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Leaders and Laggards in Life Expectancy Among European Scholars From the Sixteenth to the Early Twentieth Century

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ABSTRACT When did mortality first start to decline, and among whom? We build a large, new data set with more than 30,000 scholars covering the sixteenth to the early twentieth century to analyze the timing of the mortality decline and the heterogeneity in life expectancy gains among scholars in the Holy Roman Empire. The large sample size, well-defined entry into the risk group, and heterogeneity in social status are among the key advantages of the new database. After recovering from a severe mortality crisis in the seventeenth century, life expectancy among scholars started to increase as early as in the eighteenth century, well before the Industrial Revolution. Our finding that members of scientific academies—an elite group among scholars—were the first to experience mortality improvements suggests that 300 years ago, individuals with higher social status already enjoyed lower mortality. We also show, however, that the onset of mortality improvements among scholars in medicine was delayed, possibly because these scholars were exposed to pathogens and did not have germ theory knowledge that might have protected them. The disadvantage among medical professionals decreased toward the end of the nineteenth century. Our results provide a new perspective on the historical timing of mortality improvements, and the database accompanying our study facilitates replication and extensions.

KEYWORDS Mortality dynamics • Differential mortality • Holy Roman Empire • Thirty Years' War

Introduction

When the first mortality improvements occurred and who benefited first from these gains are among the key questions that arise in discussions of the first demographic transition. Understanding where and among whom mortality progress started is important for understanding the long-run dynamics of human well-being.

In this article, we focus on the European scientific elite: scholars active at universities or academies of sciences. Observing each scholar's first appointment or nomination to a scientific institution helps to overcome common methodological issues in historical populations given that the appointment can be used to define the entry into the population at risk. More importantly, taking into account each scholar's scien-

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tific field and potential membership in an academy of sciences provides new insights into the role of medicine and social status in the process of mortality improvements. Finally, in a world where face-to-face communication was essential for both knowledge transmission and enhancement, the length of productive life among the elite was an important determinant of the extent to which members of the elite were able to influence their cultural and economic environments (de la Croix 2017; Lucas 2009).

Drawing on local evidence and data on specific social groups, historians and demographers have already shown that mortality gains were made in the seventeenth and eighteenth centuries. Hollingsworth (1977), for instance, constructed mortality tables for the British nobility sampled from genealogical data. Vandenbroucke (1985) provided vital statistics for the Knights of the Golden Fleece, an order started in 1430 by the Dukes of Burgundy and maintained under the Habsburg rulers, the kings of Spain, and the Austrian emperors. Andreev et al. (2011) compared life expectancies of members of the British and the Russian academies of sciences.[1] Cummins (2017) greatly extended demographic research on Europe's aristocracy by analyzing the longevity of the European nobility over a long period that covered several critical events, such as the Black Death and the Industrial Revolution. Longevity started rising as early as 1400 and continued to increase over the fifteenth century. However, this first phase has been observed in Ireland and the United Kingdom only and these findings are subject to considerable uncertainty. Even though the total sample size is large, when stretched over several centuries, the uncertainty regarding any specific time point becomes large. This phase of longevity improvements was followed by another after 1650 that has been observed throughout Europe in other studies as well (Hollingsworth 1977; van Poppel et al. 2016; van Poppel et al. 2013). Building a database drawn from the *Index Bio-bibliographicus Notorum Hominum*, which contains entries on famous people from about 3,000 dictionaries and encyclopedias, de la Croix and Licandro (2015) found no trend in adult longevity among individuals born before the second half of the seventeenth century. Their findings also suggest that permanent improvements in longevity preceded the Industrial Revolution by at least a century. The longevity of famous people increased steadily starting with the generations born in the 1640–1649 period and grew by a total of roughly nine years in the following two centuries.

Although the studies of de la Croix and Licandro (2015) and Cummins (2017) are important, they are not without weaknesses. In the populations they studied, who belonged to the sample and when people entered the population at risk could not be precisely defined. Some of the individuals in these populations, such as famous martyrs, might have entered at death; others, such as artists, may have entered *post mortem*; and still others, such as members of royal families, entered at birth. In this study, we present data that overcome such weaknesses and use these data to reanalyze the timing of mortality improvements among the European elite. Furthermore, using information about relative status within the elite, we investigate whether differences in socioeconomic position were already influencing mortality when secular changes

[1] Edwards (2008), Winkler-Dworak (2008), and van de Kaa and de Roo (2007) also studied the longevity of members of academies of sciences but with a more recent focus and much smaller sample sizes. Carrieri and Serraino (2005) and Hanley et al. (2006) compared the life expectancies of popes and artists, whereas van Poppel et al. (2013) examined the longevity of artists using information from the RKDartists database.

in mortality first started, or whether this pattern is more recent. Finally, we exploit information about the scientific fields in which the scholars in our database were working to examine whether there were leaders or laggards by discipline. A particular focus of our analysis is on medicine, which may have had both positive and negative effects on longevity, depending on whether the benefits of medical knowledge offset the added hazards resulting from exposure to pathogens.

Our data set, which is mainly based on university professor catalogs and lists of memberships in scientific academies, is constructed to clearly indicate who belonged to the population and when each individual entered the risk population. An individual entered our population at risk as soon as he or she was appointed for the first time to any of the formal scientific institutions covered in our database. These institutions include all universities and technical universities established before 1800 as well as scientific academies located in the Netherlands and the territories of the Holy Roman Empire (HRE) as of 1648. Although its borders changed over time, the HRE occupied a large area of central Europe from its founding in the Middle Ages until its dissolution in 1806. Furthermore, for most academic institutions in these territories, there are data sources that provide information on each scholar's dates of appointment, exit, birth, and death.

Our sample, which covers more than 30,000 scholars born between the fourteenth and the nineteenth century, has several advantages. The sample allows us to consider left-truncation and right-censoring. Moreover, because the sample is large and focused on a well-defined population, we can use it to make precise estimates at the total population level while also performing subpopulation- and age group-specific analyses.

Relying on the new data we collected, we aim to make two contributions to the literature. First, our analysis of scholars' life expectancy provides important new information about the dynamics and the timing of mortality changes before and during the Industrial Revolution. Our new estimations confirm that life expectancy started to improve in the middle of the eighteenth century—and, hence, before industrialization. Most of the deviations of our findings from existing estimates of mortality dynamics can be explained by differences either in the methods used or in how the role of social status is taken into account. In addition, our long time series on mortality provide a novel finding on a notable mortality crisis around 1620–1650, which was likely driven by the Thirty Years' War. Studies without a long observation window such as ours, which opens before the Thirty Years' War, could mistakenly conclude that the recovery from the crisis marked the start of secular mortality improvements.

Second, we shed light on mortality differences between groups by comparing members and nonmembers of scientific academies as well as scholars in the medical field with scholars in other scientific fields. Members of scientific academies represent an elite within the elite. Although it may be assumed that higher social status translates into mortality advantages, the evidence on the association between social status and mortality is mixed. Hollingsworth (1977) and Vandenbroucke (1985) found that mortality reductions occurred as early as in the seventeenth century among the nobility, and thus showed that longevity improvements among the upper social classes anticipated the overall rise in life expectancy by at least a century. By contrast, de la Croix and Licandro (2015) found mortality reductions that in the seventeenth and eighteenth centuries took place not just in the leading countries but almost everywhere in Europe and that these mortality improvements were not dominated by any particular occupation.[2] In a literature review, Bengtsson and van Poppel (2011) concluded that the impact of social status varied across areas, time periods, and contexts. Meanwhile, we observe that among members of academies of sciences, mortality gains accelerated around the time when life expectancy started to increase sustainably. This finding suggests that as early as 300 years ago, scholars with higher social status enjoyed lower mortality.

