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Now and Then

Patterns and Trends from a Regional and Historical Perspective

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SUMMARY

English Summary

As a country that arose from many small states, Germany has always had impressive regional contrasts, which are particularly visible in the study of mortality. Regional gradients in mortality were subject to substantial changes over time. In this context, the German Baltic Sea region is an especially interesting case because it had been a forerunner in longevity in the nineteenth century but has increasingly been left behind in recent decades. This is particularly true for the eastern part of the region: The differences in life expectancy between Mecklenburg-Vorpommern (MV), which belonged to the German Democratic Republic (GDR), and Schleswig-Holstein (SH), which belonged to the former Federal Republic (FRG), had grown considerably during the time of German partition to the disadvantage of the east (MV). In spite of a sharp decline following reunification, this gap has not yet disappeared completely.

In view of such extraordinary changes, the question arises as to which factors determined the regional mortality differences in Germany in past and present, especially with regard to premature deaths. In the Western world, the nineteenth century marks the dawn of the epidemiologic transition when infectious diseases were dominating the cause-of-death spectrum, while recent decades are – as a consequence of this transition – shaped by degenerative diseases, such as cardiovascular and neoplastic diseases. Aside from altered cause-of-death and age distributions, the driving contributory factors to premature mortality have changed as well. Therefore, this doctoral thesis is based on the following underlying research questions. First, were the determinants that influenced premature mortality differentials in the German Baltic Sea region prior to the epidemiologic transition the same like today or completely different? Second, are the factors that supported longevity then still protective now or rather detrimental? Third, which requirements have to be met in this region to regain its former vanguard position? Based on three original research articles, this thesis aims to provide new insights on trends and determinants of premature mortality in the German Baltic Sea region in the nineteenth century prior to the epidemiologic transition (Studies 1 and 2) and in the last stage of this transition in the years following reunification (Study 3).

In general, premature mortality comprises all deaths below a certain age threshold, e.g. 75 years. For a better interpretation and taking account of the given data, this work focuses on certain aspects of premature mortality. Infant mortality is an important component of premature mortality and a widely used indicator for overall mortality and population health (Studies 1 and 2). It is particularly used in historical demographic research as an indicator for premature mortality due to its enormous extent in the nineteenth century and because data for older age groups are often missing in this context. Another concept in the context of premature mortality

is that of 'avoidable mortality' (Study 3). Here, premature deaths can be divided into amenable and preventable (and non-avoidable) deaths in order to assign important structural and risk-relevant factors regarding the effectiveness of health care and health policies to deaths recorded in official cause-of-death statistics.

Study 1 explored the trend of infant mortality in the nineteenth century and the impact of social differences. Using newly available individual-level data from the Hanseatic city of Rostock that has been among the biggest cities of the German Baltic Sea region, it was possible for the first time to conduct multivariate analyses on the impact of social class on infant mortality in a German city in the nineteenth century. Based on the transcribed burial and baptismal registers of Rostock's largest parish (St. Jakobi), the study reveals that the city exhibited an exceedingly low infant mortality level, in particular in the first third of the century, as compared to the rest of Germany. Using event history analyses for the early nineteenth century (1815–1829), the study also shows that the occupation of the father had a significant influence on the risk of dying of a child in the first year of life. Children of fathers in lower ranked occupations exhibited a higher mortality risk in the first year of life than children of fathers in higher ranked occupations. This social gradient was particularly true for the first month of life. However, there was an exception to this pattern with (probably unskilled) laborers showing similarly low infant mortality risks like the upper social class, which suggests that infant care and nutrition are not necessarily determined by socio-economic status.

Study 2 is the only paper so far that analyzed the interplay of social class and cause of death in infant mortality prior to the demographic transition. Based on the baptismal and burial registers of St. Jakobi, Rostock, from the pre-industrial period of 1815–1836 and the period of 1859–1882 when urbanization and industrialization were starting to emerge, the fathers' occupations were classified into three social classes and causes of death were assigned to four groups. Estimating cause-specific infant mortality risks according to social class by means of event history analysis, Study 2 reveals an almost linear social gradient in neonatal and post-neonatal mortality. Since this gradient was driven entirely by gastro-intestinal diseases and was most pronounced in neonatal mortality, it is highly probable that there were severe deficits in nutrition, sanitation and maternal care among the lower social classes even before industrialization (coupled with population growth) led to worsening living conditions. The results may be applicable to urban places in less developed countries currently facing similar sanitary conditions and accelerated population growth. Thus, the results of this work suggest that improvements in nutritional and sanitary conditions can reduce infant mortality from infectious diseases, especially by raising breastfeeding rates and access to clean water.

Study 3 explored the trends and spatial differences in premature mortality at ages 0 to 74 in the German Baltic Sea region in the years following reunification (1990–2011). In general, the

consequences of the German reunification for health and mortality have the unique character of a ‘natural experiment’. Due to the cultural, historical and geographic commonalities, this is even truer for the formerly divided German Baltic Sea region than for overall east-west comparisons. Based on official cause-of-death and population statistics, all deaths that occurred in the populations of MV and SH were assigned to amenable, preventable and ‘non-avoidable’ causes according to a revised classification of ‘avoidable mortality’. MV and SH were both divided into rural and urban areas. Employing decomposition analysis and direct standardization, the changes and differentials in cause-specific death rates without compositional distortions were estimated. The results show that premature mortality has decreased rapidly in the German Baltic Sea region since reunification. This was mainly attributable to a decline of amenable and preventable mortality. In the 1990s in particular, survival improvements were stronger in MV, thus reducing the gap to SH. The sharp fall in amenable mortality in MV in the 1990s mirrors the massive improvements in the medical environment after reunification, while the decline in preventable mortality reflects the improved effectiveness of inter-sectoral health policies in reducing risk-relevant behavior. The remaining differences between the two states relate primarily to men in the rural areas. Thus, the mortality rates in the urban areas of MV and SH have converged but the rural areas of MV still show higher levels of preventable and amenable mortality, at least among men. Overall, the results of Study 3 reveal that the accessibility and quality of medical care in the peripheral areas of MV and the effectiveness of inter-sectoral health policies in primary prevention, especially with regard to men, still have room for improvement.

Referring to the underlying research questions, this thesis demonstrates that both settings – the historical and the contemporary one – are influenced by factors on the micro and macro level. Nonetheless, the role of central determinants has changed over the course of the epidemiologic transition. In less developed settings characterized by accelerated urbanization and no (or poor) access to vaccination and antibiotics, nutrition and sanitation are more decisive factors to premature mortality differentials than in modern industrialized settings where the access to appropriate health care and risk-relevant behavior play a more important role. While the little levels of urbanization and industrialization had a rather protective effect on sanitary and housing conditions prior to the epidemiologic transition, they are now among the main causes for the economic deficit and the higher level of premature mortality in the German Baltic Sea region as compared to the south. In addition, infant mortality has become so small that breastfeeding habits, which were among its central determinants in the nineteenth century, hardly influence regional differences in premature mortality any more. To regain its former vanguard position in longevity, the German Baltic Sea region’s policies need to become more effective in improving structural conditions and in promoting healthier lifestyles, while retaining the existing environmental benefits.

Deutsche Zusammenfassung

Als ein Land, das aus vielen kleinen Staaten hervorging, weist Deutschland bis heute beeindruckende regionale Gegensätze auf, die insbesondere in der Untersuchung der Sterblichkeit sichtbar sind. Regionale Gradienten in der Sterblichkeit erfuhren über die Zeit weitgehende Veränderungen. Der deutsche Ostseeraum ist in diesem Zusammenhang ein besonders interessanter Fall, weil er noch im 19. Jahrhundert ein Vorreiter in der Langlebigkeit war, in den letzten Jahrzehnten aber mehr und mehr abgehängt wurde. Dies gilt vor allem für den östlichen Teil des deutschen Ostseeraums: Die Unterschiede in der Lebenserwartung zwischen Mecklenburg-Vorpommern (MV), das ein Teil der Deutschen Demokratischen Republik (DDR) war, und Schleswig-Holstein (SH), das zum früheren Bundesgebiet (BRD) gehörte, waren während der Zeit der deutschen Teilung beträchtlich gewachsen, zum Nachteil des Ostens (MV). Trotz eines starken Rückgangs nach der Wiedervereinigung ist diese Lücke noch nicht vollständig geschlossen.

Angesichts solch enormer Veränderungen stellt sich die Frage, welche Faktoren die Sterblichkeitsunterschiede in dieser Region bestimmten, gerade in Bezug auf vorzeitige Todesfälle. In der westlichen Welt kennzeichnet das 19. Jahrhundert den Anbruch des epidemiologischen Übergangs, als Infektionskrankheiten noch das Todesursachenspektrum dominierten, während in den letzten Jahrzehnten – als Folge dieses Übergangs – degenerative Krankheiten wie Herz-Kreislauf-Erkrankungen und Neubildungen dominierten. Neben unterschiedlichen Todesursachen- und Altersverteilungen haben sich auch die entscheidenden Einflussfaktoren der vorzeitigen Sterblichkeit gewandelt. Daher basiert diese Doktorarbeit auf den folgenden zugrundeliegenden Forschungsfragen. Erstens, waren die Determinanten, die die Unterschiede in der vorzeitigen Sterblichkeit vor dem epidemiologischen Übergang beeinflussten, die gleichen wie heutzutage oder ganz andere? Zweitens, sind die Faktoren, die die Langlebigkeit damals begünstigten, noch immer protektiv oder eher schädlich? Drittens, welche Voraussetzungen müssen in der Region erfüllt sein, damit sie ihre frühere Vorreiterrolle zurückerlangen kann? Basierend auf drei originalen Forschungsartikeln zielt diese Arbeit darauf ab, neue Erkenntnisse zu den Entwicklungen und Determinanten der vorzeitigen Sterblichkeit im deutschen Ostseeraum zu vermitteln, sowohl für die erste Phase des epidemiologischen Übergangs im 19. Jahrhundert (Studien 1 und 2) als auch für die letzte Phase dieses Übergangs in den Jahren nach der Wiedervereinigung (Studie 3).

Generell umfasst die vorzeitige Sterblichkeit alle Todesfälle unter einer gewissen Altersgrenze, zum Beispiel von 75 Jahren. Zum Zweck einer besseren Interpretation und unter Berücksichtigung der zur Verfügung stehenden Daten konzentriert sich diese Arbeit auf bestimmte Aspekte vorzeitiger Sterblichkeit. Die Säuglingssterblichkeit ist ein wichtiger Bestandteil vorzeitiger Sterblichkeit und ein vielgenutzter Indikator für Sterblichkeit insgesamt und

Bevölkerungsgesundheit (Studien 1 und 2). Sie wird insbesondere in historisch-demografischen Auswertungen als Indikator vorzeitiger Sterblichkeit verwendet, weil ihr Ausmaß im 19. Jahrhundert viel höher war als heute und Daten für höhere Altersgruppen in diesem Zusammenhang oft fehlen. Ein weiteres Konzept vorzeitiger Sterblichkeit ist jenes der ‚vermeidbaren Sterblichkeit' (Studie 3), anhand dessen vorzeitige Todesfälle in medizinisch vermeidbare und präventiv vermeidbare (sowie nicht-vermeidbare) Sterbefälle unterteilt werden können, um den in der amtlichen Todesursachenstatistik erfassten Todesfällen wichtige strukturelle und risikorelevante Faktoren in Bezug auf die Effektivität der medizinischen Versorgung und der Gesundheitspolitik zuzuordnen.

Studie 1 untersuchte die Entwicklung der Säuglingssterblichkeit im 19. Jahrhundert und den Einfluss sozialer Unterschiede. Unter Verwendung neu verfügbarer Individualdaten aus der Hansestadt Rostock, welche zu den größten Städten des deutschen Ostseeraums zählt, war es zum ersten Mal möglich, multivariate Analysen zum Einfluss der sozialen Schicht auf die Säuglingssterblichkeit in einer deutschen Stadt im 19. Jahrhundert durchzuführen. Basierend auf den transkribierten Beerdigungs- und Taufregistern von Rostocks größtem Kirchspiel (St. Jakobi), offenbart die Studie, dass die Stadt ein außerordentlich niedriges Säuglingssterblichkeitsniveau, insbesondere im ersten Drittel des Jahrhunderts, aufwies, verglichen mit dem Rest Deutschlands. Mit Hilfe von Ereignisdatenanalysen für das frühe 19. Jahrhundert (1815–1829) zeigt die Studie zudem, dass der Beruf des Vaters einen signifikanten Einfluss auf das Sterberisiko eines Kindes im ersten Lebensjahr hatte. Kinder von Vätern in niedriger gestellten Berufen wiesen ein höheres Sterberisiko im ersten Lebensjahr auf als Kinder von beruflich höher gestellten Vätern. Dieser soziale Gradient traf vor allem auf den ersten Lebensmonat zu. Es gab jedoch eine Ausnahme in diesem Muster: So wiesen (wahrscheinlich ungelernte) Arbeitsmänner ähnlich niedrige Säuglingssterberisiken auf wie die höhere soziale Schicht, was nahelegt, dass Säuglingsfürsorge und Ernährung nicht notwendigerweise durch sozioökonomischen Status bestimmt werden.

Studie 2 ist bislang der einzige Artikel, der das Zusammenspiel von sozialer Schicht und Todesursache in der Säuglingssterblichkeit analysiert hat. Basierend auf den Tauf- und Beerdigungsregistern von St. Jakobi, Rostock, aus der vorindustriellen Periode 1815–1836 und der Periode 1859–1882, als Urbanisierung und Industrialisierung bereits anfingen zu wirken, wurden die Berufe der Väter in drei soziale Schichten und die Todesursachen in vier Gruppen eingeteilt. Unter Berechnung todesursachenspezifischer Säuglingssterberisiken nach sozialer Schicht mittels Ereignisdatenanalyse offenbart Studie 2 einen nahezu linearen sozialen Gradienten in der neonatalen und postneonatalen Sterblichkeit. Da dieser Gradient gänzlich auf Magen-Darm-Erkrankungen zurückzuführen ist und am stärksten in der neonatalen Mortalität ausgeprägt war, ist es hochwahrscheinlich, dass es ernsthafte Defizite in der

Ernährung, Hygiene und mütterlichen Fürsorge in den niedrigeren sozialen Schichten gab, selbst bevor die Industrialisierung (gepaart mit Bevölkerungswachstum) zu schlechter werdenden Lebensverhältnissen führte. Die Ergebnisse können auf urbane Orte in weniger entwickelten Ländern, die gegenwärtig mit ähnlichen hygienischen Bedingungen und beschleunigtem Bevölkerungswachstum konfrontiert sind, übertragen werden. Demnach legen die Ergebnisse dieser Arbeit nahe, dass Verbesserungen in den Ernährungs- und Hygienebedingungen die Säuglingssterblichkeit durch Infektionskrankheiten senken können, vor allem durch ein Anheben der Stillneigung und des Zugangs zu sauberem Wasser.

Studie 3 untersucht die Entwicklungen und räumlichen Unterschiede in der vorzeitigen Sterblichkeit im Alter 0 bis 74 im deutschen Ostseeraum seit der Wiedervereinigung (1990–2011). Generell haben die Auswirkungen der deutschen Wiedervereinigung auf Gesundheit und Mortalität den einzigartigen Charakter eines ‚natürlichen Experiments'. Aufgrund der kulturellen, historischen und geografischen Gemeinsamkeiten trifft dies noch mehr auf den ehemals geteilten deutschen Ostseeraum zu als auf Ost-West-Vergleiche insgesamt. Basierend auf amtlichen Todesursachen- und Bevölkerungsstatistiken wurden alle Sterbefälle, die in den Bevölkerungen von MV und SH verzeichnet wurden, in medizinisch vermeidbare, präventiv vermeidbare und ‚nicht-vermeidbare' Ursachen gemäß einer überarbeiteten Klassifikation von ‚vermeidbarer Sterblichkeit' eingeteilt. MV und SH wurden jeweils in Stadt und Land aufgeteilt. Unter Verwendung von Dekompositionsanalysen und direkter Standardisierung wurden die Veränderungen und Unterschiede in den todesursachenspezifischen Sterberaten ohne kompositionsbedingte Verzerrungen berechnet. Die Ergebnisse zeigen, dass die vorzeitige Sterblichkeit im deutschen Ostseeraum seit der Wiedervereinigung stark zurückgegangen ist. Dies ist weitgehend auf eine Verringerung von medizinisch und präventiv vermeidbarer Sterblichkeit zurückzuführen. Insbesondere in den 1990er Jahren waren Überlebensfortschritte in MV stärker, was somit zu einer Verkleinerung der Lücke zu SH führte. Der starke Rückgang in der medizinisch vermeidbaren Sterblichkeit in MV in den 1990er Jahren spiegelt die massiven Verbesserungen in der medizinischen Infrastruktur nach der Wiedervereinigung wider, während die Abnahme der präventiv vermeidbaren Sterblichkeit die verbesserte Effektivität bereichsübergreifender Gesundheitspolitik in der Verringerung risikorelevanten Verhaltens reflektiert. Die verbleibenden Unterschiede zwischen den zwei Bundesländern beziehen sich in erster Linie auf Männer in den ländlichen Gebieten. So haben sich die Sterberaten in den städtischen Gebieten von MV und SH angeglichen, aber die ländlichen Regionen von MV weisen immer noch höhere Raten medizinisch und präventiv vermeidbarer Sterblichkeit auf, zumindest bei den Männern. Insgesamt zeigen die Ergebnisse von Studie 3, dass die Erreichbarkeit und Qualität medizinischer Versorgung und die Effektivität bereichsübergreifender Gesundheitspolitik in der primären Prävention, vor allem in Bezug auf Männer, noch Verbesserungsspielraum haben.

In Bezug auf die zugrundeliegenden Forschungsfragen veranschaulicht diese Arbeit, dass beide Untersuchungsfelder – das historische und das gegenwärtige – durch Faktoren auf der Mikro- und Makroebene beeinflusst werden. Gleichwohl hat sich die Rolle der zentralen Determinanten im Laufe des epidemiologischen Übergangs gewandelt. In weniger entwickelten Umgebungen, die durch beschleunigte Urbanisierung und geringen (oder keinen) Zugang zu Impfungen und Antibiotika gekennzeichnet sind, sind Ernährung und Hygienebedingungen entscheidendere Faktoren für Unterschiede in der vorzeitigen Sterblichkeit als in modernen industrialisierten Umfeldern, wo der Zugang zu adäquater medizinischer Versorgung und risikorelevantes Verhalten eine wichtigere Rolle spielen. Während die geringen Urbanisierungs- und Industrialisierungsgrade vor dem epidemiologischen Übergang eine vergleichsweise protektive Wirkung auf Hygiene- und Wohnbedingungen hatten, gehören sie inzwischen zu den Hauptursachen für das ökonomische Defizit und das höhere Niveau vorzeitiger Sterblichkeit im deutschen Ostseeraum verglichen mit dem Süden. Des Weiteren ist die Säuglingssterblichkeit so gering geworden, dass Stillgewohnheiten, welche im 19. Jahrhundert zu ihren zentralen Determinanten zählten, inzwischen kaum noch einen Einfluss auf regionale Unterschiede in der vorzeitigen Sterblichkeit haben. Um die frühere Vorreiterrolle in der Langlebigkeit zurückzuerlangen, müssen politische Maßnahmen im deutschen Ostseeraum effektiver darin werden, die strukturellen Bedingungen der Region zu verbessern und gesündere Lebensstile zu fördern, und dabei die vorhandenen ökologischen Vorteile zu erhalten.

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LIST OF ABBREVIATIONS

AIDS	Acquired immunodeficiency syndrome
BA	Bundesagentur für Arbeit [Federal Employment Agency]
COPD	Chronic obstructive pulmonary disease
DESTATIS	Statistisches Bundesamt [Federal Statistical Office]
FRG	Federal Republic of Germany
GDR	German Democratic Republic
HAART	Highly active antiretroviral therapy
HISCO	Historical International Standard Classification of Occupations
HISCLASS	Historical International Social Class Scheme
HIV	Human immunodeficiency virus
HMD	Human Mortality Database
HR	Hazard ratio
ICD	International Classification of Diseases
IMR	Infant mortality rate
INKAR	Indikatoren und Karten zur Raum- und Stadtentwicklung
LUNG	Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern
MV	Mecklenburg-Vorpommern
NAPP	North Atlantic Population Project
ONS	Office for National Statistics (United Kingdom)
RAPHIS	Rostock Archive of Historical Vital Statistics Micro Data
RKI	Robert Koch Institute
SDR	Standardized death rate
SH	Schleswig-Holstein

LIST OF STUDIES

Study 1:

Mühlichen, M.; Scholz, R. D.; Doblhammer, G. (2015): Social Differences in Infant Mortality in 19th Century Rostock: A Demographic Analysis Based on Church Records. *Comparative Population Studies* 40(2): 191–216.

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Study 2:

Mühlichen, M.; Doblhammer, G. (2019): Social Differences in Cause-Specific Infant Mortality at the Dawn of the First Demographic Transition: New Insights from German Church Records. Manuscript currently under review.

Contributions: Michael Mühlichen designed the study, prepared the data, conducted the analyses and wrote the first draft of the manuscript. Gabriele Doblhammer helped in the study design and revised the manuscript. Both authors read and approved the final manuscript.

Study 3:

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1. INTRODUCTION

As a country that arose from many small states, Germany has always had impressive regional contrasts, which are particularly visible in the study of mortality. Over the course of the last 200 years, Germany's spatial mortality gradients have experienced strong variations. The German Baltic Sea region is a particularly interesting case in this context because it had been a forerunner in longevity in the nineteenth century but has increasingly been left behind in recent decades, as gains in life expectancy have been more pronounced in the south (Dippe 1857; Würzburg 1887, 1888; Gehrmann 2000, 2011; Kibele et al. 2015). Thus, the German Baltic Sea region fell from top to bottom between the first and the last stage of the epidemiologic transition in the German regional mortality ranking. This is especially true for the eastern part of the German Baltic Sea region: The differences in life expectancy between Mecklenburg-Vorpommern (MV), which belonged to the German Democratic Republic (GDR), and Schleswig-Holstein (SH), which belonged to the former Federal Republic (FRG), had grown considerably during the time of German partition to the disadvantage of MV in the east (Kibele 2012; Kibele et al. 2015). Although the differences between the two states have been decreasing again since the German reunification in 1990, this gap has not yet disappeared completely, at least not among men (Kibele 2012; Kibele et al. 2015; DESTATIS 2019).

In view of such extraordinary changes, the question arises as to which factors determined the mortality differentials in this region, especially with regard to premature deaths. Based on three original research articles, this doctoral thesis aims to provide new insights on trends and determinants of premature mortality in the German Baltic Sea region in the nineteenth century (Studies 1 and 2) and in the time following reunification (Study 3), hereby focusing on three underlying research questions. First, were the determinants that influenced premature mortality differentials in the German Baltic Sea region prior to the epidemiologic transition the same like today or completely different? Second, are the factors that supported longevity then, e.g. the rather small levels of urbanization and industrialization, still supportive now or rather detrimental? Third, which requirements have to be met in this region to regain its former vanguard position?

As a popular recreational and holiday destination, the region actually possesses a number of factors that are conducive to living a long life, e.g. good air quality, seaside location, many lakes and forests (LUNG 2017). Possible reasons for the lower life expectancy today, especially in MV, include socio-economic and structural conditions, risk-relevant behavior as well as selective migration following reunification and poorer living conditions during the GDR era (Dinkel 2003, 2004).

The differences between the historical and contemporary mortality patterns can be seen in the light of the epidemiologic transition theory, which describes four stages of the shift from infectious to degenerative diseases as the dominating cause-of-death group and from younger to older ages (Omran 1998). While infant mortality varied roughly between 10 and 40 % in the German regions in the nineteenth century (Gehrmann 2011), it has lost its impact on life expectancy in the course of the twentieth century, amounting to less than 1 % today in all German regions (DESTATIS 2018). By extending the age range of premature mortality to 0–74, however, the dimension becomes very similar: According to the recent German life table (DESTATIS 2019), 32 % among men and 19 % among women did not experience their 75th birthday in 2016/2018.

With different age and cause-of-death patterns involved, the meaning and determinants of premature mortality have changed considerably. Therefore, premature mortality in the nineteenth century can be broached by measuring infant mortality, not only because of its enormous extent in this time but also due to the lack of data for older ages. The only transcribed historical individual-level data for the German Baltic Sea region are available at the RAPHIS (2016) database and include births and deaths with information on cause of death and social status – which are essential to estimate the impact of central contributory factors – for the Hanseatic city of Rostock, which is among the biggest cities in this region. With regard to contemporary data, premature mortality can be measured by cause of death for a wider age range (0–74) by using official cause-of-death statistics. To estimate the impact of structural and risk-relevant factors in premature mortality, the concept of 'avoidable mortality' provides a suitable basis.

Therefore, the objective of this work is to gain new insights on the determinants of premature mortality in the German Baltic Sea region, using two different concepts and two different data sets in two different times. Studies 1 and 2 focus on infant mortality in the city of Rostock during the first stage of the epidemiologic transition, with Study 1 exploring the trend of infant mortality and the impact of social differences and Study 2 addressing the interplay of causes of death and social class. Study 3 deals with spatial differences in the development of avoidable mortality in the German Baltic Sea region in the fourth stage of the epidemiologic transition since reunification.

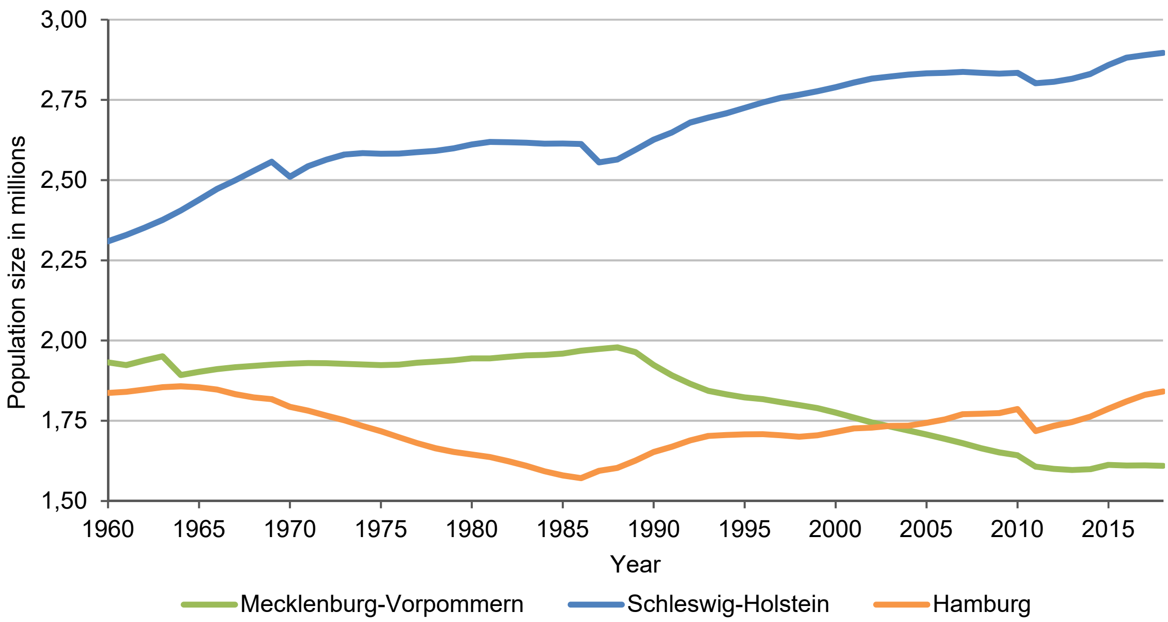
2. BACKGROUND

2.1 The German Baltic Sea Region and the City of Rostock

The two federal states that constitute the German Baltic Sea region – namely Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH) – are characterized by agriculture, tourism and lacking economic development and share a similar mentality, culture and language shaped by the Hanseatic era and centuries of Protestant tradition. Today, the two states share a common administrative unit within the framework of several federal institutions, and the south of SH and the west of MV belong to the Hamburg metropolitan region (Eltges 2014). The cooperation between the two states in economic, cultural and political terms stretches back as far as the middle of the thirteenth century with the Wendish City League of Lübeck, Stralsund, Wismar, Kiel and Rostock marking an important milestone in the development of the Hanseatic League (Dollinger 1970).

Since MV belonged to the German Democratic Republic (GDR) and SH was part of the former Federal Republic (FRG), the German Baltic Sea region is an east-west spanning region that shows geographic, cultural, historical and structural commonalities that are unique for a formerly divided and reunified region. These commonalities cannot be found to the same extent in overall east-west comparisons. Research on the question of whether these political changes had an impact on mortality trends can be seen as a natural experiment (Vaupel et al. 2003; Vogt and Vaupel 2015).

Figure 1 Population development (in millions) in Mecklenburg-Vorpommern, Schleswig-Holstein and Hamburg, 1960–2018

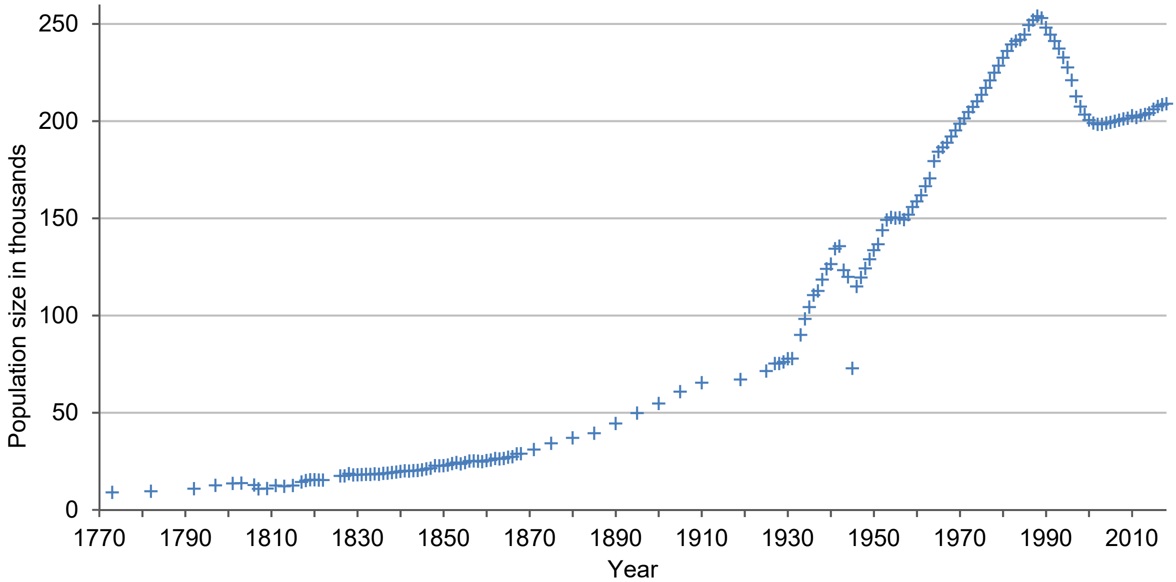


Source: Federal Statistical Office (for SH and HH); Statistical Office of Mecklenburg-Vorpommern (for MV).

Figure 1 illustrates the diverse population developments in MV, SH and the neighboring city of Hamburg, with MV's population size widely decreasing over the last decades, most pronouncedly in the 1990s, and SH and particularly Hamburg continually growing.

Rostock is the biggest and economically most important city of MV and among the largest cities on the German Baltic coast along with Kiel and Lübeck. It was one of the earliest and most influential members of the Hanseatic League (Dollinger 1970; Münch 2013). As a port city, it is shaped by trade and seafaring but also by its university, which is among the oldest in Central and Northern Europe (Manke 2000; Münch 2013). Following its origins in the twelfth century, Rostock experienced times of prosperity and growth as well as times of crisis (Schröder 2013), with its population size varying between 5,000 and 15,000 for centuries.[1] As Figure 2 shows, it was not until the early nineteenth century when Rostock's population started to grow increasingly – accelerated from the 1850s by industrialization and urbanization (Manke 2000; Scholz 2013) and interrupted by the two world wars – reaching a maximum of 254,000 inhabitants in 1988. Following the fall of the Berlin Wall, Rostock's population declined considerably because of emigration and suburbanization but started to grow again from 2003 onwards, reaching roughly 209,000 inhabitants at the end of 2018.

Figure 2 Population development (in thousands) in Rostock, 1773–2018



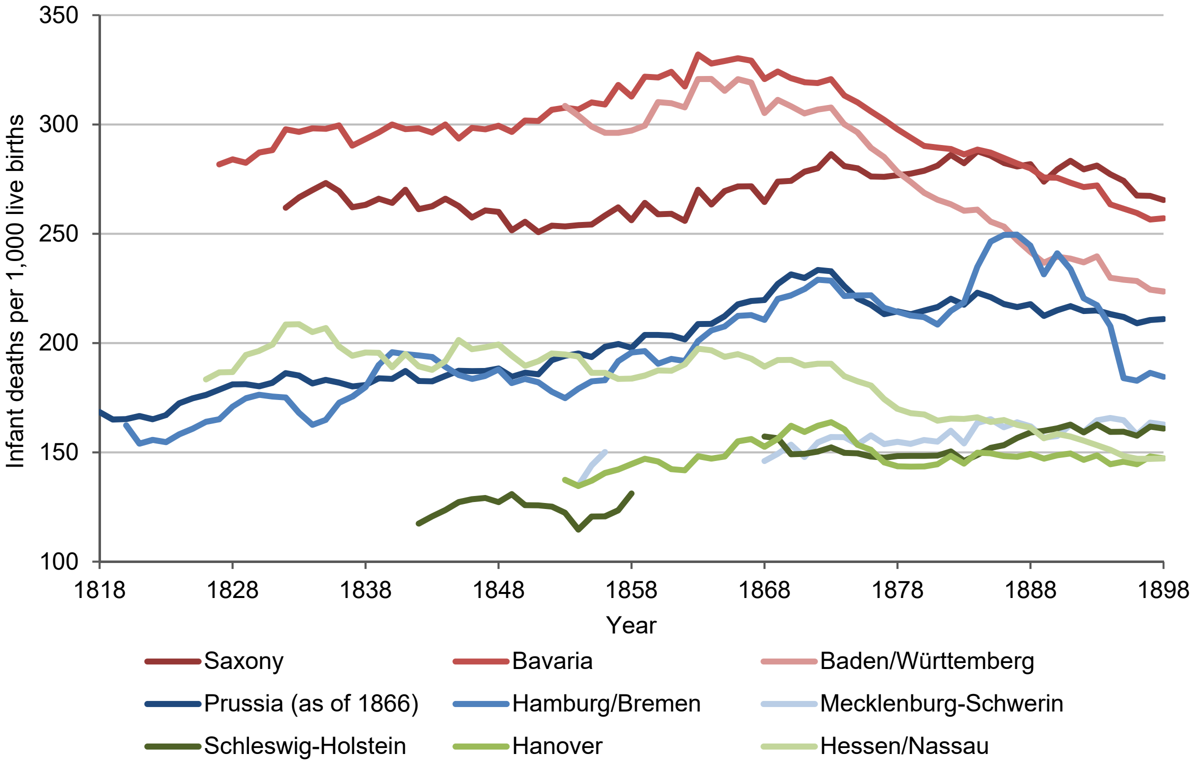
Source: Local statistical office of the Hanseatic City of Rostock; Mecklenburg-Schwerin State Calendar.

[1] The population numbers were obtained from the Local statistical office of the Hanseatic city of Rostock.

2.2 Development of Regional Mortality Differences in Germany

Analyses of regional differences in mortality in the nineteenth century usually focus on infant mortality because other age-specific numbers on deaths and population size have not been published so far for Germany on a regional level. However, overall mortality was influenced considerably by infant mortality because of the comparatively high number of infant deaths in the nineteenth century (Würzburg 1887, 1888; Gehrmann 2000, 2011). In contrast to present-day Germany, the spatial distribution of infant mortality was very heterogeneous then, as shown in Figure 3. There was a clear northwest-to-southeast divide in Germany with the northwest showing the lowest rates (Würzburg 1887, 1888; Prinzing 1899, 1900; Imhof 1981; Gehrmann 2011).[2] Previous research found comparatively low mortality levels for the coastal regions in northern Germany, particularly for Schleswig-Holstein, Mecklenburg and Lower Saxony (Dippe 1857; Würzburg 1887, 1888; Prinzing 1900; Gehrmann 2000, 2011; Toch et al. 2011). Generally, northern Germany's infant mortality rates in the nineteenth century were comparable to Sweden and Great Britain and fluctuated between 10 and 20 %, whereas infant mortality amounted to more than 30 % in wide parts of southern Germany (Mitchell 2007; Gehrmann 2011).

Figure 3 Infant mortality rate in German regions (five-year values), 1818–1898



Source: Author's calculations based on Gehrmann (2002, 2011).

[2] Comparable infant mortality data for all regions of the former German Empire only exist as from the last quarter of the nineteenth century. See Gehrmann (2011) for more details on the available data for the German regions.

Infant mortality in Rostock in the late nineteenth and early twentieth centuries was slightly higher in comparison to the rural areas of Mecklenburg but still lower than in most German regions (Prinzing 1900; Brüning and Balck 1906; Paulsen 1909).

The earliest regional analysis of life expectancy in Germany was performed by Kibele et al. (2015) for the period of 1910/1911, showing the highest levels in Schleswig-Holstein, Mecklenburg and parts of present-day Lower Saxony, Hessen and Thuringia. As in infant mortality, the northwest-to-southeast divide was the dominant pattern in life expectancy in this time. By 1970, however, the pattern had become much more diverse, and Schleswig-Holstein had lost its top position to Baden-Württemberg (Sommer 2002; Kibele et al. 2015). The higher gains in life expectancy in the south than in the north have paved the way for the reversed north-south gradient, which has become the dominating mortality pattern in both western and eastern Germany (Table 1).

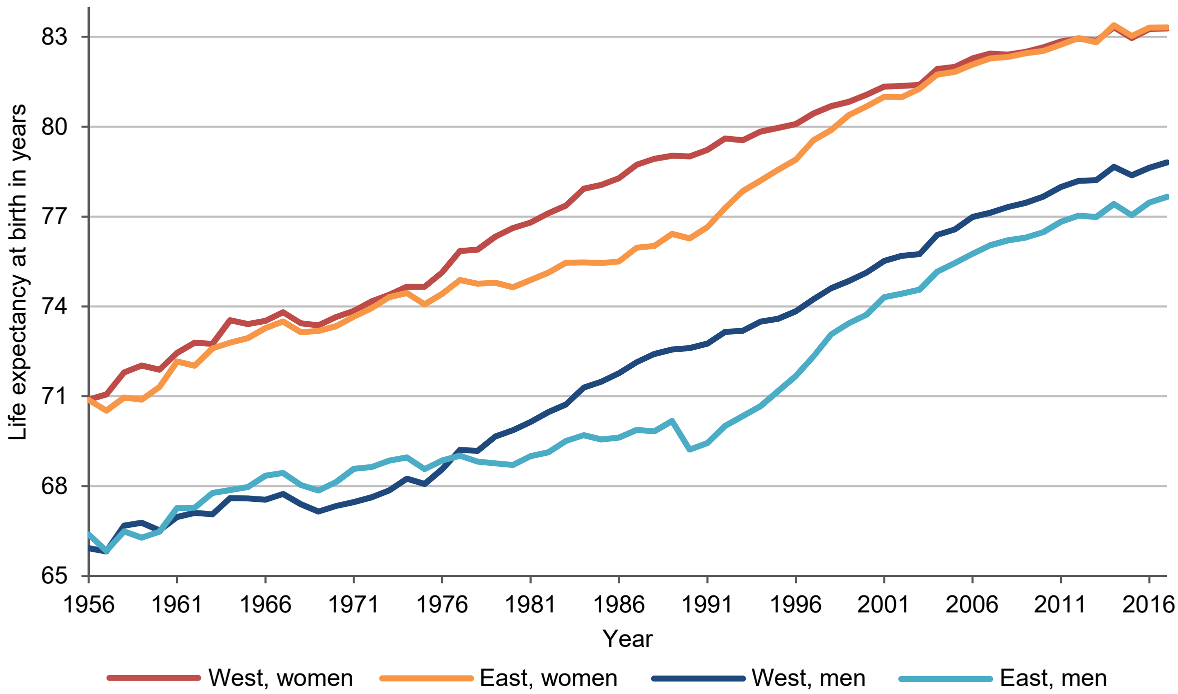
Table 1 Average life expectancy at birth by federal state and sex in Germany

Federal state	Men				Women			
	1982/84	1990/92	2000/02	2016/18	1982/84	1990/92	2000/02	2016/18
Baden-Württemberg	72.02	73.88	76.79	79.66	78.41	80.10	82.27	84.10
Bavaria	71.07	73.18	75.96	79.33	77.60	79.45	81.64	83.79
Berlin	68.62	70.94	75.24	78.30	75.28	77.35	81.09	83.19
Brandenburg	68.92	68.85	74.08	77.76	75.18	76.56	80.83	83.26
Bremen	70.28	72.29	74.67	77.18	77.66	79.03	80.80	82.47
Hamburg	70.45	72.35	75.68	78.53	77.25	79.26	81.38	83.37
Hessen	71.52	73.44	76.20	79.15	77.84	79.65	81.57	83.49
Lower Saxony	71.10	73.02	75.39	78.11	77.80	79.54	81.24	82.82
Mecklenburg-Vorp.	68.33	67.84	73.14	76.76	75.12	76.05	80.52	83.14
Northrhine-Westphalia	70.40	72.57	75.34	78.17	77.20	79.15	80.97	82.76
Rhineland-Palatinate	70.59	72.80	75.59	78.62	77.16	79.15	81.25	83.06
Saarland	69.55	71.70	74.44	77.62	76.47	78.44	80.35	82.14
Saxony		70.42	74.85	77.97		77.21	81.50	83.91
Saxony-Anhalt	68.41	68.94	73.34	76.28	73.59	76.34	80.31	82.63
Schleswig-Holstein	71.30	73.11	75.60	78.18	77.63	79.24	81.23	82.78
Thuringia	69.58	70.05	74.43	77.44	75.18	76.85	80.73	83.02
Germany		72.12	75.38	78.48		78.69	81.22	83.27

Source: Period life tables by Kibele (2012) for 1982/84–2000/02; DESTATIS (2019) for 2016/18 and total Germany.

From the 1970s, eastern Germany had increasingly fallen behind the west as regards average life expectancy. By 1990, the difference between eastern and western Germany had grown to 3.4 years (Figure 4). This east-west gradient has been decreasing since reunification. It has completely disappeared among women but it was still evident among men in 2017 (1.15 years). This is also true for the German Baltic Sea region, with men still showing an east-west divide of 1.41 years to the disadvantage of Mecklenburg-Vorpommern compared to Schleswig-Holstein, whereas among women, life expectancy has become slightly higher in Mecklenburg-Vorpommern (0.1 years in 2015/2017), as shown in Table 1. In addition, there are urban-rural gradients in Germany which are directed to the favor of the rural areas in western Germany but to the favor of the urban areas in the east (Kibele 2012).

Figure 4 Average life expectancy at birth in eastern and western Germany, 1956–2017



Source: Period life tables of the Human Mortality Database (HMD 2019).

The mortality development in Germany since the nineteenth century reflects the four stages of the epidemiologic transition theory from infectious to degenerative diseases as the dominating cause-of-death group (Omran 1971, 1998). The decrease of mortality from infectious diseases, especially at childhood age, largely contributed to the increase in life expectancy in the first half of the twentieth century and was widely achieved by public health campaigns that promoted sanitary, housing and working conditions and breastfeeding rates (Omran 1971, 1998; Vallin and Meslé 2001). Medical interventions, such as surgical innovations and the supply of vaccination and antibiotics, also contributed to this decrease, especially after 1930 (Omran 1971, 1998). From the 1970s, innovations in the treatment of chronic diseases have contributed to the continued fall in mortality, in particular in connection with cardiovascular diseases and (middle and older) adult age, supported by changes in health-related lifestyles (Omran 1998; Vallin and Meslé 2001).

