Catalina Torres*

Exploring the Urban Penalty in Life Expectancy During the Health Transition in Denmark, 1850–1910

A Word from the Jury President

Since 2015, eligible researchers have been invited to submit original papers to compete for the *Population* Early-Career Researcher Prize. For the 2021 edition, the journal received 26 manuscripts by 31 authors—16 women and 15 men—with a master's degree or PhD in diverse disciplines (demography, health sciences, sociology, history, economics, geography, statistics, etc.). This year's contenders have a truly international profile, spanning the continents of Europe, America, Asia, and Africa, with three-quarters having studied in a country other than France. The submissions covered all regions of the world and addressed a wide range of topics in population studies, including health and mortality (10 papers), family and fertility (7), population dynamics (3), and migration (3).

After a first anonymized assessment, 13 manuscripts were preselected, each sent to two external reviewers specialized in the relevant field. In parallel, members of the jury read all the texts (also anonymized) and the reviewers' reports. This year's winner was selected on 8 and 9 February 2021. The authors of several other interesting papers were invited to submit a revised version to the Editorial Board.

We are pleased to announce that the 2021 prize goes to Catalina Torres for her paper entitled 'Exploring the urban penalty in life expectancy during the health transition in Denmark, 1850–1910'. Adopting a classic historical demographic approach, Torres examines a pivotal period in the European health transition characterized by much higher mortality

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in urban than in rural areas. Using data on mortality in Denmark and causes of death in Copenhagen, she describes the spectacular increase in urban life expectancy during the late 19th century.

We hope you enjoy reading this article, and we look forward to receiving submissions for the 2022 edition.

GUSTAVO DE SANTIS

International Jury of the 2021 Competition

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Catalina Torres *

Exploring the Urban Penalty in Life Expectancy During the Health Transition in Denmark, 1850–1910

Over the last 2 centuries, life expectancy at birth (LEB) has risen at unprecedented levels (Riley, 2001). The health transition among best-practice female populations, i.e. those with the highest recorded levels in LEB, comprises four distinct phases in the historical passage from low to high life expectancy levels (Vallin and Meslé, 2009): a period of stagnation (1750–1790), followed by one of modest improvements (1790–1885), then accelerated gains (1885–1960), and finally deceleration (from 1960 onwards).

The first wave of this sustained mortality decline started in a few countries, notably in Northern Europe (Chesnais, 1992). In the 19th century, the Scandinavian countries (Sweden, Norway, and Denmark) numbered among those with the highest recorded levels in LEB (see Appendix Figure A.1 and Oeppen and Vaupel, 2002; Bengtsson, 2006; Vallin and Meslé, 2009); they were among (presumably) very few countries having experienced the four phases of the health transition, including an early stage of modest improvements covering most of the 19th century (Torres and Oeppen, 2019). The present study analyses the levels and changes in life expectancy in Denmark from 1850 to 1910 by sex, focusing on the differences between urban and rural areas. The analysis period is justified by the unprecedented processes that it comprised, especially rapid urbanization amidst deficient sanitary conditions and a persistent 'urban penalty'—high mortality levels in the cities and lower levels in the countryside.

Previous studies have explored aspects of the development of mortality in 19th-century Denmark. For example, Johansen (2002) argued that the period 1840–1890 was one of demographic stability, without major developments in mortality and fertility. However, Jarner et al. (2008) observed gains in Danish life expectancy from 1835 to 1900, mostly driven by reductions in child mortality (ages 1–10). Infant mortality (age 0) did not decline significantly until the turn of the 20th century. Løkke (2002) reported a similar finding, showing that the 'great decline' in infant mortality started in the 1880s in Copenhagen and in the 1900s in the rest of the country. Regardless of the discrepancies concerning most of the 19th century, these studies reported a substantial decline in mortality in Denmark from the late 1880s or the 1900s onwards, depending on the area examined and the measure of mortality used.

What may explain this decline? While the smallpox vaccine was among the most consequential medical innovations of the late 18th and 19th centuries, its role in the decline of mortality remains inconclusive, with academics holding opposing views.(1) In Denmark, the vaccine was introduced in 1801 and made mandatory from 1810, through indirect obligation. Since only vaccinated individuals had access to some important social institutions, such as confirmation and marriage, people were generally motivated to get vaccinated (Sköld, 2000). Johansen (2002) observed an infant mortality decline from 1775 to 1840 and argued that the vaccine could not explain it because the reductions were concentrated in the first month of life, when most infants are protected by maternal immunity via breastfeeding. Instead, he argued that improved maternal nutrition and increased availability of educated midwives are the most likely explanations. Indeed, major public health investments were implemented in Denmark from the early 19th century due to increased concern with high infant and maternal mortality (Løkke, 2007). One measure was improved access to qualified medical personnel, especially well-trained midwives (Woods et al., 2006). Besides their role as birth attendants, midwives were generally active promoters of healthy practices, such as adequate breastfeeding and better childcare and hygiene. Differences in breastfeeding practices have been found to play a key role in striking disparities in infant mortality between certain historical populations (Knodel and Kintner, 1977; Kibele et al., 2015). In 19th-century Denmark, infants were generally breastfed—there were no regions 'where the ideal was not to breastfeed at all'—but breastfeeding was not optimally practised in all regions (Løkke, 2002, p. 137). Infant mortality was lower in Scandinavia, which had a long-standing breastfeeding tradition, than in most other countries in 19th-century Europe.

Regarding improved nutrition, new agricultural techniques were implemented during the late 18th and early 19th centuries in Denmark, such as the introduction of new crops and the development of enclosures.(2) The years 1785 and 1786 'were probably the last years in which undernourishment contributed to a significant rise in mortality in Denmark' (Johansen, 2002, p. 104). The second half of the 19th century witnessed economic growth and a transition from traditional agriculture to modern industrialization. Reductions in mortality in the late 18th and early 19th centuries have been associated with agricultural improvements in other

(1) For example, some authors observed that the number of smallpox deaths diminished considerably in Sweden even before the introduction of the vaccine (Fridlizius, 1984; Bengtsson, 2006). Nevertheless, there is evidence that, in some areas, a significant acceleration in the decline of smallpox deaths occurred after the vaccine was introduced (Ager et al., 2017). Mercer (1985) and Bonanni (1999) agree that the smallpox vaccine played an important role in the mortality decline of the late 18th and early 19th centuries in Europe.

(2) Enclosures are portions of land surrounded by a fence preventing common use of the land; they were sometimes constructed for agricultural efficiency.

Nordic countries (e.g. Drake, 1965). However, the role played by improved nutrition has generated intense academic debate. Some studies maintain that better nutrition was key (McKeown and Record, 1962; McKeown et al., 1972; Fogel, 1986). For others, the importance of additional factors, such as early efforts in the public health domain, should not be neglected (Razzell, 1974; Szreter, 1988).

With industrialization came rapid urbanization in Denmark: 80% of the population lived in rural areas in the early 19th century, a figure that persisted almost unchanged until the 1840s but declined to about 60% by the early 1900s. Rapid urban population growth could produce devastating effects on health, as crowding in insanitary environments increased the risk of infection and hence of mortality. Indeed, child mortality increased in the 1850s and 1860s due to various epidemics (e.g. scarlet fever, whooping cough, measles, and diphtheria). This phenomenon, which also occurred in other European countries, has been associated with worsening hygienic conditions resulting from urbanization (e.g. Woods, 2000). Although the compositional changes caused by urbanization could have a substantial effect on life expectancy (e.g. Torres et al., 2019), in Denmark life expectancy continued to increase despite urban population growth.

During the study period, urbanization in Denmark consisted mainly in the growth (in number and size) of small and medium cities. Copenhagen stood as the only truly large urban agglomeration (more than 100,000 inhabitants) all throughout the 19th century. Its population growth took place within the city walls until the late 1850s. Then, new houses constructed in the surroundings allowed further expansion, as the development of industry attracted many migrants. In other Danish cities, agricultural production and commercialization were the principle attractions. Along with the fear caused by mortality crises associated with cholera outbreaks in the 1850s, the unprecedented and rapid urbanization during the second half of the century motivated greater interest by health authorities in improving public health and living conditions, especially in cities. For instance, in the 1880s and 1890s, improvements in the quality of water supplies, sewage systems, and housing were put in place in Copenhagen; earlier efforts in the Danish capital and other cities go back to the 1850s, e.g. first waterworks following laws enacted in 1856–1857 (such as city planning, sewage, and water supply acts) and the opening of the old city fortifications to allow further population growth and alleviate overcrowding.

Johansen (2002) is probably the only study in English to have examined long-term changes in major demographic trends in Denmark, including mortality in the 19th century. However, analyses at the subnational level cover mainly short periods and specific subpopulations by age or place. Another relevant document (in Danish) is the summary on population statistics for the 19th century published by Statistics Denmark (Danmarks Statistik, 1905), which includes statistical tables of population counts and vital statistics (births, marriages, deaths) by decade according to different characteristics such as age, sex, urban–rural location, marital status, and month of occurrence, among others.