The role of the medical profession in these trends is less clear. Given that the germ theory of disease was not well developed before the second half of the nineteenth century, it may be assumed that individuals working in the medical profession prior to that time received little protection from their medical knowledge while also being exposed to elevated infection risks (de la Croix and Sommacal 2009). It is, therefore, possible that medical professionals had a net disadvantage. For example, to protect against the bubonic plague, people used beak-like masks that did little more than protect against the smells that were believed to be the main disease vector. Thus, for medical professionals, the combination of increased exposure to sick people and the lack of medical knowledge may have been life-threatening. Our results partially support this reasoning: although we find only weak evidence of a systematic disadvantage among medical professionals before sustained improvements in longevity began, we show that once mortality improvements started, medical professionals experienced life expectancy gains later than the rest of the scientific elite.

Scholars in the Holy Roman Empire

Universities and Scientific Academies

Our data set contains information on scholars who were active in the HRE. The Empire was founded around 962 as Otto I sought to revive the Roman Empire by laying claim to the imperial cult of Rome. Thus, the HRE existed long before the first universities appeared in this area. Although the borders of the Empire changed over its almost 850 years of existence, its elective monarchy unified the Germanic population and other peoples over this long period through a unique set of cultural and political arrangements. In the nineteenth and twentieth centuries, following the dissolution of the Empire in 1806, the territory of the German state declined substantially, and the populations of central Europe shifted. To take advantage of the relatively stable institutional setup provided by the HRE, we focus on populations living within the Empire's 1648 borders and in the Netherlands. As shown in gray in Figure 1, the territories of the Empire correspond to the current territories of Austria, Belgium, Germany, Liechtenstein, Luxembourg, Slovenia, and the Czech Republic as well as small parts of Croatia, France, Italy, Poland, and Switzerland. The territories that made up the Netherlands are depicted in light gray.

Scholars might have been active in universities, academies of sciences, or courts. Because the first two types of institutions are quantitatively the most important, we define *scholars* as individuals who were active in one of these two types of scientific

[2] Furthermore, Bengtsson and Dribe (2011) found evidence of the late emergence of a mortality advantage in Sweden. Using data from Geneva, Schumacher and Oris (2011) documented an advantage among the higher classes that ended in the seventeenth and eighteenth century.

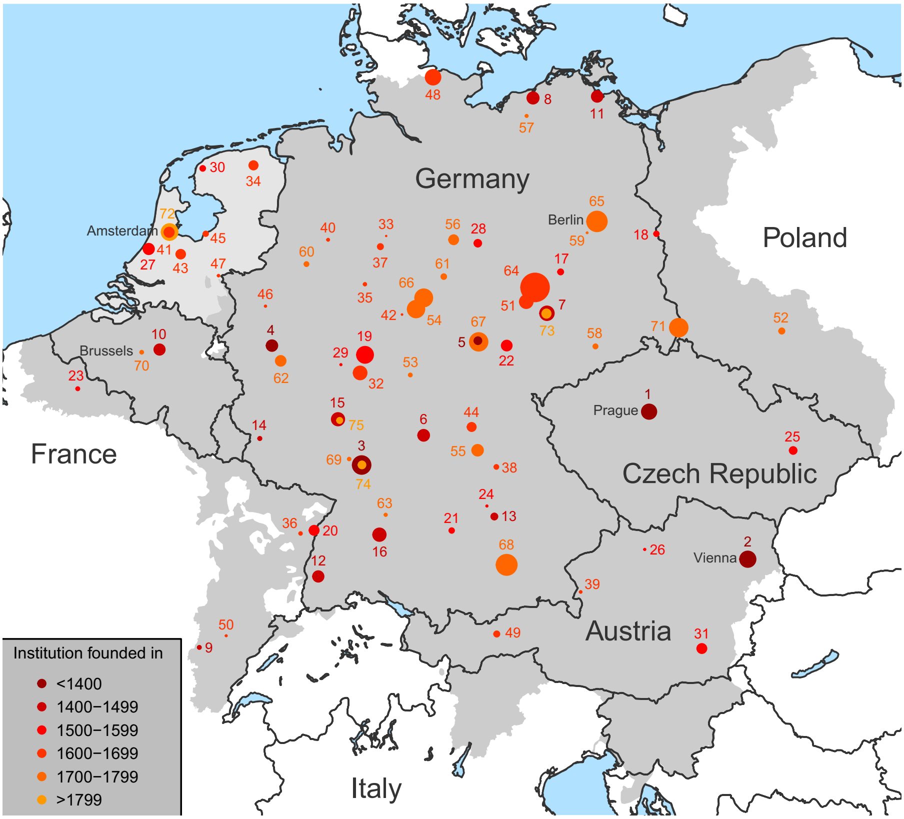

Fig. 1 Universities and academies in the territories of the Holy Roman Empire and the Netherlands. Universities and scientific academies located in the 1648 territories of the Holy Roman Empire (gray) and of the Netherlands (light gray). The area of the circle is proportional to the number of observations of the institution, and the color indicates the century of foundation. Numbers 1–63 mark universities sorted by year of foundation, and numbers 64–75 mark academies of sciences. For an entire list of the corresponding institutions, see Table A1 in the online appendix.

institutions, and we restrict our sample to scholars who were born before 1900. This precise demarcation of our population should not mask the fact that many conditions changed since the creation of Prague University in 1348. Rules for granting degrees, such as a doctoral degree, or the social status of university professors changed, for instance, after the Humboldt reform (Schimank and Winnes 2000). Salaries prior to the modern period were often low, paid in kind, or not paid at all, for example, during the Thirty Years' War (Klinge 2004; Langer 2011; Vandermeersch 2003). Still, considering a changing environment, we are as close as possible to a well-defined population. Any other professions, even the nobility, would face similar changes.

We include in our database scholars who were appointed to universities that were founded before 1800. Based on Frijhoff (1996) and Steiger (1981), we identify 63 such universities. Universities founded later than 1800 are excluded because the HRE ended in 1806 and because the European university underwent radical changes around this time. A large number of universities disappeared at the beginning of the nineteenth century. In Germany, for instance, 18 of 34 universities were closed (Charle

2004). More importantly, universities founded in the nineteenth century followed a new university model shaped by the Humboldt reform (Schimank and Winnes 2000). Thus, because our focus is on older universities, our results are not affected by the significant changes that occurred around 1800.

Still, the 63 older universities were rather heterogeneous along several dimensions. The map of Figure 1 illustrates the spatial distribution of these institutions as well as the number of scholars related to each institution by the area of the circle. Established in 1348, the University of Prague (marked 1 on the map) was the oldest university in the HRE, followed by the University of Vienna (2) founded in 1365 and the University of Heidelberg (3) founded in 1386. The University of Bonn (62) and Karl's High School (63) were the two youngest universities. In addition, four more applied universities, such as the Freiberg University of Mining and Technology (58), were among the institutions established in the eighteenth century. In the Dutch territories, university education started in 1575 with the establishment of Leiden University (27). Although seven universities were founded in the Netherlands before 1800, the University of Nijmegen (46) educated students for only a very limited number of years, and the universities in Franeker (31) and Harderwijk (45) closed near the end of the Napoleonic era. Several universities in the HRE met the same fate. These universities were closed either in response to geopolitical movements, as was the case in Cologne (4) and Erfurt (5), or as a result of secularization, as was the case in Bamberg (44) and Dillingen (21).

Figure 1 also includes the 12 academies of sciences (sometimes combined with arts) for which we have data. Although other academies existed during the period we cover, these institutions were, on average, of lesser importance.[3] Over the course of history, large numbers of scientific academies have appeared, and some have disappeared. By far the most important of the scientific academies we cover is the *Collegium Naturae Curiosorum*, established in 1652 and better known as *Leopoldina* (64). The Bavarian Academy of Sciences and Humanities (68) and the Royal Netherlands Academy of Arts and Sciences (72) were also well-known. The latter academy was founded in 1808. We include this institution because academies did not undergo the same structural changes as universities. Thus, there was no reason to exclude these more recently established institutions.