Thus, the two periods of observation in this doctoral thesis reflect two different stages – the first and the fourth – of the epidemiologic transition with varying cause-of-death regimes, age patterns and mortality determinants (Omran 1998). In the nineteenth century, high values of infant and child mortality contributed to the low levels of life expectancy, whereas mortality has increasingly shifted to older ages ever since (Omran 1998; Vallin and Meslé 2001). For this reason, we chose two different approaches for our two study periods to estimate premature mortality.

2.3 Determinants of Avoidable Mortality

In general, premature mortality comprises all deaths below a certain age limit. This threshold is usually set at 65, 70 or 75 years of age in contemporary analyses (e.g. Wells and Gordon 2008; Shiels et al. 2017; Plümper et al. 2018). However, most works rather focus on certain aspects of premature mortality that are better interpretable. Therefore, many studies use the concept of 'avoidable mortality', which was first developed by Rutstein et al. (1976), to assign premature deaths to amenable and preventable deaths based on the International Classification of Diseases (ICD).

Amenable mortality comprises causes of death that could be avoided though timely and effective health care, whereas preventable mortality includes causes of death that could be avoided through primary prevention in terms of effective inter-sectoral health policies (Nolte et al. 2002; Page et al. 2006; ONS 2011). Extensive levels of amenable mortality point to structural deficits in terms of the accessibility and quality of health care, whereas high rates of preventable mortality indicate deficits in the effectiveness of inter-sectoral health policies in reducing risk-relevant behavior, particularly smoking, alcohol abuse and dangerous driving through primary prevention (Nolte et al. 2002; Page et al. 2006). Therefore, the concept of avoidable mortality broaches structural and risk-relevant factors of mortality.

Structural factors play an important part in mortality differences between eastern and western Germany. Aside from political, economic and social differences, two different health systems developed during German partition (1949 to 1990), with medical technology in the GDR becoming increasingly antiquated in comparison to the FRG (Dinkel 2003; Gjonça et al. 2000; Luy 2004a, 2004b). Consequently, the difference in life expectancy between eastern and western Germany had grown from the 1970s until reunification but has been decreasing ever since. The remaining east-west gap is associated with avoidable mortality (Nolte et al. 2002; Kibele and Scholz 2009; Sundmacher et al. 2011; Kibele 2012). Structural factors also play a principal role in urban-rural gaps in eastern Germany. In the east, overall mortality in urban districts is lower than in rural districts but the opposite is true for the west (Kibele 2012). This contrast also applies to the German Baltic Sea region. The disadvantage of the rural areas in MV is particularly connected with cardiovascular diseases, whereas the disadvantage of the urban areas in SH is connected with neoplasms (Müller and Kück 1998; Heitmann et al. 2001; Kibele 2012; Mühlichen 2014, 2015). This east-west contrast originated from differences in spatial planning during the period of German partition. The west was committed to achieving regional equality of living conditions in accordance with its constitution, whereas spatial planning in the east concentrated on the central cities, which benefited from better medical care and selective immigration (Werner 1985; Bucher 2002; Mai 2004). As a long-term consequence, most urban areas in eastern Germany still show better working and structural conditions and thus attract immigrants with ‘good risks’ from the rural areas, which even further enhances the urban-rural contrast (Sander 2014).

Risk-relevant factors include smoking, alcohol abuse, unhealthy nutrition, low levels of physical activity and dangerous driving. Previous research has found relatively high rates of smoking, alcohol consumption, fatal traffic accidents and obesity and a lack of sporting activity in MV compared to other German federal states (Mons 2011; RKI 2011; DESTATIS 2017). Even though traffic accident mortality has been declining in MV since 1990, it is still significantly higher than in SH and most other German states, which is most likely a consequence of the many narrow tree-lined roads in the rural areas of MV which make dangerous driving even more dangerous (Dinkel 2003; DESTATIS 2017). Moreover, men in MV reported more often than in other federal states that they suffered from unhealthy working conditions, based on a survey by RKI (2011). In SH and Hamburg, women showed relatively high rates of smoking and alcohol consumption, whereas the rates for men were below the German average (Mons 2011; RKI 2011). As a result, previous research has found high rates of alcohol and tobacco-related mortality among men in MV and among women in SH (Mons 2011; Kibele 2012).

In general, determinants of mortality can be divided into micro-level (individual-level) and macro-level (contextual) components (Kibele et al. 2015). The concept of avoidable mortality addresses both contextual (structural) and individual-level (risk-relevant) factors. However, mortality rates may also differ by other micro-level factors like socio-economic status, migration biography and early life circumstances (Boyle 2004; Doblhammer 2004; Kibele and Janssen 2013; Grigoriev et al. 2019). However, given that German cause-of-death statistics offer no insight into these factors and linkages to other data sources are not possible to date on the individual level, the influence of these variables on avoidable mortality cannot be measured at present. Macro-level factors like socio-economic, housing and ecological conditions were found to have an influence on regional differences in overall mortality (Morgenstern 1995; Valkonen 2001; Kibele 2012). In addition, regional variations in religious norms and breastfeeding habits affected mortality outcomes in historical settings (van Poppel 1992), which is addressed in the following section. Previous studies on avoidable mortality in Germany explored east-west differences (Nolte et al. 2002; Kibele and Scholz 2009) and cross-sectional differences at the district level (Sundmacher et al. 2011; Kibele 2012). However, long-term trends have not been estimated for Germany at a regional level yet.

Therefore, we aimed to close this research gap, using the east-west spanning German Baltic Sea region, which is – as opposed to overall east-west comparisons – not affected by the north-south gradient in German mortality, thus providing a clearer view of (avoidable) east-west differences. Doing this, we took account of urban-rural differences to gain a deeper understanding of where convergence has already taken place and where this has not been the case yet.

2.4 Determinants of Infant Mortality

Infant mortality is another aspect of premature mortality. It is a widely used indicator for mortality and population health (Masuy-Stroobant and Gourbin 1995; Reidpath and Allotey 2003; Gonzalez and Gilleskie 2017). Its decrease in many industrial countries from the late nineteenth century onwards was among the driving factors of the increased life expectancy and, hence, of the first demographic transition (Schofield et al. 1991; Chesnais 1992; Kirk 1996).

The determinants of infant mortality before this transition have long been among the core issues of historical demographic research. One of the reasons for this is that a number of less developed countries are currently facing poor sanitary conditions arising from urbanization, similar to those which industrial countries faced prior to the first demographic transition (Pozzi and Ramiro Fariñas 2015). The determinants are complex and manifold and reach far beyond the field of demography (Ehmer 2004: 92–94). Generally speaking, the determinants can be divided into endogenous and exogenous components (Bourgeois-Pichat 1951).

Endogenous Factors

In the context of infant mortality, endogenous factors refer to biological conditions that determine the infant's constitution at birth, such as birth weight, fetal age at birth (gestation week) and congenital anomalies, and are usually related to neonatal deaths (in the first 28 days of life) (Bourgeois-Pichat 1951; Imhof 1981; Knodel and Hermalin 1984; Breschi et al. 2000; Reid 2001; van Poppel et al. 2005).

A common cause of neonatal deaths in nineteenth-century Germany was called 'Schwäche', which can be translated as 'weakness' or 'wasting' and was often used synonymously with 'Auszehrung' (cachexia) (Vögele 1994; Lee and Marschalck 2002). One of the main risk factors is a low birth weight, which is closely related to an early gestation week but also influenced by maternal age at childbirth, poor harvest yields, birth rank and birth spacing (Würzburg 1888; Imhof 1981; Knodel and Hermalin 1984; Knodel 1988; Kloke 1997).

Exogenous Factors

Exogenous factors are associated with environmental conditions originating in the post-natal period, such as nutrition, sanitation/hygiene, accidents as well as social, economic, environmental and climatic conditions, and are more closely linked with post-neonatal infant deaths (Bourgeois-Pichat 1951; Imhof 1981; Breschi et al. 2000; Reid 2002; van Poppel et al. 2005).

Social and economic factors have received the biggest attention in the context of historical infant mortality because many historical sources such as church records included the father's occupation and legitimacy of birth, whereas other variables were usually not recorded on the individual level. The impact of social class in this context has long been debated in research, not only regarding the question of whether a social gradient exists in infant mortality but also regarding the direction of such a gradient. Some studies found no socio-economic effect (e.g. Knodel 1988; Bengtsson 1999), while others found a lower infant mortality level among the upper social classes (e.g. Woods et al. 1988, 1989; Derosas 2003; van Poppel et al. 2005; Molitoris 2017), and again others saw the lower classes benefiting most from the wider practice of breastfeeding compared to the upper classes in some places (e.g. Imhof 1984; Kloke 1997).

This contrast makes clear that the results depend on place and time and on the chosen occupational classification. Moreover, many authors argued that the socio-economic status only has an indirect impact on infant mortality, since breastfeeding (as a protective factor for infant survival) as well as the quality of food, care, personal hygiene and sanitary conditions may differ between social groups (Hanssen 1912; Imhof 1981; Haines 1995; Scott and Duncan 2000; Gehrmann 2011; Ekamper and van Poppel 2019). According to Kloke (1997), differences between regions and groups in infant mortality were significantly influenced by differences in breastfeeding habits. Preston and Haines (1991: 209) concluded that knowledge (in terms of nutrition and care) outweighs resources.

With regard to birth legitimacy, most authors found a higher risk of infant death among children born out of wedlock than for legitimate children in the nineteenth century (e.g. Prinzing 1900, 1902; Imhof 1981; Woods et al. 1988, 1989; Preston and Haines 1991; Kloke 1997). Although some of the unmarried women later legitimized the birth through marriage, they were a minority in Germany in the late nineteenth century (Prinzing 1902). The reason for the higher infant mortality rate among illegitimate infants has been described as a lack of care and breastfeeding caused by the comparatively unfavorable financial situation that forced mothers to go to work and leave the child in the care of confidants or an institution (Preston and Haines 1991: 30; Vögele 1994). Thus, the legitimacy of birth had only an indirect effect but it influenced nutritional and hygienic conditions (Spree 1988; Kintner 1994).

The impact of exogenous factors differed by cause of death. The spectrum of causes was dominated by infectious diseases and epidemics in the time prior to the epidemiologic transition (Omran 1971, 1998). The most common causes related to exogenous factors were gastro-intestinal and respiratory infections.

Gastro-intestinal diseases constituted the most frequent cause-of-death group among infants in nineteenth-century Germany, accounting for up to 70 % of the cause-of-death spectrum in some regions (Vögele 1994). Gastro-intestinal diseases such as ‘convulsions’, stomach disorder, cholera and diarrhea were particularly prevalent in urbanizing and industrializing cities (Woods et al. 1988; Vögele 1994). The decrease in infant mortality in Germany from the late nineteenth century is closely linked to improved sanitary, nutritional and housing conditions in the cities, and to public health campaigns aimed at promoting breastfeeding (Imhof 1981; Kintner 1986; Vögele 1994; Vögele and Woelk 2002). Gastro-intestinal diseases peaked in the summer season because substitute nutrition was more likely to perish and sanitary conditions were worse in the warm months of the year, especially in the urban areas (Würzburg 1891; Prausnitz 1901; Gottstein 1935; Knodel 1988: 62; Woods et al. 1988, 1989; Gehrmann 2002). Thus, the extent of gastro-intestinal diseases was associated with the question of whether or not a mother breastfed her child. Unmarried mothers and mothers who were extensively involved in their husband’s work (e.g. on a farm) had less time to care for their children and were more likely to use substitute nutrition (Imhof 1981; Preston and Haines 1991: 30; Vögele 1994). However, breastfeeding practices also differed by region and thus gave rise to spatial differences in infant mortality (Bluhm 1912; Knodel and Kintner 1977; Kintner 1985; Kloke 1997).

Respiratory diseases such as ‘breast disease’, pneumonia, bronchitis and whooping cough were particularly prevalent in cities with poor housing and living conditions (Lee and Marschalck 2002). As opposed to gastro-intestinal diseases, these were most common in the cold months of the year, with (in)adequate clothing being an important risk factor (Peiper 1913; Selter 1919; Derosas 2009). According to Waldron (1983), boys exhibit a higher risk of respiratory disease-related infant death than girls due to the lower physical maturity of infant boys’ lungs.

Up to now, the interplay of cause-specific infant mortality and social class in the nineteenth century prior to the first demographic transition has not been explored. Since causes of death provide deeper insights into the potential reasons for differentials and trends in infant mortality, this is a surprising research gap that can be explained by the following reasons:

1) Official cause-of-death statistics did not exist in the nineteenth century in most countries and other sources that include useful information on both cause of death and social status are rare.

2) If such sources that include both variables survived, e.g. church records, their digitization, transcription and preparation are expensive and time consuming.

3) Due to the costs for transcription and preparation, research has mainly focused on smaller parishes or shorter periods, resulting in infant death numbers that would become too small for cause-specific analysis.

The only study that broached this connection was performed by Molitoris (2017) for Stockholm, another city located in close proximity to the Baltic Sea. However, the multivariate analyses focused on child mortality (0–9 years) instead of infant mortality and on a later period when the demographic and epidemiologic transitions had already begun. The author found a social gradient in child mortality for the late nineteenth century to the advantage of the upper social classes, which was mainly attributable to gastro-intestinal and respiratory diseases.

Using the large, newly available data source of church records from Rostock, we aimed to close this research gap. These data include information on both cause of death and social status for large numbers of residents in an urban setting prior to the demographic and epidemiologic transitions when infectious diseases were still omnipresent, infant mortality was high and industrialization and urbanization were just starting to emerge. Aside from closing this research gap, we aimed to explore the development of infant mortality in nineteenth-century Rostock by sex for the first time and to estimate the impact of the father’s occupation and birth legitimacy in neonatal and post-neonatal mortality.

3. HYPOTHESES

3.1 Social Differences in Infant Mortality (Study 1)

The first study examined the extent to which social differences had an impact on infant mortality in Rostock in the early 19th century. A special focus was on the influence of a birth's legitimacy and that of the social class. As concluding from the state of research described in the second chapter, the underlying research hypotheses were:

1) Infant mortality for children born legitimately was lower than for those born out of wedlock.
2) Infants whose fathers had a lower social status exhibited an increased mortality risk compared to newborns with socio-economically better-situated fathers.

In addition, we aimed to estimate the development of the infant mortality rate by sex for Rostock's St. Jakobi parish in the nineteenth century.

3.2 Social Differences in Cause-Specific Infant Mortality (Study 2)

The second study's objective was to measure the influence of social differences on the risk of dying from a certain cause of death in the first year of life. Based on the state of research, we formulated the following hypotheses:

1) There was a social gradient in infant mortality to the advantage of the upper social classes, which was more pronounced in post-neonatal mortality, where exogenous factors played a major role, than in neonatal mortality, which was rather related to endogenous factors.
2) This social gradient was especially related to gastro-intestinal diseases, as they are more depending on the quality of nutrition and water than other diseases. In addition, children of unmarried mothers were at particular risk because their mothers had to work more frequently, thus using artificial nutrition more often instead of breastfeeding.
3) The social gradient was more pronounced in the period 1859–82, which was characterized by the beginning of urbanization, than in 1815–36, when the population size and infant mortality were comparatively low. Assuming that the immigration of lower-class workers led to a deterioration of the living environment, we expected that the low social class, especially in case of residential segregation, was more affected by the increase of infant mortality than the upper ones.

3.3 Regional Differences in Avoidable Mortality (Study 3)

The third study spent attention to current trends in premature mortality in the German Baltic Sea region. The study's objective was to explore the regional differences of amenable and preventable mortality in Mecklenburg-Vorpommern and Schleswig-Holstein and their development since reunification. Taking account of the state of research on this issue, we examined the following four hypotheses:

1) The trends in death rates of premature mortality and their differences across the study regions were driven mainly by changes in the direct mortality component, while the extent of the compositional component differed between urban and rural regions and was of greater importance in the latter.
2) In both SH and MV, urban-rural divides were evident in premature mortality, directed to the detriment of the urban areas in SH, but to the detriment of the rural areas in MV.
3) The difference in premature mortality between urban MV and urban SH disappeared in the course of the observation period, whereas mortality in rural MV remained significantly higher as compared to the other regions.
4) The anticipated remaining difference between rural MV and rural SH was strongly connected with higher amenable and preventable mortality rates in rural MV.

4. DATA

4.1 Infant Mortality

Data

Since the official German statistics were not introduced until 1875, demographic events like births, deaths and marriages were usually recorded by the local churches in the time prior to that. Therefore, the analysis of mortality in Germany and/or its regions requires the digitization and preparation of the respective church records first.

In case of the German Baltic Sea region, up to now there is only one parish of which its church records were widely transcribed and prepared: This is St. Jakobi (or St. James in English), which was by far the largest parish of the Hanseatic city of Rostock and also its most heterogeneous one with regard to social structure (Szołtysek et al. 2011; Mühlichen and Scholz 2015). For this reason, we consider St. Jakobi a representative sample of Rostock.

The measurement of infant mortality requires data on live births and infant deaths. The baptismal registers of St. Jakobi provide data for the live births born in Rostock-St. Jakobi, which is the population at risk, whereas the burial registers provide data for the recorded deaths, of which deaths at age zero are relevant for measuring infant mortality.

The baptismal registers include the following information: the date of birth, the date of baptism, the child's full name, the parents' full names, the father's occupation and the birth's legitimacy as well as the birthplace, which was noted in very few cases and only if it was outside of Rostock. The burial registers contain the date of death, the date of burial, the birthplace (only from 1847 onwards), the child's full name, the cause of death and age upon death. In most cases, the name and occupation of the father were recorded as well. Concerning illegitimate births, however, the name of the mother was recorded instead. The infants' age upon death was registered varyingly in days, weeks or months or in some cases roughly as '1 year'. These individual-level data are described in more detail in Mühlichen and Scholz (2015).

We used the transcribed data for St. Jakobi, which are available at the RAPHIS database of the Max Planck Institute for Demographic Research (MPIDR). However, we extended the time series by transcribing more of the digitized scans, which were collected at the MPIDR, and performed a comprehensive error correction and harmonization of the data sets. For Study 1, we analyzed the 1815–1829 period. Following progress in the data preparation process, we were able to analyze the 1815–1836 and 1859–1882 periods in Study 2, which allowed for cause-specific analyses of infant mortality due to the increased number of cases.

Matching and Selection

A central part of an individual-level survival analysis is to link the recorded deaths to the population at risk. This step is also necessary to calculate the exact span of days of life until death, which is in many cases not accurately recorded in the burial register. Due to the limitation of the baptismal data to the periods of 1815–1836 and 1859–1882, we limited the burial data, which are actually available for the whole nineteenth century, to 1815–1837 and 1859–1883 in order to avoid mismatches. Moreover, we harmonized the spelling variants of the surnames and first names in preparation of the matching process.

Since there is no personal identification number as a key variable in historical registries, the matching process had to be done by name. This was a very time-consuming process, especially because identical persons from both data sets are often not clearly linkable to one another for different reasons: 1) There are many similar names, which requires considering the parental names and occupations; 2) the order of the first names of identical persons is not always the same in the two registers; and 3) the spelling of the first and last names often differ slightly in the two registers.

For Study 1, we linked the infant deaths to the live births of 1815–1829 manually in Excel. First, we harmonized the columns of the two data files that include the births from the baptismal register and the infant deaths from the burial register. Subsequently, we attached the rows with the infant deaths to the baptismal data file. We sorted the data file by last and first names of the infants in order to find potential matches one upon the other, in consideration of parental information. The maternal or alternative surnames were considered as well. After transferring the necessary mortality data into the rows that included the baptismal data, we deleted the previously attached rows again.

For Study 2 that refers to the periods of 1815–1836 and 1859–1882, we went a more automated way in three steps: First, we carried out a matching procedure in SAS to link identical persons from the baptismal and burial files by the first two letters of their surnames and first names and their sex. Second, we conducted a fuzzy matching procedure in R in order to link persons from both files who have a widely identical surname and first name, thus taking account of identical persons who were recorded differently in both registers with regard to the first two letters in their names or in case of a wrongly typed sex. Third, we carried out a matching procedure in SAS to link persons from the two files by the first four letters of their surname and their sex, thus considering cases whose order of first names was differently recorded in the two registers. To avoid too many mismatches, the year of birth had to be approximately equal (+/-2) in all three procedures.

We added the found matches from the three procedures to an Excel document and checked it carefully to exclude all matches that were wrong or included more than once. Furthermore, we added the unmatched infant deaths to an Excel sheet and the unmatched live births to another sheet and checked them manually to find additional matches, for instance those whose mothers married between childbirth and infant death and thus changed their surname. In the end, after excluding stillbirths and children born outside of Rostock, 90.2 % of the infant deaths recorded in the burial register were successfully linked to the live births from the baptismal register. From 1 December 1876 onwards, children who died before their baptism were no longer recorded in the baptismal register. That is why the list of unmatched infant deaths includes 113 of such cases. In order to avoid undercoverage of the population at risk from late 1876 to 1882, we added these cases manually to the file of matches. Although the exact date of birth was not given in the burial register, the age upon death was accurate enough in these cases for survival analysis, given mostly in days or weeks. Counting these cases in, the linkage quota increases to 94.1 %. That means that only 174 infant deaths from the burial register could not be matched, whereas 2,761 cases were matched. By merging the two files, we can calculate the exact age upon death from the date of birth, which is given in the baptismal register, and the date of death, which is given in the burial register. Doing this, 72 children turned out to be one year and older upon death, thus exceeding the age range for infant death. We classified these cases as ‘no infant death’. Children who were one year of age or even older upon baptism were excluded as they were most likely born in another place than Rostock and therefore are not part of the population at risk. The final version of the merged data file thus contains 16,880 live-born children, of whom 2,689 died in their first year of life, which is a share of 15.9 %.

Construction of Variables

Infant death is the main outcome variable. We constructed further outcome variables for neonatal (up to 28 days of life) and post-neonatal death (from 29 days onwards) as well as cause-specific variables for infant deaths due to gastro-intestinal diseases, respiratory diseases, weakness/cachexia and other diseases. Table 2 shows our cause-of-death classification, which was done with the help of medical historian Hans-Uwe Lammel and by the use of a historical disease encyclopedia (Höfler 1899). Our classification is similar to Reid (2002), but shows fewer disease groups and thus higher frequencies in each group. Due to the limited observation period in Study 1 and thus a rather low number of cases, we extended the neonatal mortality range slightly to 30 days.

Table 2 Classification of causes of death in the burial registers of St. Jakobi, Rostock, 1815–1836 and 1859–1882

Gastro-intestinal diseases	**Respiratory diseases**	**Weakness/ cachexia**	**Other diseases**	**…**
Brechdurchfall	Bräune	Auszehrung	[not specified]	keine Backen im Mund, sehr kurze Zunge
Brechleiden	Bronchialeiterung	bald nach der Geburt gestorben	Augenübel	Kindertyphus
Brechruhr	Bronchialkatarrh	Bleichsucht	Ausschlag	Knochenfraktur
Bruch	Brustbräune	Blutarmut	Backenkrampf	Kopfkrampf
Cholera	Brustentzündung	Englische Krankheit	Blasenausschlag	Kopfkrampf und Zahnen
Cholerine	Brustfieber	Entkräftung	Blattern	Kopfkrankheit
Darmkatarrh	Brustkatarrh	Frühgeburt	Blutverlust	Kopfschaden
Diarrhoe	Brustkrampf	gleich nach der Geburt gestorben	Drüsen	Kopfschlag
Durchfall	Brustkrankheit	Schwäche	Drüsenkrampf	Krampf und Zahnen
Krampf	Brustleiden		Drüsenkrankheit	Krampfschlag
Leberleiden	Brustübel		Drüsenleiden	Masern
Magendarmentzündung	Brustverschleimung		durch die Amme erdrückt	Mundkrampf
Magenentzündung	Diphtherie		durch Operation bei Entbindung	Nabelentzündung
Magenfieber	Grippe		Eiterung	Nierenleiden
Magengeschwulst	Halsbräune		Entzündung	Operation
Magenkatarrh	Halsentzündung		Entzündung des Zellgewebes	Rose
Magenkrampf	Halsgeschwulst		Erkrankung des Hüftgelenks	Rotlauf
Magenkrankheit	Halsleiden		Fieber	Rückenleiden
Magenleiden	Husten		Folge der Masern	Rückenmarksleiden
Magenschwäche	Husten und Zufall		Frieseln	Scharlach
Magenübel	Katarrh		Gehirnentzündung	Scharlachfrieseln
Magenverschleimung	Keuchhusten		Gehirnkrampf	Schlag
Nabelbruch	Keuchhusten und Krampf		Gehirnleiden	Schlag und Zahnen
Ruhr	Luftröhrenentzündung		Gehirnschlag	Schlagfluss
Unterleibsentzündung	Lungenentzündung		Gelbsucht	Schleimfieber
Unterleibsleiden	Lungenkatarrh		Geschwür	Schwamm
venerisches Gift der Amme	Lungenkrampf		Hautausschlag	Schwamm und Brustkrankheit
Wassersucht	Lungenkrankheit		Hautentzündung	Syphilis
Wurmfieber	Lungenleiden		Hautkrankheit	Typhus
	Lungenschlag		Herzentzündung	unbekannt
	Lungenübel		Herzleiden	Verblutung und Mord
	Lungenverschleimung		Herzschlag	Zahnen und Krampf
	Mundfäule		Hirnhautentzündung	Zahnfieber
	Rachenbräune		Hirnleiden	Zahnkrampf
	Rippenfellentzündung		im Bett erdrückt	Zellgewebeeiterung
	Schwindsucht		innere Geschwüre	Zellgewebekrankheit
	Zahnen		kein Anus	
	Zahnhusten		kein Hirnschädel	

We constructed the following covariates: sex, period, season of birth, legitimacy and father's occupation. Sex is categorized as male or female; the years of birth are allocated to the periods 1815–1836 and 1859–1882; the legitimacy of birth refers to married (including retroactively legitimated births) and unmarried parents; the father's occupation is divided into high-level, medium-level and low-level status. Study 1 uses sex, season of birth, legitimacy and father's occupation as covariates; Study 2 uses sex, period and father's occupation. However, in both studies, we consider the father's occupation as the main explanatory variable since it is the only indicator of social class available in the church records.

We classified the father's occupations in a way that allows for aggregating by both, occupational groups and social classes. Thus, we sorted our classification first by occupational group and second by the status within that group. Based on the HISCO, HISCLASS and NAPP classifications[3] and on studies about historical social structures in the cities of the German Baltic Sea region (Brandenburg et al. 1991; Brandenburg and Kroll 1998; Lorenzen-Schmidt 1996; Manke 2000) as well as old German lexica[4], we developed a classification that is less complex and easier to use than the HISCO/HISCLASS system and more aligned to our northern German setting. It is a three-digit system with a [--0] for a non-specified rank within the occupational group and higher digits – [--1], [--2] etc. – for specified ranks within that group. In the first version of this classification used in Study 1, we only included three ranks, which was sufficient for the period 1815–1829 because of a rather little occupational variety: [--0] for a non-specified or medium status, [--1] for a high status and [--2] for a low status within the occupational group. By including the years 1830–1836 and, in particular, 1859–1882 for Study 2, the increased occupational variety made an extension of the classification necessary. In this case, it is still a three-digit system but with [--0] for the general, non-specified rank, [--1] for the lowest rank followed by [--2] for a medium status, [--3] for a high status and [--4] for an elite status. For example, number 300 refers to a craftsman in the field of construction whose rank is not specified, e.g. mason or carpenter; 301 refers to the lowest rank within the group of construction craftsmen (apprentices and building laborers); 302 refers to a journeyman mason or carpenter; 303 refers to a master craftsman in this field and 304 refers to a master builder or building contractor. We assigned all codes to three social classes: A) high-status occupations, B) medium-status occupations and C) low-status occupations. We included all newborns whose parents were unmarried at the time of birth in the third category. Table 3 shows the final version of our classification with three-digit codes for each occupation and its assignment to a social class.[5]

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[3] The Historical International Standard Classification of Occupations (HISCO) is described in van Leeuwen et al. (2002). Its adaptation for the North Atlantic Population Project (NAPP) is described in Roberts et al. (2003). The Historical International Social Class Scheme (HISCLASS) is described in van Leeuwen and Maas (2011).

[4] We used the lexica of Adelung 1793–1801, Pierer 1857–1865, Meyers 1905–1909, and Brockhaus 1911 that are freely accessible through the online library Zeno.org (2018).

[5] The first version of our classification used for Study 1 is detailed in Mühlichen and Scholz (2015). The main difference compared to Study 2 is that laborers as well as deceased, non-specified and unmarried fathers were dropped from the third social class to form an own group. In addition, retroactively legitimated births (12 cases) were coded as legitimate births and included in the social class derived from their father's occupation.

Table 3 Classification of occupations by social class and frequency among the fathers of live births in the baptismal registers of St. Jakobi, Rostock, 1815–1836 and 1859–1882

Group	Code	German description	English translation	Class
a) Trade and administration				
Trade	100	Händler[a]	Tradesman[a]	B
	101	Handlungsgehilfe, -diener, -reisender	Merchant's apprentice, travelling salesman	C
	102	Krämer, Warenhändler	Grocer, shopkeeper	B
	103	Kaufmann	Merchant	A
Carrying trade	111	Kutscher, Sänftenträger	Cabman, litter bearer	C
	112	Fuhrmann	Wagoner	B
	113	Fuhrunternehmer, Droschkenbesitzer	Haulage contractor, cab owner	A
Gastronomy	121	Kellner, Portier, Büfettier	Waiter, porter, bartender	C
	122	Koch, Kantinenpächter	Cook, canteen tenant	C
	123	Gastwirt, Herbergierer	Innkeeper	B
	124	Hotel- oder Gasthofbesitzer, Hoteldirektor	Hotel or inn owner, hotel director	A
Bank, insurance	131	Bank- oder Versicherungsdiener	Bank or insurance servant	C
	132	Bank- oder Versicherungsbeamter	Bank or insurance official	B
	133	Bank- oder Versicherungsinspektor	Bank or insurance inspector	A
	134	Bank- oder Versicherungsdirektor	Bank or insurance director	A
Adminis-tration, justice	141	Beamter im unteren Dienst	Low-level official	C
	142	Beamter im mittleren Dienst	Middle-level official	B
	143	Beamter im höheren Dienst	High-level official	A
	144	Hochrangiger Beamter	Top-ranking official	A
Post	151	Postbeamter im unteren Dienst	Low-level post official	C
	152	Postbeamter im mittleren Dienst	Middle-level post official	B
	153	Postbeamter im höheren Dienst	High-level post official	A
Security	161	Polizei- oder Feuerwehrdiener, Wächter	Police or fire servant, watchman, guard	C
	162	Mittlerer Polizei- oder Feuerwehrbeamter	Middle-level police or fire officer	B
	163	Höherer Polizei- oder Feuerwehrbeamter	High-level police or fire officer	A
Education, science	171	Student, Famulus, Schul- oder Universitätsdiener	Student, famulus, school or university servant	C
	172	Lehrer, Dozent, Wissenschaftler (ohne Doktortitel)	Teacher, lecturer, scientist (without doctoral degree)	B
	173	Doktor, Professor	Doctor, professor	A
	174	Schuldirektor, Universitätsrektor	School or university director	A
Medicine, health	181	Krankenwärter, Pflegekraft, Masseur	Nurse, caregiver, masseur	C
	182	Chirurg, Zahnarzt, Magnetiseur, Tierarzt	Surgeon, dentist, magnetizer, veterinarian	B
	183	Doktor der Medizin	Doctor of medicine	A
	184	Hospitalmeister	Hospital administrator	A
Church	191	Kirchendiener	Church servant	C
	192	Diakon, Kantor, Magister	Deacon, cantor, magister	B
	193	Pastor	Pastor	B
	194	Kirchenvorsteher	Church leader	A
b) Transport and military				
Railways	201	Bahnbeamter im unteren Dienst	Low-level railway official	C
	202	Bahnbeamter im mittleren Dienst	Middle-level railway official	B
	203	Bahnbeamter im höheren Dienst	High-level railway official	A
Navigation	210	Seefahrer[a]	Sailor[a]	C
	211	Matrose, Leichterschiffer, Schiffsarbeiter	Seaman, lighterman, ship worker	C
	212	Bootsmann	Boatswain, petty officer	C

	213	Steuermann	Steersman, helmsman	B
	214	Schiffer, Kapitän	Skipper, ship's master	B
Machine construction	221	Maschinenarbeiter	Machine worker	C
	222	Maschinist	Machinist	B
	223	Maschinenmeister	Master machinist	B
Military	231	Soldat	Soldier	C
	232	Unteroffizier	Non-commissioned officer	C
	233	Offizier	Commissioned officer	B
	234	Hauptmann	Captain	B
c) Crafts and arts				
Construction	300	Maurer, Steinmetz, Zimmermann, Maler u. a.[a]	Mason, stone mason, carpenter, painter etc.[a]	B
	301	- Gehilfe, Lehrling, Bauarbeiter	- Apprentice, building laborer	C
	302	- Geselle	- Journeyman	B
	303	- Meister	- Master	B
	304	Baumeister, -unternehmer	Master builder, building contractor	A
Shipbuilding	310	Schiffszimmermann[a]	Ship carpenter[a]	B
	311	- Gehilfe, Lehrling, Werftarbeiter	- Apprentice, shipyard worker	C
	312	- Geselle	- Journeyman	B
	313	- Meister	- Master	B
	314	Schiffsbaumeister	Master shipwright	A
Wood, metal	320	Tischler, Böttcher, Instrumentenmacher, Schmied u. a.[a]	Joiner, cooper, instrument maker, smith etc.[a]	B
	321	- Gehilfe, Lehrling	- Apprentice	C
	322	- Geselle	- Journeyman	B
	323	- Meister	- Master	B
Textiles, clothing, leather	330	Schneider, Weber, Schuhmacher, Riemer u. a.[a]	Tailor, weaver, shoemaker, leather worker etc.[a]	B
	331	- Gehilfe, Lehrling	- Apprentice	C
	332	- Geselle	- Journeyman	B
	333	- Meister	- Master	B
Other materials	340	Sonstiger Handwerker[a]	Other craftsman[a]	B
	341	- Gehilfe, Lehrling	- Apprentice	C
	342	- Geselle	- Journeyman	B
	343	- Meister	- Master	B
Hairdressing	350	Frisör, Barbier, Perückenmacher[a]	Hairdresser, barber, wig maker[a]	B
	351	- Gehilfe, Lehrling	- Apprentice	C
	352	- Geselle	- Journeyman	B
	353	- Meister	- Master	B
Nutrition	360	Bäcker, Müller, Schlachter, Zigarrenmacher etc.[a]	Baker, miller, slaughterer, cigar maker etc.[a]	B
	361	- Gehilfe, Lehrling	- Apprentice	C
	362	- Geselle	- Journeyman	B
	363	- Meister	- Master	B
Beer	370	Bierbrauer[a]	Brewer[a]	A
	371	Brauerlehrling	Apprentice brewer	C
	372	Kleinbierbrauer, Schoppenbrauer	Micro-brewer	B
	373	Braumeister	Master brewer	A
	374	Brauereibesitzer	Brewery owner	A
Print, Press, Photography	380	Drucker, Redakteur, Fotograf, Lithograf[a]	Printer, editor, photographer, lithographer[a]	B
	381	Buchdruckergehilfe	Apprentice book printer	C
	382	Buchdruckergeselle	Journeyman book printer	B
	383	Buchdruckereifaktor	Printing factor	B
	384	Buchdruckereibesitzer	Printing house owner	B

Arts	391	Musiker, Bildhauer, Künstler, Schauspieler, Gymnastiker	Musician, sculptor, artist, actor, gymnast	C
	392	Meister oder Lehrer der Künste	Master or teacher of arts	B
	393	Musik- oder Schauspieldirektor	Musical or theatrical director	A
	394	Städtischer oder königlicher Musikdirektor	City or royal musical director	A
d) Unskilled work and manufacturing				
Unskilled work	400	Arbeitsmann[a]	Laborer[a]	C
	401	Diener, Tagelöhner	Hired servant, day laborer	C
	402	Träger	Porter	C
	403	Vorarbeiter	Foreman	B
Factory work	411	Fabrikarbeiter	Factory worker	C
	412	Fabrikgeselle	Factory journeyman	B
	413	Werkmeister	Master workman	B
	414	Fabrikant, Fabrikdirektor	Manufacturer, factory owner	A
e) Agriculture				
Land use and holding	501	Ackersmann, Pächter	Field worker	C
	502	Büdner, Häusler, Ökonom	Cottager	B
	503	Eigentümer	Proprietor	A
	504	Gutsbesitzer	Landowner	A
Grain crop	511	Schnitter	Harvester	C
	512	Vorschnitter	Harvester foreman	B
Gardening	520	Gärtner[a]	Gardener[a]	B
	521	Gärtnergehilfe, Gartenarbeiter	Apprentice gardener, garden worker	C
	522	Handels-, Landschafts-, Gemüse-, Obst-, Kunstgärtner	Market gardener, landscaper, horticulturist, fruit grower, nurseryman	B
	523	Gärtnereibesitzer	Gardening shop owner	B
Distillery	531	Brennerknecht	Distiller's servant	C
	532	Branntweinbrenner	Distiller	C
	533	Brennereiverwalter	Distillery administrator	B
Fishing	540	Fischer[a]	Fisherman[a]	C
Animal breeding	551	Stallknecht	Groom	C
	552	Hirte, Schäfer, Bereiter	Shepherd, horsebreaker	C
	553	Reitlehrer	Riding instructor	B
Forestry, Hunting	561	Forstarbeiter, Kammerjäger	Forestry worker, exterminator/ gamekeeper	C
	562	Förster, Jäger	Forester, hunter	B
	563	Forstmeister, Jägermeister	Master forester, professional hunter	B
f) Unknown or not employed				
	600	Keine Angabe	Not specified	C
	610	Pensionär, Rentier, Privatmann	Pensionary	A
	620	Invalide	Disabled person	C
	630	Schüler	Pupil	C
	640	Vater unbekannt[b]	Father unknown[b]	C

Notes:

[a] General category without specified status/rank/position within occupational group.

[b] In the survival analyses, all unmarried fathers were put in this category, even if the job was specified.

4.2 Avoidable Mortality

Data

For Study 2, we used official year-end population numbers and official cause-of-death statistics. We obtained the population statistics directly from the statistical offices of Mecklenburg-Vorpommern and Schleswig-Holstein/Hamburg, aggregated by sex and age at the district level for the years 1989–2011. The cause-of-death data are individual-level data, however, that include all deaths according to sex, age, district and cause of death from 1990 to 2011, with causes of death recorded according to the International Classification of Diseases (ICD).[6] We accessed and aggregated the cause-of-death data in the Wiesbaden location of the *Forschungsdatenzentrum der Statistischen Ämter der Länder*. We did not use pre-1990 data because they are not available for MV on the district level and due to different coding practices in East and West Germany prior to reunification (Dinkel 2003).

We aggregated the population and cause-of-death numbers by year, sex, region and age group. We chose age groups that are large enough to feature a sufficient number of cases[7] and share a similar cause-of-death structure: 0–14, 15–34, 35–49, 50–59, 60–64, 65–69 and 70–74. We excluded the 75+ age group "as 'avoidability' of death and reliability of death certification become increasingly questionable at older ages" (Nolte and McKee 2004: 65) and analyzed it separately for sensitivity analyses. In order to avoid random variation over time, we used five-year values. Thus, all analyses refer to the period 1992–2009 instead of 1990–2011.

Our regional focus was on the two federal states of Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH). In consideration of regional gradients within these states, we further divided them into an urban and a rural part, based on the administrative distinction between *kreisfreie Stadt* (urban district) and *Landkreis* (rural district), which was in force until 4 September 2011. This way, we constructed four regions: Urban MV, Rural MV, Urban SH and Rural SH.

For sensitivity analyses, we added the neighboring city of Hamburg for comparison and further divided the rural areas of MV into a western (Mecklenburg) and eastern (Vorpommern) part and SH into a northern and southern part to take account of structural and socio-economic differences. Since the administrative district borders of MV changed in the early 1990s and in 2011, we used additional municipal-level data for population numbers and causes to keep our

[6] In Germany, causes of death were recorded according to the ninth revision of the International Classification of Diseases (ICD-9) from 1980 to 1997 and according to the tenth revision (ICD-10) from 1998 onwards.

[7] Due to the data protection regulations of the *Forschungsdatenzentrum der Statistischen Ämter der Länder*, any aggregated number of deaths per region, sex, cause of death, age group and calendar year had to exceed the number of two.

regional divisions constant over the study period. The composition of the study regions is displayed in Table 4 and Figure 5, including the city of Hamburg and the sub-divisions of rural MV and rural SH which we added for sensitivity analyses.

Table 4 Composition of the study regions

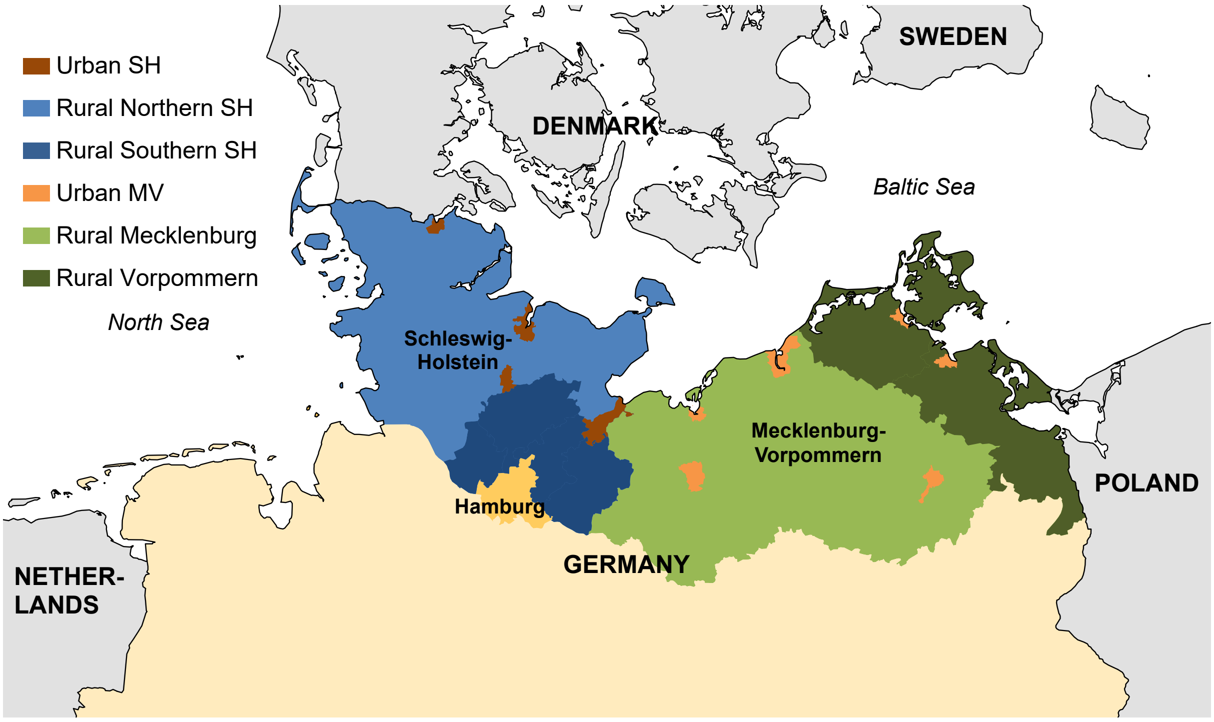
Region	Administrative districts (according to current territorial status as from 4 September 2011)	Population size on 31 December 2011
Urban MV	Urban districts of Rostock and Schwerin; former urban districts of Greifswald, Neubrandenburg, Stralsund and Wismar	521,525
Rural MV	Landkreis Rostock, Ludwigslust-Parchim, Mecklenburgische Seenplatte (excl. Neubrandenburg), Nordwestmecklenburg (excl. Wismar), Vorpommern-Greifswald (excl. Greifswald) and Vorpommern-Rügen (excl. Stralsund)[a]	1,113,209
Urban SH	All urban districts: Flensburg, Kiel, Lübeck and Neumünster	618,914
Rural SH	Dithmarschen, Nordfriesland, Ostholstein, Plön, Rendsburg-Eckernförde, Schleswig-Flensburg, Steinburg, Herzogtum Lauenburg, Pinneberg, Segeberg, Stormarn[b]	2,218,727

Notes:

[a] Vorpommern-Greifswald (excl. Greifswald) and Vorpommern-Rügen (excl. Stralsund) were analyzed separately as 'Rural Vorpommern' (360,634 inhabitants), the rest as 'Rural Mecklenburg' (752,575 inhabitants) for sensitivity analyses.