Unlike Johansen's study, the analysis presented here relates to all urban and rural categories in Denmark, thus giving an overview of the mortality dynamics and the urban penalty during the urbanization process observed from 1850 to 1910. Changes in mortality are broken down by the contributions of specific age groups. For Copenhagen, a similar decomposition by age groups and causes of death is presented, which can help in understanding better the mechanisms behind the urban mortality decline in Denmark, as Copenhagen was by far the country's largest city and, like others in Europe, it experienced an impressive mortality decline in the late 19th century (e.g. Preston and Van de Walle, 1978; Woods, 2000). Considering that changes in overall mortality patterns stem from significant reductions in mortality from specific causes and at certain ages (e.g. Omran, 1971), the latter analysis is also helpful for understanding some of the forces behind the general mortality decline in Denmark, given the growing share of the urban population during the period. By further exploring mortality dynamics by age, sex, urban–rural category, and causes of death (for Copenhagen), this article aims to shed light on the rise in life expectancy in Denmark and on the experience of its urban penalty. Another contribution of this study concerns its data, as all the historical data digitized to carry out the analyses are provided in the online Supplementary Material (https://doi.org/10.34847/nkl.cbf6srxa).

I. Data

1. Population and death counts, 1850–1910

This study uses demographic data from official census, vital statistics, and health reports produced by Statistics Denmark and the Danish Royal College of Health in the 19th and early 20th centuries. Population counts were obtained from the census conducted every 10 years from 1850 to 1890, as well as those for 1901 and 1911 (Danmarks Statistik, 1850–1913). This information corresponds to the population enumerated on 1 February of each census year by sex, age, and urban–rural category. The number of cases of unknown age were redistributed proportionally according to the procedure explained in Wilmoth et al. (2017).

As for the vital statistics of deaths, births, and marriages, the statistical office produced reports covering 5-year periods. For this study, the volumes from 1850–1854 to 1906–1910 were used to digitize the number of deaths by sex, age, and urban–rural category (Danmarks Statistik, 1858–1919). This information is available for the years ending in 0–4 and 5–9 from 1850 to 1894 (e.g. 1850–1854, 1855–1859, ..., 1890–1894), and then for the years ending in 1–5 and 6–0 (e.g. 1896–1900, 1901–1905, and 1906–1910). The data allow us to construct the 5-year age groups commonly used in aggregate life tables, namely: 0, 1–4, 5–9, 10–14, etc. The last, open-ended age category is 85+.

Regarding the urban–rural classification used in the historical reports, towns and cities were places that had received royal permission to develop trade and commerce, regardless of population size. The urban–rural categories in the data used here are the following:

- *Landdistrikter*: Up to 1900, this category comprises rural areas and trading posts (*Handelspladser*). The latter were small towns with limited trading privileges. Denmark had seven of these during the second half of the 19th century, including Frederiksberg (contiguous with Copenhagen). From 1901, the trading posts were moved into the urban categories.
- *Provinsbyer*: Provincial towns (excluding Copenhagen) were urban agglomerations with full trading rights. Denmark had 67 such places until the late 1890s, which increased to 73 by the beginning of the 20th century, as most trading posts (except Frederiksberg) acquired the status of provincial towns.
- *Hovedstaden* (capital city): This category included only Copenhagen until 1900. Then, because of administrative changes, the large trading post of Frederiksberg acquired a different status and was grouped with Copenhagen and a few other surrounding areas into the capital city category.

This classification has some limitations. First, the provincial towns category is probably too heterogeneous, as it comprises towns with vastly different population sizes and possibly different characteristics: while some were proper urban centres, others may have been semi-urban with even a few rural characteristics, especially earlier in the study period when urbanization was less advanced. Secondly, grouping the trading posts with rural areas may be problematic, especially for Frederiksberg, whose population grew from around 8,000 inhabitants in 1860 to more than 76,000 by 1901; by 1880, it had a larger population than Aarhus (the second largest city). Thirdly, administrative units were reclassified around the turn of the 20th century. For these reasons, the comparisons of mortality over time within urban–rural categories refer to two distinct periods, namely 1850–1900 and 1901–1910.

Finally, regarding the quality of the mortality data used here, the only issue discussed in the original sources is the transfer of certain deaths from rural to urban areas, as some young rural residents died in city hospitals and data are reported by place of occurrence, not place of residence of the deceased (Danmarks Statistik, 1905). This transfer affected mainly the age-distribution of deaths in the provincial towns but was less of an issue for Copenhagen, at least during the period covered in this study.

2. Causes of death in Copenhagen, 1876–1900

Death counts by age group and cause of death for the city of Copenhagen from 1876 to 1900 were digitized from reports published by Statistics Denmark (Danmarks Statistik, 1882, 1886, 1890) and The Royal College of Health (Det

Kongelige Sundhedskollegium, 1892–1901).[3] Those data were aggregated into the same 5-year intervals as the data for all causes combined, except for 1875–1879, where the year 1875 is excluded in the cause-of-death data because of the introduction of a new nomenclature (see below).

The age categories in the data by cause of death are wider than those used in the vital statistics for all causes combined, as from age 25 onwards the remaining age groups span 10 years instead of 5, until the last age group of 85+. For this study, the few cases with known cause but unknown age at death were redistributed proportionally among the age groups (see the procedure in Wilmoth et al., 2017).

The original reports provide a list of 114 causes of death (see online Supplementary Material, Table A1). According to the nomenclature adopted in 1875, those causes could be organized into eight main groups: (1) epidemic diseases, (2) blood poisoning, (3) constitutional diseases, (4) violent deaths, (5) congenital malformations, (6) local diseases of the internal organs, (7) diseases of the external parts of the body, and (8) other frequent causes (Det Kongelige Sundheds-Collegium, 1875; see also Johansen, 1999). Inspired by those used in England and in Sweden at the time, this classification was used in Denmark from 1876 to 1930. Previously, a few other systems had been used but were deficient, especially before 1832, when causes of death were reported to clerics by relatives of the deceased. The 1875 nomenclature was the result of intense debate and work by a special commission, whose inquiries led to the conclusion that it was best to focus on urban areas first, where authorized physicians could verify the reporting of the causes of death. In Copenhagen, this verification became mandatory in 1830. Thus, for this study, the cause-of-death data used are the best available. However, even though the same nomenclature of causes of death was used during the study period, medical knowledge improved over time. Issues related to those improvements are discussed in the next section.

II. Methods

This study's analyses are based on aggregate life tables for the urban–rural populations, by sex for each 5-year period from 1850–1855 to 1906–1910. They were built using conventional demographic methods (Preston et al., 2001). A brief description of the methods for estimating the age-specific death rates by urban–rural category is presented below (for further details, see online Supplementary Material: 'Estimation of age-specific death rates by urban–rural category').

Annual population counts by sex, age, and urban–rural category at the beginning of the year were estimated from the census, assuming exponential

(3) While similar series are not available for Denmark as a whole, they are for the non-rural categories (i.e. Copenhagen, provincial towns, and trading posts). For this study, only data for Copenhagen were digitized, given possible differences in data quality between the capital (generally more reliable) and other towns and cities (Johansen, 1999).

growth from one census to the next.(4) From the annual population estimates thus obtained, mid-year population counts (or exposures) were computed and pooled into groups of 5 years. At the national level, the accuracy of these estimates was confirmed by separate comparisons with data for Denmark from the Human Mortality Database (HMD). At the subnational level, the exposures were applied as weights to the total population exposures obtained from the HMD. This correction provides even more accurate exposures for the urban–rural categories, as the HMD estimates benefit from more detailed data and more sophisticated techniques than those using observations at 10-year intervals. The resulting exposures, together with the death counts available from the vital statistics, were used to compute the age-specific death rates. Then, the life table for each category was constructed: one for each 5-year period, national/subnational urban–rural category, and sex, for a total of 96 life tables (see online Supplementary Material, Table A2). Using these life tables and the method proposed by Horiuchi et al. (2008), the changes in LEB during the study period were decomposed into the corresponding age and cause contributions. The decompositions by age were performed on all national and urban–rural populations;(5) for Copenhagen, the age and cause contributions from 1876–1879 to 1896–1900 were also estimated.