Data and Sources of the Data Set

We use a range of sources to compile our sample of scholars. We assign the institutions to four quality groups based on data availability and the data sources used. In the first quality group are the institutions for which we have *(almost) complete data*. In this optimal case, we rely on two types of high-quality sources: online professor catalogs, such as the *Catalogus Professorum Lipsiensium*; or books that provide biographical information on professors, such as Drüll (2009, 2012) and Drüll-Zimmermann (1991, 2012) on the University of Heidelberg. Overall, the first quality group includes 23 universities and 10 academies of sciences. Our sources of data for these academies include official lists of members provided either directly by the academy or by their publications.

[3] For an overview on academies, see the Scholarly Societies Project (http://www.references.net/societies/).

For other universities, the catalogs do not capture either the whole time span or all faculties. Because these sources still provide highly reliable information, they are included in the second quality group, which is made up of institutions with *partially complete data*. For instance, Günther (1858) provided information on the University of Jena professors only up to the university's 300th anniversary in 1858, whereas Flessa (1969) provided information on only medical faculty professors in Altdorf. In addition to 15 universities, the Royal Academy of Sciences, Letters and Fine Arts of Belgium is included in this second quality group.

The sources we use for the institutions in the third quality group enable us to further complete our list of scholars. The available data for the institutions in this third quality group are less complete (*noncomplete*). For 12 universities, we reconstruct as many observations as possible from a variety of sources, including lists on Wikipedia, which are whenever possible backed-up with additional sources, such as the *Deutsche Biographie* (2014–2020).[4] For example, we collect data on scholars from the University of Erfurt (5) and Brandenburg University in Frankfurt (18) using this strategy. The remaining scientific academy, the Palatinate Academy of Sciences in Mannheim (68), is also assigned to the quality group *noncomplete data*.

The remaining 14 universities are in the last quality group, *scattered data*. Their members are captured either via other universities of a higher class or using data collections, such as Fischer (1978). The oldest university in this quality group is the University of Trier (14).[5]

By combining the data from the sources in all four quality groups and removing duplicates, we gather information on 33,498 scholars. This population forms our total sample of scholars who were born before 1900 and who were active in the defined universe of universities and scientific academies. Individuals entered the population of scholars at the time when they were first appointed. Individuals exited the population at death if that event is observed. If death is not observed, they are censored at the last exit from one of our institutions.

Data Quality

Given that our historical data cover more than four centuries, some uncertainty about these data is understandable, particularly at the very beginning of our time span. In this section, we discuss two potential caveats: missing values and heaping in the years of birth and death.

Table 1 summarizes important descriptive statistics. The total sample of scholars declines from 33,498 to 31,176 if we consider only those individuals for whom the year of appointment and of death or exit are known. The sample further shrinks to 27,842 if we include only those individuals for whom their ages at the events are known; we use this as the baseline sample for our mortality estimations. Most cases for which the ages are unknown suffer from multiple missing values. In 96.2% of

[4] The reliability of Wikipedia information is not always easy to validate. Less than 2% of our observations are solely based on Wikipedia. We checked that all our results are robust to the exclusion of all institutions without traditional sources; for details, see the Robustness section and the online appendix.

[5] Table A1 in the online appendix provides complete overviews of the quality groups and sources of all 75 institutions.

Table 1 Observations by year of appointment

	All Appointments[a]	Appointments With Known Age[b]							
			Mean Age at:			University Appointments		Academy Appointments	
Year	*N*	*N*	Appointment	Death	Death Observed (%)	Total	Medicine (%)	Total	Medicine (%)
<1400	217	46	37.5	63.3	97.8	46	2.2	0	—
1400–1449	616	87	32.5	64.2	98.9	87	8.0	0	—
1450–1499	607	162	33.0	62.5	97.5	162	6.2	0	—
1500–1549	770	349	32.3	60.5	98.6	349	8.0	0	—
1550–1599	998	719	33.3	60.6	97.4	719	11.7	0	—
1600–1649	1,085	893	34.0	58.8	96.9	891	10.7	2	100.0
1650–1699	1,662	1,458	33.9	60.2	96.9	1,213	7.9	245	84.5
1700–1749	2,401	2,194	34.8	62.0	97.9	1,497	7.5	697	42.0
1750–1799	3,468	3,228	35.7	64.1	97.1	1,556	11.6	1,672	28.9
1800–1849	4,506	4,306	37.6	67.0	98.6	1,516	17.2	2,790	20.0
1850–1899	5,920	5,802	38.2	69.2	98.2	2,187	22.2	3,615	19.6
1900–1929	5,845	5,730	40.3	72.0	92.5	2,962	26.9	2,768	18.6
≥1930	3,081	2,868	53.9	76.9	92.6	1,258	24.6	1,610	25.7
All	31,176	27,842	39.0	67.8	96.2	14,443	17.1	13,399	23.7

[a] Used in the analyses presented in Figure 3.

[b] Used in the analyses presented in Figures 4–7.

cases in which we observe age, we also observe death. The share of right-censored cases for which death is unknown increases slightly for the most recent periods because our data sources, such as Conrad (1960) for the University of Tübingen, are from a time when many of the scholars were still alive. We know the age at death for scholars who died after the date of publication only if we find them in other sources.

In the 1400–1700 time span, the mean age at first appointment was rather stable, at ages 32 to 35. In the more recent period, the mean age at first appointment increased, reaching as high as age 40 in the early twentieth century. By contrast, the mean age at death followed a U-shaped pattern. Starting at around age 64 for scholars appointed in the early fifteenth century, it declined to age 59 among those who entered the data set in the first part of the seventeenth century. The mean age at death increased to more than 70 years for scholars appointed at the onset of the twentieth century.

The population of scholars was heterogeneous along several dimensions, two of which we focus on here. First, to explore the role of medical knowledge, we distinguish between scholars with and without a medical background. To identify these individuals, we ascertain whether the scholars in our sample studied medicine, held a PhD in medicine, were active in a medical faculty, held a chair in medicine, were active in a field of research linked to medicine, or belonged to a class of medicine in an academy of sciences. Second, we distinguish scholars by the scientific institutions to which they belonged. Members of academies of sciences represent a sort of elite within the knowledge elite. Because these scholars had more scientific achievements and better access to networks than nonmembers, they likely had higher social status. Thus, we use memberships in academies as social status indicators that we can link to mortality dynamics.

Numbers for the four groups of scholars are shown in Table 1: scholars active only in universities, and among them, those linked to the medical profession; and scholars affiliated with an academy, and among them those linked to medicine. In total, our data cover 14,443 scholars affiliated with a university only and 13,399 scholars with an academy affiliation. Although only a small percentage of scholars appointed before the seventeenth century were active in the field of medicine, this share had increased to one-quarter by the end of the follow-up.

Uncertain or unknown years of birth and death may be approximated by years ending with 0 or 5. The use of this approach might reduce the share of missing values, but it could also cause birth and death year heaping in our data. To check the scale of the heaping, we follow the concept of the Whipple-Index (Hobbs 2004) and compare the observed number of birth years ending with 0 or 5 with the overall number of births in the same period.

Panel a of Figure 2 displays the shares of births per 50-year period ending with 0 or 5. If there was no heaping, we would expect 20% of the birth years to end with 0 or 5. We observe that more than one-half of birth years ended with 0 or 5 in the fifteenth century. However, data quality improves rather quickly thereafter: by the beginning of the seventeenth century, the share was already close to 0.2. If we restrict the sample to scholars without an uncertain year of birth, the data quality improves significantly and becomes acceptable starting in the sixteenth century.[6]

We observe less year heaping for mortality data than for birth data. In previous centuries, birth data was reliably recorded for some families, such as those of scholars,

[6] For more detailed information, see Figures A1–A5 in the online appendix.

