relatively well-off farmers who owned their own land (38%). Agricultural workers without land ownership had slightly higher probabilities of not having great-grandchildren (43%), whereas non-agricultural workers had proportions more comparable to high-status individuals (52%). As such, it seems that men and women employed in agricultural occupations had higher proportions with descendants than other groups. The findings suggest that either having a high- or low-status occupation and social position implied that an individual had relatively fewer children and a lower likelihood of lineage survival. Having a mid-level social position was associated with a higher probability of having any descendants. As we can evaluate the impact of outmigration, we can be sure that most of the occupational differences in reproduction are not related to outmigration propensities, but to differences in mortality and fertility.

Left (4a): Descendants in each generation surviving to at least age 15. Right (4b): Descendants in each generation surviving to at least age 45.

Our original cohort consists of the complete population of Skellefteå. As such, many of the men and women are related to each other, and often have siblings in the same population. Although this is true of any human population, it means that to some extent, our men and women are not independent lineage founders. To further examine this, we use a model with only first-born and another model with only last-born individuals within a sibling group. We report our findings from this subsample in Supplemental Fig. S1. Overall, the lineage cessation probabilities in both subpopulations are very similar to our complete population.

Beyond our bivariate analyses, we also run several ordinary least square regressions (linear probability models) where we examine the independent effect of previously presented covariates. We do this to examine the extent of how survival to age 45 in G1, fertility in G1 and occupation in G1 are independent of each other. These results are presented in Supplemental Table 2. We use three dependent variables: having at least one child, at least one grandchild or at least one great-grandchild. Overall, our multivariate regression results are very consistent with previous bivariate associations, and almost all differences regarding survival status, sex and occupational status are mediated by fertility in G1. Put differently, we find that while there are substantial differences by G1 occupation for proportions without decendants, these are entirely determined by occupational differences fertility in G1. There are no effects of G1 occupation, in G2 and G3, after accounting for the number of children G1 themselves have. G1s having children in their 30 s is associated with slightly higher lower lienage extinction than having children in their 20 s, after accounting for total number of children born. After accounting for fertility in G1, we find no additional effect of pre-mature mortality in G1. An interaction between sex and fertility suggests that having no great-grandchildren is more common among women than among men with only one or two children.

4. Conclusions

Kinship is an important domain of the life course and family. Yet, only some people in a society contribute with descendants for future generations. We studied family line cessation spanning more than a century, providing an accurate empirical assessment of a phenomenon that previously has only been assessed through fewer generations or by using indirect and imprecise methods, such as surnames. Our study shows that even in a population characterised by strong population growth, the extinction of individual lineages was common. It also shows that almost half of those born from 1885 to 1899 who reached age 15 had no great-grandchildren by the early 21st century. The proportion having no grandchildren was almost as high. The main reason for the lineage cessation was low fertility. Childlessness for survivors to age 45 was high in the first generation (26% for women and 27% for men), and proportions of people without great-grandchildren were much higher among those who had only one or two children. Premature mortality in the first generation contributed to a lesser but still substantial degree of childlessness (mortality between ages 15 and 45 contributed 12% for men and 8% for women).

The most important risk factor for lineage extinction was having few or no children in the first generation. In general, as average fertility was above 2, and number of children among those reproducing are higher than the population average, we find that lineage extinction for higher-order descendants contributes relatively little, conditional on having a couple of children in the first generation (which is common). This is not surprising from an analytical perspective, but is nevertheless a feature of how descendant trees are distributed that is worth highlighting.

The extinction risk was not evenly distributed between social groups; it was highest among high- *and* low-status occupational groups. The lower lineage extinction among farmers is consistent with the later fertility transition among these groups (Dribe and Scalone, 2014). Our findings support the notion that evolutionary advantages of high fertility are very strong. We also show that when an individual has at least five children, eventual lineage survival to the fourth generation is almost certain (around 95% had at least one great-grandchild).

More research is needed to understand the social, biological, demographic and economic implications of expanding and shrinking family lines. The large-scale lineage cessation we observed can have both individual and population-level consequences. That a large share of the population fails to reproduce is evidence of a cultural and genetic evolutionary process (Grönqvist, Öckert, & Vlachos, 2017; Kolk, Cownden, & Enquist, 2014). Lineage extinction willimpact the distribution and diversity of genetic patterns at the population level, with implications for contemporary gene distributions (Elwert, 2020).

The extent of lineage extinction has important implications for the accumulation of wealth in families and for economic inequality (Elinder, Erixson, & Waldenström, 2018). A given scale of linage extinction could have consequences for social inequality, for the dilution or concentration of financial resources due to inheritance, and whether wealth in families will be passed on to later generations. Inequalities in reproduction across multiple generations may be linked to contemporary wealth inequality, which would be a highly relevant topic for future research. More research needs to be done on whether specific socioeconomic or cultural characteristics of the past could influence contemporary fertility and mortality patterns and whether the association of these characteristics with lineage cessation is becoming weaker or stronger across generations. We also need to better understand individuals' preferences for how family lines change, the risk of cessation across generations, and the importance people do or do not place on such aspects.

The changes we observed occurred in a context in which the Swedish population almost doubled in size (through natural population growth) – and in a period when Sweden had among the highest standards of living and lowest mortality rates in the world. The current demographic situation in Sweden, where natural population growth is much lower, with below-replacement fertility, and high shares who do not reproduce (yet with very low mortality), most likley represent a situation where lineage cessation is much higher than what the case has been in the past century. As the research question we answered in this paper is not yet known for most individuals born in the 20th century, simulations would be needed to estimate contemporary family lineage cessation probabilities, their causes, and socioeconomic correlations. With the current research design, we answered the question of lineage continuity for the latest cohorts where this is possible to assess with observed empirical demographic data. A major conclusion of our research is that a measure such as lineage extinction is always going to be highly influenced by demographic trends over multiple generations. We think that our data in a broad sense could be representative for other Northwest European populations with similar timing of the demographic transition and 20th-century fertility patterns. We are equally sure that the extent of lineage cessation we show is going to be very different both for earlier and later cohorts, as well as contexts with different mortality and fertility patterns over the 19th and 20th centuries.

Acknowledgements

We want to thank the helpful staff at the demographic database at Umeå University for helping us construct the data that is the basis of our dataset. This work was supported by Riksbankens Jubileumsfond (P17-0330:1), Vetenskapsrådet (2019-02552), the Research Council of Norway (Centres of Excellence-nr 262700) and the Global Challenges Foundation (grant "Sustainable Populations in the Time of Climate Change"). We want to acknowledge the substantial help from Martin Fieder and Jude Mikal for contributions to this project.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.alcr.2022.100481.

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