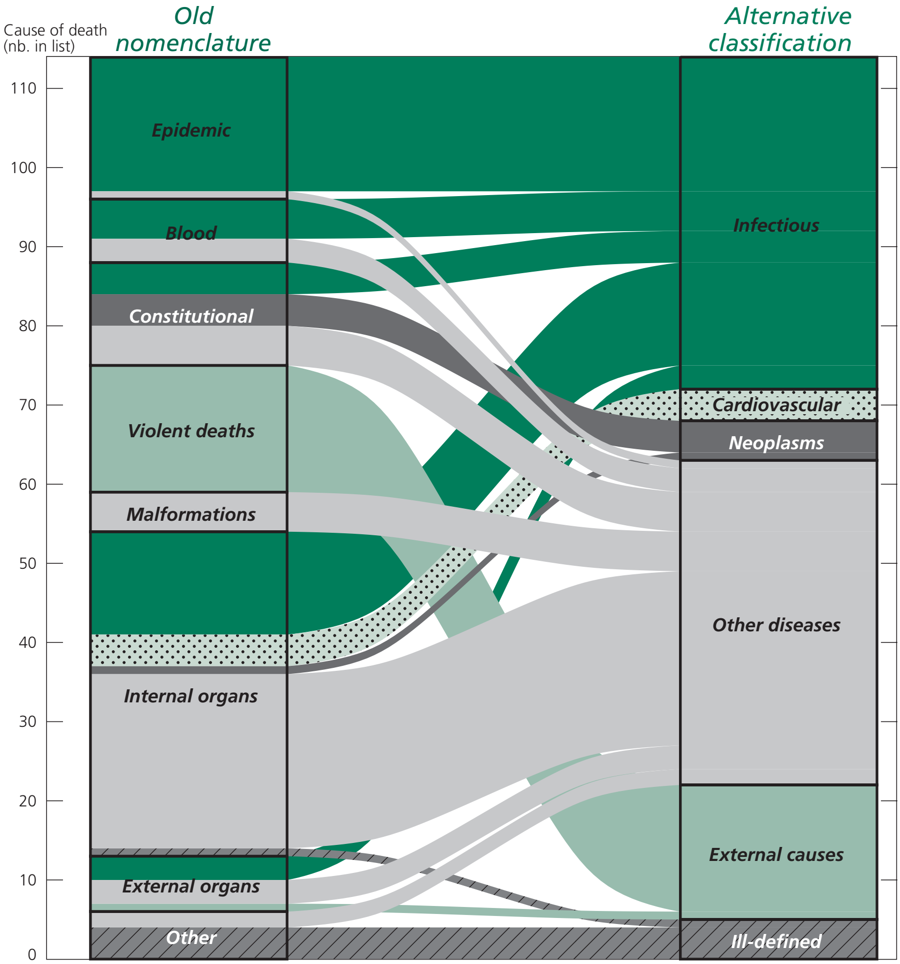
The data by causes of death for Copenhagen were corrected (details are provided in the online Supplementary Material: 'Estimation of age-specific deaths rates by urban–rural category') and then grouped into the categories listed in Box 1. This classification was used instead of the historical nomenclature of 1875, as it benefits from modern medical knowledge and is closer to the classification systems used in modern cause-of-death analysis, facilitating understanding of the results. As shown in Figure 1, the alternative classification differs considerably from the old. Specifically, the group of infectious diseases is much larger in the alternative classification.

Compared to the group 'Other frequent causes' in the old nomenclature, the group for the 'Ill-defined' causes of death in the alternative classification also includes the cause 'disease with unknown cause', but it excludes 'atrophy among infants' and 'death during or shortly after childbirth (excluding puerperal fever)'. These causes were assigned to the group 'Other diseases' in the alternative classification (subgroups 'Constitutional diseases, malnutrition, and congenital malformations' and 'Maternal deaths', respectively). In historical populations, 'atrophy' could be related to 'weakness' or congenital conditions among infants (e.g. Mühlichen and Scholz, 2015). Almost 20% of infant deaths in Copenhagen were due to atrophy in the late 1870s (see Appendix Figure A.2).

(4) Owing to the comparability issues between the urban–rural categories in the 19th and 20th-century data, population estimates for the period 1890–1900 were calculated differently; see online Supplementary Material, Box A1.

(5) Given the administrative changes from 1901 (see Section I), the urban–rural decompositions stop in 1896–1900. For the total population, the decompositions over time comprise the entire observation period, i.e. from 1850–1854 to 1906–1910.

Figure 1. The 114 causes of death in the historical data for Copenhagen according to the nomenclature of 1875 and the alternative classification



Note: Each cause of death is represented on the *y*-axis based on its number in the original lists of causes of death (see online Supplementary Material).

Source: List of causes of death (old nomenclature): Danmarks Statistik, 1882, 1886, 1890; Det Kongelige Sundhedskollegium, 1892–1901; Det Kongelige Sundheds-Collegium, 1875.

This proportion decreased continuously during the study period, while the proportion of infant deaths from 'Congenital weakness' increased. This indicates that medical knowledge improved during the study period, as 'atrophy' (together with 'convulsions', another important cause of death among infants) was most likely a symptom in Danish historical statistics (Johansen, 2002). Removing it from the category of poorly defined causes has a substantial impact on the importance of this group. According to the alternative classification, deaths from ill-defined causes did not continuously decrease (Appendix Figure A.3). Moreover, 'senility', which concerns only the oldest age groups, appears

Box 1. Alternative classification of causes of death: groups and subgroups

I. Infectious diseases
1. General infections (excluding tuberculosis)
2. Tuberculosis
3. Infections of the respiratory system
4. Other infections

II. Neoplasms

III. Cardiovascular diseases

IV. Other diseases
1. Constitutional diseases, malnutrition, and congenital malformations
2. Maternal deaths
3. Other

V. External causes

VI. Ill-defined causes

to have been the most important cause within that group. Since the oldest age groups do not contribute substantially to the changes in LEB in the context of this study and since the remaining causes in the ill-defined group show no continuous decline (if anything, the proportion of deaths from 'senility' at old ages increases slightly), it seems reasonable to conclude that, despite the improvements in medical knowledge over this period, these advances will not impact the results significantly when using the alternative classification.

III. Results

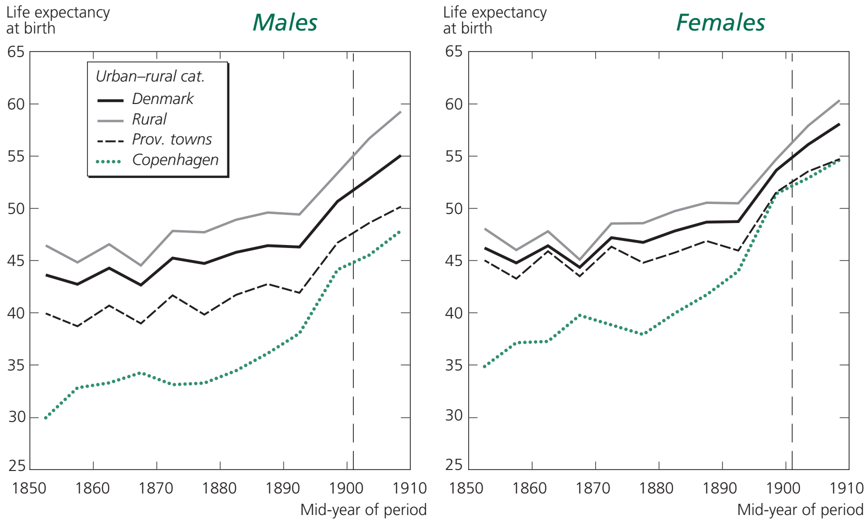
1. Trends in LEB: from slow gains to rapid improvements

Estimates of LEB by sex and urban–rural category are shown in Figure 2. From 1850–1854 to 1906–1910, LEB increased by more than 11 years in Denmark. Two distinct phases can be observed: first, a period of slow gains up to the early 1890s, followed by one of rapid increase.

Table 1A shows that the minimal contribution of age 0 to changes in LEB at the national level was characteristic of the 19th century:[6] from 1850 to 1900, Danish LEB increased by about 7 years, most of which was due to mortality reductions among children (mainly ages 1–4). The positive contribution from young adult ages (15–44) was considerable too. These observations are also valid for the rural category and the provincial towns. In contrast, over the same period, LEB in Copenhagen increased by about 16 years for females and

(6) Age contributions (in years) to changes in life expectancy by 5-year period from 1850 to 1910 are illustrated in Figure A1 in the online Supplementary Material.

Figure 2. Life expectancy at birth in Denmark by sex and urban–rural category, 1850–1910



Notes: Five-year period estimates; points located in the middle of each period. The vertical line on 1901 represents the occurrence of administrative changes (see Section I). Estimates from other sources were used to verify the accuracy of the results: at the national level, HMD data. For the urban–rural categories, estimates for 1835–1844, 1845–1849, and 1850-1854 from Danmarks Statistik (1863).

Sources: Author's estimates based on historical census and vital statistics reports.

14 years for males, mostly due to the positive contributions of infant mortality reductions. The latter were concentrated in the last 2 decades of the century. The provincial towns were the group with the smallest increase in LEB from 1850 to 1900.

The period of rapid increase in LEB started with impressive improvements in survival during the 1890s, when all urban–rural categories experienced the largest gains. Those gains were most pronounced in urban areas (especially in Copenhagen) and smaller but still substantial in rural ones. Table 1B shows that, at the national level and for both sexes, the main contributions to the increase in LEB came from mortality reductions at ages 1–4 and then 5–14. The small contribution at age 0 for the entire country was primarily driven by improvements in infant mortality in Copenhagen: among the urban–rural groups, only the Danish capital experienced substantial reductions in infant mortality. In the other areas, gains in life expectancy were mainly due to reductions in child mortality (ages 1–4 and 5–14).