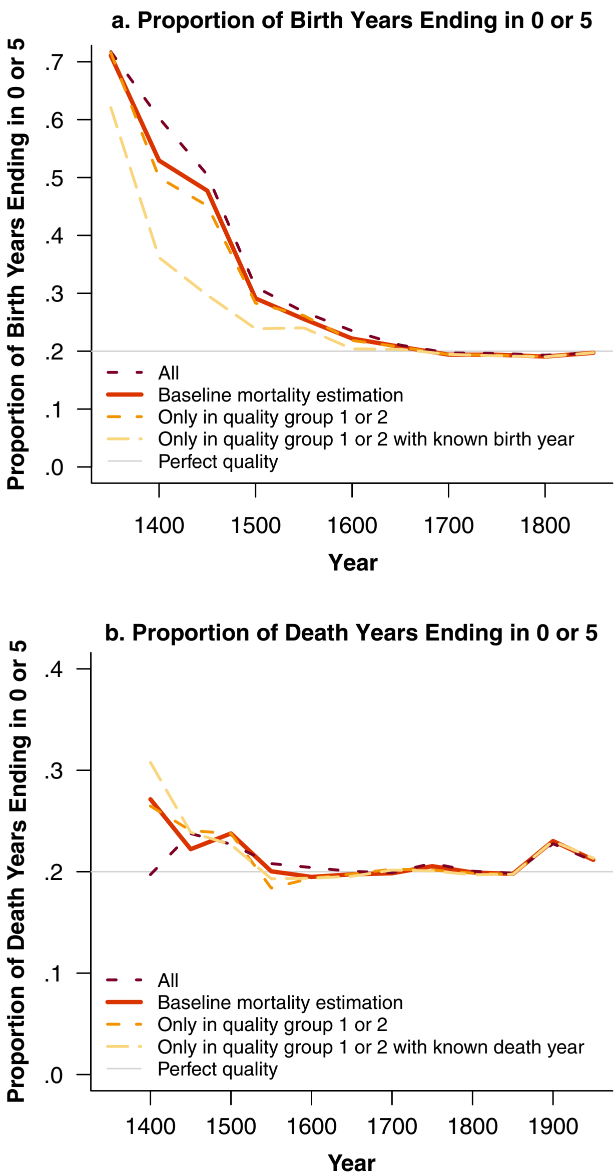

Fig. 2 Birth and death year heaping. *All* includes all scholars with either a known year of birth or a known year of death. *Baseline mortality estimation* restricts the sample to the 27,769 scholars with known ages at appointment and at death or exit used in the estimations of life expectancy (column 2 in Table 1). *Only in quality group 1 or 2* further limits the sample to scholars with data from quality groups 1 (almost complete data) and 2 (partially complete data). Finally, *Only in quality group 1 or 2 with known birth or death year* excludes all observations with the year of birth or death marked as approximated in the sources.

clergyman, or nobles, whereas the birth dates of children in ordinary families were less well-documented or were approximated in the data sources. However, when an individual was appointed to one of our institutions, he or she likely became sufficiently important to have his or her death date recorded. Hence, the share of death years ending with 0 or 5 is generally much closer to 0.2 (Figure 2, panel b). Furthermore, the observed heaping is not always due to poor data quality; for example, the peak in 1900–1949 (Figure 2, panel b) is driven by the exceptionally high mortality at the end of World War II.

Significant birth year heaping and some death year heaping is found at the beginning of our observation window. Whether this heaping biases any of our results depends on whether the years are systematically adjusted upward or downward. This is difficult to evaluate directly. As an indirect robustness check, we replicate our analyses while excluding all individuals with a year of birth ending with 0 or 5. The results are robust to this check, as discussed later.

The Population of Scholars

The scholars' years of first appointment and of death—or of last exit if the year of death is missing—enables us to calculate the dynamics of the total number of scholars. Panel a of Figure 3 plots the 25-year moving averages of the first appointments, deaths, and deaths or exits due to censoring. The figure shows a general increasing tendency in appointments that was followed by a comparable increase in deaths.

The flows displayed in panel a of Figure 3 are turned into stocks of scholars in panel b. This figure shows three periods marked by the trend line imposed on the total stock of scholars. First, before 1618, appointments exceeded outflows except for very short periods in the middle of the fifteenth and sixteenth century. The number of scholars grew by an average of 0.5% per year, hence at the same pace as the total population.[7] Second, around 1618, appointments started to decline and continued to decline until approximately 1648. In the 1618–1648 period, outflows exceeded appointments, and for roughly one-quarter of a century, the population of scholars decreased by approximately 0.6% annually. Third, the appointments bounced back starting around 1648. From that year until around 1900, appointments strongly exceeded deaths, and the population of scholars grew at an annual rate of 0.8%.

After the first academy was founded, the shares of the sample belonging to universities and academies were soon balanced. After 1800, one-half of the sample were active in at least one academy of sciences. However, to avoid small sample noise—and given that before the eighteenth century, the *Leopoldina* was the only academy to which scholars could be appointed—we limit our investigation of the link between social status and mortality to the periods after 1700, when the second academy was established. Before 1700, we can compare only the *Medicine and Universities* and *Nonmedicine and Universities* groups. However, because panel b of Figure 3 shows that only a few scholars were engaged in medicine before the seventeenth century, we limit our investigation of mortality dynamics to the period after 1600.

[7] Pfister and Fertig (2010) documented an average growth rate of approximately 0.5% per annum for the German population.

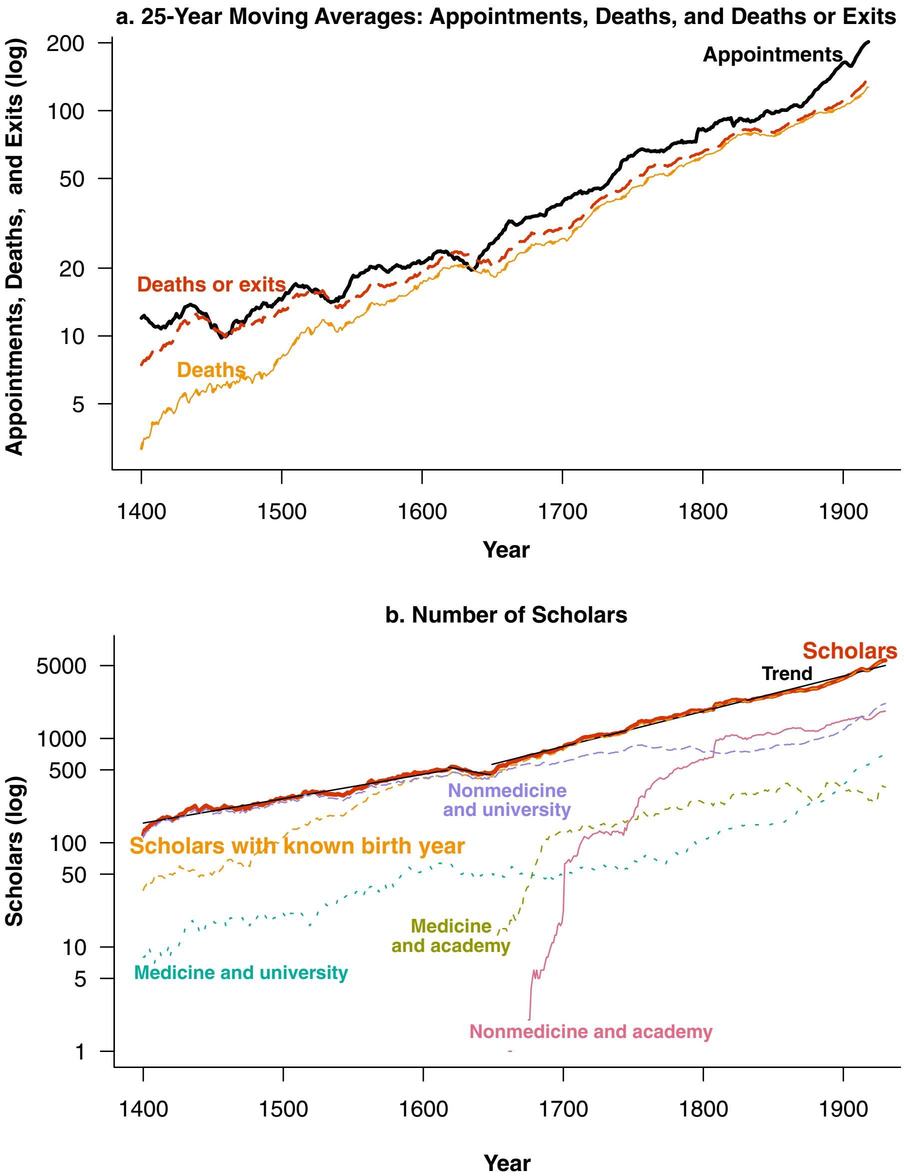

Fig. 3 The dynamics in the population of scholars

The trends that we observe in the numbers of appointments and exits/deaths in panel a of Figure 3—and hence, in our total population—capture different developments. First, the appointment numbers are sensitive to the size of each institution. Second, the appearance and disappearance of universities and academies—such as the closing of a number of institutions after the Napoleonic Wars—alters the number of appointments and exits. Because we lack exhaustive sources for all the institutions in our sample, a certain number of scholars within each institution might be missing.