[b] Herzogtum Lauenburg, Pinneberg, Segeberg and Stormarn are the surrounding districts of Hamburg and were analyzed separately as 'Rural Southern Schleswig-Holstein' (983,709 inhabitants), the rest as 'Rural Northern Schleswig-Holstein' (1,235,018 inhabitants) for sensitivity analyses. Hamburg had a population size of 1,798,836 on 31 December 2011.

Figure 5 Map of northern Germany including the division of the study regions



Base map: © GeoBasis-DE / Bundesamt für Kartographie und Geodäsie

Selection of Causes of Death

Our cause-of-death classification bases on the concept of *avoidable mortality*. Since its first version, which was developed by Rutstein et al. (1976), many refined versions with varying cause-of-death selections have been published (Nolte and McKee 2004). In general, 'avoidable' deaths are linked either to causes that should be amenable to health care (*amenable mortality*) or to causes that should be avoidable through primary prevention (*preventable mortality*). Amenable mortality is widely used as an indicator of the effectiveness of health care in terms of early diagnosis and medical treatment; preventable mortality is an indicator of the effectiveness of inter-sectoral health policies in reducing risk-relevant behavior (Nolte et al. 2002).

Table 5 shows our list of amenable causes, which is primarily based on Nolte and McKee (2003; 2004; 2008; 2012) because it is the most widespread classification and suitable for regional comparisons as it mostly uses three-digit codes and wider cause-of-death groups instead of single four-digit causes, thus providing sufficient numbers of cases and reducing incompatibilities due to different coding practices over time or across regions.[8] Table 6 displays our list of preventable causes, which is primarily based on Page et al. (2006) because it is by far the most comprehensive classification in this regard.

To keep in line with current research, we added a few conditions to both cause-of-death selections (see the notes of Tables 5 and 6). We also took a few minor adjustments to improve the compatibility between ICD-9 and ICD-10 in case of restricted access to three-digit codes. In contrast to studies like Tobias et al. (2010) and Plug et al. (2011), we did not set any arbitrary threshold for excluding causes that were rare or did not experience a recent intervention. Since we aggregated all causes into three groups (amenable, preventable and other causes) and did not analyze them individually, it was unnecessary to exclude them.

[8] See Mackenbach et al. (2013) for the limitations of amenable mortality analysis in international comparisons.

Table 5 Causes considered amenable to health care, ages 0-74 unless otherwise stated

Disease group	Cause of death[a]	Age[b]	ICD-9 code	ICD-10 code
Infectious	Intestinal infections	0-14	001-9	A00-9
	Tuberculosis		010-8, 137	A15-9, B90
	Whooping cough	0-14	033	A37
	Measles	1-14	055	B05
	Other infections		032, 034-8, 045, 084, 381-3, 681-2, 730	A35-6, A38-41, A46, A80, B50-4, H65-70, L03, M86, M89-90
Neoplasm	Colorectal cancer		153-4	C18-21
	Bone cancer		170	C40-1
	Skin cancer		172-3	C43-4
	Breast cancer		174	C50
	Cancer of cervix uteri		180	C53
	Uterus cancer	0-44	179, 182	C54, C55
	Testis cancer		186	C62
	Bladder cancer		188	C67
	Eye cancer		190	C69
	Thyroid cancer		193	C73
	Hodgkin's disease		201	C81
	Leukemia	0-44	204-8	C91-5
	Benign neoplasm		210-29	D10-36
Endocrine	Diseases of the thyroid		240-6	E00-7
	Diabetes mellitus (50% of deaths)	0-49	250	E10-4
Neurological	Bacterial meningitis		320	G00
	Epilepsy		345	G40-1
Cardiovascular	Rheumatic heart disease		390-8	I00-9
	Hypertensive disease		401-5	I10-3, I15
	Ischemic heart disease (50%)		410-4	I20-5
	Heart failure		428-9	I50-1
	Cerebrovascular disease (50%)		430-8	I60-9
Respiratory	Influenza		487	J10-1
	Pneumonia[c]		480-6	J12-8, A48.1
	Asthma[d]	0-44	493	J45-6
	Other respiratory diseases	1-14	460-79, 488-9, 494-5, 497-519	J00-9, J20-39, J47-99
Digestive	Peptic ulcer disease		531-4	K25-8
	Appendicitis		540-3	K35-8
	Abdominal hernia		550-3	K40-6
	Cholelithiasis and cholecystitis		574-5	K80-2
Genitourinary	Nephritis and nephrosis		580-9	N00-7, N17-9, N25-7
	Hyperplasia of prostate		600	N40
Maternal/infant	Maternal death		630-76	O00-99
	Perinatal deaths (excl. stillbirths)		760-79	P00-96, A33
	Congenital anomalies		740-59	Q00-99
External	Treatment complications		E870-9	Y60-84

Notes:

[a] This classification is primarily based on Nolte and McKee (2003; 2004; 2008; 2012) but includes the following additions: Selected infections for which "early detection and effective intensive support coupled with appropriate antibiotic therapy can massively reduce case fatality rates" (Page et al. 2006: 205), heart failure due to effective treatment (Tobias et al. 2010; Plug et al. 2011), malignant melanoma (listed as part of skin cancer) due to advances in early detection and adjuvant therapy (Page et al. 2006; Tobias et al. 2010), bladder cancer due to improved treatment and survival (Page et al. 2006), bone cancer due to advances in adjuvant therapy (Tobias et al. 2010), thyroid cancer due to advances in diagnosis and adjuvant therapy (Page et al. 2006; Tobias et al. 2010) and benign neoplasms and eye cancer due to effective medical and surgical treatment (Tobias and Jackson 2001; Page et al. 2006). In accordance with Page et al. (2006), we split ischemic heart disease, cerebrovascular disease and diabetes equally on a 50:50 basis into amenable and preventable causes (according to age, sex, region and

year) because survival improvement in these diseases is more or less equally split between incidence reduction and improved treatment effectiveness.

[b] The general upper age limit is 75 years but we set deviating age limits for childhood infections, leukemia, uterus cancer and diabetes in accordance with Nolte and McKee (2004: 64–67). In addition, we extended the age range for asthma, thus following Tobias et al. (2010: 14).

[c] In ICD-9, legionellosis (482.84) is part of the pneumonia group. For ICD-10, however, it became part of the bacterial diseases group (A48.1). Because of the limitation to three-digit codes, we could not consider A48.1 for the period from 1998 onwards. However, this is statistically negligible.

[d] In ICD-9, chronic obstructive asthma (493.2) is listed in the asthma group. In ICD-10, it is recorded as J44.8 in the group of chronic obstructive pulmonary disease (COPD). This is statistically negligible, though, and additionally does not affect this study because there has never been a 493.2 code in the German modification of ICD-9. Presumably, this disease was registered in the COPD group even before 1998.

Table 6 Causes considered avoidable through primary prevention, ages 0-74 unless otherwise stated

Disease group	Cause of death[a]	Age[b]	ICD-9 code	ICD-10 code
Infectious	Hepatitis		070	B15-9
	HIV/AIDS[c]		042-4	B20-4
	Sexually transmitted diseases		090-9	A50-64
Neoplasm	Cancer of lip, oral cavity, pharynx		140-9	C00-14
	Cancer of esophagus		150	C15
	Cancer of stomach		151	C16
	Cancer of liver		155	C22
	Cancer of larynx		161	C32
	Cancer of trachea, bronchus, lung		162	C33-4
Endocrine/ nutritional	Nutritional deficiency anemia		280-1	D50-3
	Diabetes mellitus (50% of deaths)	0-49	250	E10-4
	Alcohol and drug related diseases		291-2, 303-5	F10-6, F18-9
Cardiovascular	Ischemic heart disease (50%)		410-4	I20-5
	Cerebrovascular disease (50%)		430-8	I60-9
	Aortic aneurysm		441	I71
Respiratory	Chronic obstructive pulmonary disease		490-2, 496	J40-4
Digestive	Cirrhosis of liver		571	K70, K73-4
External	Land transport accidents		E810-29, E846-8	V01-4, V06, V09-80, V82-9, V98-9
	Falls		E880-6, E888	W00-19
	Fires, burns		E890-9	X00-9
	Accidental poisonings		E850-69	X40-9
	Drowning		E910	W65-74
	Suicide		E950-9	X60-84
	Violence		E960-9	X85-Y09

Notes:

[a] This classification is primarily based on Page et al. (2006) but we added laryngeal cancer as it is highly associated with tobacco and alcohol consumption (Ahrens et al. 1991; Simonato et al. 1998; Tobias and Jackson 2001; Phelan et al. 2004). Both alcohol and tobacco consumption are problematic in MV (Baumeister et al. 2005; Mons 2011). Furthermore, in accordance with Tobias et al. (2010), we excluded self-inflicted injuries from the suicide group since cause and motivation are not clear and extended the group of land transport accidents by motor vehicle non-traffic accidents, other road vehicle accidents and vehicle accidents not elsewhere classifiable to avoid differences due to different coding practices.

[b] The general upper age limit is 75 years, with the exception of diabetes, thus following Nolte and McKee (2004: 64–67). In contrast to Page et al. (2006), we widened the age range for chronic obstructive pulmonary disease according to Tobias et al. (2010: 14).

[c] The introduction of HAART (highly active antiretroviral therapy) in 1996 positively affected treatment and survival of HIV/AIDS. Studies on amenable mortality that do not examine preventable deaths should consider HIV as an amenable cause (Tobias et al. 2010; Plug et al. 2011).

5. METHODS

5.1 Analytic Strategy

As a first step of analyzing infant mortality in nineteenth-century Rostock, we calculated the infant mortality rate for male and female live births. In order to test the two hypotheses of Study 1 and the three hypotheses of Study 2, which require multivariate analysis methods, we conducted Cox proportional-hazards models. For Study 3, we tested the first of the four hypotheses by using decomposition analysis, and the other three by measuring differential long-term trends by means of directly standardized death rates.

We used Excel for all data entries, error corrections and harmonization of the transcribed church records and for the data preparation, direct standardization and decomposition analysis of the official data. Moreover, we used SAS, R and Excel for matching the baptismal with the burial data and SPSS for the final data preparation of the merged church records for survival analysis. For the survival analysis itself, we used Stata.

5.2 Infant Mortality Rate

We chose to set the focus of our historical analyses on infant mortality because the first year of life is the time when the people were baptized and thus the only age group with a nearly full coverage of the population in the church records. Age-specific population numbers are otherwise not available for nineteenth-century Rostock, except for the censuses of 1819, 1867 and 1900. In addition, infant mortality is – due to its extent – a decisive determinant of premature mortality in the nineteenth century and it is less affected by migration than older age groups.

For Study 1, we therefore calculated the *infant mortality rate* (IMR) based on our aggregated numbers of infant deaths and live births. In general, the IMR is the number of infant deaths, divided by the number of live births. Concerning the reference period, there are two ways of assigning infant deaths to live births: the cohort perspective and the period perspective.

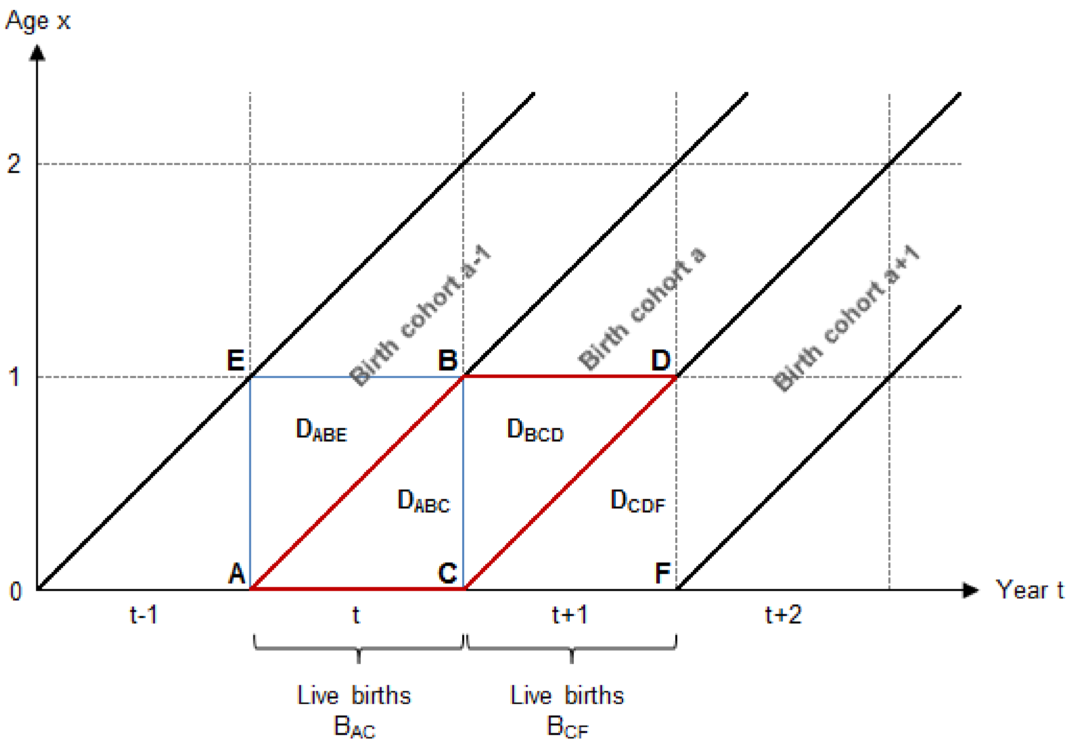
From a cohort perspective, the *birth year method* developed by Becker (1869; 1874) and Zeuner (1869) is a simple and accurate method. According to it, the IMR $_1q_0$ of a year t is the share of infant deaths in the respective birth cohort or, more specifically, the number of infant deaths $_1D_0$ of a birth cohort a, that took place in the year t or $t+1$, divided by the number of live births B from the same birth cohort born in the year t:

$$ {}_1q_{0,t} = \frac{{}_1D_{0,a,t} + {}_1D_{0,a,t+1}}{B_{a,t}} \cdot 1{,}000 \,. \tag{1}$$

We used this measure for descriptive analyses in Study 2 regarding the periods 1815–1836 and 1859–1882, for which we matched the infant deaths with the live births of their cohort. Since this matching procedure is not always possible due to data limitations, the period perspective is a widely used alternative. The simplest way is to use the calendar year, not the birth cohort, as the time reference. This way, the IMR according to this *calendar year method* is the number of infant deaths in the year *t*, divided by the number of live births born in the same year:

$$ {}_1q_{0,t} = \frac{{}_1D_{0,t}}{B_t} \cdot 1{,}000 \,. \tag{2}$$

Figure 6 Birth cohorts, live births, and infant deaths (Lexis diagram)



The cohort and period perspectives on infant mortality are visualized in the Lexis diagram in Figure 6. Based on this figure, the formula for the birth year method reads:

$$ {}_1q_{0,t} = \frac{D_{ACDB}}{B_{AC}} \cdot 1{,}000 \,, \tag{3}$$

whereas the calendar year method reads:

$$ {}_1q_{0,t} = \frac{D_{ACBE}}{B_{AC}} \cdot 1{,}000 \,. \tag{4}$$

This way, we see that the calendar year method is not completely precise from a cohort perspective because it includes infant deaths (D_{ABE}) from another birth cohort (a-1) but excludes infant deaths (D_{BCD}) from the same birth cohort (a) which took place in the following calendar year (t+1). This is, for example, the case when an infant born on 1 July 1815 died on 1 January 1816 and thus did not die in the same year he or she was born.

Since the live births of the baptismal registers have been transcribed only partially so far, we were not able to use the birth year method for all of the nineteenth century. For this reason, we developed a method that combines the cohort perspective of the birth year method and the simplicity of the calendar year method without the need to match the infant deaths to their exact birth cohort. As the logic of the birth year method is to consider infants who died in the same year they were born as well as those who died in the following year, we added this logic to the calendar year method by adding the value c, which is the share of infant deaths of a year t which belong to the birth cohort of the same year, thus determining the distribution of infant deaths over t and $t+1$:

$$ {}_1q_{0,t} = \frac{c \cdot {}_1D_{0,t} + (1 - c) \cdot {}_1D_{0,t+1}}{B_t} \cdot 1{,}000. \quad (5) $$

This *adjusted calendar year method* considers the distribution of infant deaths, as depicted in Figure 6, that all infant deaths of a birth cohort a take place in the years t or t+1. Thus, the share c of those who died in t plus the share 1-c of those who died in t+1 is always 1. How big c is depends on the spatiotemporal setting of the study. In the nineteenth century, the share was lower than today due to the higher number of exogenous infant deaths then.

Referring to our data, c amounted to 70 %, as an analysis of the period 1815–1829 revealed. Therefore, we assumed that c is 0.7 with 1-c thus being 0.3 for our calculation of the IMR in nineteenth-century Rostock. After transcribing the year of birth, sex and birthplace as well as important remarks like ‘stillbirth’ for the missing years, we were able to measure the IMR by sex for the whole nineteenth century, not only for the fully transcribed years. We excluded stillbirths and children who were born in another place than Rostock, as they do not belong to the population at risk. Due to the use of moving three-year averages for less random variation, our period of analysis for the IMR in Study 1 finally ranges from 1801 to 1902.

5.3 Event History Analysis

The next step was to measure the impact of certain covariates on infants’ mortality risk. In our transcribed data, we do not only have the information if an infant death occurred but the age upon death as well. Thus, our data are suitable for models of event history analysis. We analyzed the mortality intensity in the first year of life, using Cox proportional-hazards models (Cox and Oakes 1984) of the form

$$h(t|x) = h_0(t) \cdot e^{\beta x}, \quad (6)$$

where $h_0(t)$ is the baseline hazard (without assumptions regarding its shape), β is the parameter to be estimated and x the covariates. The power e^{β} is calculated from the hazard ratio, which is the ratio of two compared hazard rates. For simplicity, we interpret the hazard ratios as relative risks.

For Studies 1 and 2, we performed separate Cox regressions for neonatal, post-neonatal and overall infant mortality. In addition, we performed cause-specific models for neonatal, post-neonatal and overall infant mortality in Study 2. We measured the analysis time by the age in days, ranging from birth to infant death or – in the case of survival – the first birthday. Thus, we set the age of newborns who survived their first year at the censored time of 365 days. Regarding neonatal mortality, the censored time is 29 days. The analysis of post-neonatal mortality involves left-truncated data because neonatal deaths are excluded by definition.

5.4 Direct Standardization

Since infant mortality has decreased to less than 1 % in recent decades in the Western world, the understanding of premature mortality has changed. Through the improvements in demographic statistics, it is easily possible to measure cause-specific mortality for single years of age, thus enabling us to use the *avoidable mortality* approach for Study 3.

In general, crude death rates that include several age groups are hardly comparable because they depend on the respective age structure, which differs between populations and is subject to change over time. In order to show cause-specific mortality differences over time, without being distorted by compositional effects, the use of standardized death rates is the most practical way. Directly standardized death rates, which were first introduced by Neison (1844), show no compositional distortions because the age and sex structure is standardized. Furthermore, they have the advantage of being additive: “the sum of death rates by cause equals the death rate from all causes” (Meslé 2006: 36). Thus, we calculated death rates with a directly standardized age and sex structure for each region differentiated by sex and cause of death groups according to Preston et al. (2000: 24):

$$SDR_t = \sum_x d_{x,t} \cdot C_x , \quad (7)$$

where SDR_t is the standardized death rate at time *t* (given in years), $d_{x,t}$ is the death rate at age *x* and time *t* and C_x is the age-specific standard population.[9] Following Preston et al. (2000: 26), we chose the average of the two age structures of MV and SH in 2000 as the standard without disaggregation by sex (Table 7).

Table 7 Standard population: Average of the age-specific populations of Mecklenburg-Vorpommern and Schleswig-Holstein in the year 2000

Age group	Standard population
0-14	15,190
15-34	25,287
35-49	23,774
50-59	12,125
60-64	7,437
65-69	5,220
70-74	4,145
75+	6,822
∑	100,000

Source: Author's calculations based on the official population statistics of MV and SH.

Generally, the crude death rate *d* is the quotient of the number of deaths and the average population size. Adding the age dimension, the age-specific death rate is

$$d_x = \frac{D_x}{\overline{N}_x}, \tag{8}$$

where the number of deaths *D* at age *x* is divided by the average population size $\overline{N}$ at age *x*. Because of low death numbers, especially in the first two age groups, we used five-year periods, which means that

$$D_x = D_{x;t-2} + D_{x;t-1} + D_{x,t} + D_{x,t+1} + D_{x,t+2}. \tag{9}$$

We calculated the annual average population size $\overline{N}$ from the average of two year-end population numbers *N*, thus resulting in the following equations:

$$\begin{aligned}\overline{N}_x &= \overline{N}_{x;t-2} + \overline{N}_{x;t-1} + \overline{N}_{x;t} + \overline{N}_{x;t+1} + \overline{N}_{x;t+2} \\ &= \frac{N_{x;t-3} + N_{x;t-2}}{2} + \frac{N_{x;t-2} + N_{x;t-1}}{2} + \frac{N_{x;t-1} + N_{x;t}}{2} + \frac{N_{x;t} + N_{x;t+1}}{2} + \frac{N_{x;t+1} + N_{x;t+2}}{2} \\ &= 0{,}5 \cdot N_{x;t-3} + N_{x;t-2} + N_{x;t-1} + N_{x;t} + N_{x;t+1} + 0{,}5 \cdot N_{x;t+2}.\end{aligned} \tag{10}$$

[9] We adjusted the notation in this section according to Canudas Romo (2003) and Rau et al. (2008) to keep it in line with section 5.5. Please note that we omitted region, sex and cause of death from the equations in sections 5.4 and 5.5 for reasons of simplicity.

Substituting (9) and (10) in (8), the final equation for the age-specific death rate at time *t* is:

$$d_{x,t} = \frac{D_{x;t-2} + D_{x;t-1} + D_{x,t} + D_{x,t+1} + D_{x,t+2}}{0{,}5 \cdot N_{x;t-3} + N_{x;t-2} + N_{x;t-1} + N_{x;t} + N_{x;t+1} + 0{,}5 \cdot N_{x;t+2}}. \tag{11}$$

Substituting (11) in (7), Eq. 12 shows the final formula for the standardized death rate:

$$SDR_t = \sum_x \left(\frac{D_{x;t-2} + D_{x;t-1} + D_{x,t} + D_{x,t+1} + D_{x,t+2}}{0{,}5 \cdot N_{x;t-3} + N_{x;t-2} + N_{x;t-1} + N_{x;t} + N_{x;t+1} + 0{,}5 \cdot N_{x;t+2}} \cdot C_x \right). \tag{12}$$

As a statistical test for the standardized death rate, we calculated 95 % confidence intervals according to Chiang (1984):

$$CI = SDR_t \pm 1{,}96 \cdot \sqrt{\sum_x C_x^2 \cdot \underbrace{\frac{1}{\overline{N}_x} \cdot d_{x,t} \cdot (1 - q_{x,t})}_{\text{Variance of the age-specific death rate}}}, \tag{13}$$

with the age-specific death probability q_x at time *t* computed according to Farr (1859):

$$q_{x,t} = \frac{D_x}{\overline{N}_x + 0{,}5 \cdot D_x}, \tag{14}$$

with D_x and $\overline{N}_x$ calculated according to (9) and (10).

5.5 Decomposition Analysis

Since the standardization method eliminates the distortions that result from compositional changes by using an arbitrary standard population, it is not possible to measure the extent of this compositional component. By employing decomposition analysis, first introduced by Kitagawa (1955), it is however possible to measure the difference between the true, observed death rates both in terms of mortality differences (direct component) and age structure differences (compositional component).

The compositional component is of particular interest in this context because the age structure developed completely differently in MV and SH after reunification as selective migration had a rejuvenating effect on SH but caused accelerated population ageing in MV.

We conducted two different decomposition analyses. First, we decompose the difference Δ in the (cause-specific or crude) death rate *d* of a region *r* over time t_k (with k = 1,2 for the periods of 1990/1994 and 2007/2011) into a direct and compositional component according to Kitagawa (1955), using the notation of Canudas Romo (2003):

$$\Delta d(t_k) = \sum_x \frac{\frac{\overline{N}_x(t_2)}{\overline{N}(t_2)} + \frac{\overline{N}_x(t_1)}{\overline{N}(t_1)}}{2} \cdot \left(d_x(t_2) - d_x(t_1)\right) + \sum_x \frac{d_x(t_2) + d_x(t_1)}{2} \cdot \left(\frac{\overline{N}_x(t_2)}{\overline{N}(t_2)} - \frac{\overline{N}_x(t_1)}{\overline{N}(t_1)}\right), \quad (15)$$

where the term in the first line shows the direct component, which is improvement in survival, and the term in the second line represents the compositional component, which is changes in the age structure. We calculated the annual average population size $\overline{N}$ based on the average of two year-end population numbers *N*.

Second, we applied the 'difference of differences' approach of Rau et al. (2008) to Kitagawa's formula to determine the direct and the compositional effect on the changes in the mortality differences *between two regions* (r_1 and r_2) over time:

$$\begin{aligned}\Delta d(r_1,t_k) - \Delta d(r_2,t_k) = &\sum_x \frac{\frac{\overline{N}_x(r_1,t_2)}{\overline{N}(r_1,t_2)} + \frac{\overline{N}_x(r_1,t_1)}{\overline{N}(r_1,t_1)}}{2} \cdot \left(d_x(r_1,t_2) - d_x(r_1,t_1)\right) \\ &- \sum_x \frac{\frac{\overline{N}_x(r_2,t_2)}{\overline{N}(r_2,t_2)} + \frac{\overline{N}_x(r_2,t_1)}{\overline{N}(r_2,t_1)}}{2} \cdot \left(d_x(r_2,t_2) - d_x(r_2,t_1)\right) \\ &+ \sum_x \frac{d_x(r_1,t_2) + d_x(r_1,t_1)}{2} \cdot \left(\frac{\overline{N}_x(r_1,t_2)}{\overline{N}(r_1,t_2)} - \frac{\overline{N}_x(r_1,t_1)}{\overline{N}(r_1,t_1)}\right) \\ &- \sum_x \frac{d_x(r_2,t_2) + d_x(r_2,t_1)}{2} \cdot \left(\frac{\overline{N}_x(r_2,t_2)}{\overline{N}(r_2,t_2)} - \frac{\overline{N}_x(r_2,t_1)}{\overline{N}(r_2,t_1)}\right)\end{aligned}, \quad (16)$$

where the first two lines on the right hand show the direct component, which is the "contribution of survival improvement to the difference of differences of the death rates", and the last two lines show the compositional component, which is the "contribution of compositional changes over time on the difference of differences of the death rates" (Rau et al. 2008: 273).

Referring to our study regions, we analyzed the following differences:

1. the difference in the death rates between 1990/1994 and 2007/2011 for urban districts in MV **minus** the difference in the death rates between 1990/1994 and 2007/2011 for rural districts in MV,
2. the difference in the death rates between 1990/1994 and 2007/2011 for rural districts in SH **minus** the difference in the death rates between 1990/1994 and 2007/2011 for urban districts in SH,

3. the difference in the death rates between 1990/1994 and 2007/2011 for urban districts in SH **minus** the difference in the death rates between 1990/1994 and 2007/2011 for urban districts in MV and
4. the difference in the death rates between 1990/1994 and 2007/2011 for rural districts in SH **minus** the difference in the death rates between 1990/1994 and 2007/2011 for rural districts in MV.

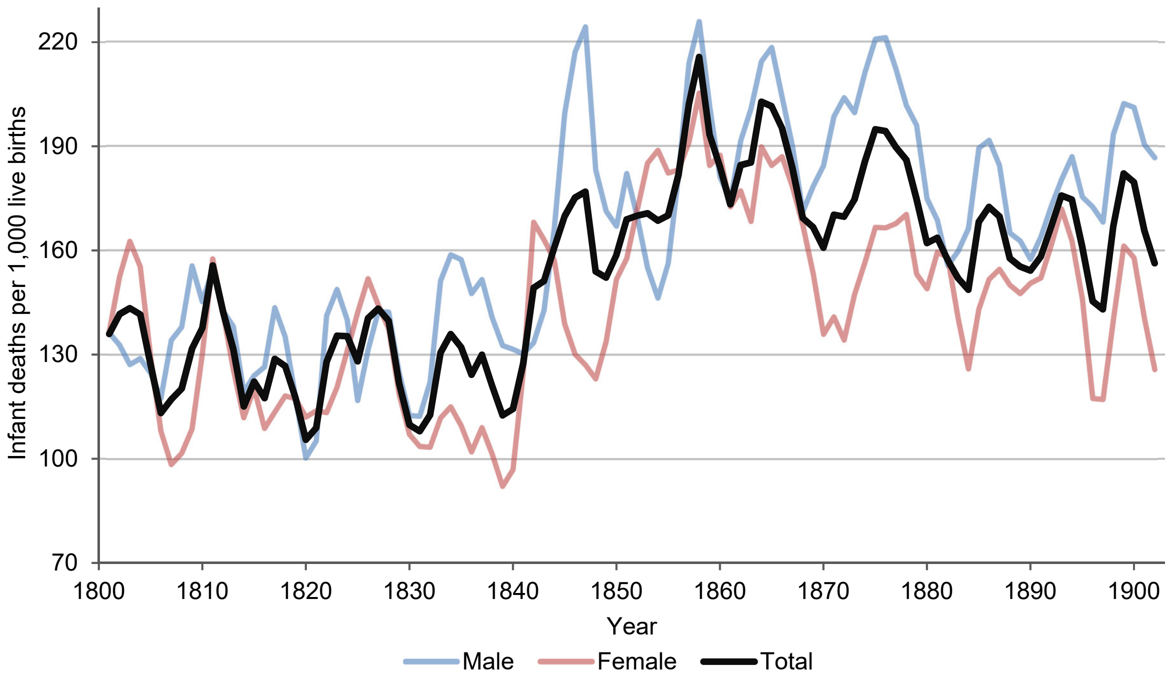
6. RESULTS

6.1 Social Differences in Infant Mortality (Study 1)

Development of Infant Mortality

The infant mortality rate in Rostock's parish of St. Jakobi remained at a roughly constant to slightly declining level until 1840, fluctuating between 105 to 156 infant deaths per 1,000 live births (Figure 7). Notable sex differences started to emerge around 1830 to the disadvantage of boys. From 1840 onwards, the level of infant mortality rose considerably, reaching 216 deaths per 1,000 live births in the year 1858. Subsequently, the infant mortality rate dropped again slightly, especially between 1876 and 1884, and fluctuated between 143 and 182 afterwards, with boys showing an upward trend and girls showing a falling one.

Figure 7 Infant mortality rate by sex in St. Jakobi parish, Rostock, 1801–1902 (moving three-year average)



Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.

Survival Analysis

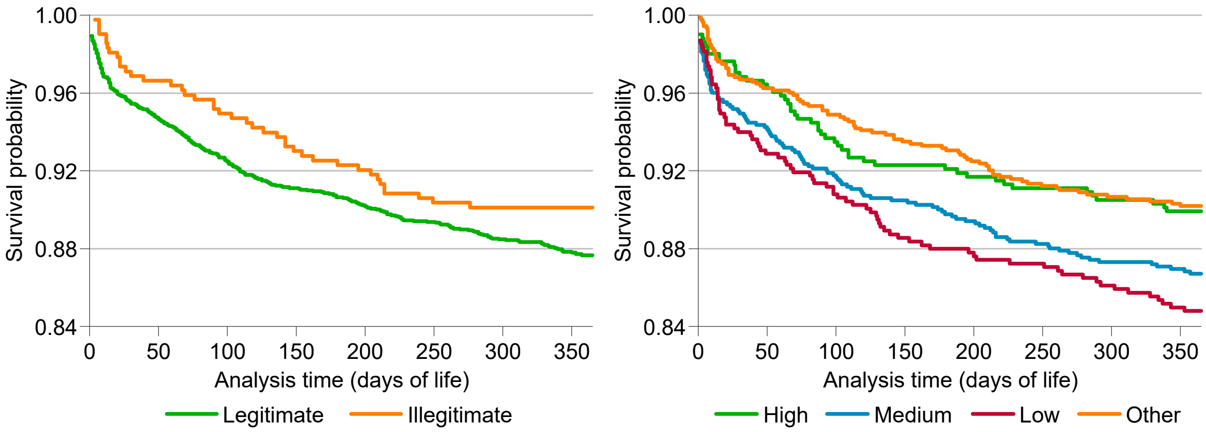
The following analyses examine the period of 1815–1829 more deeply. In total, 2,768 children were born in the study period, of whom 331 (11.96 %) died in the first year of life (Table 8). Among the infant deaths, 120 died in the first 30 days of life and 211 in the following months. Variations in the crude death rate, which is calculated here from the number of infant deaths divided by the person-years, were particularly pronounced among the social groups. The crude death rate was highest in the low social class.

Table 8 Infant deaths, censors, person-time and crude death rate by sex, season of birth, social class and legitimacy in St. Jakobi parish, Rostock, 1815–1829

Variable	Category	Infant deaths by age			Censors	Person years	Death rate
		Total	First 30 days	After 30 days			
Sex	Male	175	67	108	1,292	1,339	0.1307
	Female	156	53	103	1,145	1,191	0.1310
Season of birth	Spring	84	23	61	602	626	0.1341
	Summer	80	35	45	591	612	0.1307
	Autumn	85	33	52	599	621	0.1368
	Winter	82	29	53	645	670	0.1224
Social class	High status	51	16	35	455	469	0.1087
	Medium status	113	43	70	738	768	0.1472
	Low status	81	32	49	452	474	0.1707
	Other/unknown	86	29	57	792	819	0.1051
Legitimacy	Legitimate	290	107	183	2,063	2,144	0.1353
	Illegitimate	41	13	28	374	386	0.1063
Total		331	120	211	2,437	2,530	0.1308

Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.

Figure 8 Kaplan-Meier survival curve for the first year of life of infants born in St. Jakobi parish, Rostock 1815–1829, according to legitimacy (left) and social class (right)

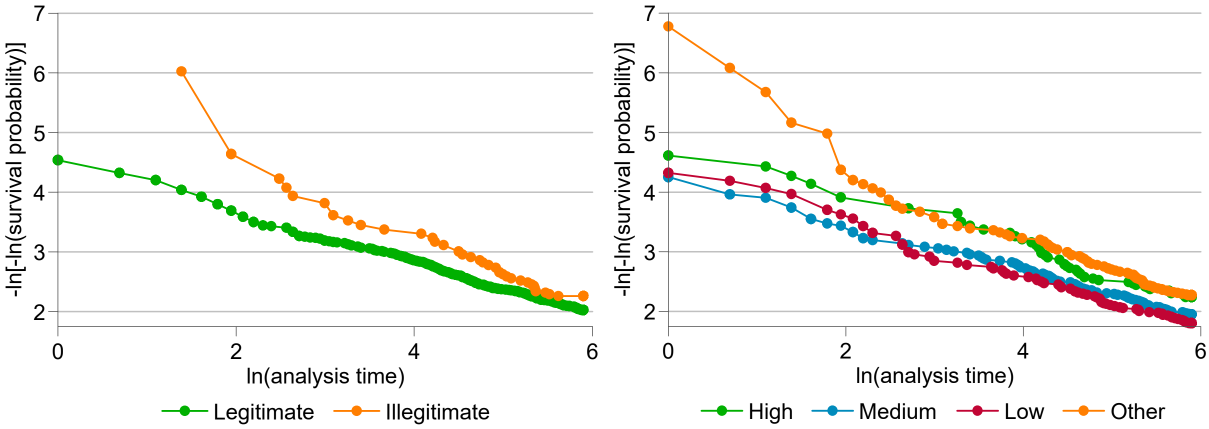


Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.

Throughout the first year of life, illegitimate births exhibited a higher survival probability than legitimate births in the period of 1815–1829 (Figure 8). In total, 90 % of the illegitimate-born and 88 % of the legitimate-born survived their first year of life. With regard to the social classes, considerable differences emerged after the first month of life, with the low-status group showing the lowest survival probability at the end of the first year of life (85 %), followed by the medium-status group (87 %) and the high-status group (90 %). The survival probability for the residual category of infants for whom the father's occupation was unknown or unassignable or the father himself was unknown or dead was also 90 %. Almost half of the members of this group coincide with the ‘illegitimate’ category of the legitimacy variable. Due to this multi-collinearity, we examined the two variables in separate models.

The log-log survival plots (Figure 9) reveal that the proportional-hazards assumption of the Cox model was violated for the variables capturing effects of legitimacy and social class, which showed different patterns for the first month of life and the following months. This implies that results for overall infant mortality would be biased. For this reason, we conducted separate models for the first month of life (Table 9) and the ensuing eleven months (Table 10).

Figure 9 Test of the proportional-hazards assumption (log-log survival plot) for the independent variables legitimacy (left) and social class (right)



Source: Author’s calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.

As the Cox models show, the risk of early infant death (in the first 30 days of life) differed by social class (Table 9). It was 65 % higher in the medium social class (hazard ratio $HR = 1.65$, p-value = 0.088) and 89 % higher in the low social class ($HR = 1.89$, $p = 0.037$) than in the high social class. The residual category, however, does not fit this pattern, as it did not differ from the reference group. With regard to birth legitimacy, the risk of dying for the illegitimate-born infants in the first 30 days of life was 31 % lower ($HR = 0.69$, $p = 0.208$) than that of the legitimate-born. This difference was not significant, though. Female infants exhibited a slight survival advantage but the sex differences were not significant as well. Regarding seasonal differences, the risk was 56 % higher for infants born in the summer ($HR = 1.56$, $p = 0.095$) compared to those born in the spring.

The risk of late infant death (in the ensuing months) did not differ significantly between the various studied groups (Table 10). The tendency in the social class and legitimacy variables was the same like in the first month but the differences between the categories were smaller.

Table 9 Early infant death: Hazard ratios from Cox proportional-hazards models for St. Jakobi parish, Rostock, 1815–1829

Variable	Category	Model 1: Social class		Model 2: Legitimacy	
		Only social class	Full model	Only legitimacy	Full model
Social class	High status (*Ref*)	1	1		
	Medium status	1.62 *	1.65 *		
	Low status	1.92 **	1.89 **		
	Other/unknown	1.04	1.06		
Legitimacy	Legitimate (*Ref*)			1	1
	Illegitimate			0.68	0.69
Sex	Male (*Ref*)		1		1
	Female		0.89		0.89
Season of birth	Spring (*Ref*)		1		1
	Summer		1.56 *		1.56 *
	Autumn		1.43		1.44
	Winter		1.21		1.20

Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.
* $p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.01$. *Ref* indicates the reference category.

Table 10 Late infant death: Hazard ratios from Cox proportional-hazards models for St. Jakobi parish, Rostock, 1815–1829

Variable	Category	Model 1: Social class		Model 2: Legitimacy	
		Only social class	Full model	Only legitimacy	Full model
Social class	High status (*Ref*)	1	1		
	Medium status	1.22	1.20		
	Low status	1.38	1.39		
	Other/unknown	0.93	0.92		
Legitimacy	Legitimate (*Ref*)			1	1
	Illegitimate			0.85	0.85
Sex	Male (*Ref*)		1		1
	Female		1.07		1.07
Season of birth	Spring (*Ref*)		1		1
	Summer		0.75		0.75
	Autumn		0.85		0.86
	Winter		0.82		0.82

Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.
* $p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.01$. *Ref* indicates the reference category.

In both analyses, adding the covariates sex and season of birth did not alter the hazard ratios for social class and legitimacy. In more detail regarding social differences, the infant mortality risk was highest among bailiffs, musicians, fishermen, innkeepers, sailors, seamen and field workers, while it was lowest among the higher ranked civil servants and academics, merchants, laborers and porters. The large group of craftsmen, both master craftsmen and journeymen, ranked in the middle.

6.2 Social Differences in Cause-Specific Infant Mortality (Study 2)

Descriptive Statistics

Study 2 is based on an extended study period with increased numbers of infants, thus enabling us to conduct cause-specific survival analyses. In total, 16,880 children were born in the periods 1815–1836 and 1859–1882, of whom 2,689 (15.93 %) died in the first year of life (Table 11). There were 823 neonatal deaths and 1,866 post-neonatal deaths (Table 12). In overall infant mortality as well as in neonatal and post-neonatal mortality, the crude death rates were highest among male infants, the 1859–82 cohorts and the lowest social class.

Table 11 Live births, infant deaths, person-time and crude death rate with confidence intervals by sex, period and social class in St. Jakobi parish, Rostock, 1815–1836 and 1859–1882

Variable	Category	Live births	Infant deaths	Person years	Death rate	95 % confidence interval	
Sex	Male	8,750	1,492	7,686	0.1941	0.1845	0.2042
	Female	8,130	1,197	7,307	0.1638	0.1548	0.1734
Period of birth	1815–1836	4,279	508	3,916	0.1297	0.1189	0.1415
	1859–1882	12,601	2,181	11,077	0.1969	0.1888	0.2053
Social class	High status	1,115	128	1,031	0.1242	0.1044	0.1477
	Medium status	6,406	958	5,749	0.1666	0.1564	0.1775
	Low status	9,359	1,603	8,213	0.1952	0.1859	0.2050
Total		16,880	2,689	14,992	0.1794	0.1727	0.1863

Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.