The largest contribution to further gains in LEB at the national level in the first decade of the 20th century occurred at age 0 (Table 1C). Reductions in child and young adult mortality (ages 1–44) played a significant role too. Moreover, the rural population experienced larger gains in LEB than the urban categories from 1901–1905 to 1906–1910. Contributing to those improvements were infant and child mortality reductions (ages 0–14), but a remarkable decline

Table 1. Age contributions (in years) to changes in life expectancy at birth in Denmark by sex and urban–rural category, 1850–1854 to 1890–1910

Sex	Place	LEB by comparison period			Age-contributions					
		Earlier	Later	Difference	0	1–4	5–14	15–44	45–64	65+
A. From 1850–1854 to 1896–1900										
Female	Copenhagen	34.9	51.4	16.6	4.5	3.2	1.3	3.8	2.6	1.2
	Prov. towns	45.0	51.6	6.5	0.7	2.0	1.1	1.1	1.1	0.5
	Rural	48.1	54.7	6.7	0.3	2.1	1.4	1.7	0.9	0.4
	Denmark	46.2	53.7	7.4	0.5	2.1	1.3	1.9	1.1	0.5
Male	Copenhagen	29.9	44.1	14.2	4.0	2.9	0.9	3.6	2.2	0.6
	Prov. towns	39.9	46.7	6.8	0.5	1.7	0.8	1.7	1.6	0.4
	Rural	46.4	53.4	6.9	0.5	2.0	1.4	1.6	1.1	0.3
	Denmark	43.6	50.7	7.0	0.6	2.0	1.3	1.7	1.2	0.3
B. From 1890–1894 to 1896–1900										
Female	Copenhagen	44.0	51.4	7.4	3.0	2.0	0.9	0.8	0.4	0.3
	Prov. towns	46.0	51.6	5.6	0.4	2.0	1.9	1.0	0.1	0.2
	Rural	50.5	54.7	4.2	0.3	1.3	1.3	0.8	0.3	0.2
	Denmark	48.7	53.7	4.9	0.7	1.6	1.3	0.8	0.3	0.2
Male	Copenhagen	38.0	44.1	6.1	2.9	1.7	0.7	0.5	0.1	0.2
	Prov. towns	41.9	46.7	4.8	0.5	1.7	1.4	1.0	0.2	0.1
	Rural	49.4	53.4	4.0	0.5	1.4	1.1	0.6	0.2	0.1
	Denmark	46.3	50.7	4.4	0.9	1.5	1.1	0.6	0.2	0.1
C. From 1901–1905 to 1906–1910										
Female	Copenhagen	52.9	54.7	1.8	1.2	0.6	-0.1	0	0.2	0
	Prov. towns	53.5	54.7	1.2	0.3	0.6	0.4	0.2	0	-0.1
	Rural	57.9	60.4	2.4	0.4	0.4	0.5	0.7	0.4	0.1
	Denmark	56.1	58.1	2.0	0.6	0.4	0.3	0.4	0.2	0
Male	Copenhagen	45.5	47.9	2.3	1.3	0.3	0.1	0.4	0.2	0.1
	Prov. towns	48.6	50.2	1.6	0.6	0.4	0.4	0	0.1	0
	Rural	56.7	59.3	2.6	0.6	0.4	0.3	0.7	0.3	0.2
	Denmark	52.8	55.1	2.2	0.8	0.4	0.3	0.5	0.2	0.1
D. From 1850–1854 to 1906–1910										
Female	Denmark	46.2	58.1	11.9	1.8	3.2	2.1	2.7	1.5	0.7
Male	Denmark	43.6	55.1	11.5	1.8	3.0	1.8	2.7	1.6	0.6

Notes: Age contributions to changes in life expectancy by 5-year period are illustrated in Figure A1 in the online Supplementary Material.
Source: Author's estimates based on historical census and vital statistics reports.

in young adult mortality (ages 15–44) was crucial as well in the rural areas, perhaps partially due to 'transferring' deaths of young rural residents to hospitals in provincial towns, as the data are by place of occurrence, not of residence. Overall, reductions in infant mortality played a substantial role in the increase in life expectancy during the first decade of the 20th century in all urban–rural categories.

Figure 2 illustrates the urban penalty in Denmark. Initially, LEB for females and males in Copenhagen was about 13.2 and 16.5 years lower, respectively, compared to their counterparts in rural areas. The gap between provincial towns and rural areas was considerably smaller (3.0 and 6.5 years for females and males). By the end of the 19th century (1896–1900), the gap in LEB between Copenhagen and the rural areas had dramatically narrowed (to 3.3 and 9.3 years for females and males) thanks to the rapid improvements in the Danish capital. However, the gap between provincial towns and rural areas was about the same as in the 1850s (3.2 and 6.7 years for females and males), which may have resulted from provincial towns having become more urban during the 19th century.

In addition, the results suggest that males were more affected by the urban penalty than females, even if the proportion of the population in the cities was slightly higher among the latter.(7) As shown in Figure 2, the gaps in LEB between the urban–rural categories are clearly wider among men compared to women, as is the gap between the Danish average (i.e. the black line in the figure) and the rural category. By age 5, substantial differences in LEB between the urban–rural categories persisted among males, whereas they were minimal among females (see online Supplementary Material, Figures A3 and A4). These contrasts might be related to men and women experiencing different occupational hazards in the cities, but they may also be associated with the 'healthy migrant effect'. Internal migration from rural to urban areas was dominated by women (indicating the possibility of positive selection in favour of urban areas), whereas international migration was dominated by men, thus depriving the cities of a similar positive effect from selection among men.

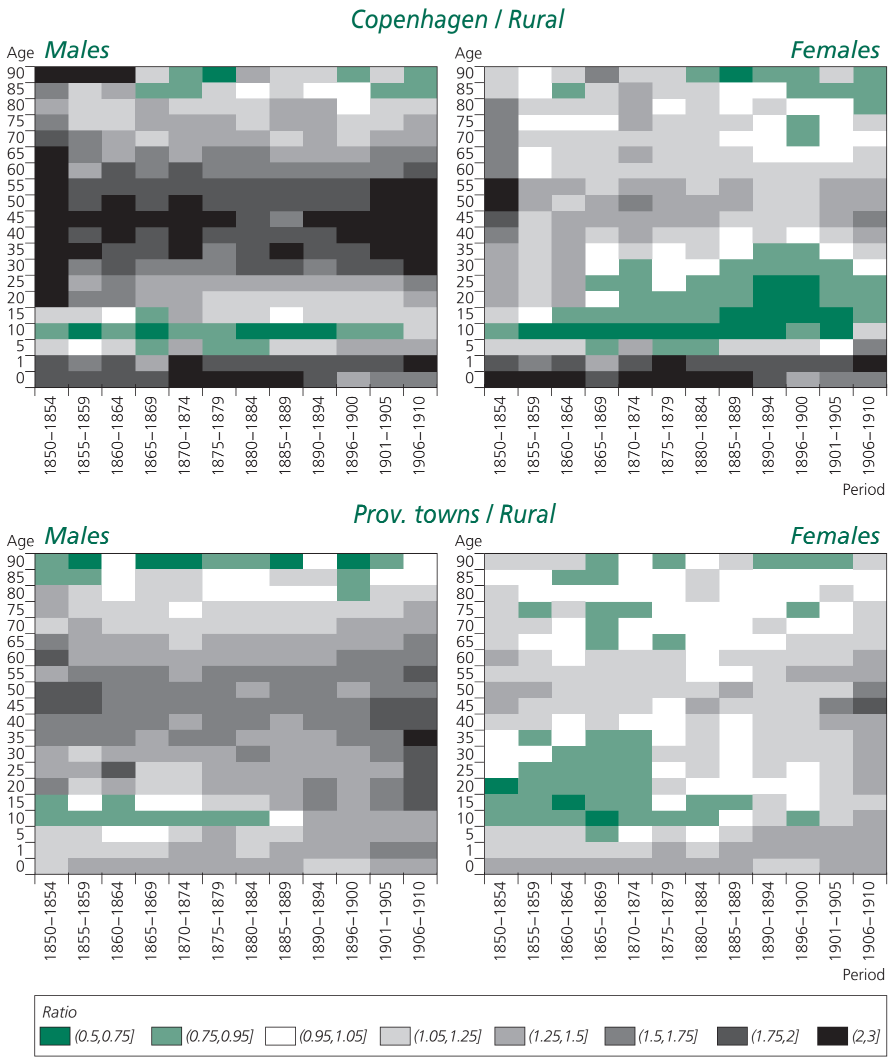
Figure 3 compares the age-specific death rates in the two urban categories to those in the rural areas and indicates that urban mortality was highest at most ages. It was especially high in Copenhagen among infants and children under age 5 as well as male adults. For women in Copenhagen, the largest penalty compared to women in rural areas was at infancy and childhood (ages 0–4), but an advantage in teen and young adult ages is observed. From ages 10–14 until about the end of reproductive age, the lower mortality rates in the Danish capital compared to rural areas became more pronounced (especially during the 1880s and the 1890s). For males, lower mortality in Copenhagen was found only for the 10–14 age group. A slight advantage around the same ages for females and males is observed in the provincial towns at the beginning of the study period, when compared to their counterparts in rural areas. However, unlike the case in Copenhagen, this modest advantage decreased and eventually disappeared in the 1880s.

2. The major impact of infectious diseases on rapid gains in LEB in Copenhagen

Figure 2 shows that gains in LEB occurred faster in Copenhagen than in the other areas of the country. Despite a brief decline in the 1870s, when

(7) Age and sex population distributions are illustrated in Figure A2 the online Supplementary Material.