Thus, sample selection is a third factor that could affect our results. Missing or uncertain information within the sample of scholars on the years of events is a fourth factor. Panel b of Figure 3 provides some insights into the role of missing events. If we limit our population to scholars whose year of birth is known, the initial population is smaller and grows faster in the early period. Given that ages are required to estimate mortality, further investigations rely on this smaller sample.

Methods

We estimate age-specific mortality rates and life expectancy at age 30 for the population of scholars and for the subpopulations. We use age 30 as the starting age for life expectancy because for younger ages, the sample of scholars becomes very small.[8] Because of the limited sample size in the early years, we first smooth the death rates over age and time (Camarda 2012). We then compute period life expectancy at age 30 over rolling 25-year intervals and apply Monte Carlo simulations to estimate the corresponding confidence intervals (Andreev and Shkolnikov 2010; Chiang 1984). In the following, years mark the middle of the 25-year intervals. The contributions of each age to changes in life expectancy are decomposed by the stepwise replacement algorithm from Andreev and Shkolnikov (2012), which is described in Andreev et al. (2002).

Findings

Life Expectancy

Three clear patterns emerge in life expectancy at age 30 for the population of scholars (Figure 4). First, we observe no systematic improvement in life expectancy among scholars before the middle of the eighteenth century. Second, we find evidence of a sharp decline in life expectancy in the first half of the seventeenth century. Scholars' life expectancy at age 30 declined from more than 30 to less than 27 years. Third, we see that thereafter, a phase of steady improvements in mortality began. Between 1750 and 1900, conditional life expectancy increased by roughly 7.5 years.

To shed light on life expectancy dynamics, we add to Figure 4 two types of historical events that might have influenced life expectancy: wars and pandemics. We identify four military conflicts that may have affected mortality dynamics: (1) the German Peasants' War, (2) the Thirty Years' War, (3) the Seven Years' War, and (4) the Revolutionary Wars. In addition, we identify two waves of the plague (years 1547–1550 and 1625–1640) that may have influenced mortality dynamics.

In the 1500–1600 period, our point estimates for life expectancy at age 30 fluctuate strongly around the smoothed average of approximately 30 years. This period includes two important historical events that may have reduced life expectancy: the German Peasants' War and the plague pandemic. Although it is possible that these events influenced the scholars' life expectancy, the small-sample variation and the width of the confidence intervals until around 1600 are so large that we cannot draw clear conclusions.

[8] For a more detailed discussion, see section A.3.1 in the online appendix.

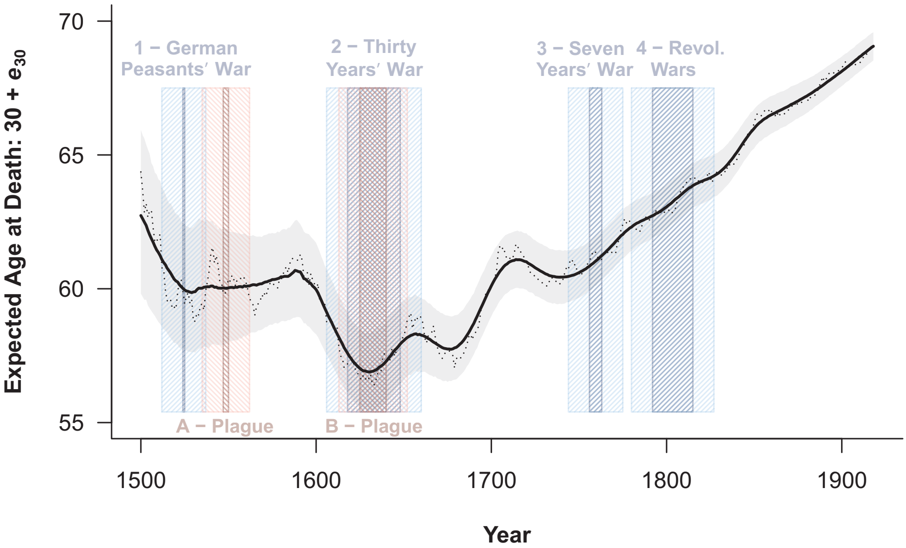

Fig. 4 The dynamics of scholars' period life expectancy and historical events. The figure applies 25-year rolling intervals and two-dimensional smoothed data. The solid black line displays our estimated period life expectancy for scholars at age 30 in 25-year rolling intervals. For instance, the year 1550 covers the 1538–1562 period. The gray area marks the corresponding 95% confidence intervals. The brighter surrounding years on the left and the right of each event indicate estimated life expectancies that include years altered by the events due to the rolling intervals.

The strongest association between life expectancy and the historical events was in the early part of the seventeenth century, where we observe a sharp decline in life expectancy coinciding with both the Thirty Years' War (1618–1648) and the second plague pandemic. It is plausible that the mortality crisis was caused by one or both of these historical events. For the Thirty Years' War in particular, mediating effects may have been more important than the direct effects of military conflicts. Greifswald, for instance, was forced to billet more than 1,000 Imperial soldiers, along with their horses and armaments, after the Duke of Pomerania surrendered in 1627. During this period, university life was limited, and professors did not receive salaries (Langer 2011). The passing soldiers spread infectious diseases, and hygienic standards deteriorated. The seemingly endless string of plague epidemics that occurred between 1625 and 1640 (surface B in Figure 4) illustrates the harsh conditions surrounding the Thirty Years' War and may explain the very high death rates. During the war, people suffered not only from the plague but also from famine (Alfani and Gráda 2018). Hence, it is likely that the three famous Malthusian mechanisms—famine, epidemics, and war—combined to lower life expectancy (Flinn 1981).

At the end of the Thirty Years' War, life expectancy started to recover and death rates decreased, albeit with some fluctuations in the first part of the eighteenth century. Still, it took almost a century for life expectancy to return to prewar and pre-plague levels. Note that this period of declining mortality could be misinterpreted as signaling the onset of systematic mortality improvements if the time span does not include the pre-crisis period.