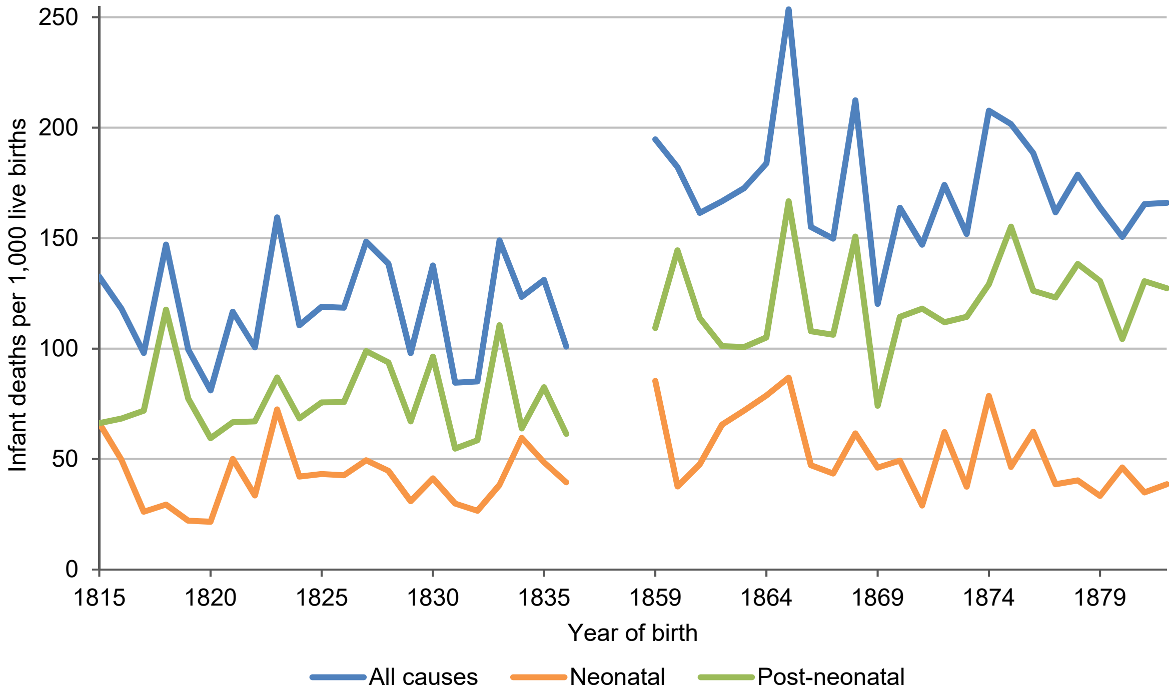
Table 12 Neonatal and post-neonatal deaths, person-time and crude death rate by sex, period and social class in St. Jakobi parish, Rostock, 1815–1836 and 1859–1882

Variable	Category	Neonatal			Post-neonatal		
		Deaths	Person years	Death rate	Deaths	Person years	Death rate
Sex	Male	479	670	0.7147	1,013	7,672	0.1320
	Female	344	628	0.5475	853	7,296	0.1169
Period of birth	1815–1836	178	330	0.5395	330	3,911	0.0844
	1859–1882	645	969	0.6659	1,536	11,057	0.1389
Social class	High status	38	86	0.4401	90	1,030	0.0874
	Medium status	266	495	0.5379	692	5,742	0.1205
	Low status	519	718	0.7232	1,084	8,197	0.1322
Total		823	1,299	0.6338	1,866	14,969	0.1247

Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.

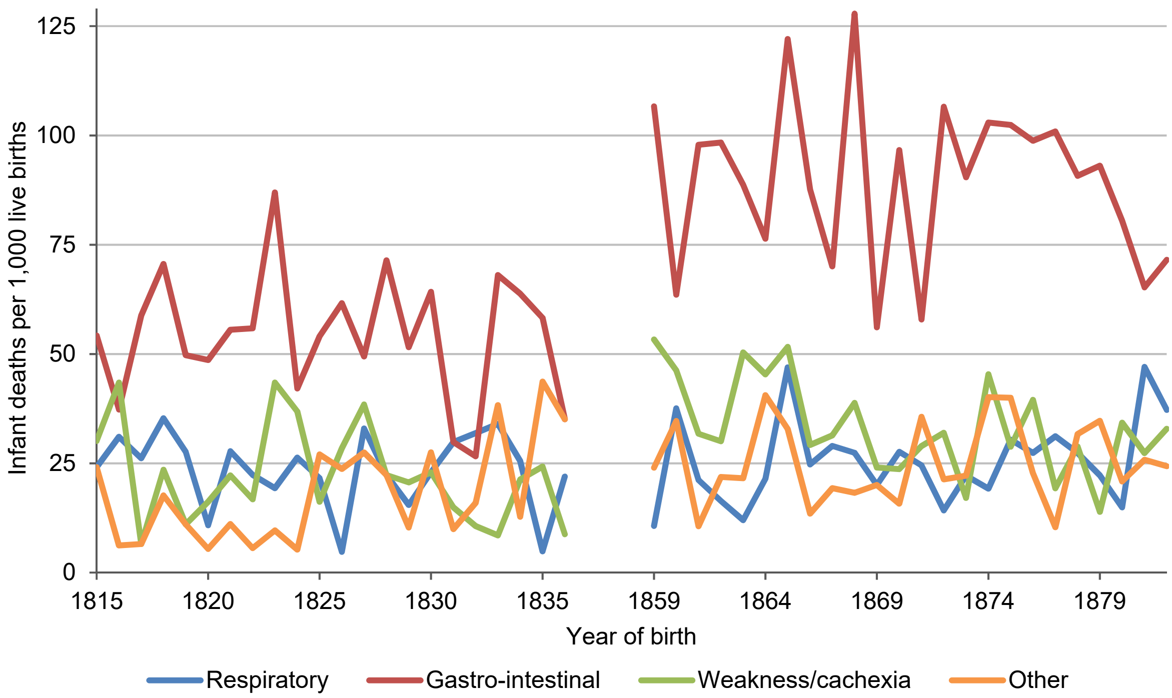
Post-neonatal mortality was higher than neonatal mortality in the study periods, particularly between 1859 and 1882 (Figure 10). The increased level of infant mortality in the second study period was particularly connected with a shift of post-neonatal mortality.

Figure 10 Infant, neonatal and post-neonatal mortality rates according to the birth-year method in St. Jakobi parish, Rostock, 1815–1836 and 1859–1882



Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.

Figure 11 Cause-specific infant mortality rates according to the birth-year method in St. Jakobi parish, Rostock, 1815–1836 and 1859–1882



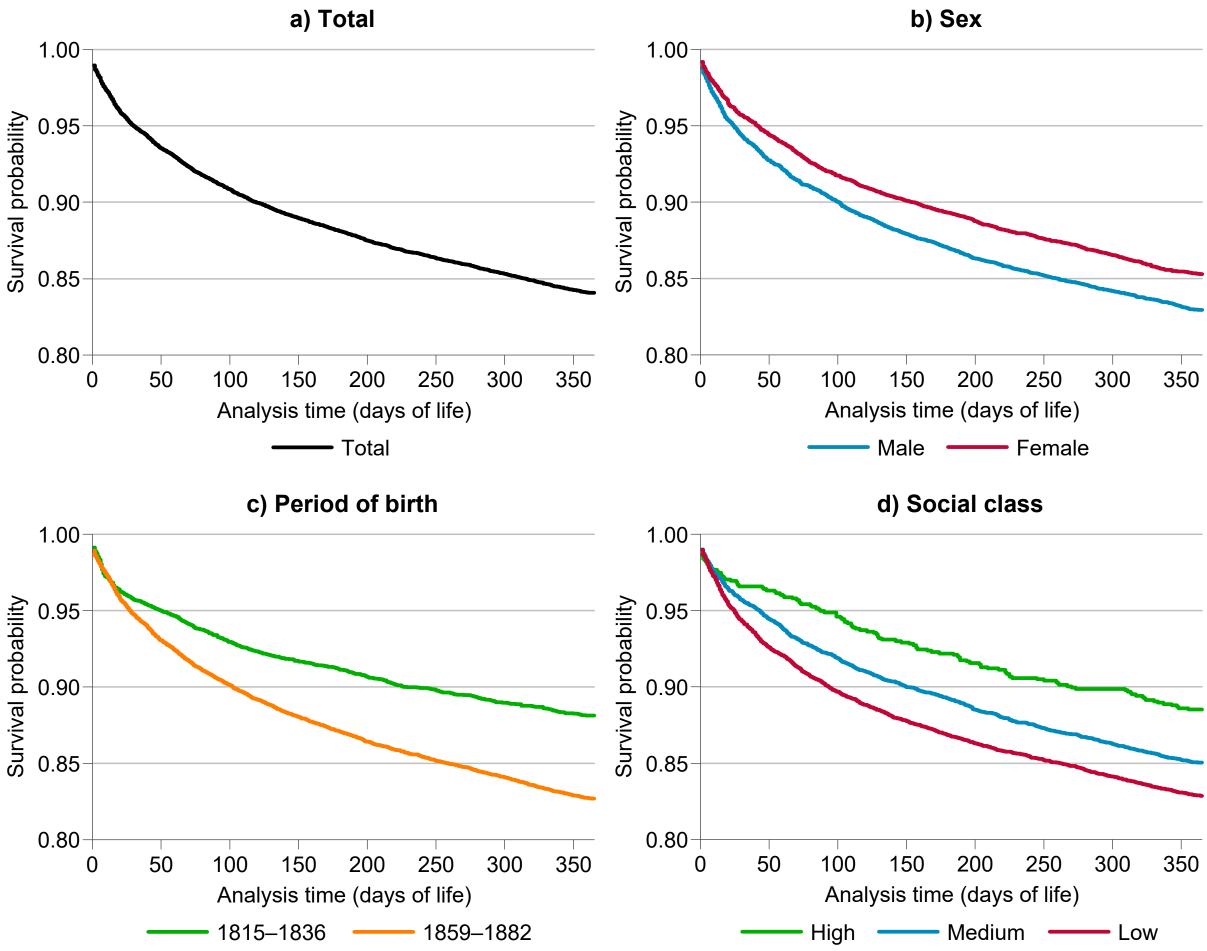
Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.

Differentiated by cause of death, the upward shift of infant mortality was especially visible in gastro-intestinal diseases (Figure 11). In total, 1,363 infants died from gastro-intestinal diseases, followed by 500 from weakness/cachexia, 427 from respiratory diseases and 399 from other diseases. The peak of infant mortality in 1865 (254 infant deaths per 1,000 live births) resulted from a peak of gastro-intestinal and respiratory diseases.

Survival Analysis

In total, 84.1 % of the live births born in the periods 1815–1836 and 1859–1882 survived their first year of life (Figure 12). Differentiated by sex, 82.9 % of male newborns survived the first year, whereas this was the case for 85.3 % among female newborns. In addition, the survival probability was remarkably lower in the second period (82.7 %) than in the earlier one (88.1 %). With regard to social class, the survival probability for the first year of life was lowest among the children of the low social class (82.9 %). For the medium class, it was 85.0 % and for the high social class it was 88.5 %.

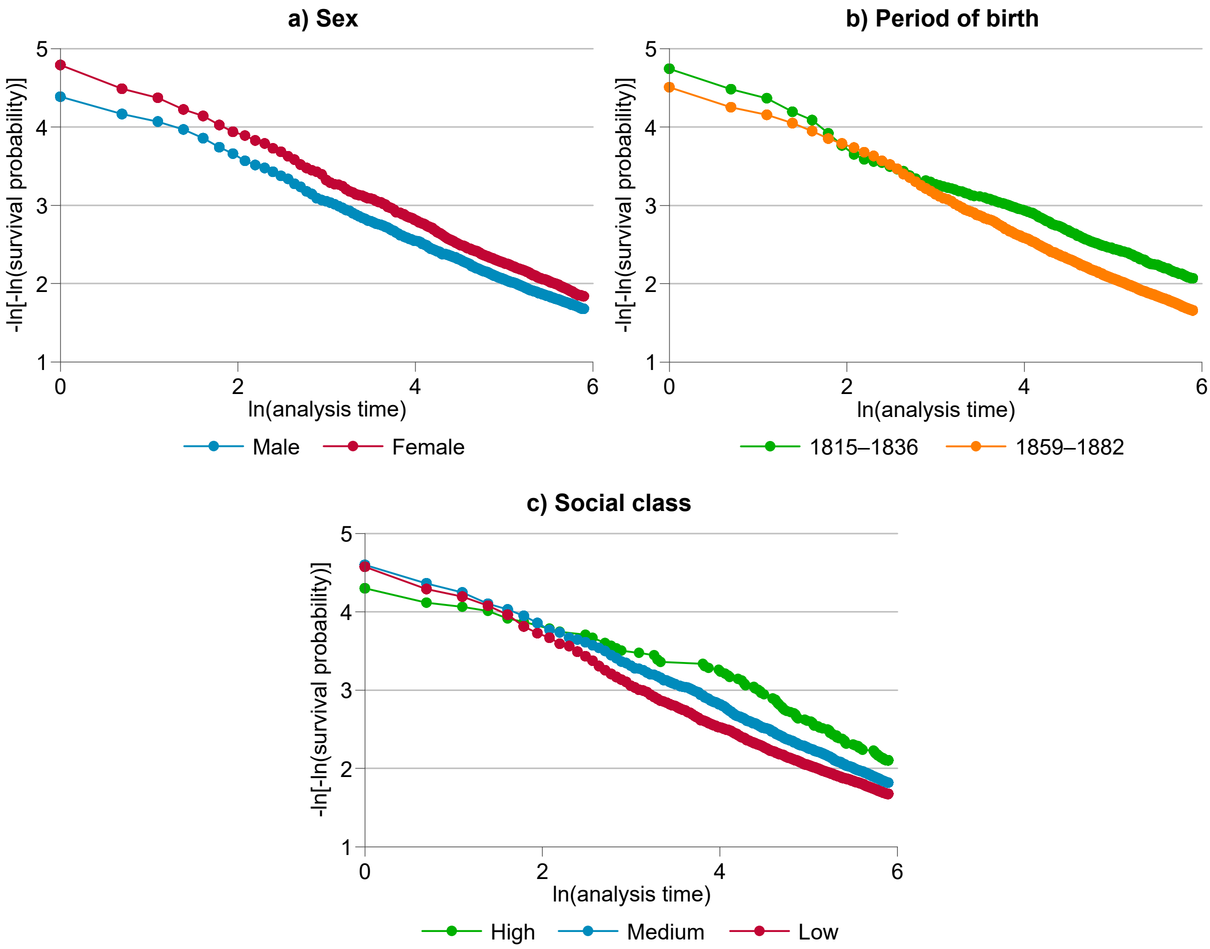
Figure 12 Kaplan-Meier survival curves by sex, period and social class in St. Jakobi parish, Rostock, 1815–1836 and 1859–1882



Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.

Figure 12 also shows that the differences between the studied sub-populations grew over time, especially in the first weeks of life, thus indicating a possible violation of the proportional-hazards assumption. Testing this assumption by means of log-log survival plots (Figure 13), our conjecture was confirmed as the patterns of the mortality differences differed between the first month and the following months of life, particularly regarding the social class variable. Therefore, we conducted separate models for neonatal (Table 13) and post-neonatal mortality (Table 14) in the following event history analyses because estimates for overall infant mortality would be biased.

Figure 13 Log-log survival plots by sex, period and social class in St. Jakobi parish, Rostock, 1815–1836 and 1859–1882



Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.

As revealed by Cox regressions, the risk of neonatal death differed by social class, period of birth and sex (Table 13). However, this was not true for every cause-of-death group. Taking all causes together, the risk of neonatal death was 21 % higher among the medium social class ($HR = 1.21$, $p = 0.272$), albeit not statistically significant, and 60 % higher among the low social class ($HR = 1.60$, $p = 0.005$) as compared to the high social class. Furthermore, it was 20 % higher in 1859–82 ($HR = 1.20$, $p = 0.031$) than in 1815–36. Female infants had a 23 % lower risk (*HR* = 0.77, *p* = 0.000) than male ones. Regarding cause-specific differences, the social gradient was only evident in gastro-intestinal diseases with *HR* = 2.09 (*p* = 0.033) for the medium and *HR* = 3.22 (*p* = 0.001) for the low social classes as compared to the high social class. The sex gradient was also most pronounced in gastro-intestinal diseases (*HR* = 0.70, *p* = 0.001). The period effect was strongest in 'weakness/cachexia' (*HR* = 1.40, *p* = 0.011) and not statistically significant in the other cause-of-death groups.

Table 13 Neonatal mortality: Hazard ratios from Cox proportional-hazards models for St. Jakobi parish, Rostock, 1815–1836 and 1859–1882

Variable	Category	All causes	Gastro-intest.	Respiratory	Weakness	Other causes
Sex	Men (*Ref*)	1	1	1	1	1
	Women	0.77 ***	0.70 ***	1.07	0.81 **	0.86
Period of birth	1815–1836 (*Ref*)	1	1	1	1	1
	1859–1882	1.20 **	1.08	2.35	1.40 **	0.86
Social class	High status (*Ref*)	1	1	1	1	1
	Medium status	1.21	2.09 **	0.83	0.99	0.71
	Low status	1.60 ***	3.22 ***	1.11	1.10	1.15

Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.
* *p* ≤ 0.1; ** *p* ≤ 0.05; *** *p* ≤ 0.01. *Ref* indicates the reference category.

Table 14 Post-neonatal mortality: Hazard ratios from Cox proportional-hazards models for St. Jakobi parish, Rostock, 1815–1836 and 1859–1882

Variable	Category	All causes	Gastro-intest.	Respiratory	Weakness	Other causes
Sex	Men (*Ref*)	1	1	1	1	1
	Women	0.89 ***	0.91	0.95	1.11	0.68 ***
Period of birth	1815–1836 (*Ref*)	1	1	1	1	1
	1859–1882	1.62 ***	1.94 ***	1.13	1.68 **	1.57 ***
Social class	High status (*Ref*)	1	1	1	1	1
	Medium status	1.34 ***	1.75 ***	0.94	0.86	1.31
	Low status	1.44 ***	1.86 ***	0.98	1.40	1.29

Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.
* *p* ≤ 0.1; ** *p* ≤ 0.05; *** *p* ≤ 0.01. *Ref* indicates the reference category.

Just like in neonatal mortality, the risk of post-neonatal death differed by social class, period of birth and sex (Table 14). Different from neonatal mortality, however, the differences between the sexes and between the highest and lowest social class were smaller in post-neonatal mortality, whereas the differences between the periods were more pronounced. Overall, the risk of post-neonatal death was 34 % higher among the medium social class (*HR* = 1.34, *p* = 0.009) and 44 % higher among the low social class (*HR* = 1.44, *p* = 0.001) as compared to the high social class. Moreover, it increased over time by 62 % (*HR* = 1.62, *p* = 0.000) from the first period to the second. The risk was 11 % lower for female infants (*HR* = 0.89, *p* = 0.009) than for male ones. The social gradient in post-neonatal mortality was driven by gastro-intestinal diseases as well with *HR* = 1.75 (*p* = 0.001) for the medium and *HR* = 1.86 (*p* = 0.000) for the low social class. The sex gradient was most pronounced in 'other causes' (*HR* = 0.68, *p* = 0.001). The period effect showed up in all cause-specific groups, strongest in connection with gastro-intestinal diseases (*HR* = 1.94, *p* = 0.000) and statistically not significant for respiratory diseases (*HR* = 1.13, *p* = 0.280).

Table 15 Interaction in neonatal mortality between period and social class: Change between the periods 1815–36 and 1859–82 by social class in Rostock, St. Jakobi parish, Hazard ratios from Cox proportional-hazards models

Outcome	Social class	All causes		Gastro-intest.		Respiratory	Weakness	Other causes
Period 1815–36	High (*Ref*)	1		1		-	1	1
	Medium	1.56		1.76		-	1.35	1.97
	Low	2.14	**	3.44	**	-	1.35	1.83
Period effect	High	1.71		1.07		-	1.91	2.13
Change by social class	High (*Ref*)	1		1		-	1	1
	Medium	0.70		1.25		-	0.66	0.22
	Low	0.68		0.92		-	0.76	0.51

Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.
* *p* ≤ 0.1; ** *p* ≤ 0.05; *** *p* ≤ 0.01. *Ref* indicates the reference category. The numbers of respiratory diseases in neonatal mortality were too small for analysis.

Table 16 Interaction in post-neonatal mortality between period and social class: Change between the periods 1815–36 and 1859–82 by social class in Rostock, St. Jakobi parish, Hazard ratios from Cox proportional-hazards models

Outcome	Social class	All causes		Gastro-intest.		Respiratory	Weakness	Other causes
Period 1815–36	High (*Ref*)	1		1		1	1	1
	Medium	1.41		1.47		1.09	1.34	2.09
	Low	1.45	*	1.41	**	1.21	2.64	1.83
Period effect	High	1.68	**	1.46		1.44	3.25	2.55
Change by social class	High (*Ref*)	1		1		-	1	1
	Medium	0.93		1.26		0.81	0.58	0.55
	Low	0.98		1.42		0.75	0.46	0.64

Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.
* *p* ≤ 0.1; ** *p* ≤ 0.05; *** *p* ≤ 0.01. *Ref* indicates the reference category.

Social class gradients did not differ significantly in the change of infant mortality between the periods 1815–36 and 1859–82, neither in neonatal (Table 15) nor in post-neonatal mortality (Table 16). However, there was a tendency that the increase in all-cause neonatal mortality was lower in the medium (*HR* = 0.70, *p* = 0.387) and low classes (*HR* = 0.68, *p* = 0.324) than in the highest social class.

6.3 Regional Differences in Avoidable Mortality (Study 3)

Decomposition of Trends in Death Rates

Study 3 dealt with the recent development of cause-specific premature mortality, not only for Rostock but for the whole German Baltic Sea region, since the German reunification. Tables 17 and 18 display the results of the decomposition analysis for men and women, respectively. The upper halves of the two tables show the decomposition of the difference in the death rates between 1990/1994 and 2007/2011 in the respective region into a direct and compositional component. The lower halves of the tables show the direct and the compositional effect on the changes from 1990/1994 to 2007/2011 in the mortality differences between two regions.

The observed cause-specific death rates decreased moderately between 1990/1994 and 2007/2011 for men and women in the four study regions, as shown in the upper halves of Tables 17 and 18. This was, however, because of diametrically opposed trends in the direct and the compositional component: The direct component was negative and the compositional component was positive in all regions and all cause-of-death groups. Thus, the direct component reveals that there was an enormous decrease in amenable and preventable mortality, especially in Mecklenburg-Vorpommern (MV). Survival improvements in ‘other causes’ were smaller over time than in amenable and preventable mortality, particularly in Schleswig-Holstein (SH). Among men, the direct component was most pronounced in preventable mortality, showing the highest effect in rural MV (-28.5 per 10,000), followed by urban MV (-15.7), urban SH (-13.1) and rural SH (-12.6). For women, however, the survival improvements were strongest in amenable mortality, showing the highest effect again in rural MV (-10.7), followed by urban MV (-8.1), urban SH and rural SH (both -5.4). The extent of the compositional component was lower than the direct component in amenable and preventable mortality. This was true for both sexes. Regarding the group of other causes, this was also true for women in urban MV, rural MV and urban SH. Thus, these results reveal that if the age structure had not changed between the early 1990s and 2007/2011, all death rates would have decreased on a larger scale than the observed crude and cause-specific death rates did. The large compositional effect is the result of an ageing population, most specifically in MV.

The lower parts of Tables 17 and 18 show that the direct component was stronger than the compositional one regarding the change of the difference in observed death rates between urban and rural MV as well as between rural SH and rural MV. The impact of preventable and amenable causes was greatest in these two direct mortality differentials as well. Regarding the change in the difference between rural and urban SH and between urban SH and urban MV, the compositional effect was stronger, though. These results refer to both sexes.

Table 17 Decomposition of the difference in the cause-specific death rates of MV and SH (per 10,000) into direct and compositional components, men aged 0–74

Region	Cause of death	Death rate 1990/94	Death rate 2007/11	Δ	Direct	Compo-sitional
Urban MV	Amenable causes	14.248	13.889	-0.359	-9.874	9.515
	Preventable causes	29.888	28.306	-1.582	-15.718	14.136
	Other causes	16.175	19.530	3.355	-6.050	9.404
	Total	60.312	61.725	1.414	-31.642	33.055
Rural MV	Amenable causes	19.309	15.590	-3.718	-13.940	10.222
	Preventable causes	42.586	30.709	-11.877	-28.507	16.630
	Other causes	17.927	19.668	1.741	-7.536	9.277
	Total	79.822	65.968	-13.854	-49.983	36.129
Urban SH	Amenable causes	15.757	12.898	-2.859	-6.792	3.933
	Preventable causes	30.065	22.713	-7.352	-13.097	5.745
	Other causes	17.500	21.056	3.556	-0.980	4.536
	Total	63.322	56.667	-6.655	-20.869	14.215
Rural SH	Amenable causes	13.662	11.917	-1.745	-7.039	5.294
	Preventable causes	25.638	20.375	-5.263	-12.619	7.356
	Other causes	14.590	19.595	5.005	-0.881	5.886
	Total	53.890	51.887	-2.003	-20.540	18.537
Urban MV minus rural MV	Amenable causes	-5.060	-1.701	3.359	4.066	-0.707
	Preventable causes	-12.698	-2.403	10.296	12.789	-2.494
	Other causes	-1.752	-0.138	1.613	1.486	0.127
	Total	-19.511	-4.243	15.268	18.341	-3.074
Rural SH minus urban SH	Amenable causes	-2.094	-0.981	1.114	-0.247	1.361
	Preventable causes	-4.427	-2.338	2.088	0.477	1.611
	Other causes	-2.910	-1.461	1.449	0.099	1.350
	Total	-9.431	-4.780	4.651	0.329	4.322
Urban SH minus urban MV	Amenable causes	1.509	-0.991	-2.500	3.082	-5.581
	Preventable causes	0.177	-5.593	-5.770	2.622	-8.392
	Other causes	1.324	1.526	0.202	5.069	-4.868
	Total	3.010	-5.058	-8.068	10.773	-18.841
Rural SH minus rural MV	Amenable causes	-5.646	-3.673	1.973	6.901	-4.927
	Preventable causes	-16.948	-10.334	6.614	15.888	-9.274
	Other causes	-3.338	-0.074	3.264	6.655	-3.391
	Total	-25.932	-14.081	11.851	29.443	-17.592

Source: Author's calculations based on the official cause-of-death and population statistics of MV and SH.

In more detail, decreases in direct mortality differentials were strongest between rural SH and rural MV (29.4 for men and 15.7 for women). Among men, there was a remarkable decrease in the direct mortality differentials between urban and rural MV as well (18.3). Among women, however, both the direct (4.6) and the compositional component (3.1) had the same direction in contributing to the change in the difference between urban and rural MV. The two tables reveal a decline of the differences in the observed death rates between the study regions over time, except for the gap between urban SH and urban MV, which increased for both men and women. Among men, the gap between these two regions even changed the direction to the disadvantage of the latter (from 3.0 to -5.1). This is mainly the result of compositional changes (-18.8), whereas the direct component points in the other direction (10.8). Among women, the compositional component (-15.0) was also more pronounced than the direct one (11.4) in this regard. Thus, if the age structures of the two federal states had not changed, the death rates in urban MV would have improved to a greater extent than in urban SH, thereby narrowing the gap.[10] The decrease in the difference between rural and urban SH was mainly due to compositional changes as well (4.3 for men and 4.5 for women), whereas the direct effect approximated zero for both sexes.

Table 18 Decomposition of the difference in the cause-specific death rates of MV and SH (per 10,000) into direct and compositional components, women aged 0–74

Region	Cause of death	Death rate 1990/94	Death rate 2007/11	Δ	Direct	Compo-sitional
Urban MV	Amenable causes	12.386	10.123	-2.263	-8.073	5.809
	Preventable causes	11.689	9.572	-2.117	-7.006	4.890
	Other causes	12.341	11.575	-0.766	-6.760	5.994
	Total	36.415	31.269	-5.146	-21.839	16.693
Rural MV	Amenable causes	16.379	10.538	-5.841	-10.749	4.909
	Preventable causes	14.234	9.552	-4.682	-8.692	4.010
	Other causes	14.536	12.214	-2.323	-7.001	4.679
	Total	45.149	32.304	-12.845	-26.443	13.598
Urban SH	Amenable causes	14.319	9.527	-4.793	-5.366	0.573
	Preventable causes	12.544	9.755	-2.789	-3.299	0.510
	Other causes	13.302	12.055	-1.247	-1.810	0.562
	Total	40.165	31.337	-8.828	-10.474	1.646
Rural SH	Amenable causes	12.883	9.724	-3.160	-5.354	2.194
	Preventable causes	10.400	8.504	-1.896	-3.586	1.690
	Other causes	11.562	12.062	0.500	-1.754	2.255
	Total	34.846	30.290	-4.556	-10.694	6.139
Urban MV minus rural MV	Amenable causes	-3.993	-0.416	3.577	2.676	0.901
	Preventable causes	-2.545	0.020	2.565	1.686	0.879
	Other causes	-2.195	-0.639	1.556	0.241	1.316
	Total	-8.733	-1.034	7.699	4.603	3.096
Rural SH minus urban SH	Amenable causes	-1.436	0.197	1.633	0.011	1.621
	Preventable causes	-2.143	-1.251	0.892	-0.287	1.179
	Other causes	-1.740	0.007	1.747	0.055	1.692
	Total	-5.319	-1.047	4.272	-0.220	4.493
Urban SH minus urban MV	Amenable causes	1.934	-0.596	-2.529	2.707	-5.236
	Preventable causes	0.855	0.183	-0.672	3.707	-4.379
	Other causes	0.961	0.480	-0.481	4.951	-5.432
	Total	3.749	0.067	-3.682	11.365	-15.047
Rural SH minus rural MV	Amenable causes	-3.496	-0.815	2.681	5.395	-2.714
	Preventable causes	-3.833	-1.048	2.786	5.106	-2.321
	Other causes	-2.974	-0.152	2.823	5.247	-2.424
	Total	-10.303	-2.014	8.289	15.748	-7.459

Source: Author's calculations based on the official cause-of-death and population statistics of MV and SH.

The direct component in the group of other causes for the change in the differences between urban SH and urban MV (about 5 per 10,000 for both men and women) and between rural SH

[10] As the following section will show, the standardized death rates of men in urban MV have never been significantly lower than in urban SH since reunification.

and rural MV (6.7 for men and 5.2 for women) was relatively high, compared to the inner-state regional differences in other causes. This was due to a stronger decrease of other premature mortality in MV than in SH, even though it was still minor in comparison to the decreases of amenable and preventable mortality.

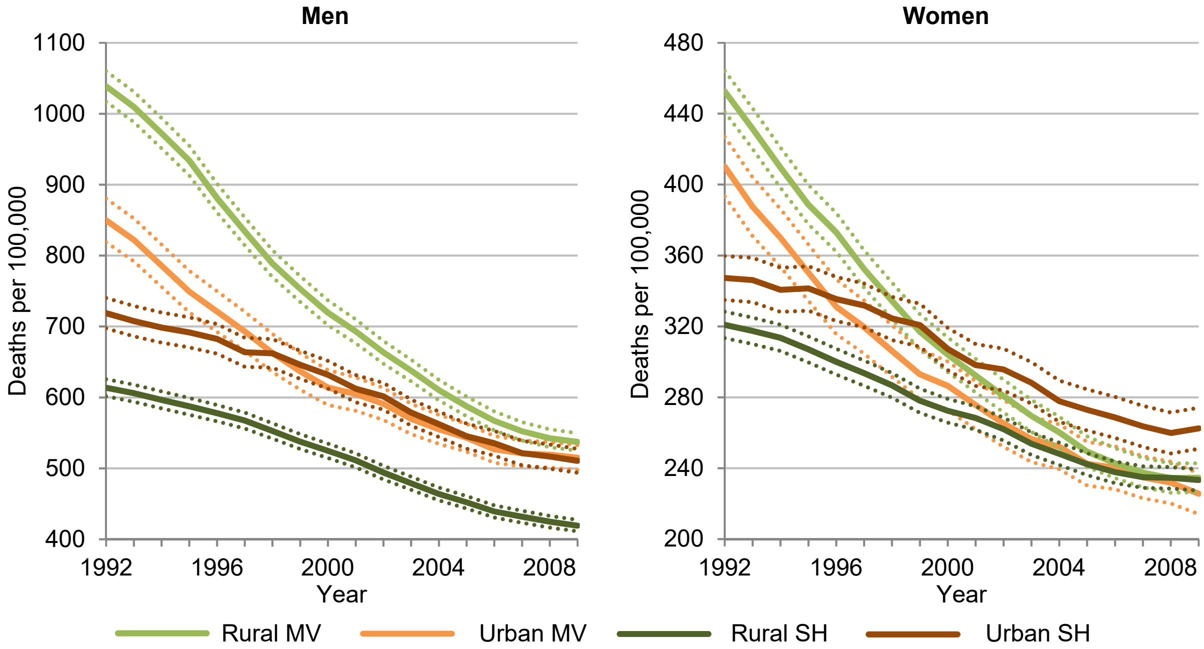
Standardized Death Rates

The method of direct standardization allows us to see the trends of cause-specific premature mortality over time, without compositional distortions. Figures 14–17 show the standardized death rates from 1990/1994 to 2007/2011, including 95 % confidence intervals for measuring significance, broken down by causes of death for the population aged 0 to 74 in the urban and rural districts of MV and SH, with men shown on the left and women on the right. For reasons of simplicity, we named the five-year periods after the middle year in the figures (e.g. 2009 instead of 2007–2011).

As already indicated in the decomposition analysis, the decline in overall premature mortality was greater in MV than in SH, starting from a considerably higher level in the early 1990s (Figure 14). A process of equalization shaped the 1990s, with MV catching up to the mortality levels of SH. This process slowed down eventually, though. The gap between urban MV and urban SH disappeared in the mid-1990s. For women, it even changed to the opposite, with urban SH displaying the highest level of premature mortality at the end of the observation period, while urban MV, rural MV and rural SH no longer differed significantly from one another. Among men, however, rural MV exhibited a significantly higher mortality level compared to the other three regions throughout the observation period, although the difference decreased to a considerable degree. In general, both MV and SH showed an urban-rural gradient in all-cause premature mortality. These gradients were diametrically opposed in the two federal states, though: Whereas the divide was directed to the favor of the urban areas in MV, it was directed to the favor of the rural areas in SH. The gap between rural and urban SH was significant and widely constant over time for both sexes. The gap between urban and rural MV, however, had decreased since the mid-1990s and was only still significant for men at the end of the observation period, as it became very small among women. There was also a considerable sex gradient: Premature mortality was about twice as high for men compared to women.

The development of amenable mortality (Figure 15) was very similar to overall premature mortality, with the main difference being, however, that all significant regional differences disappeared for women. The trend in preventable mortality (Figure 16) was similar in comparison to overall premature mortality as well. The difference was, however, that the gap in preventable mortality between urban MV and urban SH among men was still evident and even increased in the final years of the observation period. Survival improvements in the group of other causes of death (Figure 17) were comparatively low, except for urban and rural MV in the early 1990s. In this cause-of-death group, urban SH showed the highest mortality rate, while the other three regions did not show significant differences from one another anymore, which was true for both men and women.

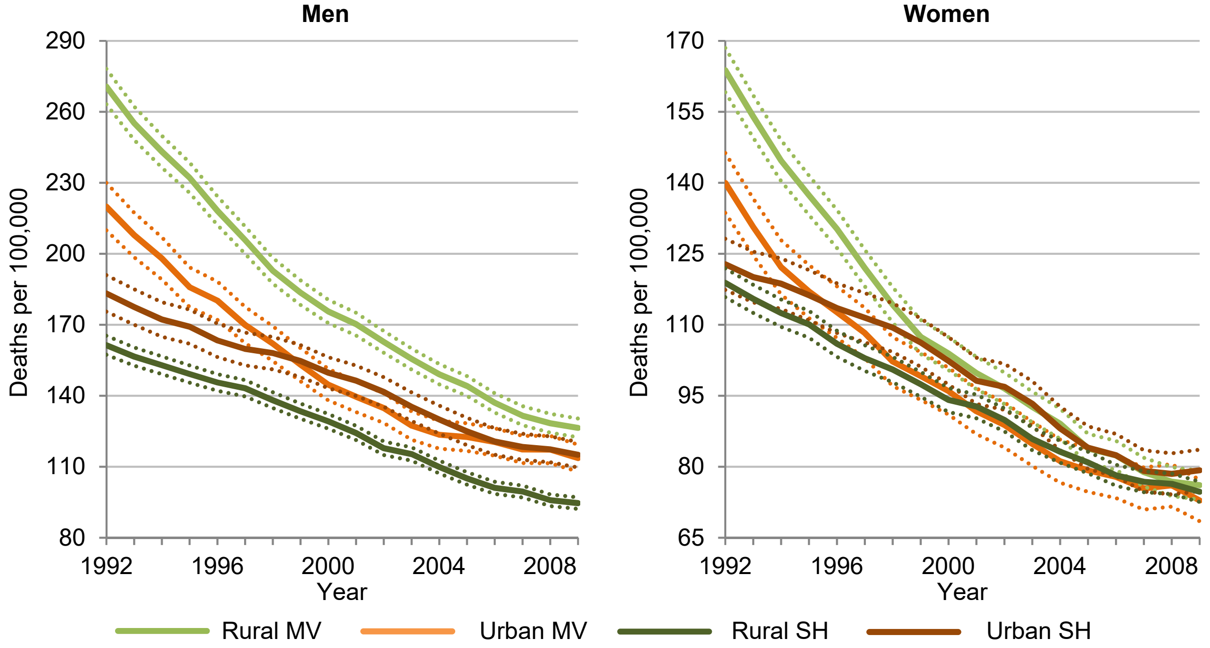
Figure 14 All-cause premature mortality in the urban and rural areas of Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH), standardized death rate, years 1992–2009, ages 0–74



Source: Author's calculations based on the official cause-of-death and population statistics of MV and SH.

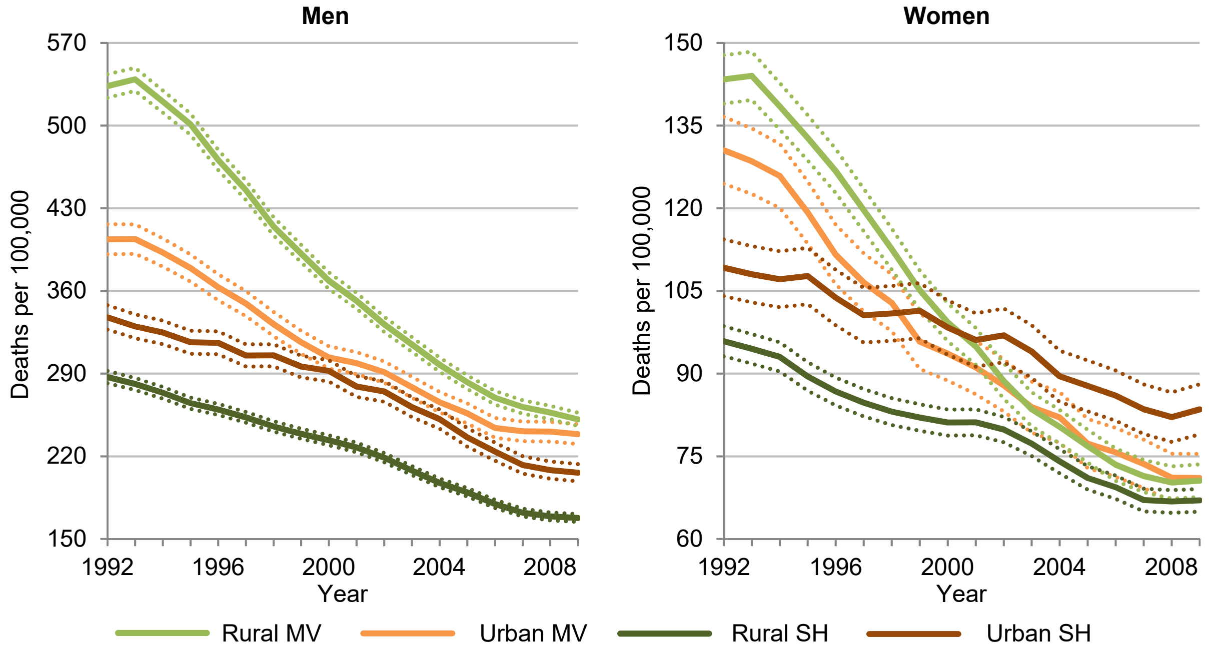
The displayed trends clearly show that the remaining difference in premature mortality between MV and SH among men was primarily caused by higher rates of amenable and preventable mortality in rural MV. The urban areas of MV, however, also showed significantly higher rates of preventable mortality compared to both rural and urban SH. With regard to women, on the contrary, the differences between urban MV, rural MV and rural SH in amenable, preventable and other premature mortality disappeared during the observation period. The resulting gap between urban SH, that exhibited the highest rates in all three cause-of-death groups in the final years of observation, and the other three regions was only significant in preventable mortality, though.

Figure 15 Amenable mortality in the urban and rural areas of Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH), standardized death rate, years 1992–2009, ages 0–74



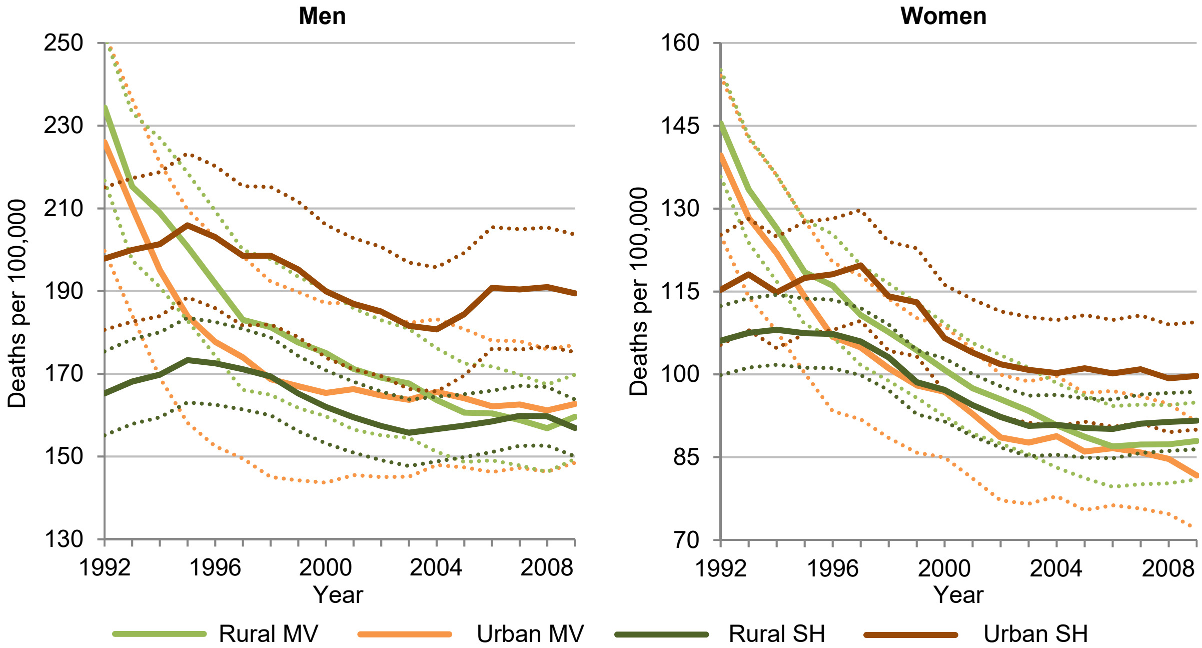
Source: Author's calculations based on the official cause-of-death and population statistics of MV and SH.

Figure 16 Preventable mortality in the urban and rural areas of Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH), standardized death rate, years 1992–2009, ages 0–74



Source: Author's calculations based on the official cause-of-death and population statistics of MV and SH.

Figure 17 Other premature mortality in the urban and rural areas of Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH), standardized death rate, years 1992–2009, ages 0–74



Source: Author's calculations based on the official cause-of-death and population statistics of MV and SH.