Figure 3. Relative differences between urban and rural age-specific death rates in Denmark by sex and period



Notes: Approximately equal mortality rates in the two places being compared are represented in white, where urban death rates are below or above the rural levels by no more than 5%. Higher urban mortality is represented in grey, while lower urban mortality is represented in green (the darker the shade, the larger the relative difference between the urban and rural death rates).

Source: Author's estimates based on historical census and vital statistics reports.

the quality of water supplies deteriorated (Johansen, 2002), Copenhagen's pronounced increase in LEB from the mid-19th century onwards is quite remarkable, given its rapid population growth (especially during the 1880s and 1890s) and deficient hygienic conditions. Figure 4 shows that reductions in mortality from infectious diseases contributed the most to the changes in

LEB in the capital.[8] Although all age groups benefited from mortality reductions during the 1890s, the substantial increase in LEB during that decade was due mainly to reductions in mortality from infectious diseases among infants and children (ages 0–9); congenital malformations and other diseases also played a role among infants. Reductions in mortality from tuberculosis, especially among young adults (ages 15–45), also contributed significantly to the gains in life expectancy beginning in the 1880s.

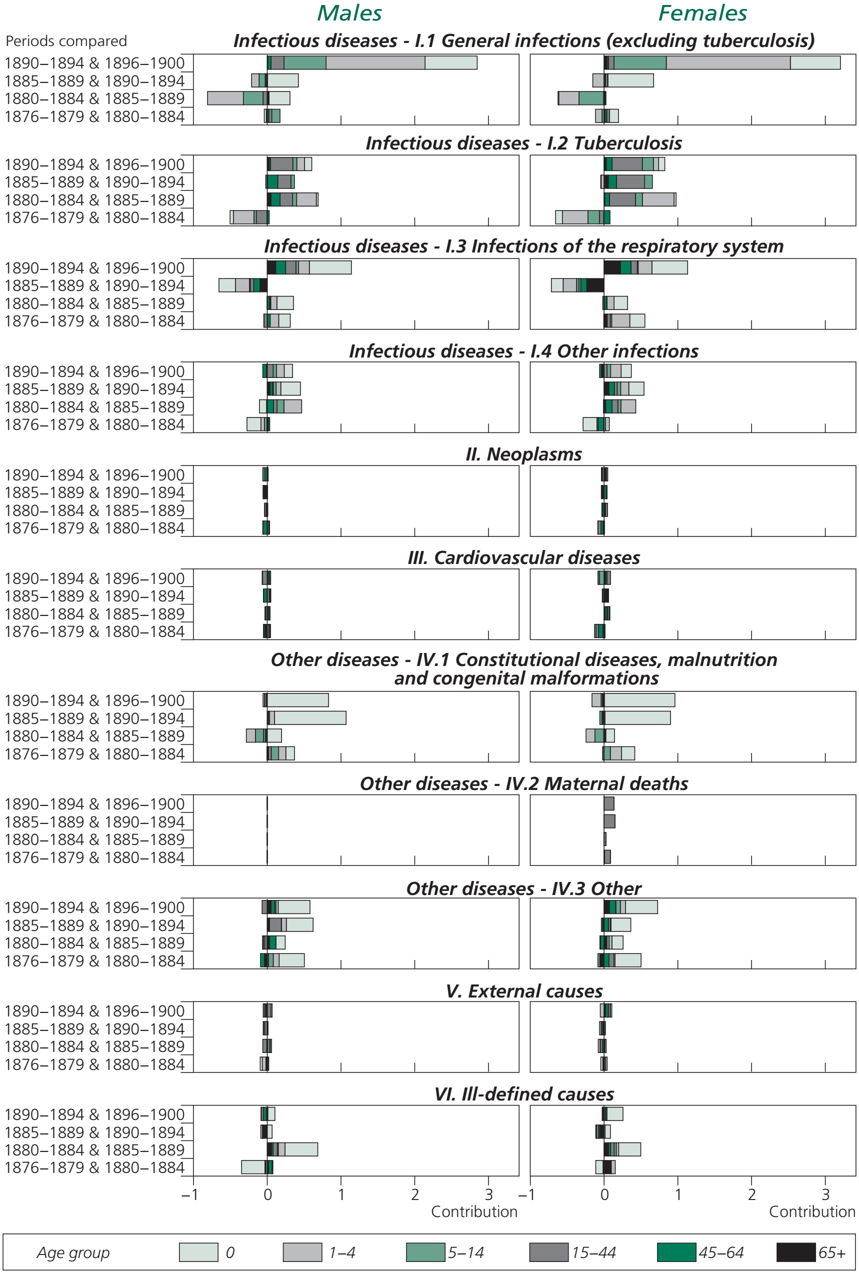
Reductions in mortality from only three infectious diseases (diphtheria, croup, and measles) constituted about 45% of the total positive contribution from ages 1 to 4 to the impressive increase in LEB in Copenhagen from 1890–1894 to 1896–1900.[9] As for infants (age 0), reductions in all infectious diseases account for 35% (females) to 38% (males) of that age's positive contribution over the same period. Among these, reductions in infant mortality caused by diarrhoea were the greatest. The main contribution from young adults (aged 15–44) was associated with reductions in mortality from tuberculosis, which represent about 10% (males) and 16% (females) of the positive contribution from those ages.

The causes of death 'atrophy' and 'convulsions' (within the 'congenital malformations' and 'other diseases' groups, respectively) contributed substantially to the changes in LEB in Copenhagen during the study period. A major part of the positive contribution from age 0 to the changes in LEB in Copenhagen was associated with those two causes alone. However, infant mortality reductions from those two causes may reflect improvements in identifying causes of death, as the proportion of deaths from those two causes at age 0 decreased while it increased for other, similar, or related causes (Appendix Figure A.2). This would be an issue if the decompositions were based on single causes of death rather than large groups of causes, as is the case here using the classification shown in Box 1. As historical studies have found that deaths by 'atrophy' are related to congenital conditions, the decline and increase in the proportion of infant deaths from 'atrophy' and 'congenital weakness' is well contained in the subgroup 'congenital malformations' (IV.1). Furthermore, studies have indicated that 'convulsions' could be related to diarrhoea (e.g. Reid, 2001). Although the decrease in the proportion of infant deaths from convulsions does not correspond entirely to the increase in that of infant deaths from diarrhoea (Appendix Figure A.2), a substantial part of the contribution from the subgroup 'other diseases' (IV.3) at age 0 may correspond to diarrhoea, in which case the contribution from infectious diseases at age 0 would be somewhat larger than illustrated in Figure 4.

(8) Total contributions from groups of causes of death, all ages combined, are provided in Figure A5 in the online Supplementary Material.

(9) The contribution of each detailed cause is shown in Figure A6 in the online Supplementary Material.

Figure 4. Age and cause-of-death contributions (in years) to changes in life expectancy in Copenhagen between consecutive periods, from 1876–1879 to 1896–1900, by sex



Interpretation (example): From 1890–1894 to 1896–1900, reductions in mortality due to general infections (excluding tuberculosis) contributed more than 3 years to the gain in female LEB; those improvements were mainly concentrated at ages 0–14 for females and males.

Source: Author's calculations based on historical census and vital statistics reports.

Discussion

This study explores the changes in Danish LEB from 1850 to 1910, focusing on the differences between urban and rural populations. During this period, urbanization progressed rapidly while deficient sanitary conditions posed critical problems for population health. From the perspective of the health transition (Vallin and Meslé, 2009, 2010), this article covers the passage from a phase of modest gains to one of accelerated improvements in life expectancy. According to the results, that transition occurred in the 1890s in Denmark.

Advances in scientific knowledge from the 1880s about the origins and transmission of infections most likely played a key role in this transition. According to Thelle (2018) ‘until the 1880s, the dominant framework for understanding the spread of disease, in Copenhagen especially, had been the idea of the miasma’ (p. 249), which had an impact on urban planning. Concerns about the devastating effects of infections were present in Danish society, especially in urban areas and during the mid-19th century, when cholera outbreaks raised mortality levels substantially, while the population also experienced concomitant epidemics of scarlet fever, whooping cough, measles, and diphtheria. This phenomenon, also observed in other European countries, has been associated with worsening hygienic conditions resulting from urbanization (e.g. Caselli, 1991; Vallin, 1991; Woods, 2000), as the incidence of infectious diseases increased due to the ‘unplanned proliferation of overcrowded cities and towns lacking even the most basic sanitary facilities such as proper water supply and waste disposal systems’ (Szreter, 1988, p. 18). Thus, on an international level, the scientific discoveries of Pasteur and others provided a fundamental basis for effective improvements in public health, particularly to the quality of water supplies as well as new regulations and surveillance of food production and distribution. However, in Denmark, general improvements in other areas may have played a role in increasing life expectancy during the 1890s, as rural areas and most provincial towns did not experience until the early 20th century the improvements in public health that Copenhagen had witnessed (Johansen, 2002).