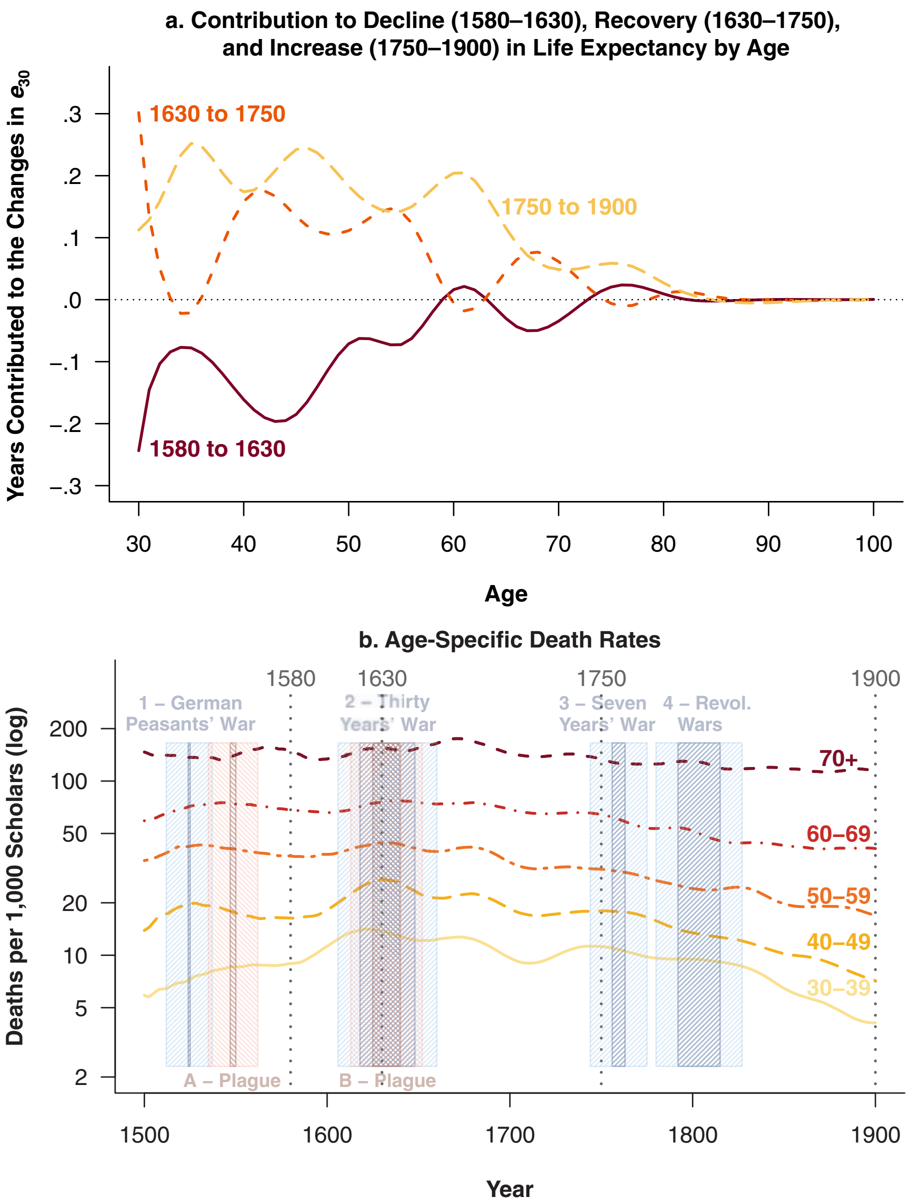

Fig. 5 Decomposition of gains in life expectancy. The figure applies 25-year rolling intervals and two-dimensional smoothed data.

Figure 4 shows that systematic mortality improvements that cannot be interpreted as recovery from a crisis started around 1750. From that point onward, life expectancy increased without interruptions. Thus, no clear association between subsequent wars and life expectancy is observable.

Panel a of Figure 5 shows which ages contributed to the life expectancy changes across the three stages we identify: decline from 1580 to 1630; recovery from 1630

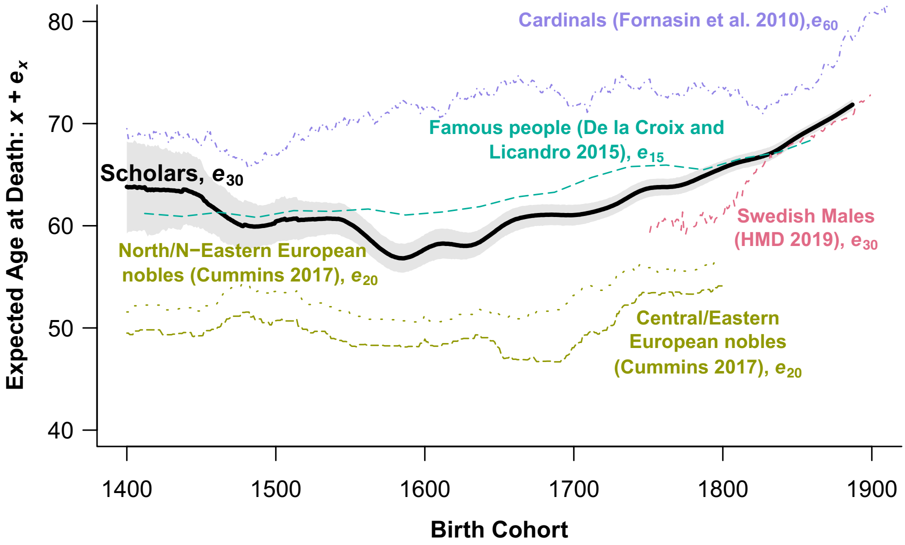

Fig. 6 The dynamics of scholars' cohort life expectancy in light of the literature. The figure applies 25-year rolling intervals and two-dimensional smoothed data of scholars.

to 1750; and increase from 1750 to 1900. Panel b shows age-specific mortality trends over the whole period.

In the first stage, not all ages were equally affected by declining life expectancy. Almost all of the life expectancy losses were among people under age 60 (Figure 5, panel a). Older people (ages 60–69 and 70+) also experienced mortality increases during this period (Figure 5, panel b), but their contributions to life expectancy losses were small because so few individuals survived to these advanced ages. The decomposition also shows that people under age 60 were the main contributors to life expectancy gains in the late seventeenth and early eighteenth centuries: the increase in life expectancy was effectively driven by the same ages that drove the seventeenth-century mortality crisis. When the secular increase in longevity started in the mid-eighteenth century, people at ages 60–80 joined people under age 60 in contributing to life expectancy increases (panel a). Panel b shows that after 1750, mortality declined fastest in the older age groups.

Comparison With Other Studies

We have presented our results by period to facilitate the analysis of *when* mortality improvements started. Many other studies have used the cohort perspective. For comparative purposes, we convert our data to the cohort perspective. The message of our cohort results is similar to that of our findings from the period perspective: cohort life expectancy did not improve between the 1400 and 1700 birth cohorts; life expectancy declined for the cohorts born in the late sixteenth century who were adults during the Thirty Years' War and the second plague pandemic; and secular improvements in life expectancy began with the cohorts born in the eighteenth century. Figure 6 compares our cohort life expectancy estimates at age 30 with others found in the literature.

We compare our results with five other sets of findings pertaining to nobles in 1400–1800 in north and northeastern Europe as well as central and eastern Europe (Cummins 2017); famous people in 1400–1875 (de la Croix and Licandro 2015); cardinals in 1400–1900 (Fornasin et al. 2010); and Swedish life expectancy in 1751–1899 (from the Human Mortality Database [HMD] 2019).

We highlight two dimensions of this comparison: trends and levels. The trends show qualitative similarities: nobles (Cummins 2017), famous people (de la Croix and Licandro 2015), and scholars of the HRE (this manuscript) all experienced periods of stagnation in mortality followed by sustained increases in life expectancy. However, the mortality improvements started earlier among famous people (1680s) and later among Sweden's male birth cohorts (1800) and cardinals (1850s) than among scholars and nobles. More importantly, none of the other populations underwent the mortality crises observed among cohorts born at the end of the sixteenth century. Because of the differences in territorial coverage, the impact of the Thirty Years' War is likely less important in this comparison.