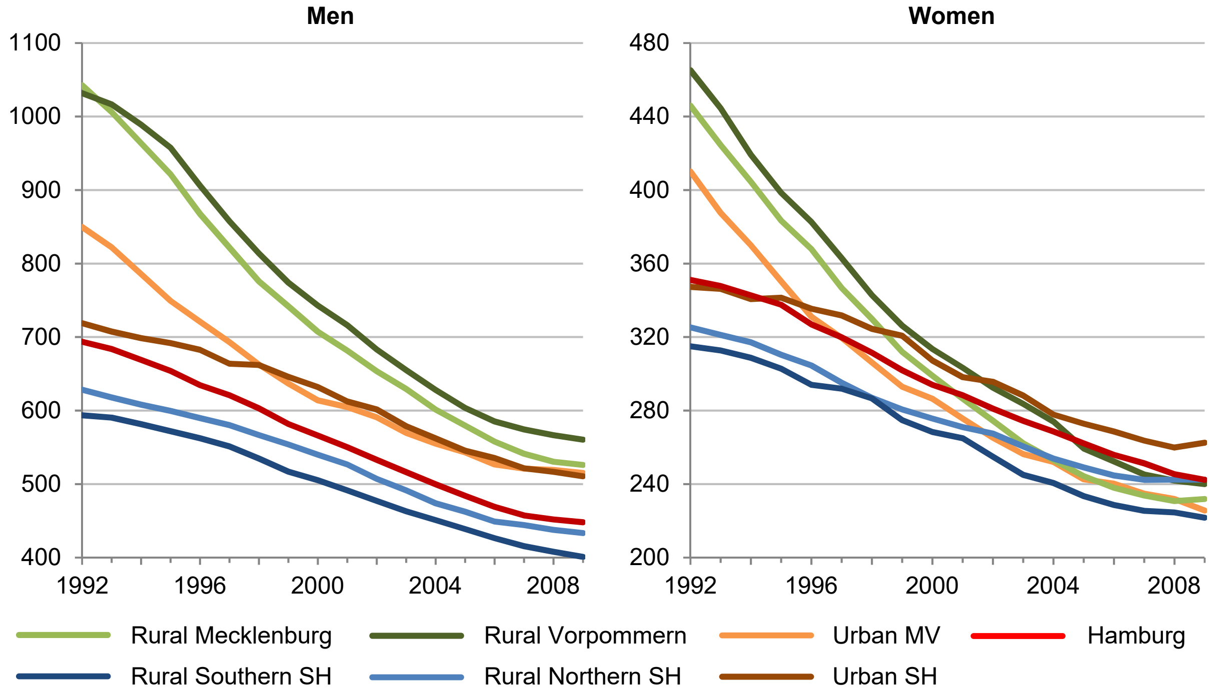
Overall, preventable mortality was considerably higher than amenable mortality among men, whereas amenable mortality was slightly higher than preventable mortality among women. Following the tremendous fall of amenable and preventable mortality, the share of other 'non-avoidable' causes in premature mortality has increased since reunification.

Sensitivity Analyses

For sensitivity analyses, we further divided the rural areas of both federal states according to structural and socio-economic characteristics and added the neighboring metropolitan city of Hamburg for comparison (see Table 4 and Figure 5 for details). The standardized death rates for these regions are displayed in Figures 18–21. We omitted confidence intervals and axis titles and used different scales of measurement for men and women to make the regional differences and trends in mortality more visible in the graphics.

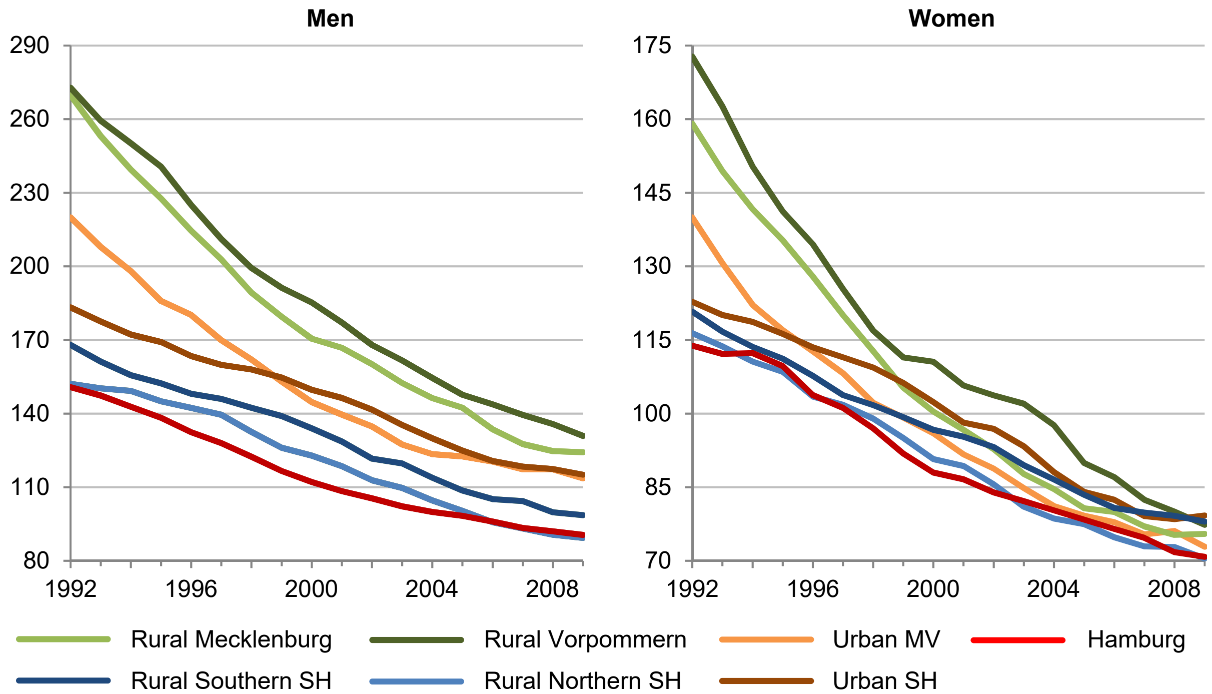
These figures show that the urban-rural differences within the two federal states were of greater extent than the differences between the north and south in rural SH or between the rural areas of Mecklenburg and Vorpommern. In comparison with SH and MV, the city of Hamburg exhibited a lower level of amenable mortality, whereas the trend of preventable mortality in Hamburg was very similar to urban SH.

Figure 18 All-cause premature mortality in the urban and rural areas of Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH), and Hamburg, standardized death rate (deaths per 100,000), years 1992–2009, ages 0–74



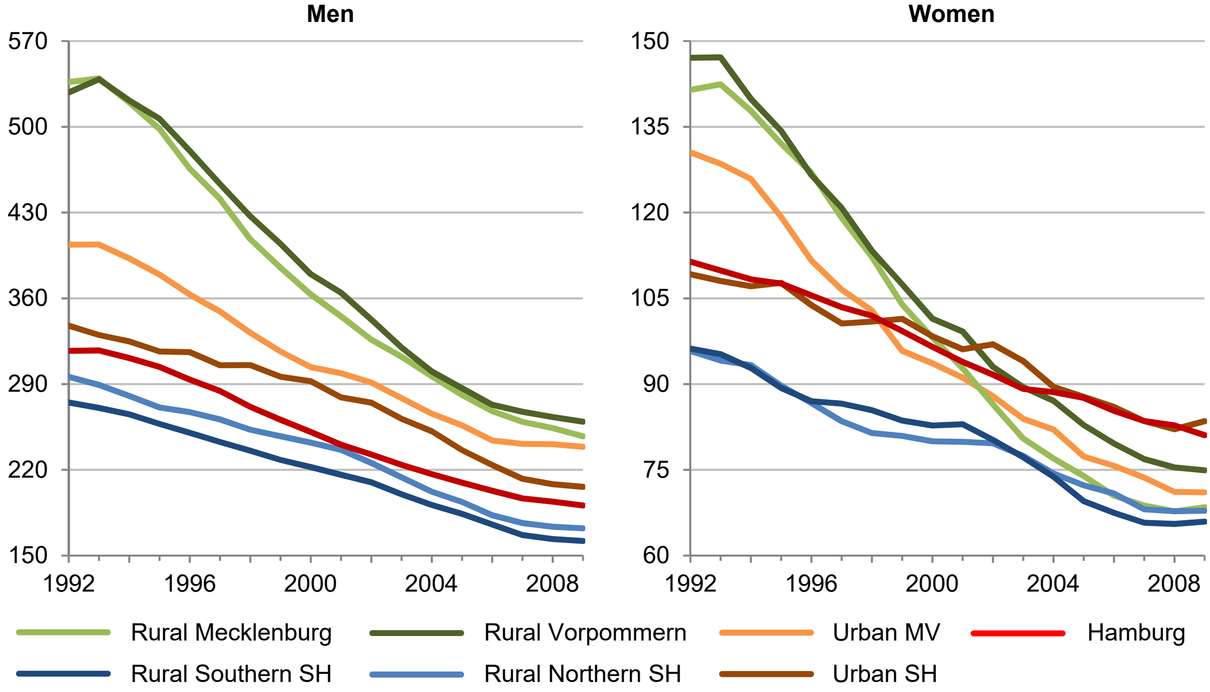
Source: Author's calculations based on the official cause-of-death and population statistics of MV and SH.

Figure 19 Amenable mortality in the urban and rural areas of Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH), and Hamburg, standardized death rate (deaths per 100,000), years 1992–2009, ages 0–74



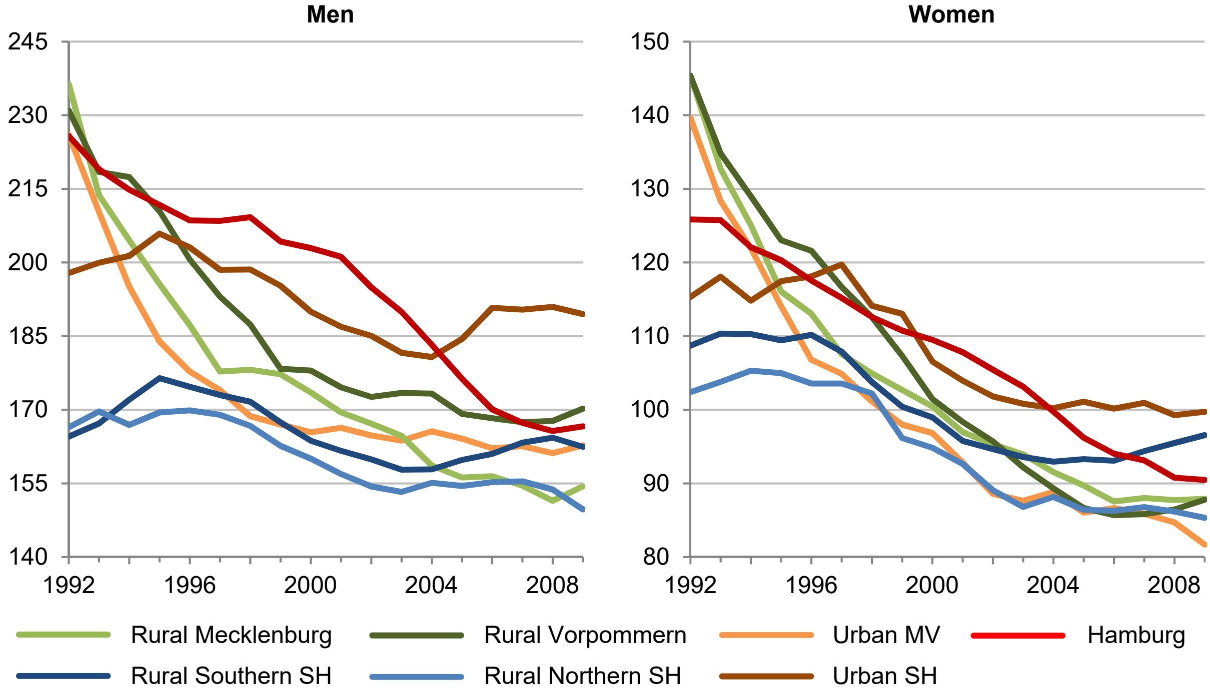
Source: Author's calculations based on the official cause-of-death and population statistics of MV and SH.

Figure 20 Preventable mortality in the urban and rural areas of Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH), and Hamburg, standardized death rate (deaths per 100,000), years 1992–2009, ages 0–74



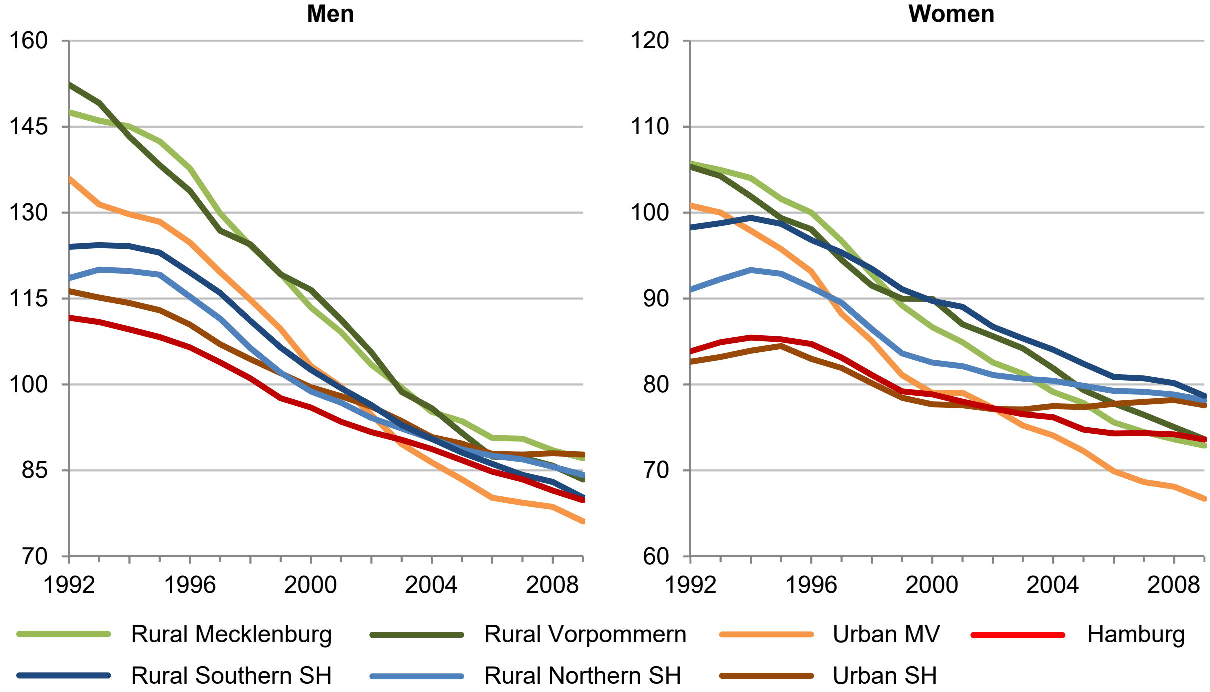
Source: Author's calculations based on the official cause-of-death and population statistics of MV and SH.

Figure 21 Other premature mortality in the urban and rural areas of Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH), and Hamburg, standardized death rate (deaths per 100,000), years 1992–2009, ages 0–74



Source: Author's calculations based on the official cause-of-death and population statistics of MV and SH.

Figure 22 All-cause mortality in the urban and rural areas of Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH), and Hamburg, deaths per 1,000 inhabitants, years 1992–2009, ages 75 and older



Source: Author's calculations based on the official cause-of-death and population statistics of MV and SH.

In the 75 and above age group (Figure 22), there was an urban-rural divide to the disadvantage of the rural regions in the 1990s, which was true for both MV and SH and for both sexes. In MV, this gradient persisted throughout the observation period, while it completely disappeared in SH in the 2000s. In both sexes, urban MV exhibited the lowest level of all-cause mortality in this age group in the final years of the study period.

7. DISCUSSION

7.1 Objectives of the Studies

The German Baltic Sea region is an east-west spanning region of two federal states in the north of Germany – Mecklenburg-Vorpommern (MV) and Schleswig-Holstein (SH) – that show strong historical, cultural and economic commonalities. This doctoral thesis is based on three original research articles that provide new insights on the development and determinants of premature mortality in this region.

Studies 1 and 2 focused on infant mortality in the nineteenth century when the region was a forerunner in survival, using event history analyses based on the newly available data source of church records from the Hanseatic city of Rostock. Study 1 aimed to reconstruct the development of infant mortality and to estimate the impact of social class and birth legitimacy on early and late infant mortality in the early nineteenth century. Study 2 aimed to explore the interplay of social class and cause of death in neonatal and post-neonatal mortality before and during urbanization in the nineteenth century.

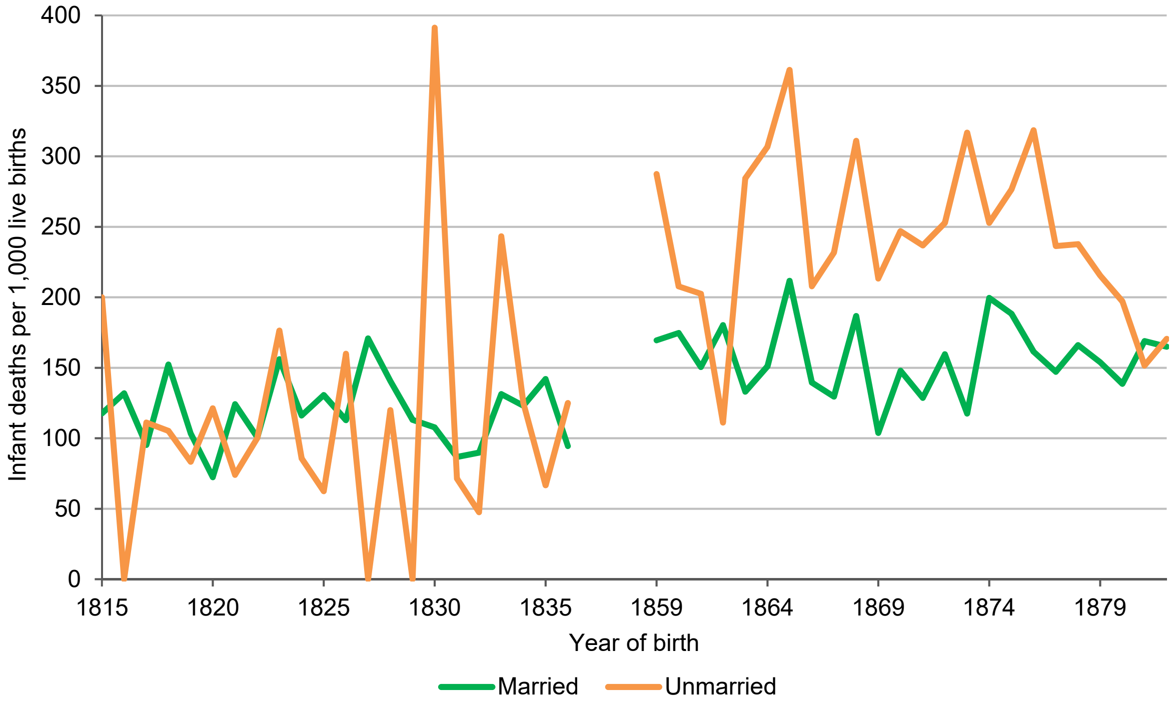
Study 3 dealt with premature mortality in the time following reunification, when the German Baltic Sea region showed higher mortality levels compared to the south of Germany and considerable east-west differences. Applying the concept of avoidable mortality based on official German cause-of-death statistics and using methods of decomposition and standardization, Study 3 aimed to find out to what extent differences between SH and MV were driven by structural and risk-relevant factors. Applying an urban-rural differentiation, Study 3 also aimed to demonstrate where the levels of mortality have already converged between the east and the west and where this has not been the case.

7.2 Reflection of the Results

Impact of Birth Legitimacy on Infant Mortality

Focusing on the period from 1815 to 1829, the first hypothesis of Study 1 was that *infant mortality for children born legitimately was lower than for those born out of wedlock*. As opposed to previous studies (e.g. Prinzing 1902, 1911; Brüning and Balck 1906; Brüning and Josephy 1928), we could not find a significant effect of legitimacy of birth. In contrast, we even found a tendency towards a higher level in early and late infant mortality for the children born legitimately. Preston and Haines (1991: 30) and Vögele (1994) described the phenomenon that single mothers were more likely to hand their children over to relatives or institutions outside of the city and to return to work (e.g. as domestic servants) to improve their poor financial situation. In such a case, respective infant deaths would not have been recorded in Rostock but elsewhere and thus underestimated. In the year 1800, over 30 % of women aged 21 to 30 were employed as domestic servants in Rostock (Manke 2000: 336), which substantiates this speculation. As a sensitivity analysis, we calculated the Cox model only for stillbirths, which revealed a 28 % higher mortality risk for illegitimate births than for legitimate births. Although this difference is also not significant, this is a further indication for an underreporting of infant deaths among children born out of wedlock caused by out-migration.

Figure 23 Infant mortality rates according to the birth-year method for children of married and unmarried parents in St. Jakobi parish, Rostock, 1815–1836 and 1859–1882



Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock.

A further possible explanation addresses timely fluctuations in the infant mortality rate. Since we were able to extend the study period for Study 2, we performed a supplementary analysis of infant mortality by legitimacy of birth in 1815–1836 and 1859–1882 (Figure 23). The trend of the infant mortality rate among illegitimately born children showed large variations fluctuating between 0 and 391 infant deaths per 1,000 live births. The inclusion of the years 1830–1836 and, even more, 1859–1882 in Study 2 changed the advantage of illegitimate-born infants to the opposite. The same is true for the sex gradient to the disadvantage of male newborns, which we could only find in the added years of Study 2. On the one hand, these differences are due to comparatively low numbers in Study 1. There were 2,768 live births in Study 1 compared to 16,880 in Study 2. Only 41 infant deaths were recorded among illegitimate births between 1815 and 1829. On the other hand, the chosen period plays a part as well. The inclusion of the year 1830 alone would have minimized the advantage of the children born out of wedlock considerably. Therefore, when fluctuations of infant mortality – or of any other object of investigation – are high and numbers are low (such as in Study 1), the results of a study depend on the chosen period to a certain degree.

Impact of Social Class on Infant Mortality

The second hypothesis of Study 1 was that *infants whose fathers had a lower social status exhibited an increased mortality risk compared to newborns with socio-economically better-situated fathers*, which was supported by our data. Children of fathers with lower ranked occupations such as lower administrative employees, seamen, fishermen and field workers showed the highest risk of dying during their first year of life, while those from the group of higher ranked civil servants, merchants and lawyers, who formed Rostock's elite (Manke 2000: 369–370), showed the lowest infant mortality risk. Although the tendency was the same in the first 30 days of life as well as in the ensuing months, the effect of social class was not significant in the latter. An exception to this pattern is the residual category, which showed similarly low mortality risks like the upper social class. This was due in particular to low risks among the children of laborers ('Arbeitsmänner') and porters ('Träger') and could be related to good economic conditions in this period for these occupational groups but perhaps their children were just more likely to be breastfed. Nonetheless, this result supports the statement by Preston and Haines (1991: 209) that knowledge in terms of infant care and nutrition outweighs resources. Moreover, it suggests that infant care and nutrition were not necessarily predetermined by socio-economic status.

We also addressed the social gradient using the extended period of Study 2. The first hypothesis of Study 2 was that *there was a social gradient in infant mortality to the advantage of the upper social classes, which was more pronounced in post-neonatal mortality than in neonatal mortality*. While our data confirmed the existence of a social gradient in both neonatal and post-neonatal mortality, it was more pronounced in neonatal than in post-neonatal mortality, just like in Study 1. Different from Study 1, however, the social gradient was stronger and children of laborers and porters did not deviate from the social gradient anymore in the added years of Study 2, as deeper analyses of our data revealed.

Social differences in infant mortality have been found in several places in Europe (e.g. Woods et al. 1988, 1989; Oris et al. 2004; van Poppel et al. 2005; Breschi et al. 2011), but to our knowledge, such a clear, almost linear, social gradient like in Study 2 has not been reported in connection with nineteenth-century infant mortality so far. Previous research saw social differences more related to post-neonatal mortality (e.g. Bourgeois-Pichat 1951; Imhof 1981; Breschi et al. 2000; van Poppel et al. 2005) but some studies also found significant social differences in neonatal mortality (Landers 1993; Derosas 2003, 2009).

Impact of Season of Birth on Infant Mortality

As shown in Study 1, the season of birth had a significant influence on survival in the first month of life, whereby infants born in the summer months (June to August) exhibited the highest mortality risk. Breschi and Livi Bacci (1997) were able to show for five countries that in the nineteenth century mortality in the first two years was associated with the month of birth and that this pattern differed between the countries: In Italy, for example, children born in the summer had the lowest mortality risk, whereas this was true for children born in the winter in Switzerland. A comparable pattern to that of Rostock (and Switzerland) was also found for Denmark (Doblhammer and Vaupel 2001; Doblhammer 2004). Since the effect of the birth month in Rostock with its summer peak was highly significant in the first thirty days of life, this indicates a great extent of gastro-intestinal disorders in the neonatal stage. This was tested in more detail in Study 2 as follows.

Interplay of Social Class and Cause of Death in Infant Mortality

To gain deeper insights into the determinants of the social differences found in our data, we performed cause-specific analyses of neonatal and post-neonatal mortality. The second hypothesis of Study 2 was that *the social gradient was especially related to gastro-intestinal diseases*, which was confirmed by our data. The social gradient was driven entirely by gastro-intestinal diseases in both neonatal and post-neonatal mortality, whereas social class had no significant effect in the other disease groups. This close connection with gastro-intestinal diseases strongly indicates an effect of nutrition and sanitation on infant mortality, as these two factors are closely associated with gastro-intestinal diseases, much more than with other diseases (Kintner 1986; Preston and Haines 1991; Vögele 1994). Since nutritional and sanitary conditions may differ by social status (Haines 1995; Kloke 1997; Scott and Duncan 2000; Oris et al. 2004; Ekamper and van Poppel 2019), we assume that social class was, rather, a proxy for these two factors and did not have a direct effect, thus following Bengtsson and van Poppel (2011).

On the one hand, our results support previous research that established nutrition and sanitation as principal determinants of infant mortality (e.g. Kintner 1986; Preston and Haines 1991; Scott and Duncan 2000; Kesztenbaum and Rosenthal 2017). In the context of nutrition, breastfeeding is the most important factor because breast milk transfers antibodies against infection from mother to child and because birth intervals tend to be prolonged (Bengtsson 1999; Scott and Duncan 2002: 147–157). Artificially fed infants did not only miss this natural protection but were also more likely to come into contact with contaminated or perished food, especially in the warm months of the year, as refrigerators were not yet invented then. For this reason, differences in breastfeeding habits were found to be one of the principal determinants of nineteenth-century infant mortality and its regional variation (Knodel and Kintner 1977; Kintner 1985; Kloke 1997). In the context of sanitation, the supply of clean water and its spatial variation were found to be important determinants as well (van Poppel and van der Heijden 1997; Jaadla and Puur 2016; Kesztenbaum and Rosenthal 2017).

On the other hand, our results indicate that the nutritional and sanitary conditions differed among the three social classes in nineteenth-century Rostock, as has also been argued for other places in Europe (e.g. Haines 1995; Kloke 1997; Scott and Duncan 2000; Oris et al. 2004; Ekamper and van Poppel 2019). Unmarried mothers who had to earn their own living and mothers who had to support their husbands at work were part of the lower social class and were more likely to use artificial nutrition instead of breastfeeding (Imhof 1981; Preston and Haines 1991: 30; Vögele 1994). With respect to sanitation, the neighborhoods of nineteenth-century Rostock presumably differed in the access to clean water, and they probably also showed differences in their social structure, as was the case in Amsterdam, for instance (Ekamper and van Poppel 2019). For this reason, residential segregation coupled with spatial differences in sanitary conditions could be another explanation for the higher infant mortality from gastro-intestinal diseases in Rostock's lower social classes.

Our results therefore suggest that infants of lower social status had a higher risk to experience substitute nutrition (instead of breastfeeding), malnourishment, poor access to clean water and neglect. The vast majority of infant deaths from gastro-intestinal diseases (and respiratory and 'other' diseases as well) occurred in the post-neonatal stage but the social gradient in gastro-intestinal diseases was strongest in neonatal mortality. Thus, although gastro-intestinal diseases were relatively rare in the cause-of-death spectrum of the first four weeks of life, they had a significantly greater impact – when they did arise – on the lowest social class than on the two higher ones. This result indicates severe deficits in maternal care among the lower social classes, particularly with regard to malnutrition and neglect (Derosas 2003, 2009).

Development of Social Differences in Infant Mortality

As revealed in Study 1, the city of Rostock exhibited a comparatively low infant mortality level, in particular in the first third of the century, as was true for all of northern Germany. The trend was similar to Prussia and the other hanseatic cities of Bremen and Hamburg (Figure 3), albeit on a lower level. Almost every German region exhibited on onward shift in infant mortality in the course of the nineteenth century, except for Hessen-Nassau, but at different times. Rostock experienced a remarkable increase in the infant mortality rate between 1840 and 1858, which does not apply to any other German region with available data. This implies a unique situation for the city in that period, which is probably due to its later and rather moderate increase of the population, as compared to cities like Hamburg and Bremen that experienced a steadier and greater increase between 1823 and 1887, rising from 154 infant deaths per 1,000 live births to 255. The shift in infant mortality in Rostock was most likely related to the change in sanitary, housing, working and nutritional conditions caused by the growth of the population. Changes in infant care in terms of nutrition and hygiene could be a possible reason as well. The decrease between 1876 and 1884, which was evident not only in Rostock but in most other German regions as well, may be partly related to the introduction of compulsory immunization against smallpox in the German Empire in 1874 (Thießen 2013). Although vaccination was applied only to children aged 1 and 12, it also reduced the risk of smallpox transmission to infants in their environment.

The time of this shift is directly between the two periods of observation in Study 2. While the population size and infant mortality rate were relatively low in the first period, the second period marks the beginning of urbanization and accelerated population growth. Assuming that the increase of infant mortality between the two periods was associated with the immigration of low-status workers, the third hypothesis of Study 2 was that *the social gradient was more pronounced in the period 1859–82 than in 1815–36*, with the lower classes thus being more strongly affected. However, this hypothesis was not supported by the data, as our results show that the increase in infant mortality was similar for all social classes and that the deficits in nutrition, sanitation and maternal care in the low social class were evident even before industrialization and urbanization had led to worsening living environments. This deterioration then affected all social groups.

As opposed to our hypothesis, we found a tendency towards a higher increase in neonatal mortality for the highest social class, which was not statistically significant, though. The reasons for this possibly refer to changes in residential patterns or changes in maternal care, for instance. Residential segregation coupled with spatial variation in sanitary conditions was found to have an impact on infant mortality differentials (Ekamper and van Poppel 2019). Based on our results, it is probable that there was greater residential segregation in the first period than in the second. If the increasing immigration then altered the residential patterns of the city, the high-status population would have become more likely to come into contact with (immigrated) low-status groups and their associated diseases than before. For this reason, we can assume that the advantage that the high social class possibly enjoyed in terms of sanitary conditions in the first period had decreased in the course of urbanization but further research is necessary to substantiate this explanation.

Survival Improvements versus Compositional Changes in Premature Mortality

Referring to contemporary determinants of premature mortality, the first hypothesis of Study 3 was that *the trends in death rates of premature mortality and their differences across the study regions were driven mainly by changes in the direct component, while the extent of the compositional component differed between urban and rural regions and was of greater importance in the latter*. Using decomposition analysis, we found partial support for this hypothesis based on the given data.

On the one hand, the trends of amenable and preventable mortality were driven more by the direct component, i.e. survival improvements, than by the compositional component, i.e. changes in the age structure, in all regions and both sexes. Regarding the changes over time in the difference between the observed death rates of urban and rural MV and in the difference between the observed death rates of rural SH and rural MV, the direct component was also more pronounced. This is due firstly to the immense reduction in the level of avoidable mortality in rural MV, which was, by comparison, high in the early 1990s. Secondly, urban and rural MV had similar age structures at the time of reunification and suffered both from selective emigration, especially in the 1990s and in the peripheral areas (Weiß 2006; Lehmann 2008).

On the other hand, the changes over time in the difference between the observed death rates of rural and urban SH and in the difference between the observed death rates of urban SH and urban MV were driven more by compositional changes, which was true for both sexes. Since the gap between urban and rural SH remained constant throughout the observation period, the minor changes in the difference between the two areas were largely associated with changes in the age structure. Regarding the difference between urban SH and urban MV, however, there was a strong direct effect but the compositional one was even more pronounced, as the population in urban MV was younger than in urban SH in 1990/1994 but higher in 2007/2011. In fact, the average age in MV has risen to a much greater extent than in SH as a consequence of increasing life expectancy, low fertility and – in particular – selective migration (Dinkel 2004; Grünheid 2015). Furthermore, the gap in mortality between these two regions was considerably smaller than between the rural areas of both states at the beginning of the study period.

In general, the results of the decomposition analysis reveal that changes in the age structure distorted the observed death rates considerably. The direct component and the compositional component had a diametrically opposed effect on the death rates. Consequently, if the age structure had not changed during the study period, the decrease in mortality rates would have been much greater, particularly in MV but also in SH.

Moreover, deeper age-specific analyses of the data show that the direct component grew with age. The older age groups thus benefited more from survival improvements than the younger ones. An exception to this pattern is men in rural MV who exhibited the highest survival improvements at age 50–59, particularly in connection with preventable mortality. In all four regions and both sexes, the direct component was more effective at ages 0-64, whereas the compositional component was more pronounced in the 65–69 and 70–74 age groups.

Urban-Rural Gradients in Premature Mortality

The second hypothesis of Study 3 was that *in both SH and MV, urban-rural divides were evident in premature mortality, directed to the detriment of the urban areas in SH, but to the detriment of the rural areas in MV*, which was supported by the data. Using direct standardization, we found diametrically opposed urban-rural gradients in all-cause premature mortality in MV and SH to the favor of urban MV and rural SH. This regional contrast in SH, showing higher mortality rates in urban than in rural districts is typical for western Germany, while the opposed gradient is typical for eastern Germany (Kibele 2012).

This study shows that the higher premature mortality level in urban SH was particularly attributable to causes of death that should be avoidable through primary prevention and – with reference to men only – causes that should be amenable to health care. The urban penalty in SH was concentrated on men and women aged 35 to 74 and especially in connection with neoplasms considered amenable or preventable. Rural SH, on the other hand, showed a higher mortality from traffic accidents in the 15–34 age group and from cardiovascular diseases in the 75+ age group, as additional age- and cause-specific analyses of the data show. In SH, there was also an urban-rural gradient in premature mortality from ‘other causes’, albeit this divide was not significant for women. Aside from the varying effectiveness of health policies and health care, this divide was possibly also associated with different compositions of socio-economic status – as shown by macro-economic indicators (INKAR 2015) –, and thus different compositions of risk-relevant behavior.

In MV, on the contrary, the rural-urban gap in premature mortality became very small and was only still significant for men. This decrease can be seen in the light of the shifting of mortality to older ages caused by improvements in medical infrastructure following reunification, from which rural MV profited more since the need to catch up was greater there (Bucher 2002; Dinkel 2003; Mai 2004). Among men, the rural-urban gap in MV is closely associated with regional differences in amenable mortality. Supplementary age- and cause-specific analyses show that cardiovascular diseases in particular played a more prominent role in rural MV than in urban MV, especially at ages 60 and older. Preventable mortality was also lower in urban MV than in rural MV, but to a decreasing extent, and was associated with excess road traffic mortality in rural MV. At ages 75 and older, however, the rural-urban divide was still very pronounced in both sexes and attributable in particular to cardiovascular diseases. This result confirms that timely medical treatment of strokes and heart attacks is still a challenge in the peripheral regions of the east (Kibele 2012).

Convergence and Persistent Disparities in Premature Mortality

The third hypothesis of Study 3 was that *the difference in premature mortality between urban MV and urban SH disappeared in the course of the observation period, whereas mortality in rural MV remained significantly higher as compared to the other regions*. We found confirmation for men that mortality differences between the two federal states related only to the rural areas at the end of the observation period and no longer to the urban areas. With regard to women, however, rural MV no longer differed significantly from rural SH and urban MV, whereas urban SH fell on the last position in premature mortality as compared to the other three study regions. The convergence between women in MV and SH was not only a result of the catching-up process in MV, but also attributable to relatively small improvements in survival in SH compared to the rest of Germany.

Going more into detail, the fourth hypothesis of Study 3 was that *the anticipated remaining difference between rural MV and rural SH was strongly connected with higher amenable and preventable mortality rates in rural MV*, which was partly confirmed by the data. For men, the gap between rural MV and rural SH was indeed associated with differences in amenable mortality. Levels of preventable mortality, however, were significantly higher in both urban and rural MV than in SH. The gap in amenable mortality suggests comparatively worse accessibility to appropriate health care in rural MV, whereas the gap in preventable mortality was mainly attributable to higher levels of smoking- and alcohol-related causes in MV among men, as supplementary analyses show. Furthermore, traffic accident mortality was still relatively high in rural MV at the end of the observation period in spite of an enormous decrease. With regard to women, however, the gap between MV (both urban and rural) and rural SH has completely disappeared in amenable, preventable and other premature mortality, whereas the highest rates in these three cause-of-death groups, significantly in preventable mortality, were recorded for urban SH in the last years of observation. In general, the convergence in mortality between eastern and western Germany is partly related to higher smoking rates among middle-aged western German women (Myrskylä and Scholz 2013). This is also true for the German Baltic Sea region, as supplementary cause-specific analyses show: Tobacco-attributable mortality, e.g. lung cancer, was comparatively high among women in SH, particularly in the cities. This excess smoking-related mortality of women in SH outweighed the higher levels of alcohol-related mortality of women in MV.

In neighboring Denmark, the high smoking rates among women decisively contributed to the stagnation in the development of female life expectancy between 1980 and the mid-1990s (Juel 2008; Christensen et al. 2010). Since the female cohorts with the highest smoking rates are currently dying out, Denmark experienced an increase in life expectancy in recent years (Lindahl-Jacobsen et al. 2016). However, this is not the case yet for the German Baltic Sea region. As supplementary analyses based on the German Microcensus show, the female cohorts with the highest smoking rates are younger in SH and MV than in Denmark. In SH, these cohorts have reached the mortality-relevant age, in particular with regard to cancer mortality, whereas the respective cohorts are younger in MV. For this reason, the example of Denmark may probably serve as an indicator of the future trend in preventable and overall mortality among women in the German Baltic Sea region. Vogt et al. (2017) forecasted that the higher smoking rates of younger female cohorts in eastern Germany will reverse the contemporary mortality advantage of the east in comparison to the west in the not too distant future.

Sex Differences

Study 3 also revealed considerable differences between men and women. This sex gap in mortality in favor of women is a typical result for Western countries (Trovato 2005). It can be explained by biological and non-biological factors, with the latter in turn being influenced by the former: On the one hand, women are biologically/genetically more ‘robust’, whereas, on the other hand, non-biological factors such as riskier behavior and unhealthier working conditions of men compared to women have a decisive impact as well (Luy 2003, 2009; Luy and Gast 2014; RKI 2014). Particularly the higher smoking rates of men compared to women were found to be an important contributory factor in several Western countries (Valkonen and van Poppel 1997; Trovato 2005). In MV, the sex gap is more pronounced than in any other German federal state (DESTATIS 2019). Although health policies and advances in health care applied to both sexes, they were obviously less effective among men. The accessibility and quality of medical care should not differ by sex as well. Nonetheless, the gap in amenable mortality between SH and MV only referred to men, which suggests that, especially when the distance to a medical doctor is longer, men tend to avoid or postpone their visit to the doctor, although this is clear disadvantage in terms of early detection of diseases, e.g. cancer. “Overall, women are more likely than men to engage in health behaviors associated with primary prevention”, as concluded by Hiller et al. (2017: 348). Compared to the other German federal states, men in MV exhibit relatively high rates of obesity, smoking and alcohol abuse (RKI 2011; 2014). Salzmann (2012) deduced that an adoption of a less risky lifestyle has only taken place slowly among men in MV.

In both SH and MV, the spectrum of causes of death in amenable mortality was dominated by cardiovascular diseases among men, but with decreasing weight and followed by neoplasms. Among women, neoplasms were more frequent than cardiovascular diseases, though, which is attributable to the fact that women-specific neoplasms like breast, uterine and cervical cancer are outnumbering testicular cancer, the only included men-specific cancer. In the spectrum of preventable causes of death, neoplasms played the most important part among both men and women, followed by cardiovascular diseases.

Considerable sex differences were also visible among infants in Study 2. Male infants exhibited a significantly higher risk of dying than female ones in our data, particularly in neonatal mortality. Although there was no statistically significant interaction effect between sex and social class in our data, there was a tendency that the survival advantage of female infants was most pronounced in the highest social class, especially in connection with gastro-intestinal diseases, as supplementary analyses show.

7.3 Limitations and Strengths

Historical Data

The first potential bias in Rostock's church records is the differentiation between live births and stillbirths made by the pastor. We cannot ascertain whether there were (informal) rules for this classification and whether these rules were subject to changes within the periods studied. In Study 1, all unbaptized infants that died in the observation period were stillbirths. This may be related to the practice that newborn children were baptized only a few days after birth in this period and children who were expected to die were baptized in extremis, usually by the midwife, as notes in the church records illustrate. However, it is also possible that a newborn was only considered a live birth once it has been baptized and when it died without being baptized, it was recorded as a stillbirth. At least in the added years of Study 2, we could not verify such a practice since the deaths of unbaptized live births were also included in the registers.

Second, we cannot ascertain whether and how many children left the parish and died elsewhere in the first year of life. This makes under-recording of infant mortality possible, which is of special relevance in terms of illegitimate births, as discussed in section 7.2. Immigration, on the other hand, is not a problem since the place of birth was recorded in the church records. Thus, we could exclude all immigrated infants.

Third, the results concerning the social differences are shaped by our chosen occupational classification. In general, a perfect classification of the fathers' occupation by socio-economic status is impossible, as the job descriptions include no information on wealth and income. According to Manke (2000: 369–371), Rostock's political and economic elite was formed by merchants, brewers and lawyers, whereas the large group of craftsmen was very heterogeneous in its social structure, and the lower class consisted mainly of (day) laborers. We took account of this in our classification but some uncertainties remain. For instance, we included all merchants and brewers in the upper social class although some were possibly less wealthy.

Fourth, causes of death were recorded in absence of any systematic cause-of-death classification in the observation periods of Studies 1 and 2. For example, the most frequently recorded cause of death in the two periods is 'Krampf', which can be translated as 'convulsion'. However, convulsions do not describe the actual underlying disease, merely the last symptoms before death that usually result from gastro-intestinal disorders, at least in the context of infant mortality (Kintner 1986; Preston and Haines 1991: 6). For this reason, we included all convulsions in the gastro-intestinal disease group. Overall, the accuracy of the recorded causes of death was not optimal, particularly at the beginning of the nineteenth century, but it improved over the course of the century. Furthermore, the diagnoses were not recorded by a medical doctor but by the respective pastor. Whether or not the pastors conferred with a doctor in some instances is unclear, but they had at least some basic medical knowledge, as the variety of recorded diagnoses as well as clerical statute books from that time suggest (Gesenius 1839, 1847; Millies 1895, 1896).

Aside from these limitations, the analyses based on Rostock's church records also show considerable strengths. First, the data offer rare insights into an urban setting in the nineteenth century prior to the first demographic transition. Second, the given information on the father's occupation permitted us to conduct a social class differentiation. Third, the large number of cases in Study 2 enabled us to analyze cause-specific models of infant mortality. Fourth, the quality of the given cause-of-death information is still comparatively good for the time. Even after harmonizing all different spellings in Study 2, there were still 150 diseases included in our data. In only 60 out of 2,689 infant deaths was the cause of death unspecified or unknown, which is a very low number for the time. Fifth, the available information on the age upon death permitted us to apply separate models for neonatal and post-neonatal mortality, which was necessary because the proportional-hazards assumption of the Cox model was violated for total infant mortality in Studies 1 and 2 due to varying mortality patterns in the first month and the ensuing time up to one year. Sixth, we conducted a sensitivity analysis for Study 2, using competing-risks regression according to Cleves et al. (2010: 365–391) for the multivariate models which showed the same results.