The 1890s were also the time by which knowledge of proper childcare practices became more widespread among the population (Løkke, 2002). While infants were traditionally breastfed—which considerably reduces infant mortality risks in contexts with high prevalence of infectious diseases—the practice was not optimal everywhere (e.g. in some regions, infants received a combination of mother’s milk and artificial foods, or weaning occurred at the wrong time, compromising the infants’ immunity). Despite local exceptions, breastfeeding is most likely one of the reasons why infant mortality was so low in Scandinavian countries compared to others (Edvinsson et al., 2008).

Important innovations in Danish social welfare policy also started in the 1890s (e.g. the old-age-pension law in 1891 and the health insurance law in

1892; see Løkke, 2007). Although it is uncertain that the effect of these measures was so rapid as to provoke substantial mortality reductions in all urban–rural categories in the same decade, they deserve some mention here because they are concrete examples of a changing mentality and a sense of awareness about the quality of life and public health.

The results of the decompositions by age showed that reductions in child mortality (especially at ages 1–4) contributed the most to the gains in LEB during the second half of the 19th century. At the national level and in rural areas, infants (age 0) contributed little to those improvements. Nevertheless, in Copenhagen, substantial reductions in infant mortality contributed significantly to the impressive gains in LEB, especially from the 1880s. These reductions, together with those observed among small children and young adults, played a key role in reducing the disparity in LEB between the Danish capital and rural areas. Only in the beginning of the 20th century did infants become the main contributors to gains in LEB at the national level. If the mortality data were by place of residence instead of place of occurrence, the results of the decompositions would have been similar for rural areas, as the large contribution from young adults (ages 15–44) to the gains in rural LEB in the first decade of the 20th century may be partly due to numerous young rural residents having died in urban hospitals, biasing estimates of urban mortality upwards (e.g. Ramiro-Fariñas, 2007). This issue was particularly pronounced in the provincial towns; it also happened in Copenhagen, but to a much smaller extent.(10)

As for the contributions by age and cause of death to the considerable gains in LEB in Copenhagen, reductions in child mortality from a few infectious diseases (namely diphtheria, croup, measles, scarlet fever, and whooping cough) played a key role. Among infants, reductions in only two infectious diseases were behind the observed positive effect from that age group, namely diarrhoea and whooping cough. Reductions from other causes (namely 'convulsions', congenital conditions, as well as some respiratory diseases, e.g. pneumonia and bronchopneumonia) also contributed substantially to the increase in LEB from 1890–1894 to 1896–1900 (as indicated in the previous section, transferring the infant deaths due to convulsions to the group of infectious diseases would only increase the positive contribution of the latter group). At young adult ages, reductions in mortality from respiratory tuberculosis were found to contribute substantially to the increase in LEB. The reduction of mortality from all these diseases was fundamental for the urban–rural gap to narrow. Mortality decline from all the causes mentioned previously has also been observed in other populations in the late 19th century (e.g. Crimmins and

(10) For instance, for 1915, the report (vol. of 1919 in Danmarks Statistik, 1858–1919) presents corrections that allow us to appreciate the differences between deaths by place of residence versus place of occurrence. In that year, an excess of 726 men and 586 women in total were recorded as having died in the provincial towns, or 18% and 15% above the corresponding numbers of deaths by place of residence. In some young age groups, the respective proportions are as high as 35% or more. In Copenhagen, the total excess was only 1.5% for males and 1.2% for females.

Condran, 1983; Williams and Galley, 1995; Burström and Bernhardt, 2002; Cutler and Miller, 2005). In their study about Victorian England, Williams and Galley observed that '[…] of all the causes of death, it was the filth diseases such as diarrhoea where the gap between town and country was widest' (Williams and Galley, 1995, p. 414).

A further aspect revealed here is that, despite the urban penalty, there was an urban advantage in survival at young adult ages, especially among women in Copenhagen. This advantage grew during the second half of the 19th century and was greatest in the 1880s and 1890s when the Danish capital experienced unprecedented population growth. This development could be associated with a health selection process (the 'healthy migrant effect'), as people who migrate are presumably healthier than those who do not, and the period studied was one of significant population redistribution from rural to urban areas. Another possibility is that some young adults who contracted tuberculosis in the city returned to their home in the countryside, where they finally died, thus lowering the urban mortality related to that disease among young adults (Flinn et al., 1977; Hinde, 2015; Reid and Garrett, 2018). As shown here, most of the positive contribution from young adult ages to the increase in LEB in Copenhagen in the 1890s was associated with reductions in tuberculosis. As for the advantage concerning young women, low maternal mortality may have played a role, as numerous young adult women worked as unmarried servants in the cities; for women in that situation, it was uncommon to have children. Moreover, for women who did have children, maternal mortality declined during the study period (e.g. Løkke, 1997), contributing somewhat to the gains in female LEB observed in Copenhagen. All these mechanisms are not mutually exclusive, and they may explain the urban mortality advantage among young adults.

Finally, by exploring the trends and changes in LEB by sex, urban–rural category, and cause of death (for Copenhagen), this article contributes to the knowledge about the mortality decline in Denmark, including its experience of the urban penalty.

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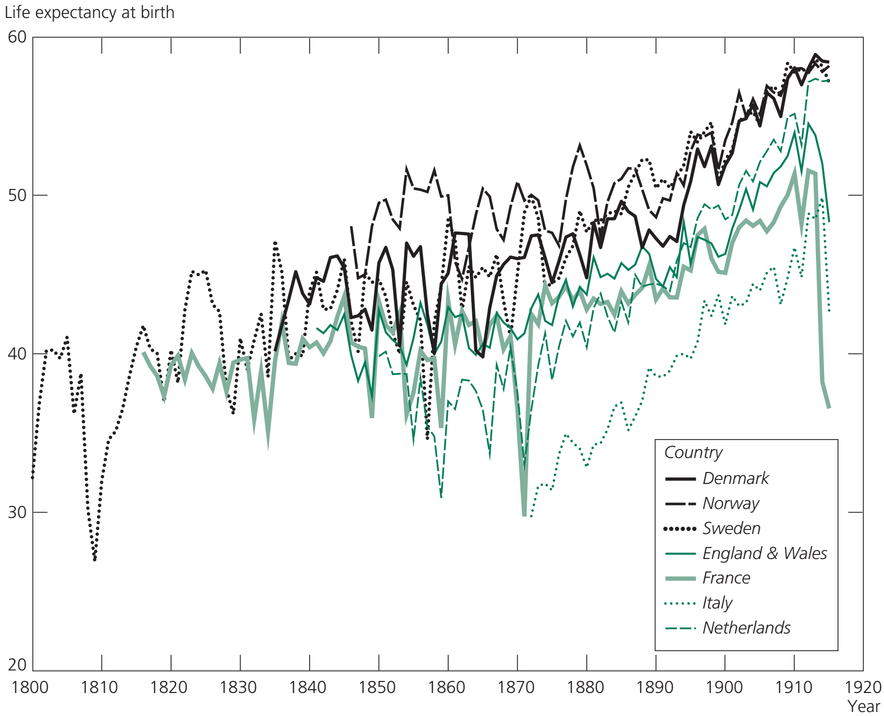
Appendix

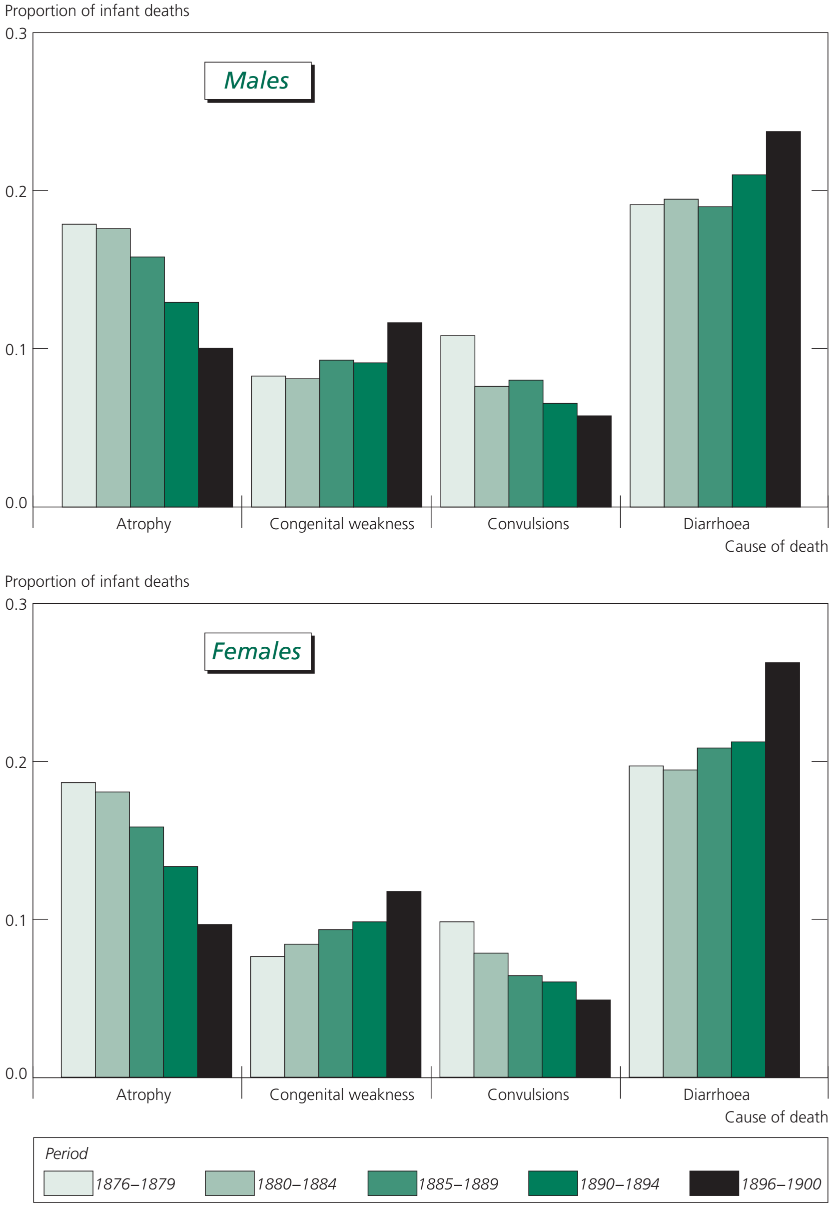
Figure A.1. Life expectancy at birth in Scandinavian and other European countries, 1800–1915