However, these studies reported disparate levels of life expectancy, primarily because they used different starting ages. Cummins (2017) used age 20, and Fornasin et al. (2010) used age 60; de la Croix and Licandro (2015) excluded famous individuals who died before age 15. Only the Swedish life expectancy from the HMD is based on a starting age of 30. These different starting ages lead to predictable differences in levels. It is, for example, worth considering what difference it makes that Cummins used age 20 and therefore included a larger share of young adult mortality. In the HMD life tables for Sweden, mean age at death conditional to surviving to age 20 for the 1800 male cohort is 56.1, and 59.2 conditional on surviving to age 30. The differences between our 1800 cohort and Cummins' nobles are 9.2 years in north and northeastern Europe and 11.5 years in central and eastern Europe. Hence, these differences are larger than the 3.1 years in the HMD for Swedish cohorts. The remaining life expectancy discrepancies between scholars and nobles can be explained by the high shares of violent deaths among nobles (Cummins 2017). The life expectancy gap between scholars and cardinals is 7.9 years in 1800, and is thus smaller than the difference based on the calculation from HMD's life tables for Swedish males (12 years). Finally, we do not observe any noteworthy systematic deviation from the unconditional mean age at death estimated by de la Croix and Licandro (2015) for famous people who survived until age 15.

Life Expectancy, Social Status, and Medical Knowledge

Figure 7 illustrates the mortality dynamics of scholars separated into four groups according to their field of science and membership in an academy of sciences. The figure starts in 1600 for university scholars and in 1700 for academy members because these stratified samples would be too small for the earlier years. Panel a compares university professors who were and were not in the field of medicine. We observe no systematic mortality difference between these groups of scholars until the early to mid-eighteenth century, when life expectancy started to increase among scholars not in medicine. Mortality improvements among scholars linked to the medical field were delayed. In line with van Poppel et al. (2016), we find that life expectancy was lower for scholars in medicine than for other scholars for approximately 100 years. However, this mortality gap decreased toward the end of the nineteenth century.

Panel b compares mortality improvements among scholars who were or were not in medicine, and who were active in academies of sciences. The pattern is similar to that observed among university scholars: starting from around 1750, scholars who were not in medicine experienced mortality declines, and those who were in medi-

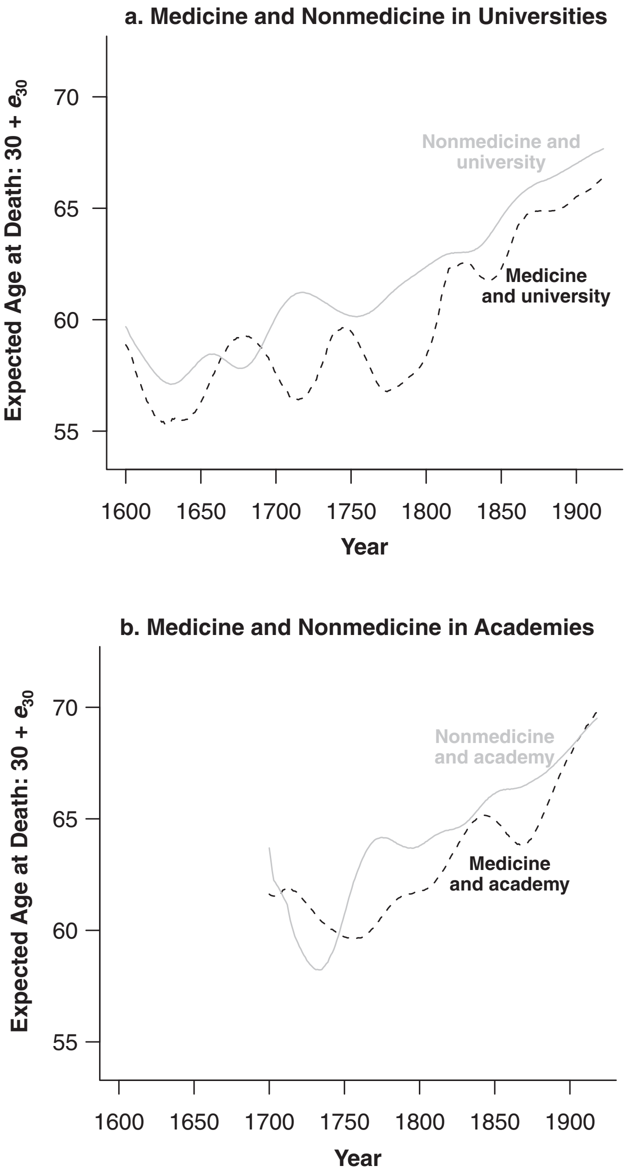

Fig. 7 Social status, medicine, and life expectancy. The figure applies 25-year rolling intervals and two-dimensional smoothed data.

(continued)

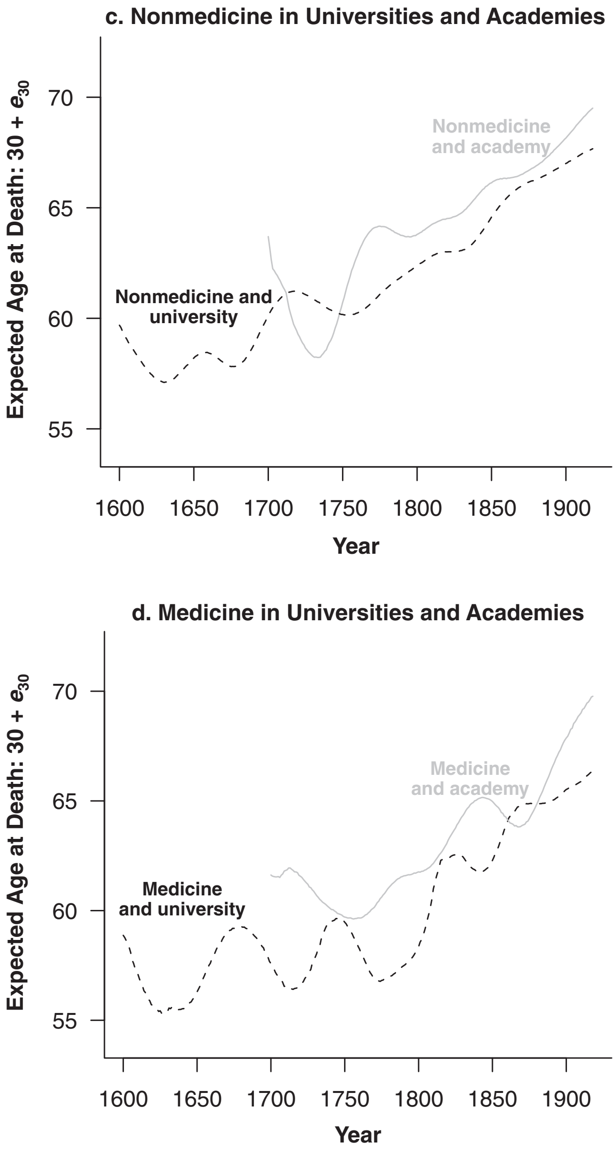

Fig. 7 (continued)

cine experienced these declines with a delay, with the gap narrowing toward the end of the nineteenth century.

Panels c and d compare university scholars with those nominated to a scientific academy. Panel c refers to scholars outside medicine, and panel d refers to scholars in medicine. Both panels show that from around 1750, members of the academies had a higher life expectancy. This mortality advantage lasted for approximately 100 years, until 1850. Thereafter the differences fluctuated so strongly that we refrain from drawing conclusions other than that the advantage existed from approximately 1750 to 1850 and then perhaps diminished.

Robustness

We analyzed whether the following findings remained after data limitations: life expectancy stagnated from 1500 to 1600; the early seventeenth century was marked by a mortality crisis; secular increases started around 1750; and scholars who were outside medicine and belonged to academies of sciences had a mortality advantage compared with scholars who were in medicine and were not appointed to academies.

We first limited the sample to data from institutions for which we had (almost) complete data or partially complete data (the first two quality groups presented in the data section). It also excludes institutions without traditional sources, such as books. Second, to test the robustness with respect to birth and death year heaping, we excluded all observations with a year of birth ending with 0 or 5. Third, we estimated life expectancy with varying starting ages: 25, 35, 45, and 55. Our key results were robust to these tests (see Figures A7–A10 in the online appendix).