Contemporary Data

The first potential bias of Study 3 refers to the used cause-of-death classification. The fall in premature mortality was closely linked to a decrease in avoidable mortality, which points to the suitability of the chosen classification. There was a decline in other 'non-avoidable' premature mortality in MV during the early 1990s, though, that might seem counterintuitive but can be seen in the light of the immense general improvements in living conditions in eastern Germany following reunification and the consequent shifting of mortality to older ages (Vogt 2013).

The second potential bias refers to the question of whether there were different age-specific patterns that were overlaid in the age-standardized death rates. Supplementary in-depth analyses of the used data show that the differences among men were rather consistent over age, whereas differences among women reflect different cohort-specific smoking rates. Thus, preventable mortality among women aged 50–69 is higher in SH, especially in urban SH, but among women aged 15–49 it is higher in MV, particularly in urban MV. Among both men and women, excess mortality of rural MV in comparison to the other three regions is strongest in the 15–34 age group, which is connected with fatal traffic accidents, and in the 70–74 age group, which is due mainly to excess cardiovascular mortality.

Third, the regional classification shows some differences between SH and MV. As a commonality, all urban districts in MV and SH are classified as 'Oberzentrum' (high-level urban center) in official regional planning, with the exception of Wismar, which nevertheless does partly fulfil functions of an 'Oberzentrum'. Regarding the rural areas, however, population density is considerably lower in rural MV (about 50 inhabitants per square kilometer) than in rural SH (ca. 145). Consequently, there are structural advantages in the rural areas of SH which most likely benefit the accessibility of medical care. The supplementary analyses that further divided the rural areas of MV and SH show that there were inner-regional differences to the advantage of the southern districts in SH and of the western districts (Mecklenburg) in MV but they were rather small in comparison to the chosen urban-rural distinction. In addition, the urban-rural distinction delivers a clearer view of where differences remained (between the rural areas of both states) and where they widely disappeared (between the urban districts). Thus, the chosen regional classification proved appropriate to show where convergence has already taken place and where it has not. In comparison to SH and MV, the neighboring metropolitan city of Hamburg exhibited a lower level of amenable mortality, thus indicating a comparatively good accessibility and quality of health care. However, the preventable mortality level in Hamburg was very similar to urban SH, which is attributable to the smoking rates that were also very similar to urban SH, as supplementary analyses of the German Microcensuses 2005, 2009 and 2013 show.

Fourth, an inclusion of important individual-level variables like socio-economic status and migration biography in a multivariate model would help improve the understanding of the observed differences. However, these variables are not included in German cause-of-death statistics and linkages to other data sets that may include them are not possible up to now. Different outcomes of preventable mortality imply that health policies aiming at primary prevention are not equally effective among all population groups, particularly in connection with socio-economic status. Salzmann (2012) identified unemployment as one of the major drivers of male excess mortality in MV compared to the German average. In fact, MV has always been among Germany's federal states with the highest levels of unemployment since reunification. In January 2019, the unemployment rate in MV stood at 8.5%, compared to 4.8% in SH and 5.3% nationwide (BA 2019). Furthermore, the level of education among young men, particularly in the peripheral regions of eastern Germany, has much room for improvement compared to young women (Sievert and Kröhnert 2015).

Selective migration influences socio-economic compositions. MV has experienced large losses in net migration since reunification, whereas SH has reported migration gains, especially from MV (Bucher and Heins 2001b; Dinkel 2004; Fischer and Kück 2004; Heiland 2004; Sander 2014). This negative net migration is particularly pronounced among young and highly-qualified people in the rural areas of MV (Bucher and Heins 2001a; Lehmann 2008; Schultz 2004; Weiß 2006). The metropolitan region of Hamburg plays a special role in this context, as the southern districts of SH benefit from suburbanization-related immigration from Hamburg, whereas only few municipalities in western MV are located close enough to Hamburg (and Lübeck) to profit from this as well (Dinkel 2004; Sander 2014). Consequently, the outmigration of young and better-educated people most likely contributes to the higher mortality levels in rural MV, while average life expectancy is highest in the university city of Rostock that has profited from migration gains since the early 2000s (INKAR 2015).

7.4 Conclusions and Implications

This doctoral thesis offers new insights into the development and determinants of premature mortality in the German Baltic Sea region and marks an important contribution to the population history of this region.

The newly available data from Rostock's church records allowed us to analyze the trends of infant mortality differentials in an urban setting in the nineteenth century. Study 1 reveals that the city of Rostock exhibited a comparatively low infant mortality level, especially in the first third of the century, which was true for all of northern Germany, and is the first to estimate the impact of socio-economic differences on infant mortality in a northern German city in the early nineteenth century, using event history analyses. Children of fathers in lower ranked occupations exhibited a higher mortality risk in the first year of life than children of fathers in higher ranked occupations in Rostock's St. Jakobi parish between 1815 and 1829. This social gradient was particularly true for the first month of life. However, there was an exception to this pattern with (probably unskilled) laborers showing similarly low infant mortality risks like the upper social class, which suggests that infant care and nutrition are not necessarily determined by socio-economic status, thus supporting the statement by Preston and Haines (1991: 209) that knowledge outweighs resources.

Study 2 is the first paper at all to analyze the interplay of social class and causes of death in the time prior to the epidemiologic and demographic transitions. By means of continued transcription and data preparation, it was possible to extend the data used in Study 1 considerably, with the number of cases thus being high enough to conduct cause-specific event history models. In the periods under study (1815–1836 and 1859–1882), there was an almost linear social gradient in neonatal and post-neonatal mortality. Since this gradient was driven entirely by gastro-intestinal diseases and was most pronounced in neonatal mortality, it is highly probable that there were severe deficits in nutrition, sanitation and maternal care among the lower social classes. The social gradient did not change significantly from the first period (1815–1836) to the second (1859–1882), which suggests that these poor conditions among the lower classes were evident even before industrialization (coupled with population growth) led to worsening living environments. The results may be applicable to urban places in less developed countries currently facing similarly poor sanitary conditions and accelerated population growth. In conclusion, improvements in nutritional and sanitary conditions can reduce infant mortality from infectious diseases, particularly by raising breastfeeding rates and access to clean water. All social groups benefit from these improvements but the reverse is also true, as deteriorating environmental conditions coupled with an increase in infant mortality may affect all parts of the population. Gastro-intestinal diseases caused by malnourishment, poor access to clean water and neglect may still be the main cause of excessive infant mortality rates in less developed countries (Dyson 1984; Boschi-Pinto et al. 2008; Kotloff et al. 2018).

While Studies 1 and 2 provide new insights into the trends and determinants of infant mortality in a historical urban setting in the German Baltic Sea region and the interplay between social differences and causes of death, further research is needed. Transcribing and preparing all of

Rostock's church records and censuses would allow other important influencing factors of infant mortality to be incorporated. For example, information on birth ranks, birth intervals, maternal age at childbirth and parental death could be included in the event history models as additional covariates by using family reconstitution methods based on Rostock's church records. Furthermore, linking these data to the censuses of Rostock would permit cartographic analysis of infant mortality by neighborhood, as Ekamper and van Poppel (2019) showed for Amsterdam, adding environmental variables like the supply of water and sewers. Therefore, much can still be gained from the Rostock data to obtain a better understanding of the driving factors of infant mortality in an urbanizing setting at the dawn of the demographic transition.

Study 3 addressed contemporary differentials in premature mortality in the German Baltic Sea region since the German reunification, dealing with the question of whether there are still east-west differences that can be considered avoidable. Based on official cause-of-death and population statistics, the study shows that the remaining difference in premature mortality between the east (MV) and the west (SH) is widely associated with excess avoidable mortality of men in the rural areas of the east. The accessibility and quality of medical care in the thinly-populated rural areas of the east can still be improved in comparison to the rural areas of the west, whereas the urban areas of MV have caught up to the urban areas of SH. Moreover, inter-sectoral health policies aiming at primary prevention need to become more effective, in particular among men in the east with regard to smoking, alcohol abuse and dangerous driving. However, women in urban SH whose high rate of smoking becomes visible in the rate of preventable mortality need to be addressed, too. In conclusion, German health policies need to focus more on the accessibility of appropriate medical care in the thinly-populated areas of eastern Germany and men-specific measures of primary prevention in particular. This involves educational policies as well to reduce the educational disadvantage of men because the level of education influences not only the socio-economic status later in life but also the health-related lifestyle (Klein et al. 2001). Furthermore, the creation of adequate opportunities in the labor market, particularly for the highly educated young people, is one of the major current and future challenges for MV.

While Study 3 provides new insights into east-west differences in avoidable mortality in a region that shows strong cultural, historical and geographic commonalities and is not affected by the German north-south gradient, further investigations are needed to analyze the impact of socio-economic differences and long-term consequences of selective migration in this context. However, a German mortality register that provides information on these variables or permits linkages to other data sources that include these variables would have to be installed first. Moreover, the analyses of other east-west spanning regions along the former inner-German border would also be a fruitful addition to research. The German reunification has been the only worldwide contemporary example of a political unification of a formerly divided nation so far. Thus, further research could focus on similar ‘natural experiments’ like the contribution of different health care systems on mortality differences between politically divided but ethnically homogenous populations over time.

The first fundamental question of this doctoral thesis was whether the determinants that influenced premature mortality differentials in the German Baltic Sea region prior to the epidemiologic transition were the same like today or completely different. The results of this thesis illustrate the altered meaning and patterns of premature mortality over the course of the epidemiologic transition, thus confirming the observations made by Omran (1971, 1998). In less developed settings characterized by accelerated urbanization and no (or poor) access to vaccination and antibiotics, nutrition and sanitation are central determinants in premature mortality, especially at younger ages. In modern industrialized settings, however, the access to appropriate health care and risk-relevant behavior at adult ages play a more decisive role. Nonetheless, the two settings have in common that both individual-level and contextual factors are evident in differentials of premature mortality and have to be addressed to explain and reduce them.

The second underlying question was whether the factors that supported longevity then, e.g. the rather small levels of urbanization and industrialization, are still protective now or rather detrimental. Prior to the epidemiologic transition, the German Baltic Sea region most likely exhibited more supportive individual-level and contextual characteristics in comparison to the south of Germany, at least with regard to infant nutrition and sanitary conditions. The combination of comparatively high breastfeeding rates and little industrialization (and thus less problematic sanitary and housing conditions) was protective against infectious diseases, which dominated the cause-of-death spectrum in this time (Omran 1971; Kintner 1985, 1994). Meanwhile, the region, especially its eastern part, shows worse compositions of risk-relevant behavior than the south (Baumeister et al. 2005; RKI 2011, 2014; Salzmann 2012). Over the course of the epidemiologic transition with its improvements in medical care and public health, child mortality and infectious diseases have lost their significance and the little level of industrialization has lost its favoring impact on longevity. On the one hand, the little levels of industrialization and population density, particularly in the east, foster the excellent air quality and short ways into nature (LUNG 2017) and are in this sense conducive to living a long life. On the other hand, these characteristics belong to the central causes for socio-economic disadvantages which have turned out to be among the driving factors for current regional mortality differences in Germany, especially regarding men (Kibele 2012; Grigoriev et al. 2019). Social differences influenced risk-relevant behavior in the past – as Study 2 suggested with regard to infant nutrition and maternal care –, and it still does today in connection with smoking, alcohol abuse and overweight, for instance (Cavelaars et al. 1997). Furthermore, the low population density weakens the financial incentive for physicians and medical institutions to move to the rural areas of MV and is thus an obstacle for a better accessibility of health care in the countryside.

To regain its former vanguard position in longevity in Germany – thus referring to the third and last underlying research question – the German Baltic Sea region's policymakers have to find ways to improve the region's structural conditions in terms of medical care, labor market and selective migration, while retaining and stressing the region's environmental benefits. In addition, the region's inter-sectoral health policies need to become more effective in reducing smoking, alcohol abuse, physical inactivity and traffic accidents and, thus, in promoting healthier lifestyles. Sweden – on the other side of the Baltic Sea – is a good example that high levels of life expectancy are possible in a widely rural country in northern central Europe (Christensen et al. 2010).

All in all, the German Baltic Sea region is a rare example of an area that lost its vanguard position in longevity and has been increasingly left behind in recent decades, which shows that mortality gradients do not necessarily stand the test of time and that factors that were once protective can become detrimental. Therefore, this example illustrates how important it is that regional governments and local policymakers stay in contact with science, keep pace with economic and technological developments and align their policies to current social, economic and health-related challenges.

8. REFERENCES

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9. ORIGINAL PUBLICATIONS

9.1 Study 1

Michael Mühlichen, Rembrandt D. Scholz and Gabriele Doblhammer (2015):

Social Differences in Infant Mortality in 19th Century Rostock: A Demographic Analysis Based on Church Records.

Comparative Population Studies 40(2): 191–216.

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Contributions: Michael Mühlichen designed the study, prepared the data, conducted the analyses and wrote the first draft of the manuscript. Rembrandt D. Scholz contributed to the introduction and revised the manuscript. Gabriele Doblhammer contributed to the discussion and revised the manuscript. All authors read and approved the final manuscript.

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Social Differences in Infant Mortality in 19th Century Rostock

A Demographic Analysis Based on Church Records

Michael Mühlichen, Rembrandt D. Scholz, Gabriele Doblhammer

Abstract: The article examines the historical development of infant mortality in the Hanseatic city of Rostock, with a special focus on the question of how socio-economic factors influenced infant mortality in the early 19th century. Compared with the rest of Germany, the city exhibited an exceedingly low infant mortality level, in particular in the first third of the century. Our analyses show that the occupation of the father had a significant influence on the survival probability of a child in the first year of life in the early 19th century. Newborn children of fathers in lower ranked occupations exhibited a greater mortality risk in the first year of life than the offspring of fathers with occupations of higher status. The analyses are based on the registries of burials and baptisms of St. James's Church *(Jakobikirche)* in Rostock, which are largely preserved and much of which has been digitalised. Based on these individual data, this is the first event history analysis model conducted in the context of infant mortality in a German city in the 19th century. This article is also the first to reveal Rostock infant mortality rates for the entire 19th century according to sex, thus closing two research gaps.

Keywords: Infant mortality · Rostock · Historical demography · Church records · Event history analysis

1 Introduction

The analysis of infant mortality is an important element of mortality research. In the late 19th century, in some German regions more than one third of all live births did not survive the first year of life (*Würzburg* 1887, 1888; *Prinzing* 1900). Thus, infant mortality substantially determined the overall mortality rate. Today, according to the Federal Statistical Office (31.12.2013), the infant mortality rate in Germany is only 3.3‰. Due to its low level and minor variation, infant mortality has largely lost its influence on the average life expectancy. The rise in life expectancy in the first half of the 20th century in Germany was mainly caused by the decline in infant mor-

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tality and was significantly responsible for the introduction of the first demographic transition.

There are many studies about the development and the determinants of infant mortality in the 19th century. Nonetheless, some German regions have not yet been sufficiently covered by research and not all influencing factors and causes for regional differences have been clarified (*Imhof* 1981; *Gehrmann* 2000, 2011; *Kloke* 1997). This is mainly due to the focus of interest in research and differing methods and definitions. While today there are internationally comparable classifications for stillbirths and live births,[1] this was not always the case in the past. A number of questions have been left unanswered. What role does the documentation of deaths and births before and after baptism play? How do different levels of education and different religions affect registration? When is a stillbirth documented? Since when have what variables been recorded in the context of infant mortality?

Mecklenburg-Schwerin is a region that was distinguished in the 19th century by particularly low infant mortality and high life expectancy compared to other regions in Germany (*Dippe* 1857). The historical demographic data for the region of Mecklenburg-Schwerin is very favourable. Historical population data have been registered going back to the 19th century as individual data in the form of household lists for a number of censuses for the entire region. Church records have also been almost completely preserved. This provides us with individual data to document demographic events. However, using this kind of data for research requires considerable effort since the existing sources must first be digitalised.[2]

Sources of information on infant mortality in the respective local context have existed since the introduction of church records. Analyses on mortality on the basis of church records were conducted, for example, by *Halley* (1693), *Kundmann* (1737), *Süßmilch* (1761), *Blayo* (1975), *Wrigley* and *Schofield* (1981), *Schultz* (1991), *Gehrmann* (2000, 2011), *Johansson* (2004, 2009) and *Breschi et al.* (2014), whereby *Gehrmann* not only uses church records as a data basis, but also all other available sources concerning population statistics.

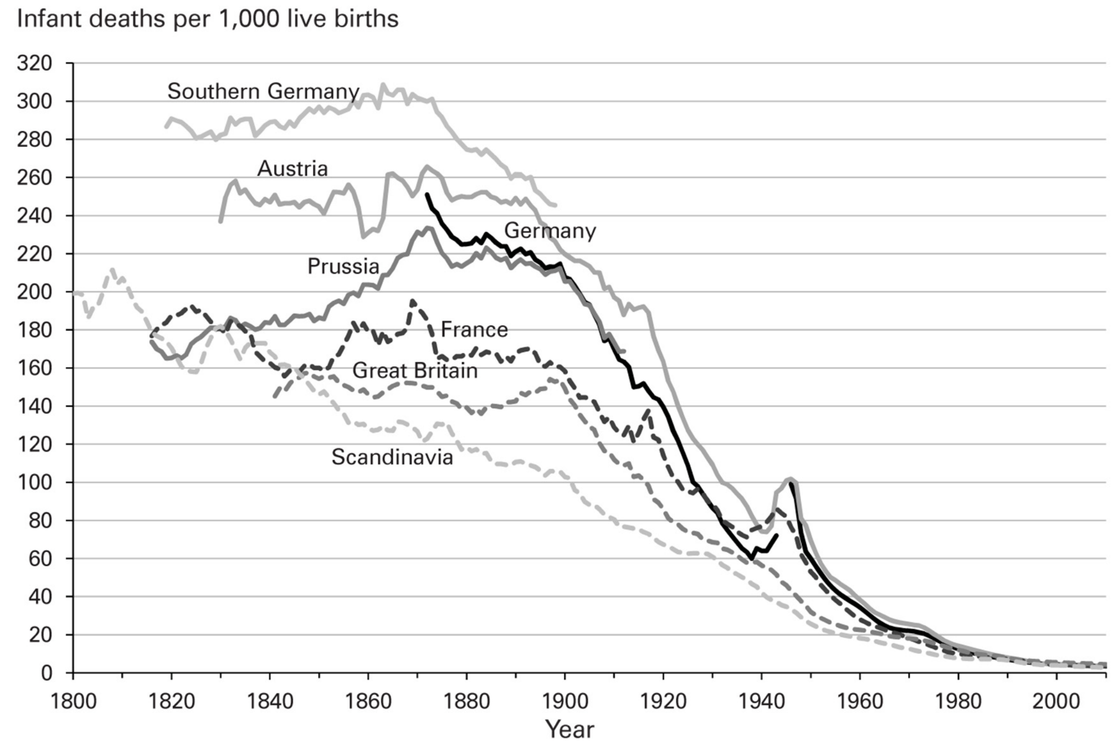
Only the introduction of official statistics makes comprehensive statistical statements possible for entire regions. The first country to begin to document demographic events at the national level was Sweden in the year 1751. The other European countries followed its lead beginning in the mid-19th century (*Westergaard* 1932; *Hollingsworth* 1969; *Rödel* 1990; *Ehling* 1996). Comparable data for Germany

1 Classifications in Germany: A live birth means that at least one of three vital signs occurs (breathing, pulsation of the umbilical cord or heartbeat). If none of these are observed, but the birth weight is at least 500 g the birth is considered a stillbirth. If none of the characteristics occurs and the birth weight is under 500 g, the birth is considered a miscarriage, which is not registered (Deutsche Verordnung zur Ausführung des Personenstandsgesetzes (Kapitel 5, § 31)).

2 Notable for Mecklenburg-Schwerin is the census of 1819, including the city of Rostock and its analysis. This is the pilot project Mecklenburg in the Demographic Transition of the 18th and 19th Centuries (title translated by CPoS). In addition, various research findings on the urban population and social history at the beginning of the 19th century were provided by Rostock historians (*Krüger/Kroll* 1998; *Krüger* 1998, 2000, 2003; *Manke* 2000, 2005a/b).

on regional infant mortality rates cannot be obtained until 1875 through the foundation of the empire and the establishment of the Imperial Statistical Office (*Westergaard* 1932: 239). The development of infant mortality rates for selected countries is shown in Figure 1. In Scandinavia, a decline in infant mortality can be observed throughout the entire period. In the other countries the decline did not begin until the late 19th century, since industrialisation and accompanying urbanisation at first caused a decline in the survival probability of infants. The 20th century brings a strong decline and levelling off at a very low level. Figure 1 also shows the rise in infant mortality during the two World Wars and the post-war period.

Fig. 1: Infant mortality in selected European countries, 1800-2010 (moving 5-year average)

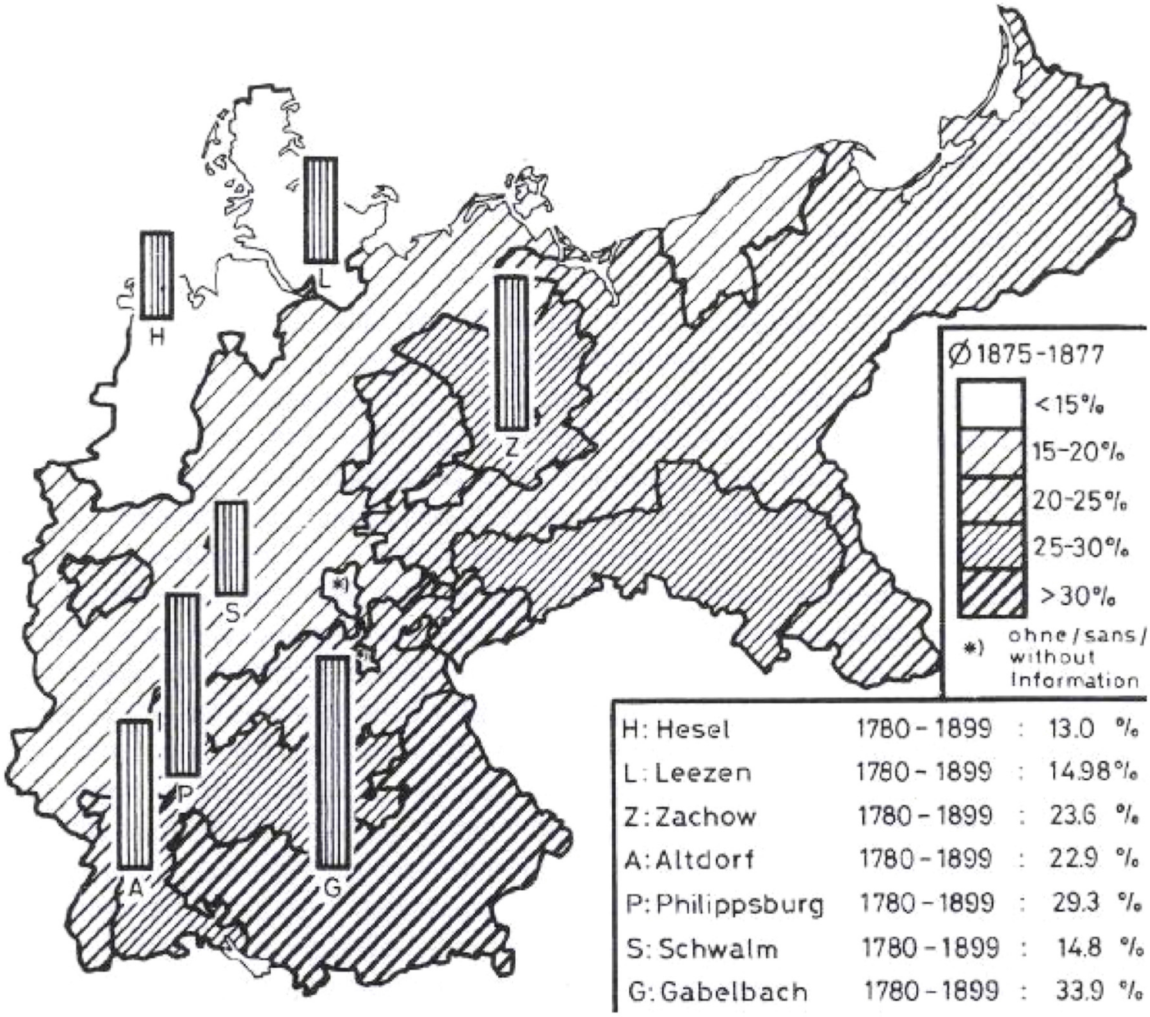


Notes: Scandinavia consists of the countries of Sweden (from 1800), Denmark (from 1835) and Norway (from 1846); Great Britain consists of England and Wales (from 1841) and Scotland (from 1855); Southern Germany consists of Bavaria (from 1819), Saxony (from 1831), Baden (from 1852), Württemberg (from 1859 as well as 1819-1822 and 1847-1856) and the Grand Duchy of Hesse (from 1863); Prussia (from 1816) in its 1866 borders.

Source: Human Mortality Database (for Austria from 1947, France, Scandinavia and Great Britain), Federal Statistical Office (for Germany), *Gehrmann* 2002 and 2011 (for Prussia), *Gehrmann* 2011 (for Southern Germany) and *Mitchell* 2007 (for Austria until 1946); own calculations using the calendar year method.

The difference in infant mortality rates between Prussia and the south of Germany also indicates the considerable north-south divide that existed in the 19th century in Germany. Generally, the Baltic Sea region had a comparatively low infant mortality rate. This applies not only to countries like Sweden and Denmark, but also to the German Baltic regions of Schleswig, Holstein, Mecklenburg and Pomerania. The survival rates of small children in the 19th century were not only better in the north than in the south, but also tended to be better in the west than in the east. Infant mortality was lowest in the northwest and highest in the southeast. The primary cause is assumed to be the frequency and duration of breastfeeding which was differently distributed across the regions, both between northern and southern Germany as well as between the urban and rural areas (*Gehrmann* 2000, 2011; *Imhof* 1981; *Kintner* 1985; *Knodel* 1968, 1988; *Prinzing* 1900). The first regional studies by the Imperial Statistical Office on infant mortality (Fig. 2) in Germany in the period of 1875 until 1877 reveal an infant mortality rate of over 30 percent in Bavaria and Swabia, while it was below 15 percent in East Frisia and Schleswig-Holstein.

Fig. 2: Regional infant mortality rates in Germany 1875-1877 including selected places: Hesel, Leezen, Zachow, Altdorf, Philippsburg, Schwalm and Gabelbach 1780-1899 (micro study)



Source: Official regional data: *Würzburg* (1887), micro study: *Imhof* (1981); diagram: *Imhof* (1981)

One factor often mentioned in the literature with regard to regional infant mortality differences is confessional affiliation and the related differences in value orientation. The north of Germany was largely Protestant whereas the south is predominantely Catholic. It is interesting that infant mortality in mostly Protestant Franconia was considerably lower than in neighbouring Catholic Bavaria (*Imhof* 1981; *Prinzing* 1900). Seasonal weather events were also different from region to region and thus had different impacts on infant mortality, particularly with regard to non-breastfed children (*Prinzing* 1899; *Stöckel* 1986).

Moreover, in many parts of Germany infant mortality was higher in the cities than in rural regions (*Spree* 1988; *Gehrmann* 2002; *Prinzing* 1900). While infant mortality in rural areas was significantly correlated with living and working conditions there, the higher level in the cities was caused by the arising processes of urbanisation and industrialisation. These differences declined, however, towards the end of the 19th century and at the beginning of the 20th century shifted in favour of the cities, which can be ascribed to the improvements to nutritional, hygienic and housing conditions that began in the cities (*Gehrmann* 2011; *Imhof* 1981; *Prinzing* 1899, 1900; *Stöckel* 1986).

The Rostock paediatrician Hermann Brüning rendered outstanding services to the analysis of infant mortality rates in Rostock and Mecklenburg. He ascertained an infant mortality rate of 15.1 percent for legitimate and 24.2 percent for illegitimate live births in the city of Rostock between 1901 and 1905 (*Brüning* 1908: 375). He also discovered a correlation between social class and infant mortality, with a higher mortality in low social classes.

Our study examines the extent to which social differences are revealed in infant mortality rates in Rostock's St. James's church congregation at the beginning of the 19th century. A systematic investigation of the historic demographic sources of births and deaths in the church records in the 19th century enables us to conduct analyses that were not possible until now[3] due to the lack of digitalised sources.[4]

We specifically focus on the influence of a birth's legitimacy and that of the father's occupation. We assume that the infant mortality rate of children born within marriage is lower than those born illegitimately and that those infants whose fathers have a low occupational status exhibit an increased mortality risk compared to newborns with occupationally better situated fathers.

The influencing factors of mortality change over the first year of life (*Brüning* 1928; *Brüning/Mahlo* 1929; *Imhof* 1981). While mortality in the first thirty days after birth is still greatly determined by the development of the foetus during the mother's pregnancy and problems during childbirth, environmental influences be-

3 *Mühlichen* (2011), Master's thesis, University of Rostock.

4 For two years, the state of Mecklenburg-Western Pomerania funded the Rostocker Forschungsverbund Historische Demografie, a cooperation of the University of Rostock and the Max Planck Institute for Demographic Research. The project digitalised the original handwritten sources of the Mecklenburg-Schwerin censuses of the years 1867 and 1900 as well as selected demographic events (births, deaths, marriages) from Rostock church records in the period between 1800 and 1900.

come increasingly important in the following eleven months. Therefore, all analyses are conducted separately for the first thirty days of life and for the ensuing eleven months.

2 Historical findings on the influence of socio-economic differences on infant mortality rates

The influencing factors on infant mortality in the 19th century are manifold and difficult to distinguish from one another since they are sometimes mutually dependent. Regional differences in infant mortality were far greater in the 18th and especially in the 19th century in Germany than they are today; however a comprehensive explanation of these differences has not yet been satisfactory because of the difficulties regarding the source material and the complexity of the causes which reach far beyond the field of historical demography (*Ehmer* 2004: 92-94).

In an article based on his own extensive research as well as studies by *Bluhm* (1912), *Krieg* (1890), *Prinzing* (1899, 1900, 1931), *Würzburg* (1887, 1888) and others as well as official data, *Imhof* (1981) cites the primary influencing factors. These are the season of birth, region of birth, frequency and duration of breastfeeding, times of crisis, birth legitimacy, birth weight, birth order, family size, child spacing, sex, age of the mother, social class, working, housing, nutritional and hygienic conditions as well as the parents' confession and value orientation.

In the following, we will specifically highlight socio-economic factors, although the behavioural patterns responsible for differences in infant mortality cannot be solely explained by social factors (*Spree* 1980). *Imhof* (1981) and *Gehrmann* (2011), for example, provide a more comprehensive overview of the state of research on other influencing factors in Germany in the 19th century. Our socio-economic factors include birth legitimacy, social class and working conditions.

Birth legitimacy differentiates between whether an infant was born within or outside of marriage. This factor is highly significant since a far higher mortality rate in infancy among children born out of wedlock is proven by the contemporary population statistics and medical literature (e.g. *Prinzing* 1900; 1911; *Saul* 1909) than among legitimate children. Although some of the unmarried women later legitimized the birth through marriage, they are, however, not the majority (*Prinzing* 1902: 44). The main cause for higher mortality among illegitimate infants was a lack of care caused by the comparatively unfavourable financial situation that forced mothers to go to work and leave the child in the care of confidants or an institution (*Vögele* 1994: 411; *Preston/Haines* 1991: 30). Nevertheless, the influence of legitimacy on infant mortality was rather low compared to the influence of nutritional, working and hygienic conditions (*Kintner* 1994; *Spree* 1998).

The national and international findings differ regarding the influence of the working conditions of fathers and mothers – their occupational class, income and workload – on the mortality of their children in the first year of life. *Bengtsson* and *Lundh* (1994) were unable to find evidence of an effect of real wages on infant mortality in Scandinavia, while for Sweden, *Sundin* (1995) specifically sees the upper class as profiting at least in times of a particularly rapid decline in infant mortality. By contrast, *Woods et al.* (1988, 1989) and *Haines* (1995) ascertain an influence of social class and income for England and Wales, at least on the rate of infant mortality but less on the time and extent of infant mortality decline in the late 19th and early 20th century. Compared with France, *Woods* (1994) however sees the reasons for the lesser infant mortality rates in England specifically in the more pronounced breastfeeding habits, lower fertility and illegitimacy rates as well as the extensive absence of times of crisis. German contemporaries such as *Prinzing* (1899) and *Hanssen* (1912) also see greater explanatory power in breastfeeding practices than in socio-economic factors, although *Prinzing* (1899: 588) considers the better economic and structural conditions in western provinces the cause at least for the west-east differences in Prussia. *Hanssen* (1912: 8) writes that for Schleswig-Holstein an influence of social class is only measureable for non-breastfed infants. However, observing the neighbouring region of Mecklenburg-Schwerin, *Saul* (1909: 38) finds that infant mortality was higher for children of workers with lower economic status such as day labourers, factory workers and servants compared to financially better situated workers. Women's workloads are also significant. Specifically, infants whose mothers worked in factories showed a lower survival probability, however in 19th century Mecklenburg this was hardly ever the case compared to Germany's industrialised regions. Nonetheless, a mother's involvement in farm work also had negative effects (*Gehrmann* 2011; *Heller/Imhof* 1983; *Prinzing* 1899). Socio-economic factors thus have an indirect effect on infant mortality rates by influencing the breastfeeding behaviour and the quality of nutrition as well as care and welfare (*Imhof* 1981: 359; *Kloke* 1997: 76).

Value orientation is another influencing factor manifested in "regionally, denominationally, socially divergent attitudes of the population towards fertility, towards sexuality, towards health and disease, towards dying and death" (*Imhof* 1981: 366; translated by CPoS). Wars and times of crisis, for example, presumably had a rather negative influence on the appreciation of life and hence infant mortality was relatively high in particular in regions with a high frequency of crises and war (*Imhof* 1981: 367). *Imhof* (1981: 375) identifies two contrary dispositions: the "system of conservation of human life" and the "system of wastage". The former is distinguished by a general appreciation of life, expressed, for example, in lengthy breastfeeding of an infant, while the latter – marked by trauma and times of crisis – meets life with a certain indifference and was more characteristic of the south of Germany than the north. "This indifference was a direct and inevitable consequence of the demography of the period." (*Ariés* 1975: 99; translated by CPoS)

Looking at religious denomination, Protestant regions in southern Germany often feature far lower infant mortality rates than Catholic ones. A good example in this context is the Kingdom of Bavaria (*Prinzing* 1900: 620). As an attempted explanation, *Imhof* (1981: 378-379) cites the notion widespread among Catholics at that time, expressed in the imagination of the so-called *"Himmeln"*: in order to safeguard the survival of at least the older siblings, poor families with many children sometimes neglected the youngest child and even resigned themselves to its death in order to spare it from suffering under the humble circumstances and give it, as offspring without sin, a place in heaven where it could in turn safeguard a place for its family. Then again, in regions of mixed religions no significant differences could be found in infant mortality rates between the two Christian denominations (*Kloke* 1997: 266). The differences found in Bavaria ought to be seen in the light of the German north-south divide that dominated at that time. In addition, the Protestant town of Laichingen in Württemberg exhibited particularly high rates of infant mortality at a level of at times 40 to 50 percent (*Medick* 1997: 359-365). In the late 19th century there was a similar north-south divide in the Netherlands as well, to the disadvantage of the largely Catholic regions in the south, which can be explained with a considerably lower propensity to breastfeed and greater scepticism towards new ideas for fighting disease and hygienic improvements compared to the Protestant-dominated north (*Wolleswinkel-van den Bosch et al.* 2000).

Therefore, the literature ascribes far greater influence to the regionally different nutritional and breastfeeding habits. For example, *Imhof* (1981: 347-349, 353-354), *Kloke* (1997: 54, 157, 266) and *Gehrmann* (2002: 546) highlight that the survival probability of infants was distinctly better in regions where they were breastfed frequently and for a long time than in regions where this was not the case. "In the northern German villages with low infant mortality rates it appears that almost all mothers breastfed their infants, and did so for a relatively long time; at least for the entire first year. In southern German communities with a high infant mortality, by contrast, the contemporaries already complained that many mothers did not breastfeed their children or only very briefly." (*Ehmer* 2004: 94; translated by CPoS) Especially in the summers, infant mortality increased considerably due to gastro-intestinal diseases caused by the poor supplemental foods that spoiled more quickly in warm weather (*Kloke* 1997). *Lee* and *Marschalck* (2002) ascertained a rise in the mortality of newborns in the city of Bremen between 1861 and 1863 and between 1870 and 1872 in the third, sixth, ninth and twelfth months of life, which they explain by the fact that infants were often weaned at exactly these ages. According to *Imhof* (1981: 373), mothers at that time were often quite aware that breast milk was the healthiest food for infants. The fact that many nonetheless did not breastfeed their babies in many regions could have something to do with a lack of time to care for the child, specifically if the mother was single and working or involved in her husband's work, for example on the farm. The above-mentioned "system of wastage" could also be an explanatory approach, according to Imhof.

At the end of the 19th century, nutritional, as well as hygienic and housing conditions began to improve, leading to a rise in the survival probability of infants, particularly due to the accompanying decline in gastro-intestinal diseases (*Gehrmann* 2011; *Imhof* 1981).

3 Data and Methods[5]

This study is based on the newly digitalised registries of burials and baptisms from St. James's church records, which provide the necessary data on births and deaths. St. James's Church was by far the largest of the four Rostock parishes at the time alongside St. Mary's, St. Nicholas's and St. Peter's (*Szołtysek et al.* 2010: 10).[6] In 1905 more than half of Rostock's inhabitants were members of St. James's Church, which led in that same year to the division of the congregation due to the insufficient ability to care for them all, and finally the 1908 completion of the Church of the Holy Spirit in the Kröpeliner-Tor district (*Schulz* 2008: 24). The study is based on a complete survey of all births and deaths in St. James parish in Rostock.

Both the baptism and the burial registry contain full names making individuals identifiable and enabling us to merge the baptism and burial data set to one complete data set. This data merging was conducted for the period between 1815 and 1829 and serves as the data basis for the following analyses. The example in Figure 3 shows the baptism registry entry for Emma Krüger on the left in the second line. She was born in 28 January 1815 and baptised the same year on 5 February. On the right, the burial registry contains an entry in the second line showing that she died on 31 December 1815 and was buried on 5 January 1816. The baptism registry contains further information: the occupation and name of the father and the name of the mother as well as the godparents present at the baptism. In addition to the name and occupation of the father, the burial registry also contains the age upon death and the cause of death. The birthplace is also sometimes cited but only if it was not Rostock. Information about any employment pursued by the mother is not included in the registries.

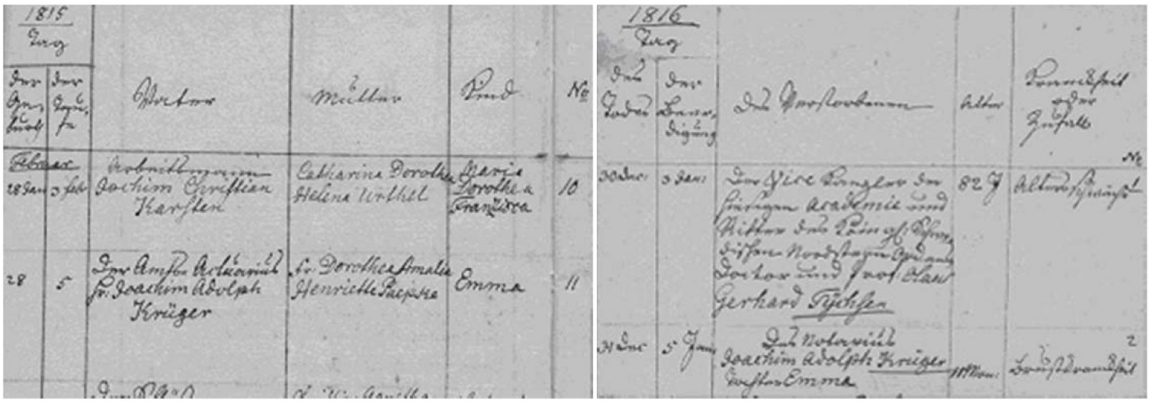
The population at risk for the mortality analyses includes all births registered in Rostock for St. James parish as live births in the studied periods. In-migrating infants who are not included in the baptismal registry of St. James parish, but are listed in the burial registry, are excluded from the analyses (20 cases; 6 percent). We cannot ascertain whether and how many newborns left the city or changed parishes and died in the first year of life. This makes an under-recording of infant mortality possible. Moreover, since there were no uniform procedures in the 19th century how to classify live births and stillbirths we can also not exclude biases based on this.

The mortality intensity in the first year of life is analysed using event history analysis (*Allison* 1984; *Diekmann/Mitter* 1984; *Blossfeld et al.* 1986), whereby the analysis time is measured by the age in days. It begins at the time of birth at the age of 0 days and ends with the death in the first year of life or – in the case of censored

5 See *Mühlichen/Scholz* (2015) for detailed descriptions of the sources and data.

6 As most of northern Germany, the city of Rostock was largely Protestant in the 19th century. Not until 1909 was a Catholic church re-established. St James's, Rostock's largest church at the time, no longer exists. Most of the church was destroyed in 1942 by a British air raid. The remaining structure was razed in 1960 (*Köppe* 2010; *Kuzia* 2004).

Fig. 3: Excerpts from the registries of baptisms and burials of St. James parish, Rostock



Source: Baptismal register 1815 and burial register 1816 of the church records of St. James parish, Rostock.

data – with the first birthday and thus exclusion from the population at risk. The age of newborns who survive the first year of life is set at the censored time of 365 days.

Cox proportional hazards models of the form $h(t \mid X)=h_0(t)\cdot e^{\beta x}$ are calculated to ascertain the influence of the newborns' characteristics on their mortality risk. In the calculation, $h_0(t)$ is the semi-parametric baseline hazard, β is the parameter to be estimated and x the covariates. The power e^{β} is the hazard ratio calculated from the ratio of two compared hazard rates and is considered the relative risk in the interpretation.

The covariates are sex, season of the birth, birth legitimacy and occupation of the father. When the data processing is complete, the data set contains 2,768 live births in the period 1815 to 1829, of which 331, or 12.0 percent, died in the first year of life. There are also 124 stillbirths. The share of stillbirths among all births between 1815 and 1829 is 4.3 percent. Stillbirths are, however, excluded from all analyses and tables.

Sex is categorised as male or female, the seasons of birth are distinguished into spring, summer, autumn and winter. The meteorological categorisation of seasons is used here with spring lasting from March until May, summer from June until August, autumn from September until November and winter from December until February.

The legitimacy of birth is either classified as legitimate or illegitimate. Legitimacy does not have its own column in the registries, but an illegitimate birth can be recognized from notes such as "illegitimate" or "allegedly […] is the father."