Note: HMD data for Denmark from 1835 to 1854 were corrected, as for those years stillbirths are mistakenly included among the death counts at age 0 (see Torres, 2019).

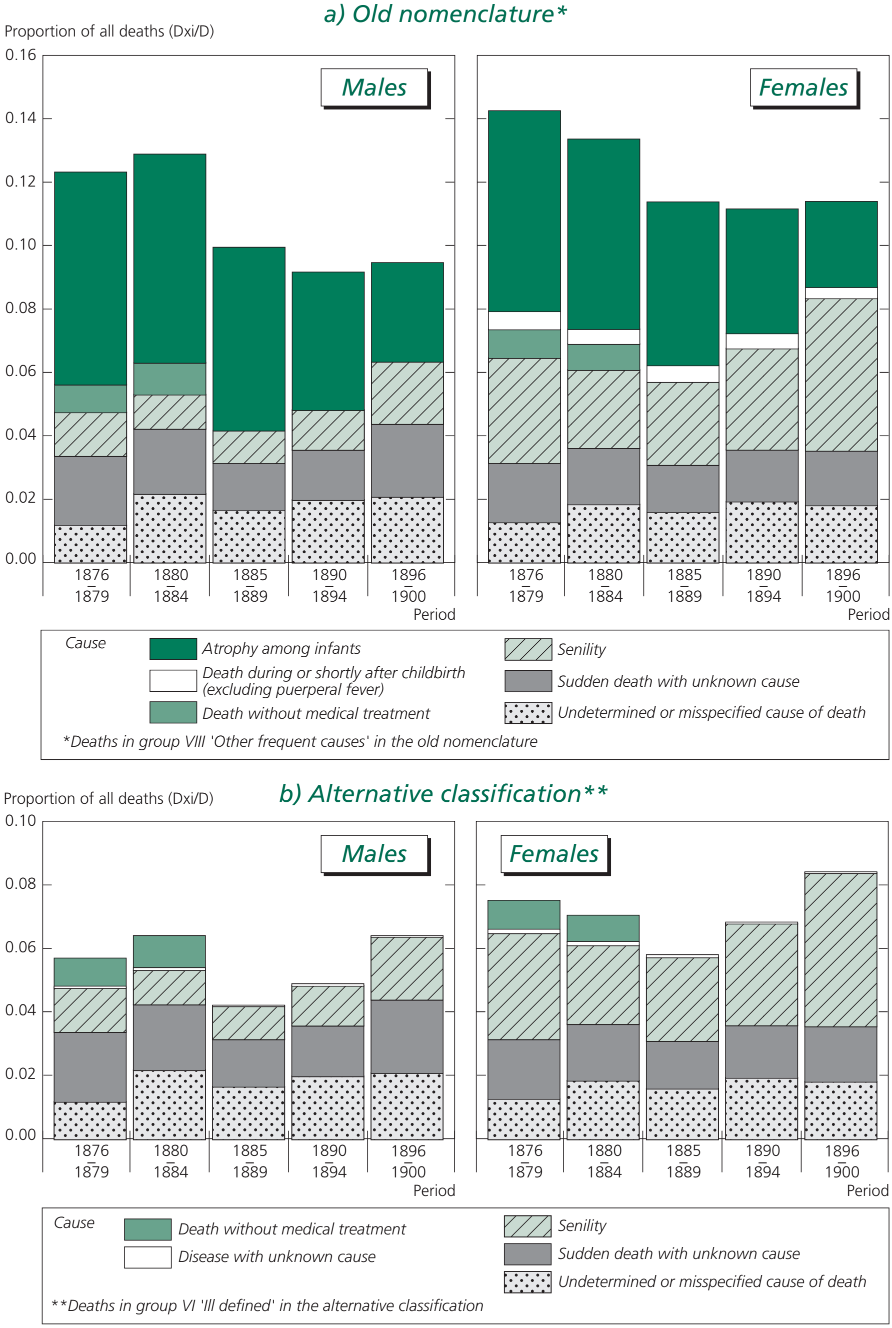
Source: Human Mortality Database.

Figure A.2. Proportion of infant deaths from selected causes in Copenhagen by period and sex, 1876–1900



Source: Author's calculations based on data from reports by Statistics Denmark (Danmarks Statistik, 1882, 1886, 1890) and The Royal College of Health (Det Kongelige Sundhedskollegium, 1892–1901).

Figure A.3. Proportion of all deaths from ill-defined causes in Copenhagen by period and sex, 1876–1900



Note: Dxi/D = Number of deaths at age *x* from cause *i* divided by the total number of deaths. For proportions by age group, see Figure A7 in the online Supplementary Material.

Source: Author's calculations based on data from reports by Statistics Denmark (Danmarks Statistik, 1882, 1886, 1890) and The Royal College of Health (Det Kongelige Sundhedskollegium, 1892–1901).

References

Ager P., Worm Hansen C., Sandholt Jensen P., 2017, Fertility and early-life mortality: Evidence from smallpox vaccination in Sweden, *Journal of the European Economic Association*, 16(2), 487–521.

Bengtsson T., 2006, Linear increase in life expectancy: Past and present, in Bengtsson T. (ed.), *Perspectives on mortality forecasting III. The linear rise in life expectancy: History and prospects*, Stockholm, Swedish Social Insurance Agency, 83–99.

Bonanni P., 1999, Demographic impact of vaccination: A review, *Vaccine*, 17(Suppl. 3), S120–S125.

Caselli G., 1991, Health transition and cause-specific mortality, in Schoefield R., Reher D., Bideau A. (eds.), *The decline of mortality in Europe*, Oxford, Clarendon Press, 68–96.

Chesnais J.-C., 1992, *The demographic transition: Stages, patterns, and economic implications*, Oxford, Oxford University Press.

Cutler D., Miller G., 2005, The role of public health improvements in health advances: The twentieth-century United States, *Demography*, 42(1), 1–22.

Burström B., Bernhardt E., 2002, The changing cause of death pattern among infants, Stockholm 1878–1925, in Carling J. (ed.), *Nordic demography: Trends and differentials*, Oslo, Nordic Demographic Society, 53–64.

Crimmins E. M., Condran G. A., 1983, Mortality variation in U. S. cities in 1900: A two-level explanation by cause of death and underlying factors, *Social Science History*, 7(1), 31–59.

Danmarks Statistik, 1850–1913, Official census reports, *Statistisk Tabelværk*, Copenhagen, https://www.dst.dk/da/Statistik/Publikationer/VisPub?cid=19590

Danmarks Statistik, 1858–1919, Official vital statistic reports, *Statistisk Tabelværk*, Copenhagen, https://www.dst.dk/da/Statistik/Publikationer/VisPub?cid=20308 and https://www.dst.dk/da/Statistik/Publikationer/VisPub?cid=20307

Danmarks Statistik, 1863, *En Fremstilling af nogle Dödeligheden vedrörende Forhold i Kongeriget Danmark, Hertugdömmet Slesvig og Hertugdömmet Holsteen i Aarene 1845-1854*, *Statistisk Tabelværk*, Copenhagen.

Danmarks Statistik, 1882, *Vielser, Fødsler og Dødsfald i Aarene 1875-1879 samt Dødsaarsagerne i Aarene 1876-1879*, *Statistisk Tabelværk*, Copenhagen.

Danmarks Statistik, 1886, *Døds-Aarsagerne i Staden København, de øvrige Kjøbstaeder og de 6 saakaldte Handelspladser i Fem-Aaret 1880-1884*, *Statistisk Tabelvær*k, 4 række, litra A., Nr. 4, Copenhagen.

Danmarks Statistik, 1890, *Dødsaarsagerne i Staden København, Frederiksberg og Provins-Kjøbstaederne med de 5 saakaldte Handelspladser i Fem-Aaret 1885-1889*, *Statistisk Tabelværk*, 4 række, litra A., Nr. 6, Copenhagen.