Discussion

We gathered data from thousands of scholars in the 1648 territories of the Holy Roman Empire and the Netherlands. By combining vital information with appointment and exit information, we were able to compute mortality dynamics while taking into account left-truncation and right-censoring. Based on this novel data set, we provide new insights into when mortality first started to decline and which groups were the first to experience rising longevity. Our results show that adult life expectancy was stagnant from 1500 to 1750; the early seventeenth century was marked by a mortality crisis; secular increases started around 1750; and scholars outside medicine and within academies of sciences had a mortality advantage compared with those within medicine and not appointed to academies. These results partially corroborate and partially challenge prior findings. Furthermore, they persisted after several robustness checks were performed.

The heterogeneity in our population of scholars enabled us to study differences in the timing of mortality improvements. We showed that the higher social status of members of scientific academies relative to that of ordinary scholars at universities was associated with earlier improvements in mortality. These findings are in line with the vast literature showing that social status and life expectancy are positively correlated (Andreev et al. 2011; Elo et al. 2014; Johansson 1999). Importantly, we showed that this difference already existed in the eighteenth century. However, our results suggest that this difference may have been temporarily diminished toward the end of the nineteenth century. During this period, the comparatively elevated social status associated with being a member in a scientific academy, rather than an "ordinary" professor, might have weakened. Universities changed *from being vocational schools to being research institutions* following the Humboldt reform (Schimank and Winnes 2000).

We also found that mortality improvements were delayed among medical professionals. The lack of understanding of germ theory before the nineteenth century suggests that scholars in the medical field would have faced a mortality disadvantage. However, we found no systematic disadvantage among medical professionals until the beginning of the secular longevity improvements. The limited role of formal medicine in healing is a possible explanation for this finding. Although having an academic career was certainly useful for obtaining official positions, such as a court or personal physician, and was therefore linked to social status, it was not necessarily an advantage in competing with practitioners on the medical marketplace, such as surgeons, midwives, barbers, apothecaries, and even folk healers and illegal care providers (Broman 1995). It is even possible that the high social status of academic medical professionals gave them a mortality advantage. However, when systematic mortality improvements began and the role of formal medicine increased, gains for medical professionals were delayed. In line with van Poppel et al. (2016), we found that medical professionals had a mortality disadvantage for almost a century. Rapidly increasing medical knowledge and the diffusion of germ theory might have quickly compensated for the higher infection risks. As early as in the nineteenth century, excess mortality declined among scholars in the medical profession regardless of whether they belonged to academies of sciences.

Our estimation of scholars' longevity also provides us with insights into the capacity for knowledge accumulation and diffusion. Our finding that the rise in longevity among the educated segment of society preceded industrialization is consistent with the hypothesis that human capital played a significant role in the process of industrialization and the takeoff to modern growth (Galor 2011). The number of scholars and the length of their productive lives may have affected how much they were able to influence their cultural and economic environments—and, in turn, socioeconomic development and economic growth.[9]

The population of scholars we analyzed has the clear advantage of representing a distinct universe: individuals active at one of the defined institutions. However, our data selection also comes with limitations. First, our data refer almost exclusively to elite men (only 89 women are in the sample).

Second, given that universities and academies of sciences are urban institutions, our population was also urban. Thus, these scholars were exposed to the urban mortality penalty (Vögele 2000; Woods 2003). Because we were not able to analyze mortality among ordinary people or women, we can only speculate about the life expectancy dynamics in the general population during the era we analyzed. Our finding that the elite lost several years of life expectancy during the Thirty Years' War might suggest that the general population experienced a similar or greater mortality crisis: it is a reasonable assumption that social status had a protective effect during wars and pandemics. The differences in the timing of secular mortality gains among the upper tail of the

[9] The outstanding role of upper-tail human capital in Europe's historical developments—and, more precisely, in its knowledge accumulation, economic growth, and industrialization—has been emphasized in the recent research literature. For example, the number of people in eighteenth-century France who subscribed to the Diderot's and d'Alembert's *Grande Encyclopédie* predicts subsequent economic development at both the city and the county level (Squicciarini and Voigtländer 2015). Moreover, German cities that developed better institutions following the Reformation grew more quickly and had more residents who were registered as famous in the German biography database (Dittmar and Meisenzahl 2016).

elite (members of the academies) and the normal elite (professors) may also suggest that in the general population, secular mortality improvements did not start before the middle or the end of the eighteenth century. However, this speculation may be wrong given that most scholars were living in urban areas. Thus, the levels and the timing of mortality improvements among scholars may have differed from those of ordinary people living in rural areas (Woods 2003).

Third, the characteristics of the institutions and their members evolved over time. The structure of universities was quite different in the late medieval era than in more recent periods.[10] Prior to the modern era, scholars' salaries were often paid in kind (or not all). Thus, although working at a university was linked to higher social status, it often did not generate significant income advantages. Furthermore, the process of appointment—and, hence, of selection into our population—changed. The role of kinship in the appointment process was gradually replaced by scientific criteria (Klinge 2004; Vandermeersch 2003).

Fourth, how we defined scholars and which institutions we included are potential drivers of the estimated population size. For instance, we may have underestimated the growth in the scholar population in the nineteenth century because we did not include universities founded later than the eighteenth century. It is also possible that scholars were active in a scientific institution before the first observed appointment. If so, we lost years at risk at earlier ages, biasing our life expectancy estimates downward. The academic position that defines the entry in the data set also varies across sources.

Fifth, because the scholars were not appointed until they reached young adulthood, our investigation was limited to adult mortality. The effects of shifts in infant and child mortality on the evolution of life expectancy were neglected.

Finally, our new data set does not allow us to draw conclusions about the impact of social status or the medical profession on mortality. We could only identify associations.

In summary, our analysis of a new data set covering more than 30,000 scholars provides new information on when mortality first started to decline and on the social differences in the first mortality gains. We find that adult mortality was stagnant or declining from the sixteenth to the seventeenth century as wars and epidemics led to a mortality crisis that resulted in the loss of several years of adult life expectancy. However, secular life expectancy improvements started as early as in the eighteenth century, and the life expectancy of scholars associated with elite academies (rather than only being affiliated with a university) increased first, whereas mortality improvements were delayed for scholars in medicine. Our results provide a new perspective on the historical timing of mortality improvements and on the socioeconomic and occupational differentials in this timing. A database accompanying this article facilitates replication and extensions. ■

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[10] We summarize some major evolutions in the characteristics of the universities and their scholars in the online appendix.

Rostochiensium), the University of Bamberg (Bamberger Professorinnen- und Professorenkatalog), and the University of Utrecht (*Catalogus Professorum Academiae Rheno-traiectinae*). We also gratefully acknowledge the data on members provided by the following academies of sciences: the Academy of Sciences and Literature in Mainz, the Bavarian Academy of Sciences and Humanities, the Berlin-Brandenburg Academy of Sciences and Humanities, the Heidelberg Academy of Sciences and Humanities, the Leopoldina, and the Saxon Academy of Sciences. Furthermore, we are thankful to Dagma Drüll and Tino Fröde for sharing with us additional material and their knowledge in supplements to their published works on the University of Heidelberg and the Upper Lusatian Academy of Sciences, respectively; to Tino Steyer for providing the data on the University of Helmstedt; to the members of the working group on the Kiel professors for sharing their work in progress; to the Göttingen Academy of Sciences and Humanities and the Royal Netherlands Academy of Arts and Sciences for sending us books with the available data; and to all others who provided us with valuable information and input in the process of data collection. Finally, we thank Julie Duchêne and Guillaume Catoire for their help in building the database for Louvain, and we are deeply grateful for the patient support of Annika Onemichl in the process of gathering and cleaning the data. Our article benefited from the advice we received and discussions at the Max Planck Institute for Demographic Research as well as from participants' comments during the 2017 workshop "Elite Human Capital and the Road to Modernity: The East vs the West" in Marseilles. David de la Croix acknowledges the financial support of the project ARC 15/19-063 of the Belgian French-speaking Community. He also thanks Imera (Marseille, France) for welcoming him during fall 2017 and for funding Robert Stelter's visit there. Robert Stelter acknowledges financial support from the Max Geldner Foundation.

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