In order to operationalise the occupations, we established a new classification based on those of the *North Atlantic Population Project* (NAPP 2013) as well as studies on historical occupational and social structures in the German Baltic Sea region (*Brandenburg et al.* 1991; *Brandenburg/Kroll* 1998, *Lorenzen-Schmidt* 1996; *Manke* 2000). Our classification allows us to both count the frequencies of various types of occupations and to categorise them by employment groups or by social classes (*Mühlichen/Scholz* 2015). Broken down by social class, we have the following main

Tab. 1: Deaths, censors, person-years and mortality rate according to the independent variables in the event data set for infant mortality in Rostock in the period 1815-1829

Variable	Deaths			Censors	Person-years	Mortality rate
	Total	1st month	2nd to 12th month			
Sex						
Male	175	67	108	1292	1339	0.1307
Female	156	53	103	1145	1191	0.1310
Total	331	120	211	2437	2530	0.1308
Season of birth						
Spring	84	23	61	602	626	0.1341
Summer	80	35	45	591	612	0.1307
Autumn	85	33	52	599	621	0.1368
Winter	82	29	53	645	670	0.1224
Total	331	120	211	2437	2530	0.1308
Father's occupation						
High status	51	16	35	455	469	0.1087
Medium status	113	43	70	738	768	0.1472
Low status	81	32	49	452	474	0.1707
Other, unknown	86	29	57	792	819	0.1051
Total	331	120	211	2437	2530	0.1308
Legitimacy						
Legitimate	290	107	183	2063	2144	0.1353
Illegitimate	41	13	28	374	386	0.1063
Total	331	120	211	2437	2530	0.1308

Source: Burial and baptismal registers of the church records of St. James parish, Rostock (own calculations)

groups for the fathers' occupations: 1) high status occupations, 2) medium status occupations, 3) low status occupations and 4) other occupations or unknown. The first category includes merchants, traders, jurists, upper grade civil servants, nobility, physicians, teachers, professors, clergymen, pensioners, brewers and master craftsmen. The second category contains craftsmen, bailiffs, innkeepers and mariners. The third group consists of apprentice craftsmen, servants, porters, field workers, gardeners, fishermen, musicians, sailors, seamen, steersmen, soldiers and the unemployed. The fourth group mostly includes labourers – who are a very heterogeneous group with regard to type of work and financial situation – and fathers of whom nothing is known. Fathers who died prior to the birth as well as "illegitimate" or "alleged" fathers are also included in this category. Almost half of this fourth group therefore coincides with the category "illegitimate" of the legitimacy variable. Illegitimate fathers who married the mother of the child within the observation period are exceptions to this and are recognizable from other mutual birth entries in the data set. These men are to be found in the class allocated to their occupation (12 cases in total).

Table 1 contains an overview of the covariates and their respective distribution, the number of deaths, censors, risk times and mortality rates. We differentiate between mortality in the first thirty days and between the second and twelfth month. The mortality rate is calculated from the number of deaths in the first year of life divided by the person-years.

All data entries, error corrections and the merging of the baptism and burial data were conducted using Microsoft Excel. We used the statistical programme package SPSS 20 to process the data for the survival analysis. The event history analysis was done using STATA 11.

4 Results

Figure 4 shows the development of infant mortality in Rostock's congregation of St. James in the 19th century. The study period of the event history analysis model (1815-1829) is highlighted.[7] Until 1840 the mortality of newborns remains at a roughly constant to slightly declining level. It fluctuates in the studied period of 1815 until 1829 between 104 and 143 deaths per 1,000 live births and is 127.7 for boys and 127.9 for girls, a total of 127.8 for both sexes. Notable sex differences can only be identified from 1830 onwards to the disadvantage of boys. In addition, the level of infant mortality rises considerably from 1840, reaching 219 deaths per 1,000 live births in the year 1858. The causes for this are possibly related to the growth of the population and its consequences on the living, working, nutritional and hygienic situation. After 1858, the infant mortality rate drops again somewhat and fluctuates between 1880 and 1902, stagnating at about 170 deaths.

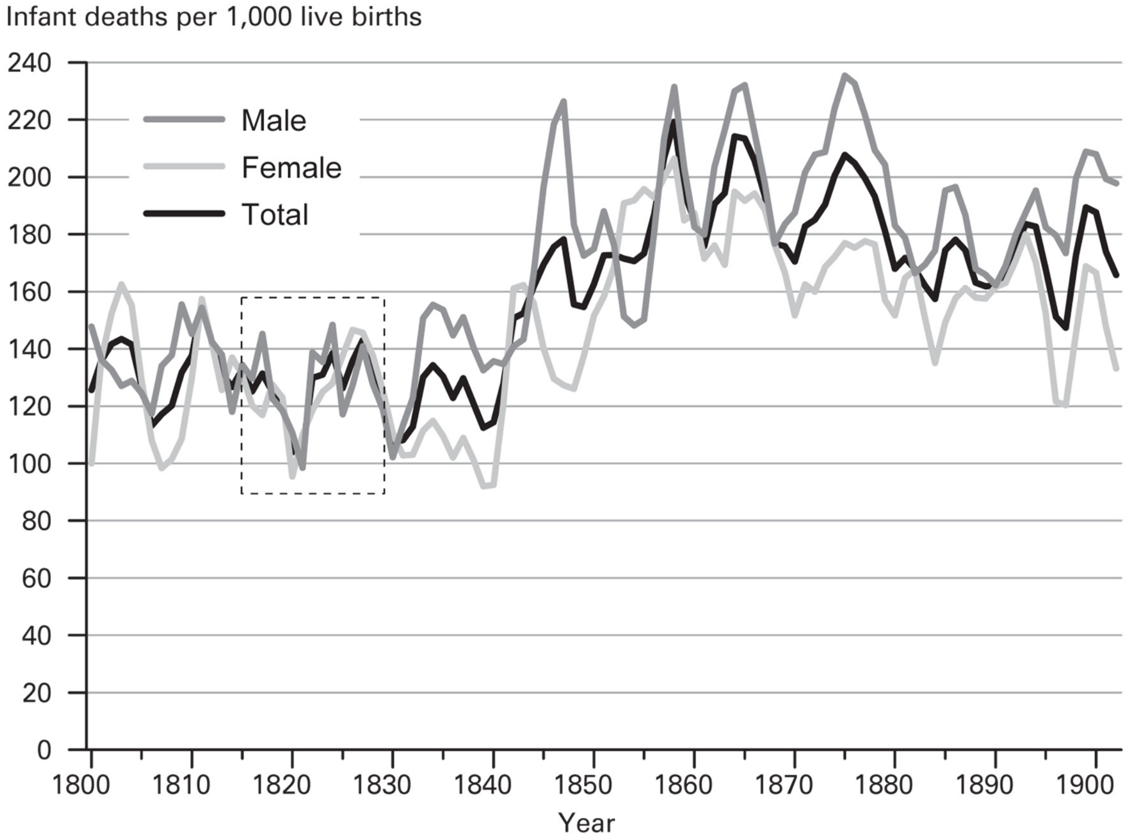
Figure 5 illustrates the Kaplan-Meier survival curves for the two independent variables legitimacy and father's occupation.

Illegitimate births exhibit a better survival curve than legitimate births. 90 percent of the illegitimate-born and 88 percent of the legitimate-born survive their first year of life. We will discuss the causes of this finding in the next chapter.

There are more distinct differences for the fathers' employment groups. In the first year of life, the survival curve for children whose fathers pursue a low-status occupation is clearly poorer compared to the other employment groups (85 percent). The share of survival for children of fathers with a medium-status occupation is 87 percent and for children of fathers with a high-class occupation is 90 percent. The category of infants for whom the father's occupation is unknown or unassignable or the father himself is unknown is also 90 percent. Almost half of the members

7 The 20 in-migrating deaths in the period of 1815 until 1829 are included in this figure in order to portray a continuous time series (no similar data processing was yet done for the years from 1830 onwards, which might allow for the exclusion of further in-migration). These cases are excluded in the ensuing analyses.

Fig. 4: Infant mortality* in St. James parish Rostock by sex, 1800-1902 (moving 3-year average)



* For the analysed period 1815-1829, we were able to calculate the infant mortality rate according to the birth year method used by *Becker* (1874) and *Zeuner* (1869). The calendar year method by Böckh (*Esenwein-Rothe* 1982: 241-248) was employed for the remaining years. The deaths in a year t were, however, not assigned to 100 percent, but to 70 percent of the births of the year t and to 30 percent of the births of the year t+1. This weighting appears more realistic after a corresponding evaluation of the years 1815 to 1829. The at times quite sizeable sex differences (e.g. in 1847) may partly be a result of the less precise calendar year method. Because of its cohort approach, the birth year method is more precise, in particular for smaller case numbers.

Source: Burial and baptismal registers from the church records of St. James parish, Rostock (own calculations)

of this group coincide with the "illegitimate" category of the legitimacy variable. Because of this multi-collinearity, we examined the two variables in separate models.

Low case numbers are to blame for the irregularity of the survival curves. Since the curves of the employment groups intersect a number of times, we also assume they do not fulfil the proportionality assumption of the Cox proportional hazards model. The log-log survival plot (Fig. 6) confirms this assumption since the curves do not run parallel to each other. For the sake of comparability, the first step is to ascertain the influence of the covariates on mortality in the entire first year of life (Table 2).

Fig. 5: Kaplan-Meier survival curve for the first year of life of infants born in Rostock to the St. James congregation between 1815 and 1829 according to legitimacy (left) and father's occupation (right)

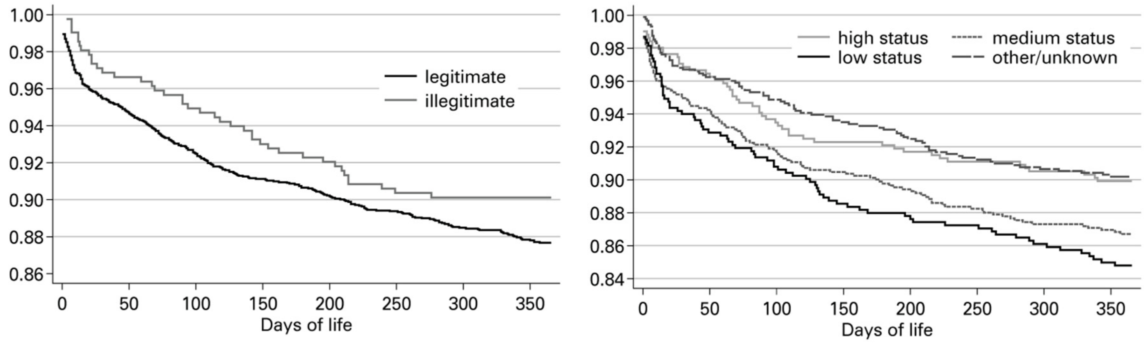
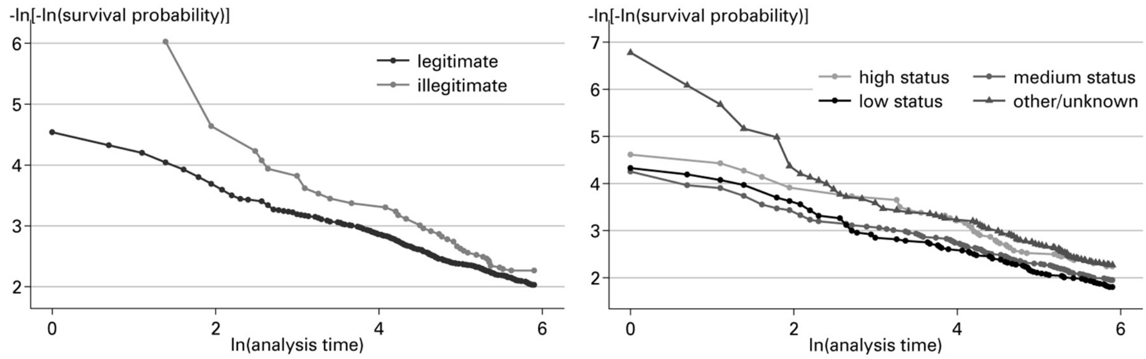


Fig. 6: Test of the assumption of proportionality (log-log survival plot) for the independent variables legitimacy (left) and father's occupation (right)



Source: Burial and baptismal registers from the church records of St. James parish, Rostock (own calculations)

The comparison of the four models for the first year of life reveals that gradually adding new independent variables does not alter the relative risks. Legitimacy and the father's occupation are integrated in separate models since half of the category of illegitimate births is identical with the category "other/unknown" occupation of the father.

The employment groups confirm the impression gained from the Kaplan-Meier survival curves (Fig. 6). Compared to the reference group consisting of children of fathers with a high-status occupation, the relative risk of not surviving the first year of life is 34 percent higher for the children of fathers in the medium employment class and 55 percent higher for the children of fathers with a low-status occupation. These differences are significant. The residual category does not differ significantly from the reference group. Going beyond these main groups, the risk among the employment groups of bailiffs, musicians, fishermen, innkeepers, sailors and seamen and field workers is the highest, while it is lowest among the higher ranked civil servants and academics, merchants, labourers and porters. The large group of craftsmen, both master craftsmen and apprentices, can be found in the middle.

Tab. 2: Relative mortality risks for live births in St. James parish, Rostock 1815-1829 (population at risk); event: death in the 1st year of life; analysis time: age in days

Variables and distribution	Model 1: Occupation		Model 2: Legitimacy	
	Only father's occupation	With control variables	Only legitimacy	With control variables
Father's occupation				
High status (RG)	1	1		
Medium status	1.35*	1.34*		
Low status	1.55**	1.55**		
Other, unknown	0.97	0.97		
Legitimacy				
Legitimate (RG)			1	1
Illegitimate			0.79	0.79
Sex				
Female (RG)		1		1
Male		1.00		1.00
Season of birth				
Spring (RG)		1		1
Summer		0.97		0.98
Autumn		1.01		1.02
Winter		0.92		0.92
Number of cases (N)	2768	2768	2768	2768
Events (E)	331	331	331	331
Risk time (t) in days	923404	923404	923404	923404

* p ≤ 0.1; ** p ≤ 0.05; *** p ≤ 0.01.

RG = reference group

Source: Burial and baptismal registers of St. James parish, Rostock (own calculations)

The relative risk of not surviving the first year of life is 21 percent lower for illegitimate live births than the reference group of the legitimately born. This difference is, however, not significant. For the control variables sex and season of birth the differences between the characteristics are small and not significant.

In the following, we again illustrate the Cox model separately for the first 30 days of life and for the remaining second to twelfth months of life (Tables 3 and 4).

Both tables show increased risks for the medium and low employment classes. However, this finding is far more distinct and significant during the first month (Table 3). The hazard ratio is 62 percent higher for the medium class and 92 percent higher for the lower class compared to the reference group. The residual category does not differ significantly from the reference group in the two periods.

With regard to birth legitimacy, the hazard ratio for the illegitimate-born infants in the first 30 days of life is 31 percent lower than that of the legitimate-born and 15 percent lower in the following period. This difference is, however, not significant.

Tab. 3: Relative mortality risks for live births in St. James parish, Rostock 1815-1829 (population at risk); event: death in the 1st month of life; analysis time: age in days

Variables and distribution	Model 1: Occupation		Model 2: Legitimacy	
	Only father's occupation	With control variables	Only legitimacy	With control variables
Father's occupation				
High status (RG)	1	1		
Medium status	1.62*	1.65*		
Low status	1.92**	1.89**		
Other, unknown	1.04	1.06		
Legitimacy				
Legitimate (RG)			1	1
Illegitimate			0.68	0.69
Sex				
Female (RG)		1		1
Male		1.13		1.12
Season of birth				
Spring (RG)		1		1
Summer		1.56*		1.56*
Autumn		1.43		1.44
Winter		1.21		1.20
Number of cases (N)	2768	2768	2768	2768
Events (E)	120	120	120	120
Risk time (t) in days	923404	923404	923404	923404

* $p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.01$.
RG = reference group

Source: Burial and baptismal registers of St. James parish, Rostock (own calculations)

The sex differences are also not significant, but it can be seen that the hazard ratio slightly favours girls in the first and boys in the second period. The seasonal differences are more pronounced in the two chosen periods than in the entire first year of life. For example, the relative risk is significantly increased by 56 percent for the first 30 days for infants born in the summer (Table 3, Model 2) compared to those born in the spring, while the summer births exhibit the lowest risk in the ensuing period.

Tab. 4: Relative mortality risks for live births in St. James parish, Rostock 1815-1829 (population at risk); event: death in the 2nd to 12th month of life; analysis time: age in days

Variables and distribution	Model 1: Occupation		Model 2: Legitimacy	
	Only father's occupation	With control variables	Only legitimacy	With control variables
Father's occupation				
High status (RG)	1	1		
Medium status	1.22	1.20		
Low status	1.38	1.39		
Other, unknown	0.93	0.92		
Legitimacy				
Legitimate (RG)			1	1
Illegitimate			0.85	0.85
Sex				
Female (RG)		1		1
Male		0.93		0.93
Season of birth				
Spring (RG)		1		1
Summer		0.75		0.76
Autumn		0.85		0.86
Winter		0.82		0.82
Number of cases (N)	2768	2768	2768	2768
Events (E)	211	211	211	211
Risk time (t) in days	923404	923404	923404	923404

* $p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.01$.
RG = reference group

Source: Burial and baptismal registers of St. James parish, Rostock (own calculations)

5 Discussion

In St. James, one of the four parishes of the city of Rostock, infant mortality at the beginning of the 19th century was significantly linked to the occupation of the father. The correlation is particularly strong during the first thirty days of life, but tends to remain detectable in the following eleven months. Children of fathers with lower ranked occupations such as lower administrative employees, seamen, fishermen and field workers have the highest risk of dying during their first year of life, while those from the group of higher ranked civil servants, merchants and lawyers, who formed Rostock's elite (*Manke* 2000: 369-370), have the lowest mortality risk. According to the literature cited in the second section, these differences may be linked to the family's economic situation, the mother's nutrition during pregnancy as well as that of the newborns during their first months. In addition, mothers were also more involved in work on farms and thus had less time to devote to their offspring. The children of seafaring workers also exhibit a comparatively high risk, which can be explained by low incomes and long and frequent absence of the fathers.

Our results with regard to legitimacy are unusual. The literature always provides evidence of increased infant mortality rates among illegitimate births both for Rostock as well as for Germany as a whole, at least in the late 19th and early 20th centuries (e.g. *Brüning/Balck* 1906 and *Brüning/Josephy* 1928 for Rostock as well as *Prinzing* 1902 and 1911 for the German Empire). We could not, however, identify this effect for St. James parish; illegitimate births even tend to have a higher survival probability, even though the effect is not statistically significant. It is possible that some of the unmarried mothers are domestic servants who handed their children over to grandmothers living in the countryside or other intimates or an institution after the baptism or perhaps even returned to the country themselves. *Vögele* (1994) as well as *Preston* and *Haines* (1991) explain this phenomenon with the unfavourable financial situation that forced single mothers to return to work and surrender their child to relatives or institutions. This would mean that respective infant deaths would not have been recorded in St. James. The high numbers of domestic servants among the female population of Rostock would also substantiate this speculation. In the year 1800, at least 30 percent of the age group between 21 and 30 (*Manke* 2000: 336) fit this description. If we further calculate the Cox model only for stillbirths, illegitimate births exhibit a 28 percent higher mortality risk than legitimate births. Although this difference is also not significant, this would be another indication for an underreporting of illegitimate infant deaths caused by out-migration.

The season of birth has a significant influence on survival in the first thirty days, whereby infants born in June, July and August exhibit the highest mortality risk. *Breschi/Bacci* (1997) were able to show for five countries that in the 19th century mortality in the first two years is linked to the month of birth and that this pattern differs between the countries. In Italy, for example, children born in the summer and infants born in the winter in Switzerland had a lower mortality rate. A comparable pattern to that of Switzerland and St. James parish can also be seen in the first year of life in Denmark of the 19th century (*Doblhammer/Vaupel* 2001; *Doblhammer* 2004). Since the effect of the birth month in St. James parish is highly significant in the first thirty days of life, this indicates endogenous factors for infant mortality, which have more to do with the development of the foetus during pregnancy than with exogenous factors such as infectious diseases. Since breastfeeding was more widespread in northern Germany than in the south, the newborns in St. James parish were better protected by the defensive substances in breast milk from seasonal gastro-intestinal and respiratory infections.

We found no significant differences with regard to sex, although the boys have an increased mortality risk in the first 30 days of life, a circumstance in which endogenous factors – specifically the birth weight and the general physical constitution at birth – play decisive roles. This effect reverses, however, in the ensuing months.

Baptism is one of the factors that could not be taken into consideration in this study. Generally, it is one of the strengths of the data set that it contains both information about baptisms as well as dates of births. Cases of unbaptised children were also recorded in the studied period of 1815 to 1829, but these only include stillbirths. Jews, for example, are also not included in these registries. While the time span between birth and baptism is always only a few days in the studied period, it becomes ever greater towards the end of the 19th century stretching to a few weeks or even months as later cohorts in the church records of St. James parish show. However, children who were expected to die soon after birth were baptised *in extremis*, usually by the midwife, as notes in the burial and baptismal registers illustrate – this applies to both the early as well as the late 19th century.

It is, however, questionable whether the registered stillbirths were actually correct. In the 19th century there had been no fixed definitions for live births and stillbirths. The pastor decided whether a deceased infant had shown any previous signs of life, but we do not know the criteria for such a decision. Looking at the available data set for the period 1815 to 1829 we cannot exclude a correlation with baptism. It is likely that a new-born was only considered a live birth once it has been baptised and when it died without being baptised, it was described as a stillbirth. This could be analysed using other Rostock church records from the same period. This is not, however, verifiable as conventional practice in the second half of the 19th century, at least not for St. James, since the deaths of unbaptised live births are also included in the registries during this time.

In summary, we can state that the available individual data from St. James parish offers new insights into infant mortality of a largely urban population in northern Germany in the early 19th century. This closes a research gap. For further analyses, the studied period would have to be enlarged, both to generate larger case numbers and to be able to examine the chronological development of social differences in infant mortality rates. The latter is of particular interest since infant mortality rates rise again from about 1840 onwards and it is unknown to which extent all social groups are affected by this increase.

Further promising analyses would be possible by merging the data from St. James parish with the 19th century Rostock censuses and the marriage and confirmation registries of St. James. In doing so, additional factors in infant mortality could be added to the analysis, such as those at the household level (*Scholz* 2013). We would thereby gain more information about the parents, such as the date of birth of the mother as well as the father, which was recorded in Rostock's marriage registries from 1853 onwards. There is also information about child spacing, birth order and number of siblings. This would not only make the data interesting for further mortality research, but also for fertility and social structure analyses as well as for genealogical studies.

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9.2 Study 2

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Manuscript

Social differences in cause-specific infant mortality at the dawn of the first demographic transition: New insights from German church records

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Little is known about social gradients in cause-specific infant mortality in the nineteenth century. To our knowledge, this is the first paper to explore this connection for the time prior to the first demographic transition. We used the church records of Rostock, an important port city on the Baltic coast in northern Germany, and prepared and merged the baptismal and burial registers of its largest parish, St. Jakobi, for the periods 1815–36 and 1859–82. Based on individual-level data (N = 16,880), we classified the fathers' occupations into three social classes and estimated cause-specific infant mortality risks for these groups using event history analysis. We found an almost linear social gradient in neonatal and post-neonatal mortality. This gradient was driven by gastro-intestinal diseases, which suggests severe deficits in nutrition and sanitation among the lower social classes, even before industrialization (coupled with population growth) led to worsening living environments.

Keywords: infant mortality; neonatal and post-neonatal mortality; social gradient; causes of death; historical demography; church records; event history analysis; Germany

[Submitted October 2019]

Introduction

Infant mortality is a widely used indicator for mortality and population health (Masuy-Stroobant and Gourbin 1995; Reidpath and Allotey 2003; Gonzalez and Gilleskie 2017). Its decrease in many industrial countries from the late nineteenth century onwards was one of the principal causes of the increased life expectancy and, hence, of the first demographic transition (Schofield et al. 1991; Chesnais 1992; Kirk 1996). The determinants of nineteenth-century infant mortality before this decrease have long been among the key issues of historical demographic research. This is due, for instance, to the poor sanitary conditions arising from urbanization that contemporary populations in a number of less developed countries are currently facing, similar to those which Western countries faced prior to the first demographic transition (Pozzi and Ramiro Fariñas 2015).

Several studies have explored social differences as well as cause-specific differences in historical infant mortality, whereas little is known about the interplay between social status and cause of death. Given that causes of death may provide deeper insights into the potential reasons for differentials and trends in infant mortality, this is a surprising gap in the research which may be explained by the following reasons. First, official cause-of-death statistics were not introduced until the twentieth century in most countries, meaning that the data simply do not exist. Second, the digitization, transcription, and preparation of alternative sources such as church records (if they survived the hazards of the last century at all) are expensive and time consuming. Third, these sources frequently do include no useful information on either social status or cause of death. Fourth, transcription costs have led to research which is mainly focussed on smaller parishes or shorter periods, resulting in infant death numbers which would become too small for cause-specific analysis.

Aiming to close this research gap, we used the large, newly available data source of church records from the Hanseatic city of Rostock, Germany. These data include information on both cause of death and social status for large numbers of residents, and describe an urban setting prior to the demographic and epidemiologic transitions when infectious diseases were still ubiquitous, infant mortality was high and industrialization and urbanization were just starting to emerge. After classifying causes of death into four groups, and fathers' occupations into three social classes, we used event history methods to estimate the impact of social differences on cause-specific infant mortality in nineteenth-century Germany.

Background

The case of Rostock, Germany

In contrast to present-day Germany, the spatial distribution of infant mortality was very heterogeneous in the nineteenth century. There was a northwest-to-southeast divide with the northwest showing the lowest rates (Würzburg 1887, 1888; Prinzing 1899, 1900; Imhof 1981; Gehrmann 2011). Infant mortality rates in northern German regions like Mecklenburg-Schwerin, Schleswig-Holstein, and Hanover were comparable to those in Scandinavia and Great Britain and fluctuated between 10 and 20 per cent (Figure 1). In parts of southern Germany, by contrast, the rate was more than 30 per cent. Several German regions experienced an increase in infant mortality in the third quarter of the nineteenth century due to worsened living environments as the result of industrialization, urbanization, and population growth, accompanied by adverse developments in infant care, infant feeding, and women's workload (Gehrmann 2011). The decrease in infant mortality in Germany started in the southern regions of Baden-Württemberg, Bavaria, and Hessen-Nassau in the last third of the nineteenth Germany, whereas the north did not follow until the early twentieth century. This decrease was a result of improved medical care, public health, sanitation/hygiene, nutrition, and work conditions (Imhof 1981; Vögele and Woelk 2002).

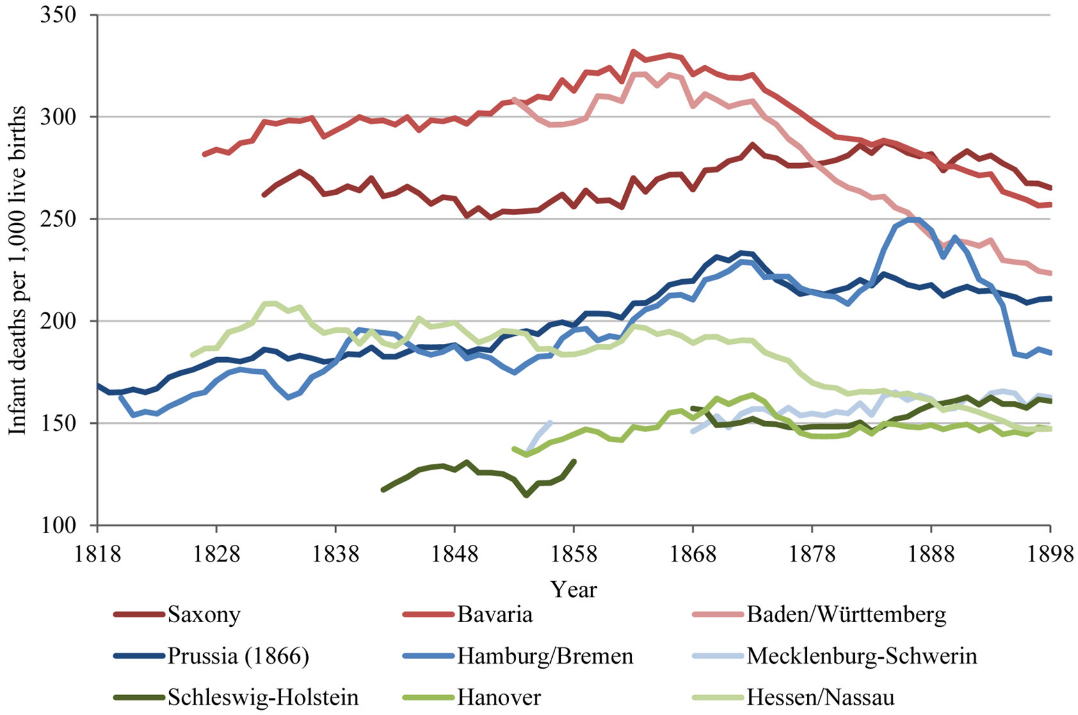

Figure 1 Infant mortality rate in German regions (five-year values), 1818–98
Source: Author's calculations based on data from Gehrmann (2002, 2011)

Located on the Baltic Sea and shaped by its port and its university, Rostock is the biggest and economically most important city in the Mecklenburg region. It was one of the earliest and most influential members of the Hanseatic League (Dollinger 1970). According to previous research, infant mortality in nineteenth-century Rostock was slightly higher in comparison to the rural areas of Mecklenburg but still lower than in most German regions (Prinzing 1900; Brüning and Balck 1906; Paulsen 1909; Toch et al. 2011; Mühlichen et al. 2015). Infant mortality in Rostock increased particularly in the early 1840s and late 1850s (Figure 2). The population grew continuously but at a low level in the first two thirds of the century, followed by accelerated growth in the last third. The increase in infant mortality peaked in 1859, with 201 infant deaths per 1,000 live births. This shift is most likely a consequence of the emerging processes of industrialization, urbanization, and work-related immigration (Manke 2000).

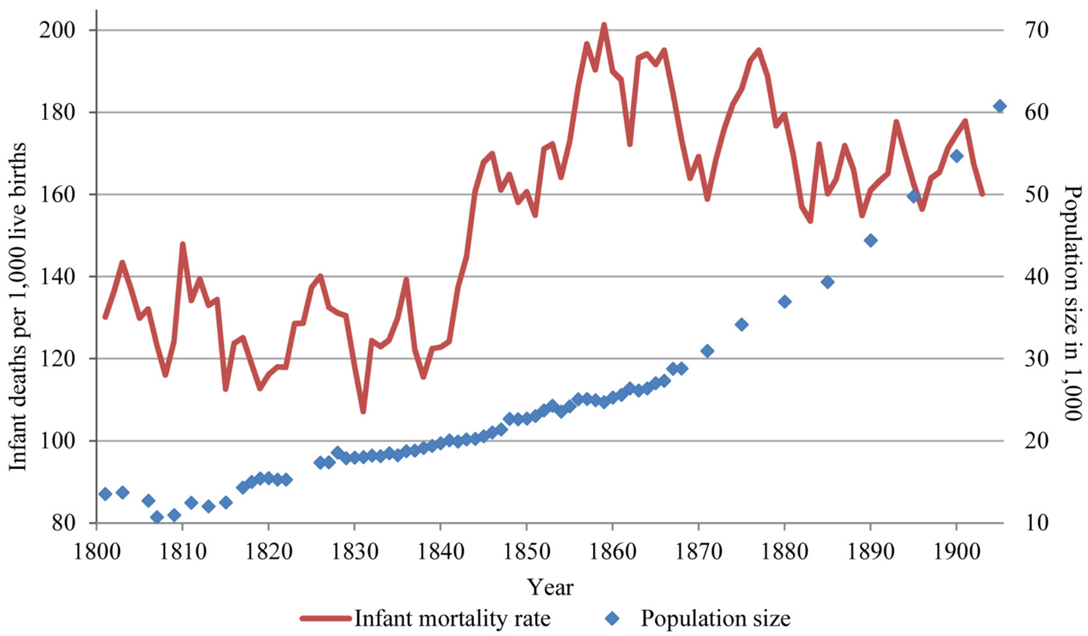

Figure 2 Population size (in 1,000) in Rostock (right scale), 1801–1905, and infant mortality rate (five-year values) in Rostock-St. Jakobi (left scale), 1801–1903

Source: Local statistical office of the Hanseatic City of Rostock and Mecklenburg-Schwerin State Calendar for the population size; Author's calculations for infant mortality based on the baptismal and burial registers of St. Jakobi parish, Rostock

Social differences in infant mortality

Determinants of infant mortality can be divided into endogenous and exogenous factors. Endogenous factors include biological conditions in terms of birth weight, foetal age at birth (gestation week), and congenital deformities, and are usually related to neonatal deaths (in the first 28 days of life), whereas exogenous factors include nutrition, sanitation/hygiene as well as social, economic, environmental, and climatic conditions and are more closely linked with post-neonatal infant deaths (after the first 28 days of life) (Bourgeois-Pichat 1951; Imhof 1981; Knodel and Hermalin 1984; Breschi et al. 2000; Reid 2001, 2002; van Poppel et al. 2005).

The socio-economic impact on infant mortality in the nineteenth century has long been the subject of debate in research. Not only the question of whether a social gradient exists in infant mortality has been debated, but so too has the direction of such a gradient. Some studies have found that socio-economic status had no effect (e.g. Knodel 1988; Bengtsson 1999), while others found a tendency which favoured the upper social classes (e.g. Woods et al. 1988, 1989; Derosas 2003; van Poppel et al. 2005; Mühlichen et al. 2015; Molitoris 2017), and again others saw the lower classes benefiting most from the wider practice of breastfeeding compared to the upper classes in some places (e.g. Imhof 1984; Kloke 1997).

The different results make clear that there is not only one single connection between socio-economic status and infant mortality. On the one hand, the results depend on the chosen classification of occupations and on time and place. On the other hand, many authors argue that the social differences only have an indirect impact, since breastfeeding (as an important factor in infant survival) as well as the quality of food, care, personal hygiene, and sanitary conditions may differ between socio-economic groups (Hanssen 1912; Imhof 1981; Haines 1995; Scott and Duncan 2000; Gehrmann 2011; Ekamper and van Poppel 2019). According to Kloke (1997), there were significant differences in breastfeeding habits among infant mortality differentials in Germany between regions and groups. Preston and Haines (1991, p. 209) concluded that knowledge outweighs resources in the context of infant mortality.

Cause-specific infant mortality

The effect of the principal influencing factors on infant mortality differs by cause of death. Prior to the epidemiologic transition, nineteenth century cause-of-death structure was largely shaped by infectious diseases and epidemics (Omran 1971, 1998).

Gastro-intestinal diseases, e.g. stomach disorder, ‘convulsions’, cholera, and diarrhoea, were the most frequent cause-of-death group among infants in nineteenth-century Germany, accounting for up to 70 per cent of the cause-of-death spectrum in some regions (Vögele 1994). These diseases were particularly prevalent in urban regions which had to cope with a large population growth following industrialization (Woods et al. 1988; Vögele 1994). Therefore, the decrease in infant mortality in Germany that started in the late nineteenth century is closely linked to improved sanitation, nutrition, and housing conditions in the German cities, and to public health campaigns aimed at promoting breastfeeding (Imhof 1981; Kintner 1986; Vögele 1994; Vögele and Woelk 2002). Since infant deaths from gastro-intestinal diseases were most common in the summer, previous research argued that the use of artificial nutrition (that was more likely to perish in the warm months of the year) instead of breastfeeding, and the poorer sanitary conditions in this season (especially in the urban areas) contributed to this peak (Würzburg 1891; Prausnitz 1901; Gottstein 1935; Knodel 1988: 62; Woods et al. 1988, 1989; Gehrmann 2002). Whether or not a mother breastfed her child was influenced by her marital and occupational status. Thus, both unmarried mothers and mothers who were extensively involved in their husband’s work (e.g. on a farm) had less time to care for their children and were more likely to use substitute nutrition (Imhof 1981; Preston and Haines 1991: 30; Vögele 1994). However, breastfeeding habits also varied by region and therefore gave rise to regional differences in infant mortality (Bluhm 1912; Knodel and Kintner 1977; Kintner 1985; Kloke 1997).

Respiratory diseases such as ‘breast disease’, pneumonia, bronchitis, and whooping cough were further common causes of death in the nineteenth century. They were particularly prevalent in cities with poor housing and living conditions (Lee and Marschalck 2002). As opposed to digestive diseases, these were most common in the cold months of the year, with (in)adequate clothing being an important influencing factor (Peiper 1913; Selter 1919; Derosas 2009). In addition, Waldron (1983) ascribed a higher risk of respiratory disease-related infant death to boys than to girls due to the lower physical maturity of infant boys’ lungs.

Another common cause of nineteenth-century infant mortality is simply called ‘weakness’, often synonymous with cachexia or ‘wasting’, and closely related to endogenous factors and early neonatal deaths (Vögele 1994; Lee and Marschalck 2002). One of the main risk factors is a low birth weight, which is closely related to an early gestation week and influenced by maternal age at childbirth, poor harvest yields, birth rank, and birth spacing (Würzburg 1888; Imhof 1981; Knodel and Hermalin 1984; Knodel 1988; Kloke 1997).

The only study that broached the interplay of cause-specific infant mortality and social class in the nineteenth century was conducted by Molitoris (2017) for Stockholm, another urban area located on the Baltic Sea. However, the multivariate analyses focussed on child mortality instead of infant mortality, thus including all children aged 0–9, and on a later period when the demographic and epidemiological transitions had already begun. The author found a social gradient in child mortality for the late nineteenth century in favour of the upper social classes which was strongly associated with gastro-intestinal and respiratory diseases.

Research hypotheses

We aimed to measure the influence of social class (as well as sex and time period as control variables) on the risk of death in the first year of life for different cause-of-death groups. Based on the current state of research, we decided to explore the following research hypotheses:

(1) There was a social gradient in infant mortality in favour of the upper social classes. This was more pronounced in post-neonatal mortality, where exogenous factors play a major role, than in neonatal mortality, which was more closely related to endogenous factors.

(2) This social gradient was particularly related to gastro-intestinal diseases, as these are more strongly influenced by the quality of nutrition and water than other diseases. In addition, children of unmarried mothers were at particular risk because their mothers had to work more often and thus were more likely to use artificial nutrition than to breastfeed.

(3) The social gradient was more pronounced in the period 1859–82, which was characterized by the beginning of urbanization, than in 1815–36, when the population size and infant mortality were comparatively low. Assuming that the immigration of lower-class workers led to a deterioration of the living environment, we expect the low social class to show a greater increase in infant mortality than the upper classes, especially in cases where there was residential segregation.

Data and methods

Data

Measuring infant mortality requires data on live births and infant deaths. Therefore, we used two different data sources. First, the baptismal registers of St. Jakobi include the population at risk, i.e. all live births registered in the St. Jakobi parish of the city of Rostock in the periods in question. Second, the burial registers of St. Jakobi include all infant deaths recorded in this parish. These sources are detailed in Mühlichen and Scholz (2015). The parish of St. Jakobi was by far the largest of the four old Rostock parishes and probably the most heterogeneous one as well with regard to social structure (Szołtysek et al. 2011; Mühlichen and Scholz 2015). Therefore, we expect St. Jakobi to constitute an appropriate sub-sample of Rostock.

We obtained the transcribed baptismal registers from the RAPHIS (2016) database of the Max Planck Institute for Demographic Research (MPIDR), which grants open access to historical vital statistics for Rostock. However, only the periods of 1815–23 and 1863–79 are gapless. Aiming to close the gaps in the database, we added the years that were only partially transcribed, and also transcribed several years ourselves using the digitized scans of the church records available from the MPIDR. In total, the baptismal data file contains a time series of 48,409 births that were recorded in the baptismal registers between 1800 and 1911 (including stillbirths up to 30 November 1876). Our study focusses, however, on the periods of 1815–36 and 1859–82 because the transcriptions contained all necessary information, including the date of birth, the date of baptism, the child's full name, the full names of the parents, the father's occupation, the legitimacy of birth, and (in some cases) the birthplace (only noted if it was outside of Rostock). The first period marks a stage of low infant mortality, whereas the second one is characterized by relatively high infant mortality (as shown in Figure 2).

For the burial registers, we used a data file which covers 1787–1910; this includes all deaths at age 0–1 (N = 10,227) and was created by Mühlichen (2011) but has not been published so far.[1] This file includes the date of death, the date of burial, the birthplace (only from 1847 onwards), the child's full name, the cause of death and age upon death given in days, weeks, or months or in some cases approximated as '1 year'. In the case of legitimate births, the father's name and occupation were recorded as well. Regarding illegitimate births, the mother's name was recorded instead.

Both data files underwent an extensive and time consuming error correction and harmonization process, particularly regarding the spelling of names, the date of birth, date of death, father's occupation and legitimacy of birth.

Matching and selection

Both the baptismal and the burial data contain enough information for us to merge the two files into one data file. This was necessary for two reasons: First, we need the population at risk included in the baptismal data and the information about infant deaths included in the burial data for survival analysis. Second, we need the date of birth from the baptismal register and the date of death from the burial register to calculate the exact span of days from birth to death, since the given age upon death is not accurate enough for many children, especially those whose age was recorded as '1 year' which makes it very difficult to identify these as infant deaths.

In preparation for the matching process, we limited the baptismal data to the 1815–36 and 1859–82 periods, and the burial data to the 1815–37 and 1859–83 periods. In addition, we harmonized the spelling variants of the surnames and first names to increase the chance of successful matches.

[1] The burial registers of St. Jakobi parish were completely transcribed for the period of 1800–1906, including a total of 35,095 deaths at all ages, and are available at the RAPHIS (2016) database.

We applied three different matching procedures to reach a maximum linkage quota. First, we conducted a matching procedure in SAS that linked persons from both files if the first two letters of their surname, the first two letters of their first name and their sex were identical. Second, we conducted a fuzzy matching in R that linked persons with an almost identical surname and first name to identify those matches with differences in the first or second letters of their names, or incorrect sex. Third, we conducted another matching procedure in SAS that merged persons if the first four letters of their surname as well as their sex were identical. The aim of this was to find identical persons even if the order of their first names was recorded differently in the registries. In all three procedures, the year of birth had to be approximately the same (+/-2). The aggregated list of matches included many individuals who were matched more than once. Therefore, we checked this list carefully and deleted all incorrect matches. In addition, we checked the lists of unmatched infant deaths and unmatched live births manually to find identical individuals with a difference in their surname, e.g. if the mother's surname was recorded as the child's surname instead of the father's in one of the two registries. After excluding stillbirths and children born outside of Rostock, 90.2 per cent of all infant deaths recorded in the burial registers were successfully linked to the live births of the baptismal registers. The unmatched infant deaths included 113 children who died before their baptism. Since children who died before their baptism were no longer recorded in the baptismal registers from 1 December 1876, we added them manually to the merged data file from the burial registers in order to avoid under-coverage of the population at risk in the last years of the study period. The age upon death in these cases was mostly given in days or weeks, thus being accurate enough to ensure that no further information was needed from other sources. Including such cases raised the linkage quota to 94.1 per cent, leaving 174 cases in the burial registers that could not be linked to the baptismal registers.

In total, we linked 2,761 cases from the burial register file to the baptismal register file. After calculating the age upon death from the date of birth and the date of death, however, 72 cases turned out to be one year or older at death, which we recorded as 'no infant death'. Moreover, we excluded children who were one year and older at baptism from the merged data file, as it is highly probable that they were not born in Rostock and thus do not belong to the population at risk. All in all, the merged data file includes 16,880 live births, of which 2,689 died in the first year of life (15.9 per cent).

Outcome variables and covariates

The main outcome variable is infant death differentiated by the following causes of death: respiratory diseases, gastro-intestinal diseases, weakness/cachexia and other diseases. The cause-of-death classification was performed with the help of medical historian Hans-Uwe Lammel and using a historical disease encyclopaedia (Höfler 1899). The grouping is similar to the one used by Reid (2002) but contains fewer categories, thus yielding higher numbers per disease group. Table 8 (in the appendix) shows all diseases recorded in our data by cause-of-death group and frequency. Furthermore, we constructed two further outcome variables for neonatal deaths (up to 28 days of age) and post-neonatal deaths (aged 29 days and older).