Danmarks Statistik, 1905, *Befolkningsforholdene i Danmark i det 19. Aarhundrede*, *Statistisk Tabelværk*, Copenhagen.

Det Kongelige Sundheds-Collegium, 1875, *Anvisning for Læger med Hensyn til Udstedelsen af Dødsattester*, J. H. Schultz.

DET KONGELIGE SUNDHEDSKOLLEGIUM, 1892–1901, *Dødsaarsagerne i kongeriget Danmarks byer* [annual volumes for the years 1890–1900], Copenhagen, Bianco lunos bogtrykkeri.

DRAKE M., 1965, The growth of population in Norway 1735–1855, *Scandinavian Economic History Review*, 13(2), 97–142.

EDVINSSON S., GARÐARSDÓTTIR Ó., THORVALDSEN G., 2008, Infant mortality in the Nordic countries, 1780–1930, *Continuity and Change*, 23(3), 457–485.

FLINN M., GILLESPIE J., HILL N., MAXWELL A., MITCHISON R., SMOUT C. (eds.), 1977, *Scottish population history from the 17th century to the 1930s*, Cambridge, Cambridge University Press.

FOGEL R. W., 1986, Nutrition and the decline in mortality since 1700: Some preliminary findings, in Engerman S. L., Gallman R. E., *Long-term factors in American economic growth*, Chicago, University of Chicago Press, 439–556.

FRIDLIZIUS G., 1984, The mortality decline in the first phase of the demographic transition: Swedish experiences, in Bengtsson T., Fridlizius G., Ohlsson R. (eds), *Pre-industrial population change: The mortality decline and short-term population movements*, Stockholm, Almquist and Wiksell International, 71–114.

HINDE A., 2015, Sex differentials in phthisis mortality in England and Wales, 1861–1870, *The History of the Family*, 20(3), 366–390.

HORIUCHI S., WILMOTH J. R., PLETCHER S. D., 2008, A decomposition method based on a model of continuous change, *Demography*, 45(4), 785–801.

HUMAN MORTALITY DATABASE, University of California, Berkeley, and Max Planck Institute for Demographic Research, https://www.mortality.org/

JARNER S. F., KRYGER E. M., DENGSØE C., 2008, The evolution of death rates and life expectancy in Denmark, *Scandinavian Actuarial Journal*, 2–3, 147–173.

JOHANSEN H. C., 1999, The development of reporting systems for causes of deaths in Denmark, *Journal of the History of Medicine and Allied Sciences*, 54(2), 154–166.

JOHANSEN H. C., 2002, *Danish population history, 1600–1939*, Odense, University Press of Southern Denmark.

KIBELE E. U., KLÜSENER S., SCHOLZ R. D., 2015, Regional mortality disparities in Germany: Long-term dynamics and possible determinants, *Kölner Zeitschrift für Soziologie und Sozialpsychologie*, 67(Suppl. 1), 241–270.

KNODEL J., KINTNER H., 1977, The impact of breast feeding patterns on the biometric analysis of infant mortality, *Demography*, 14(4), 391–409.

LØKKE A., 1997, The 'antiseptic' transformation of Danish midwives, 1860–1920, in Marland H., Rafferty A. M., *Midwives, society and childbirth: Debates and controversies in the modern period*, London, Routledge, 102–133.

LØKKE A., 2002, Infant mortality in nineteenth-century Denmark: Regionality, feeding habits, illegitimacy and causes of death, *Hygiea Internationalis*, 3(1), 115–149.

LØKKE A., 2007, State and insurance: The long-term trends in Danish health policy from 1672 to 1973, *Hygiea Internationalis*, 6(1), 7–24.

MCKEOWN T., BROWN R., RECORD R., 1972, An interpretation of the modern rise of population in Europe, *Population Studies*, 26(3), 345–382.

MCKEOWN T., RECORD R., 1962, Reasons for the decline of mortality in England and Wales during the nineteenth century, *Population Studies*, 16(2), 94–122.

MERCER A. J., 1985, Smallpox and epidemiological-demographic change in Europe: The role of vaccination, *Population Studies*, 39(2), 287–307.

MÜHLICHEN M., SCHOLZ R. D., 2015, *Demographic analysis of church records: The case of infant mortality in the Hanseatic City of Rostock in the 19th century*, MPIDR Technical Report TR-2015-002, Rostock, Max Planck Institute for Demographic Research.

OMRAN A. R., 1971, The epidemiologic transition: A theory of the epidemiology of population change, *The Milbank Memorial Fund Quarterly*, 49(4), 509–538.

OEPPEN J., VAUPEL J. W., 2002, Broken limits to life expectancy, *Science*, 296(5570), 1029–1031.

PRESTON S., HEUVELINE P., GUILLOT M., 2001, *Demography: Measuring and modeling population processes*, Oxford, Blackwell.

PRESTON S., VAN DE WALLE, E., 1978, Urban French mortality in the nineteenth century, *Population Studies*, 32(2), 275–297.

RAMIRO-FARIÑAS D., 2007, Mortality in hospitals and mortality in the city in the nineteenth-and twentieth-century Spain: The effect on the measurement of urban mortality rates of the mortality outsiders in urban health institutions, in Henderson J., Horden P., Pastore A. (eds.), *The impact of hospitals, 300–2000*, Bern, Peter Lang, 395–416.

RAZZELL P. E., 1974, 'An interpretation of the modern rise of population in Europe'—a critique, *Population Studies*, 28(1), 5–17.

REID A., 2001, Neonatal mortality and stillbirths in early twentieth-century Derbyshire, England, *Population Studies*, 55(3), 213–232.

REID A., GARRETT E., 2018, Mortality, work and migration. A consideration of age-specific mortality from Tuberculosis in Scotland, 1861–1901, *Historical Life Course Studies*, 6(Special issue 1), 111–132.

RILEY J. C., 2001, *Rising life expectancy: A global history*, Cambridge, Cambridge University Press.

SKÖLD P., 2000, The key to success: The role of local government in the organization of smallpox vaccination in Sweden, *Medical History*, 44(2), 201–226.

SZRETER S., 1988, The importance of social intervention in Britain's mortality decline c. 1850–1914: A re-interpretation of the role of public health, *Social History of Medicine*, 1(1), 1–38.

THELLE M., 2018, The Meat City: Urban space and provision in industrial Copenhagen, 1880–1914, *Urban History*, 45(2), 233–252.

TORRES C., 2019, Research note: Infant mortality in Denmark from 1835 to 1854 using the Human Mortality Database, *SocArXiv*, doi:10.31235/osf.io/guq6r.

TORRES C., CANUDAS-ROMO V., OEPPEN J., 2019, The contribution of urbanization to changes in life expectancy in Scotland, 1861–1910, *Population Studies*, 73(3), 387–404.

TORRES C., OEPPEN J., 2019, *The health transition in the Nordic Countries* (Working Paper).

VALLIN J., 1991, Mortality in Europe from 1720 to 1914: Long-term trends and changes in patterns by age and sex, in Schoefield R., Reher D., Bideau A. (eds.), *The decline of mortality in Europe*, Oxford, Clarendon Press, 38–67.

VALLIN J., MESLÉ F., 2009, The segmented trend line of highest life expectancies, *Population and Development Review*, 35(1), 159–187.

VALLIN J., MESLÉ F., 2010, Will life expectancy increase indefinitely by three months every year? *Population & Societies*, 473, December.

WILLIAMS N., GALLEY C., 1995, Urban-rural differentials in infant mortality in Victorian England, *Population Studies*, 49(3), 401–420.

Wilmoth J. R., Andreev K., Jdanov D., Glei D. A., Riffe T., 2017, *Methods protocol for the Human Mortality Database (Version 6)*, University of California, Berkeley, and Max Planck Institute for Demographic Research.

Woods R., 2000, *The demography of Victorian England and Wales*, Cambridge, Cambridge University Press.

Woods R., Løkke A., van Poppel F., 2006, Two hundred years of evidence-based perinatal care: Late-fetal mortality in the past, *Archives of Disease in Childhood-Fetal and Neonatal Edition*, 91(6), F445–F447.

Catalina TORRES • **EXPLORING THE URBAN PENALTY IN LIFE EXPECTANCY DURING THE HEALTH TRANSITION IN DENMARK, 1850–1910**

During the 19th century, Denmark experienced rapid urban population growth amidst deficient sanitary conditions. This study explores the changes in the country's life expectancy from 1850 to 1910 for both the total population and the urban and rural areas, using vital statistics data on deaths. It also examines the contributions by causes of death to the changes in life expectancy in Copenhagen. This analysis shows that in Denmark a new mortality regime began to take shape in the 1890s, marking the passage from relatively slow gains in life expectancy and fluctuating mortality to rapid and sustained improvement, especially in cities. Until the 1880s, such gains were driven mainly by mortality reductions among children aged 1–4. From the 1890s, reductions in infant mortality contributed significantly to further gains. Reductions in mortality from a few (mainly infectious) diseases were responsible for most of the gains observed in Copenhagen. Although declining, the urban–rural gap in life expectancy persisted throughout the period, particularly for men.

Keywords: historical demography, Scandinavian population, Denmark, cause-specific mortality, life expectancy at birth, urban penalty, health transition