The main variable of interest is social class. We derived social class by first sorting the data according to occupational group and then by deploying ranking within these occupational groups. This social classification is less complex and easier to use than the HISCO/HISCLASS systems and is more suitable for a German city shaped by trade and seafaring. It is a three-digit system with a [--0] for general occupational groups, a [--1] indicating the lowest social status within that group, and with [--2], [--3] and [--4] referring to the higher statuses. The distinction of the occupations and classes is based on the HISCO, HISCLASS and NAPP classifications[2] as well as on studies on historical occupational and social structures in the cities of the German Baltic Sea region (Brandenburg et al. 1991; Brandenburg and Kroll 1998, Lorenzen-Schmidt 1996; Manke 2000) and historical German lexica[3]. We assigned the occupations of the fathers to the following three groups of social classes. Social class A includes high-level officials, merchants, doctors, professors, and proprietors, and is referred to in the following as 'high status'. Social class B, 'medium status', includes craftsmen, medium-level officials, steersmen, skippers, teachers, grocers, and wagoners. Social class C, 'low status', includes labourers, seamen, low-level officials, day labourers, porters, apprentices, servants, factory workers, field workers, fishermen, artists, and unknown fathers (particularly in the case of illegitimate births). The complete list of occupations, their codes and their allocation to the social classes is given in Table 7 in the appendix. In our models, we controlled for sex and period of birth, which distinguishes between 1815–36 and 1859–82.

Analytic strategy

We applied separate models based on cause of death for neonatal and post-neonatal mortality to test the first two hypotheses. To test the third hypothesis, we specified a model with an interaction effect between period and social class.

We analyzed the risk of dying in the first year of life using event history analysis based on the Cox proportional-hazards model (Cox and Oakes 1984). The analysis time was measured by the age in days, from birth to infant death, whereby the age of new-borns who survived the first year of life was set at the censored time of 365 days. In the case of neonatal mortality, the censored time was 29 days. The analysis of post-neonatal mortality excluded neonatal deaths by definition and thus involved left-truncated data. For simplicity, we interpreted hazard ratios as relative risks.

All data entries, error corrections, and the harmonization of the baptismal and burial data were conducted using Excel. We used SAS and R for the matching procedures and SPSS to process the data for the survival analysis. The survival analysis itself was performed using Stata.

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[2] The Historical International Standard Classification of Occupations (HISCO) is described in van Leeuwen et al. (2002). Its adaptation for the North Atlantic Population Project (NAPP) is described in Roberts et al. (2003). The Historical International Social Class Scheme (HISCLASS) is described in van Leeuwen and Maas (2011).

[3] We used the lexica of Adelung 1793-1801, Pierer 1857-1865, Meyers 1905-1909, and Brockhaus 1911 that are freely accessible online at the Zeno.org (2018) library.

Results

Descriptive statistics

Our data consisted of 16,880 live births and 2,689 infant deaths (Table 1), of which 823 cases were neonatal and 1,866 cases were post-neonatal (Table 2). The crude death rates were highest among male infants, the 1859–82 cohorts and the lowest social class. This was true for total infant mortality as well as for neonatal and post-neonatal mortality.

Table 1 Live births, infant deaths, person-time and crude death rates by sex, period and social class in Rostock, St. Jakobi parish, 1815–36 and 1859–82

Variable	Category	Live births	Infant deaths	Person years	Crude death rate	95% confidence interval	
Sex	Male	8,750	1,492	7,686	0.1941	0.1845	0.2042
	Female	8,130	1,197	7,307	0.1638	0.1548	0.1734
Period of birth	1815–36	4,279	508	3,916	0.1297	0.1189	0.1415
	1859–82	12,601	2,181	11,077	0.1969	0.1888	0.2053
Social class	A: High	1,115	128	1,031	0.1242	0.1044	0.1477
	B: Medium	6,406	958	5,749	0.1666	0.1564	0.1775
	C: Low	9,359	1,603	8,213	0.1952	0.1859	0.2050
Total		16,880	2,689	14,992	0.1794	0.1727	0.1863

Source: Author's calculations and classification based on the baptismal and burial registers of St. Jakobi parish, Rostock.

Table 2 Neonatal and post-neonatal deaths, person-time and crude death rates by sex, period and social class in Rostock, St. Jakobi parish, 1815–36 and 1859–82

Variable	Category	Neonatal			Post-neonatal		
		Deaths	Person years	Death rate	Deaths	Person years	Death rate
Sex	Male	479	670	0.7147	1,013	7,672	0.1320
	Female	344	628	0.5475	853	7,296	0.1169
Period of birth	1815–36	178	330	0.5395	330	3,911	0.0844
	1859–82	645	969	0.6659	1,536	11,057	0.1389
Social class	A: High	38	86	0.4401	90	1,030	0.0874
	B: Medium	266	495	0.5379	692	5,742	0.1205
	C: Low	519	718	0.7232	1,084	8,197	0.1322
Total		823	1,299	0.6338	1,866	14,969	0.1247

Source: As for Table 1.

Throughout the observation periods, post-neonatal mortality was higher than neonatal mortality, particularly between 1859 and 1882 (Figure 3). The higher level of infant mortality in the later period was strongly associated with an upward shift of post-neonatal mortality. Differentiated by cause of death, this shift was most pronounced in gastro-intestinal diseases (Figure 4). Altogether, 1,363 infants died from gastro-intestinal diseases, followed by 500 cases from weakness/cachexia and 427 cases from respiratory diseases. 399 cases were diagnosed with other diseases. Infant mortality peaked in 1865, reaching 254 infant deaths per 1,000 live births, mainly due to a peak in gastro-intestinal and respiratory diseases.

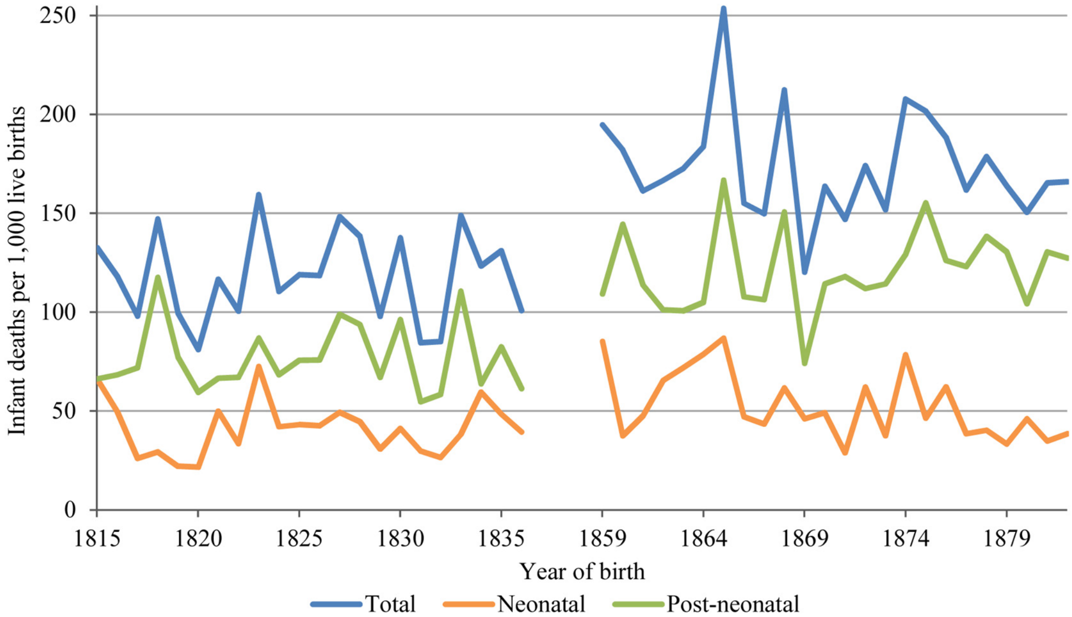

Figure 3 Infant, neonatal and post-neonatal mortality rates by year of birth in Rostock, St. Jakobi parish, 1815–36 and 1859–82

Source: Author's calculations based on the baptismal and burial registers of St. Jakobi parish, Rostock

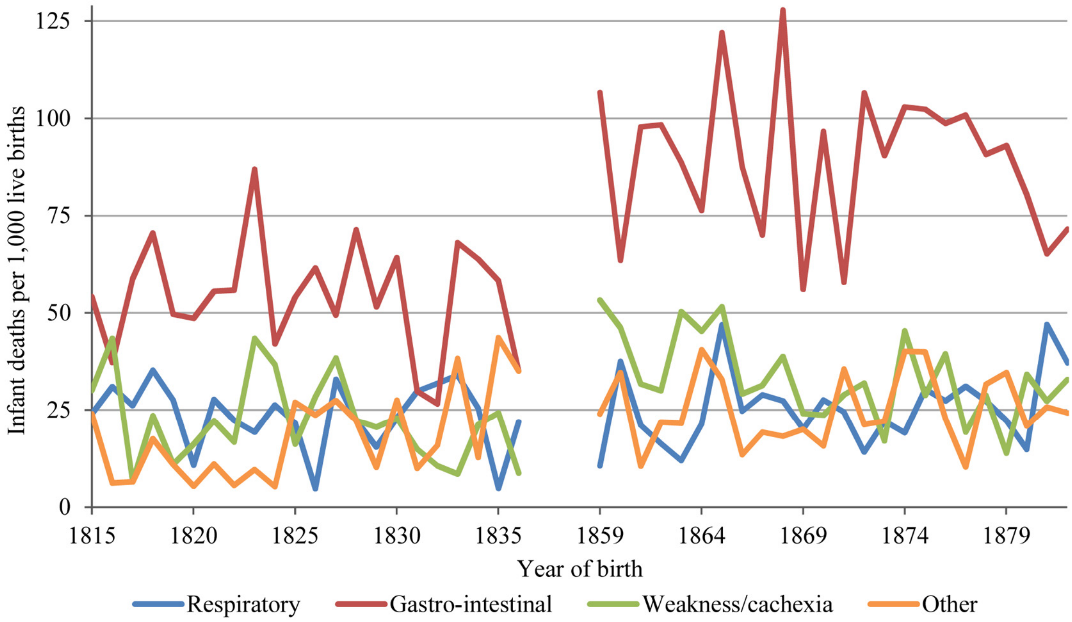

Figure 4 Cause-specific infant mortality rates by year of birth in Rostock, St. Jakobi parish, 1815–36 and 1859–82

Source: As for Figure 1.

Event history analysis

Since the mortality patterns differed between the first month of life and the ensuing months, the proportional-hazards assumption of the Cox model was violated for the variables capturing the effects of social class and period of birth, which implies that estimates for overall infant mortality would be biased. Therefore, we applied separate models for the first 28 days of life (neonatal mortality) and the remaining period up to one year (post-neonatal mortality).

The risk of neonatal death differed by social class, period of birth and sex—but not in every cause-of-death group (Table 3). With regard to all causes, it was 21 per cent higher among the medium social class (hazard ratio *HR* = 1.21, *p*-value = 0.272), albeit not statistically significant, and 60 per cent higher among the low social class (*HR* = 1.60, *p* = 0.005) as compared to the high social class. Mortality was 20 per cent higher in 1859–82 (*HR* = 1.20, *p* = 0.031) than in 1815–36. Furthermore, female infants had a 23 per cent lower risk of neonatal death (*HR* = 0.77, *p* = 0.000) than male ones. The social differences were mainly attributable to gastro-intestinal diseases with *HR* = 2.09 (*p* = 0.033) for the medium and *HR* = 3.22 (*p* = 0.001) for the low social classes. This social gradient was not evident in other cause-of-death groups. The sex gradient was strongest in gastro-intestinal diseases as well (*HR* = 0.70, *p* = 0.001). The period effect was only statistically significant in 'weakness/cachexia' (*HR* = 1.40, *p* = 0.011).

Table 3 Neonatal mortality: Hazard ratios from Cox proportional-hazards models, Rostock, St. Jakobi parish, 1815–36 and 1859–82

Variable	Category	All causes	Gastro-intest.	Respiratory	Weakness	Other causes
Sex	Men (*Ref*)	1	1	1	1	1
	Women	0.77 ***	0.70 ***	1.07	0.81 **	0.86
Period of birth	1815–36 (*Ref*)	1	1	1	1	1
	1859–82	1.20 **	1.08	2.35	1.40 **	0.86
Social class	A: High (*Ref*)	1	1	1	1	1
	B: Medium	1.21	2.09 **	0.83	0.99	0.71
	C: Low	1.60 ***	3.22 ***	1.11	1.10	1.15

Note: * p ≤ 0.1; ** p ≤ 0.05; *** p ≤ 0.01. *Ref* indicates the reference category.
Source: As for Table 1.

Table 4 Post-neonatal mortality: Hazard ratios from Cox proportional-hazards models, Rostock, St. Jakobi parish, 1815–36 and 1859–82

Variable	Category	All causes	Gastro-intest.	Respiratory	Weakness	Other causes
Sex	Men (*Ref*)	1	1	1	1	1
	Women	0.89 ***	0.91	0.95	1.11	0.68 ***
Period of birth	1815–36 (*Ref*)	1	1	1	1	1
	1859–82	1.62 ***	1.94 ***	1.13	1.68 **	1.57 ***
Social class	A: High (*Ref*)	1	1	1	1	1
	B: Medium	1.34 ***	1.75 ***	0.94	0.86	1.31
	C: Low	1.44 ***	1.86 ***	0.98	1.40	1.29

Note: * p ≤ 0.1; ** p ≤ 0.05; *** p ≤ 0.01. *Ref* indicates the reference category.
Source: As for Table 1.

The risk of post-neonatal death differed by social class, period of birth and sex as well (Table 4). Unlike in neonatal mortality, the gradients between female and male infants and between the highest and lowest social class were smaller in post-neonatal mortality but the shift from the earlier to the later period was stronger. Overall, the risk was 34 per cent (*HR* = 1.34, *p* = 0.009) higher among the medium social class and 44 per cent (*HR* = 1.44, *p* = 0.001) higher among the low social class as compared to the high social class. The risk increased over time by 62 per cent (*HR* = 1.62, *p* = 0.000) from period 1815–36 to period 1859–82. Female infants had an 11 per cent (*HR* = 0.89, *p* = 0.009) lower risk of post-neonatal death than male infants. As in neonatal mortality, the social differences in post-neonatal mortality were mainly attributable to gastro-intestinal diseases with *HR* = 1.75 (*p* = 0.001) for the medium and *HR* = 1.86 (*p* = 0.000) for the low social class. The sex gradient was strongest in 'other causes' (*HR* = 0.68, *p* = 0.001), the period effect was evident in all cause-specific groups, was particularly strong for gastro-intestinal diseases (*HR* = 1.94, *p* = 0.000) and statistically insignificant for respiratory diseases (*HR* = 1.13, *p* = 0.280).

Table 5 Interaction in neonatal mortality between period and social class: Change between the periods 1815–36 and 1859–82 by social class in Rostock, St. Jakobi parish, Hazard ratios from Cox proportional-hazards models

Outcome	Social class	All causes	Gastro-intest.	Respiratory	Weakness	Other causes
Period	A: High (*Ref*)	1	1	-	1	1
1815–36	B: Medium	1.56	1.76	-	1.35	1.97
	C: Low	2.14 **	3.44 **	-	1.35	1.83
Period effect	A: High	1.71	1.07	-	1.91	2.13
Change by	A: High (*Ref*)	1	1	-	1	1
social class	B: Medium	0.70	1.25	-	0.66	0.22
	C: Low	0.68	0.92	-	0.76	0.51

Note: * p ≤ 0.1; ** p ≤ 0.05; *** p ≤ 0.01. *Ref* indicates the reference category. The numbers of respiratory diseases in neonatal mortality were too small for analysis.
Source: As for Table 1.

Table 6 Interaction in post-neonatal mortality between period and social class: Change between the periods 1815–36 and 1859–82 by social class in Rostock, St. Jakobi parish, Hazard ratios from Cox proportional-hazards models

Outcome	Social class	All causes	Gastro-intest.	Respiratory	Weakness	Other causes
Period	A: High (*Ref*)	1	1	1	1	1
1815–36	B: Medium	1.41	1.47	1.09	1.34	2.09
	C: Low	1.45 *	1.41 **	1.21	2.64	1.83
Period effect	A: High	1.68 **	1.46	1.44	3.25	2.55
Change by	A: High (*Ref*)	1	1	1	1	1
social class	B: Medium	0.93	1.26	0.81	0.58	0.55
	C: Low	0.98	1.42	0.75	0.46	0.64

Note: * p ≤ 0.1; ** p ≤ 0.05; *** p ≤ 0.01. *Ref* indicates the reference category.
Source: As for Table 1.

Social classes did not differ significantly in the change of infant mortality between the periods 1815–36 and 1859–82, either in neonatal (Table 5) or in post-neonatal mortality (Table 6). However, there was a tendency towards a lower increase in all-cause neonatal mortality in the medium ($HR = 0.70$, $p = 0.387$) and low classes ($HR = 0.68$, $p = 0.324$) than in the highest social class.

Discussion

Based on individual-level baptismal and burial registers of the church records of St. Jakobi parish in Rostock, Germany, we found that the social gradient in nineteenth-century neonatal and post-neonatal mortality was mainly attributable to gastro-intestinal diseases. The social gradient did not change significantly from the first period (1815–36) to the second (1859–82), when urbanization and accelerated population growth started to emerge, leading to higher infant mortality. To our knowledge, this is the first study to explore the connection between social class and cause-specific infant mortality prior to the first demographic transition.

Social gradient in infant mortality

Our first hypothesis assumed *a social gradient in infant mortality in favour of the upper social classes which was more pronounced in post-neonatal mortality than in neonatal mortality*. While our data confirmed the existence of a social gradient, it was more pronounced in neonatal than in post-neonatal deaths.

Social differences in infant mortality were also found in several other places in Europe (e.g. Woods et al. 1988, 1989; Oris et al. 2004; van Poppel et al. 2005; Breschi et al. 2011), but such a clear, almost linear, social gradient has not been reported in historical infant mortality, at least not to our knowledge. In the literature, social differences are usually more closely linked with post-neonatal mortality (e.g. Bourgeois-Pichat 1951; Breschi et al. 2000; van Poppel et al. 2005) but some studies also found significant social differences in neonatal mortality (Landers 1993; Derosas 2003, 2009; Mühlichen et al. 2015). We cannot determine if the impact of social status on infant mortality was direct or indirect since our data offer no insight into potentially more decisive factors like nutrition and sanitation. These direct influencing factors may differ by social status, as argued by Imhof (1981), Haines (1995), Scott and Duncan (2000), Gehrmann (2011), and Ekamper and van Poppel (2019), for instance. However, by analyzing this gradient more specifically in terms of cause of death, we broached this question indirectly.

Social gradient in cause-specific infant mortality

Our second hypothesis was that *the social gradient was especially related to gastro-intestinal diseases*, which was supported by our data. Both for neonatal and post-neonatal mortality, the social gradient was attributable to gastro-intestinal diseases, whereas social class had no significant effect in the other disease groups. Following Bengtsson and van Poppel (2011), we assume no direct effect of social class. The close connection with gastro-intestinal diseases in particular indicates that social class was, rather, a proxy for nutrition and sanitation.

On the one hand, our results confirm previous research that cited nutrition and sanitation as principal determinants for infant mortality, since these two factors are strongly connected with gastro-intestinal diseases (Kintner 1986; Preston and Haines 1991; Vögele 1994). With respect to nutrition, breastfeeding is a protective factor for infant survival because breast milk transfers antibodies against infection from mother to child, and birth intervals tend to be prolonged (Bengtsson 1999; Scott and Duncan 2002, pp. 147–157), while artificially fed infants have no such natural protection but are also more likely to come into contact with contaminated food, or food that has already perished, which could happen quickly in the warm months of the year—in a time before the invention of refrigerators. Therefore, differences in breastfeeding practices are seen as one of the major determinants of nineteenth-century infant mortality and its regional variation (Knodel and Kintner 1977; Kintner 1985; Kloke 1997). With respect to sanitation, geographic variations in the supply of clean water were found to be important influencing factors of infant mortality differentials as well (van Poppel and van der Heijden 1997; Jaadla and Puur 2016; Kesztenbaum and Rosenthal 2017).

On the other hand, our results indicate that the nutritional and sanitary conditions varied noticeably in the three social classes in nineteenth-century Rostock, as has also been argued with regard to other places in Europe (e.g. Haines 1995; Kloke 1997; Scott and Duncan 2000; Oris et al. 2004). In the lower social classes, unmarried mothers who had to earn their own living, or mothers who had to support their husbands at work, were more likely to use artificial nutrition instead of breastfeeding (Imhof 1981; Preston and Haines 1991, p. 30; Vögele 1994). Regarding sanitation, the access to clean water probably varied in the neighbourhoods of nineteenth-century Rostock, which presumably also differed in their social structure, as was the case in Amsterdam, for instance (Ekamper and van Poppel 2019). Thus, residential segregation in connection with water quality and sanitary conditions could be another explanation for the higher gastro-intestinal mortality among infants in Rostock's lower social classes.

Our results indicate that infants of lower social status were more likely to be exposed to substitute nutrition (instead of breastfeeding), malnourishment, poor access to clean water, and neglect. While the vast majority of deaths related to gastro-intestinal diseases (as well as respiratory and 'other' diseases) took place in the post-neonatal stage, the social gradient in gastro-intestinal diseases was even stronger in neonatal mortality. Thus, although gastro-intestinal diseases as causes of death were relatively rare in the first four weeks of life compared to later, they had a significantly greater impact—when they did arise—on the lowest social class than on the two higher ones. This result suggests the existence of severe deficits in maternal care among the lower social classes, e.g. malnutrition and neglect (Derosas 2003, 2009).

Changes between the periods

As shown by Mühlichen et al. (2015), infant mortality increased considerably in Rostock in the 1840s and 1850s, which is exactly the time between our two study periods. The second period marks the beginning of urbanization and accelerated population growth. Assuming that the increase in infant mortality was driven by the immigration of low-status workers, our third hypothesis was that *the social gradient was more pronounced in the period 1859–82 than in 1815–36 and that the low social class was more strongly affected*. The data, however, suggest that the increase in infant mortality was similar for all social classes. The results also show that the deficits in nutrition, sanitation, and maternal care in the low social class were evident even before industrialization (coupled with population growth) had led to worsening living environments. This deterioration then affected all parts of the population.

Even though not statistically significant, we found a tendency which suggested that the increase in neonatal mortality was more pronounced in the highest social class. There are various potential reasons for this: On the one hand, in many places in nineteenth-century Germany, the upper social class was more likely to use substitute nutrition instead of breastfeeding their infants (Imhof 1984). It is possible, that such a trend evolved in Rostock in the middle of the nineteenth century as well. On the other hand, residential patterns with respect to sanitary conditions also had a considerable impact (Ekamper and van Poppel 2019). According to our results, we can assume that there was greater residential segregation in the first period than in the second because the accelerated population growth most likely altered the residential patterns of Rostock. If this was the case, the high-status population of Rostock was more likely to come into contact with (immigrated) low-status groups and their associated diseases than before. It is therefore probable that the advantage that the high social class possibly enjoyed in terms of sanitary conditions in the first period had decreased as the result of urbanization. However, further research is needed to substantiate these two explanations.

Potential bias and limitations

The first potential bias is the differentiation between live births and stillbirths made by the pastor. We found no explicit criteria for this classification and cannot ascertain whether (informal) rules were subject to changes within the periods studied.

Second, we cannot ascertain whether and how many infants left the parish and died elsewhere in the first year of life. This makes under-recording of infant mortality possible, which is of special relevance in terms of illegitimate births. Contrary to other historical demographic research, Mühlichen et al. (2015) found a lower infant mortality risk for illegitimate new-borns compared to legitimate ones in St. Jakobi in the years 1815–29. This was not statistically significant, though. As a possible explanation, they argued that unmarried mothers were more likely than married mothers to move to their parents in the countryside, or hand their children over to them or to other intimates or institutions. In such cases, infant deaths are not usually recorded in the burial register of St. Jakobi. In our study periods 1815–36 and 1859–82, the mortality risk is higher among illegitimate than legitimate infants, as additional analyses of our data show. The slight survival advantage of illegitimate newborns in 1815–1829 is reversed by adding the years 1830–36. Nonetheless, the risk of infant death among illegitimate births may still be underestimated as the result of unrecorded infant deaths that took place elsewhere.

Third, our results for the social gradient are shaped by our occupational classification. According to Manke (2000, pp. 369–371), Rostock's group of craftsmen was very heterogeneous in its social structure, whereas Rostock's political and economic elite consisted of merchants, brewers, and lawyers, and workmen and day labourers formed the lower class.

We considered this in our classification but some uncertainties remain. For example, we included all merchants ('Kaufmann') in the highest social class although some may have been relatively poor. In addition, we did not differentiate between master craftsmen and journeymen in terms of social class. We put all masters, journeymen and craftsmen of unspecified rank into the medium social class because the differentiation was not accurate enough in the registers (see Table 7 in the appendix).

Fourth, in the study period, individual causes of death were recorded in absence of any systematic cause-of-death classification. For instance, the most frequently recorded cause of death in our data is 'Krampf' (*N* = 1,123) which can be translated as 'cramp' or 'convulsion'. In fact, convulsions do not describe the actual underlying disease, merely the last symptoms before death, usually resulting from gastro-intestinal disorders (Kintner 1986; Preston and Haines 1991, p. 6). Therefore, we included all convulsions in the gastro-intestinal disease group (see Table 8 in the appendix). Overall, the accuracy of the recorded causes of death was less than optimal, especially at the beginning of the nineteenth century, but it improved over the course of the century. Moreover, the diagnoses were not recorded by a medical doctor but by the respective pastor. Whether or not the pastors conferred with a doctor in some instances is unclear, but they had at least some basic medical knowledge, as the range of recorded diagnoses as well as clerical statute books from that time indicate (Gesenius 1837, 1848; Millies 1895, 1896).

Strengths of the analysis

First, the large number of cases permitted us to explore cause-specific infant mortality. Second, detailed information on the father's occupation allowed us to conduct a social class differentiation. Third, the quality of the recorded cause-of-death information is comparatively good for the study period. Even after harmonizing all variant forms of spelling, there were still 150 diseases recorded in our data. In only 60 out of 2,689 infant deaths was the cause of death unspecified or unknown, which we consider a clear strength of the data (Table 8). Fourth, the data offer rare insights into an urban setting prior to the first demographic transition. Fifth, the available information on the age upon death allowed us to apply separate models for neonatal and post-neonatal mortality, which was necessary since the proportional-hazards assumption of the Cox model was violated for total infant mortality due to different mortality patterns in the first and ensuing months up to one year. Finally, we conducted a sensitivity analysis using competing-risks regression according to Cleves et al. (2010, pp. 365–391) which did not alter our results (results upon request).

Concluding remarks

Our results refer to a historical setting prior to the first demographic transition. However, they may be applicable to less developed countries currently facing poor sanitary conditions, accelerated population growth, and rapid urbanization. Improvements in nutritional and sanitary conditions can reduce the risk of infant death from infectious diseases, particularly by raising breastfeeding rates and access to clean water. All social groups benefit from these improvements. However, the reverse is also true, and deteriorating environmental conditions may affect all parts of the population, thus raising infant mortality rates in all social classes. Gastro-intestinal diseases caused by malnutrition, poor access to clean water, and neglect may still be the main cause of excessive infant mortality rates.

While our study provides new insights into the interplay between social differences and cause-specific infant mortality in the nineteenth century, further research is needed. Transcribing and preparing all of Rostock's church records and censuses would allow other important contributory factors to infant mortality to be incorporated. Thus, information on birth ranks, birth intervals, maternal age at childbirth, and parental death could be included in the analysis as additional covariates by using family reconstitution methods based on Rostock's church records. Moreover, linking these data to the censuses of Rostock would permit cartographic analysis of infant mortality by neighbourhood, as Ekamper and van Poppel (2019) did for Amsterdam, adding environmental variables like the supply of water and sewers. All in all, much can still be gained from the Rostock data in order to obtain a better understanding of the determinants of infant mortality in an urbanizing setting at the dawn of the demographic transition.

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Appendix A

Occupational classification

Table 7 Classification of occupations by social class and frequency among the fathers of infants born in Rostock, St. Jakobi parish, 1815–36 and 1859–82

Group	Code	German description	English translation	Class	N[1]
a) Trade and administration					
Trade	100	Händler[2]	Tradesman[2]	B	59
	101	Handlungsgehilfe, -diener, -reisender	Merchant's apprentice, travelling salesman	C	9
	102	Krämer, Warenhändler	Grocer, shopkeeper	B	165
	103	Kaufmann	Merchant	A	527
Carrying trade	111	Kutscher, Sänftenträger	Cabman, litter bearer	C	24
	112	Fuhrmann	Wagoner	B	189
	113	Fuhrunternehmer, Droschkenbesitzer	Haulage contractor, cab owner	A	5
Gastronomy	121	Kellner, Portier, Büfettier	Waiter, porter, bartender	C	0
	122	Koch, Kantinenpächter	Cook, canteen tenant	C	7
	123	Gastwirt, Herbergierer	Innkeeper	B	160
	124	Hotel- oder Gasthofbesitzer, Hoteldirektor	Hotel or inn owner, hotel director	A	0
Bank, insurance	131	Bank- oder Versicherungsdiener	Bank or insurance servant	C	9
	132	Bank- oder Versicherungsbeamter	Bank or insurance official	B	7
	133	Bank- oder Versicherungsinspektor	Bank or insurance inspector	A	4
	134	Bank- oder Versicherungsdirektor	Bank or insurance director	A	0
Administration, justice	141	Beamter im unteren Dienst	Low-level official	C	66
	142	Beamter im mittleren Dienst	Middle-level official	B	73
	143	Beamter im höheren Dienst	High-level official	A	211
	144	Hochrangiger Beamter	Top-ranking official	A	113
Post	151	Postbeamter im unteren Dienst	Low-level post official	C	29
	152	Postbeamter im mittleren Dienst	Middle-level post official	B	18
	153	Postbeamter im höheren Dienst	High-level post official	A	0
Security	161	Polizei- oder Feuerwehrdiener, Wächter	Police or fire servant, watchman, guard	C	9
	162	Mittlerer Polizei- oder Feuerwehrbeamter	Middle-level police or fire officer	B	6
	163	Höherer Polizei- oder Feuerwehrbeamter	High-level police or fire officer	A	0
Education, science	171	Student, Famulus, Schul- oder Universitätsdiener	Student, famulus, school or university servant	C	2
	172	Lehrer, Dozent, Wissenschaftler (ohne Doktortitel)	Teacher, lecturer, scientist (without doctoral degree)	B	111
	173	Doktor, Professor	Doctor, professor	A	96
	174	Schuldirektor, Universitätsrektor	School or university director	A	3
Medicine, health	181	Krankenwärter, Pflegekraft, Masseur	Nurse, caregiver, masseur	C	17
	182	Chirurg, Zahnarzt, Magnetiseur, Tierarzt	Surgeon, dentist, magnetizer, veterinarian	B	12
	183	Doktor der Medizin	Doctor of medicine	A	31
	184	Hospitalmeister	Hospital administrator	A	5
Church	191	Kirchendiener	Church servant	C	24
	192	Diakon, Kantor, Magister	Deacon, cantor, magister	B	10
	193	Pastor	Pastor	B	2
	194	Kirchenvorsteher	Church leader	A	0
					2,003

Table 7 *continued*

Group	Code	German description	English translation	Class	N[1]
b) Transport and military					
Railways	201	Bahnbeamter im unteren Dienst	Low-level railway official	C	28
	202	Bahnbeamter im mittleren Dienst	Middle-level railway official	B	7
	203	Bahnbeamter im höheren Dienst	High-level railway official	A	1
Navigation	210	Seefahrer[2]	Sailor[2]	C	10
	211	Matrose, Leichterschiffer, Schiffsarbeiter	Seaman, lighterman, ship worker	C	823
	212	Bootsmann	Boatswain, petty officer	C	0
	213	Steuermann	Steersman, helmsman	B	172
	214	Schiffer, Kapitän	Skipper, ship's master	B	398
Machine construction	221	Maschinenarbeiter	Machine worker	C	18
	222	Maschinist	Machinist	B	135
	223	Maschinenmeister	Master machinist	B	2
Military	231	Soldat	Soldier	C	18
	232	Unteroffizier	Non-commissioned officer	C	15
	233	Offizier	Commissioned officer	B	0
	234	Hauptmann	Captain	B	6
					1,633
c) Crafts and arts					
Construction	300	Maurer, Steinmetz, Zimmermann, Maler u. a.[2]	Mason, stone mason, carpenter, painter etc.[2]	B	820
	301	- Gehilfe, Lehrling, Bauarbeiter	- Apprentice, building labourer	C	5
	302	- Geselle	- Journeyman	B	602
	303	- Meister	- Master	B	131
	304	Baumeister, -unternehmer	Master builder, building contractor	A	38
Shipbuilding	310	Schiffszimmermann[2]	Ship carpenter[2]	B	296
	311	- Gehilfe, Lehrling, Werftarbeiter	- Apprentice, shipyard worker	C	0
	312	- Geselle	- Journeyman	B	176
	313	- Meister	- Master	B	4
	314	Schiffsbaumeister	Master shipwright	A	22
Wood, metal	320	Tischler, Böttcher, Instrumentenmacher, Schmied u. a.[2]	Joiner, cooper, instrument maker, smith etc.[2]	B	585
	321	- Gehilfe, Lehrling	- Apprentice	C	0
	322	- Geselle	- Journeyman	B	152
	323	- Meister	- Master	B	214
Textiles, clothing, leather	330	Schneider, Weber, Schuhmacher, Riemer u. a.[2]	Tailor, weaver, shoemaker, leather worker etc.[2]	B	676
	331	- Gehilfe, Lehrling	- Apprentice	C	0
	332	- Geselle	- Journeyman	B	129
	333	- Meister	- Master	B	382
Other materials	340	Sonstiger Handwerker[b]	Other craftsman[b]	B	94
	341	- Gehilfe, Lehrling	- Apprentice	C	0
	342	- Geselle	- Journeyman	B	46
	343	- Meister	- Master	B	41
Hairdressing	350	Frisör, Barbier, Perückenmacher[2]	Hairdresser, barber, wig maker[2]	B	21
	351	- Gehilfe, Lehrling	- Apprentice	C	0
	352	- Geselle	- Journeyman	B	0
	353	- Meister	- Master	B	2
Nutrition	360	Bäcker, Müller, Schlachter, Zigarrenmacher etc.[2]	Baker, miller, slaughterer, cigar maker etc.[2]	B	311
	361	- Gehilfe, Lehrling	- Apprentice	C	4
	362	- Geselle	- Journeyman	B	32
	363	- Meister	- Master	B	116

Table 7 *continued*

Group	Code	German description	English translation	Class	N[1]
Beer	370	Bierbrauer[2]	Brewer[2]	A	8
	371	Brauerlehrling	Apprentice brewer	C	0
	372	Kleinbierbrauer, Schoppenbrauer	Micro-brewer	B	9
	373	Braumeister	Master brewer	A	4
	374	Brauereibesitzer	Brewery owner	A	0
Print, Press, Photography	380	Drucker, Redakteur, Fotograf, Lithograf[2]	Printer, editor, photographer, lithographer[2]	B	72
	381	Buchdruckergehilfe	Apprentice book printer	C	12
	382	Buchdruckergeselle	Journeyman book printer	B	2
	383	Buchdruckereifaktor	Printing factor	B	4
	384	Buchdruckereibesitzer	Printing house owner	B	4
Arts	391	Musiker, Bildhauer, Künstler, Schauspieler, Gymnastiker	Musician, sculptor, artist, actor, gymnast	C	110
	392	Meister oder Lehrer der Künste	Master or teacher of arts	B	21
	393	Musik- oder Schauspieldirektor	Musical or theatrical director	A	0
	394	Städtischer oder königlicher Musikdirektor	City or royal musical director	A	0
					5,145
d) Unskilled work and manufacturing					
Unskilled work	400	Arbeitsmann[2]	Labourer[2]	C	4,460
	401	Diener, Tagelöhner	Hired servant, day labourer	C	187
	402	Träger	Porter	C	72
	403	Vorarbeiter	Foreman	B	0
Factory work	411	Fabrikarbeiter	Factory worker	C	87
	412	Fabrikgeselle	Factory journeyman	B	3
	413	Werkmeister	Master workman	B	15
	414	Fabrikant, Fabrikdirektor	Manufacturer, factory owner	A	21
					4,845
e) Agriculture					
Land use and holding	501	Ackersmann, Pächter	Field worker	C	263
	502	Büdner, Häusler, Ökonom	Cottager	B	16
	503	Eigentümer	Proprietor	A	3
	504	Gutsbesitzer	Landowner	A	7
Grain crop	511	Schnitter	Harvester	C	0
	512	Vorschnitter	Harvester foreman	B	0
Gardening	520	Gärtner[2]	Gardener[2]	B	66
	521	Gärtnergehilfe, Gartenarbeiter	Apprentice gardener, garden worker	C	0
	522	Handels-, Landschafts-, Gemüse-, Obst-, Kunstgärtner	Market gardener, landscaper, horticulturist, fruit grower	B	19
	523	Gärtnereibesitzer	Gardening shop owner	B	5
Distillery	531	Brennerknecht	Distiller's servant	C	0
	532	Branntweinbrenner	Distiller	C	23
	533	Brennereiverwalter	Distillery administrator	B	0
Fishing	540	Fischer[2]	Fisherman[2]	C	97
Animal breeding	551	Stallknecht	Groom	C	7
	552	Hirte, Schäfer, Bereiter	Shepherd, horsebreaker	C	5
	553	Reitlehrer	Riding instructor	B	1
Forestry, Hunting	561	Forstarbeiter, Kammerjäger	Forestry worker, exterminator/gamekeeper	C	4
	562	Förster, Jäger	Forester, hunter	B	2
	563	Forstmeister, Jägermeister	Master forester, professional hunter	B	0
					518

Table 7 *continued*

Group	Code	German description	English translation	Class	N[1]
f) Unknown or not employed					
	600	Keine Angabe	Not specified	C	35
	610	Pensionär, Rentier, Privatmann	Pensionary	A	35
	620	Invalide	Disabled person	C	14
	630	Schüler	Pupil	C	1
	640	Vater unbekannt[3]	Father unknown[3]	C	2,652
					2,737
Total					16,880

Notes:

[1] This classification was done using all transcribed entries of live births, stillbirths and infant deaths recorded in the baptismal and burial registers of St. Jakobi. As a result of limiting the data to the live births born in the periods 1815–36 and 1859–82, some categories show no numbers in this table.

[2] General category without specified status/rank/position within occupational group.

[3] In the survival analyses, all unmarried fathers were put in this category, even if the job was specified.

Appendix B

Cause-of-death classification

Table 8 Cause of death (harmonized German spelling) by disease group among infants born in Rostock, St. Jakobi parish, 1815–1836 and 1859–1882

Cause of death	Respiratory	Gastro-intestinal	Weakness/atrophy	Other disease
[not specified]	0	0	0	58
[unknown]	0	0	0	2
Augenübel	0	0	0	1
Ausschlag	0	0	0	1
Auszehrung	0	0	27	0
Backenkrampf	0	0	0	2
bald nach der Geburt gestorben	0	0	2	0
Blasenausschlag	0	0	0	1
Blattern	0	0	0	4
Bleichsucht	0	0	1	0
Blutarmut	0	0	4	0
Blutverlust	0	0	0	1
Bräune	9	0	0	0
Brechdurchfall	0	18	0	0
Brechleiden	0	1	0	0
Brechruhr	0	6	0	0
Bronchialeiterung	1	0	0	0
Bronchialkatarrh	1	0	0	0
Bruch	0	1	0	0
Brustbräune	2	0	0	0
Brustentzündung	7	0	0	0
Brustfieber	1	0	0	0
Brustkatarrh	2	0	0	0
Brustkrampf	29	0	0	0
Brustkrankheit	41	0	0	0
Brustleiden	11	0	0	0
Brustübel	9	0	0	0
Brustverschleimung	8	0	0	0

Table 8 *continued*

Cause of death	Respiratory	Gastro-intestinal	Weakness/atrophy	Other disease
Cholera	0	17	0	0
Cholerine	0	5	0	0
Darmkatarrh	0	1	0	0
Diarrhoe	0	4	0	0
Diphtherie	2	0	0	0
Drüsen	0	0	0	13
Drüsenkrampf	0	0	0	1
Drüsenkrankheit	0	0	0	12
Drüsenleiden	0	0	0	2
durch die Amme erdrückt	0	0	0	1
durch Operation bei der Entbindung	0	0	0	1
Durchfall	0	27	0	0
Eiterung	0	0	0	1
Englische Krankheit	0	0	4	0
Entkräftung	0	0	4	0
Entzündung	0	0	0	4
Entzündung des Zellgewebes	0	0	0	1
Erkrankung des Hüftgelenks	0	0	0	1
Fieber	0	0	0	1
Folge der Masern	0	0	0	1
Frieseln	0	0	0	11
Frühgeburt	0	0	2	0
Gehirnentzündung	0	0	0	21
Gehirnkrampf	0	0	0	2
Gehirnleiden	0	0	0	2
Gehirnschlag	0	0	0	1
Gelbsucht	0	0	0	3
Geschwür	0	0	0	2
gleich nach der Geburt gestorben	0	0	17	0
Grippe	1	0	0	0
Halsbräune	9	0	0	0
Halsentzündung	2	0	0	0
Halsgeschwulst	1	0	0	0
Halsleiden	1	0	0	0
Hautausschlag	0	0	0	2
Hautentzündung	0	0	0	2
Hautkrankheit	0	0	0	2
Herzentzündung	0	0	0	1
Herzleiden	0	0	0	5
Herzschlag	0	0	0	2
Hirnhautentzündung	0	0	0	2
Hirnleiden	0	0	0	1
Husten	10	0	0	0
Husten und Zufall	1	0	0	0
im Bett erdrückt	0	0	0	1
innere Geschwüre	0	0	0	1
Katarrh	2	0	0	0
kein Anus	0	0	0	1
kein Hirnschädel	0	0	0	1
keine Backen im Mund, sehr kurze Zunge	0	0	0	1
Keuchhusten	56	0	0	0
Keuchhusten und Krampf	1	0	0	0
Kindertyphus	0	0	0	1
Knochenfraktur	0	0	0	1
Kopfkrampf	0	0	0	3
Kopfkrampf und Zahnen	0	0	0	1

Table 8 *continued*

Cause of death	Respiratory	Gastro-intestinal	Weakness/atrophy	Other disease
Kopfkrankheit	0	0	0	15
Kopfschaden	0	0	0	1
Kopfschlag	0	0	0	1
Krampf	0	1,123	0	0
Krampf und Zahnen	0	0	0	1
Krampfschlag	0	0	0	2
Leberleiden	0	1	0	0
Luftröhrenentzündung	1	0	0	0
Lungenentzündung	82	0	0	0
Lungenkatarrh	11	0	0	0
Lungenkrampf	1	0	0	0
Lungenkrankheit	1	0	0	0
Lungenleiden	6	0	0	0
Lungenschlag	4	0	0	0
Lungenübel	8	0	0	0
Lungenverschleimung	1	0	0	0
Magendarmentzündung	0	1	0	0
Magenentzündung	0	19	0	0
Magenfieber	0	1	0	0
Magengeschwulst	0	1	0	0
Magenkatarrh	0	6	0	0
Magenkrampf	0	24	0	0
Magenkrankheit	0	3	0	0
Magenleiden	0	33	0	0
Magenschwäche	0	2	0	0
Magenübel	0	51	0	0
Magenverschleimung	0	1	0	0
Masern	0	0	0	23
Mundfäule	2	0	0	0
Mundkrampf	0	0	0	1
Nabelbruch	0	1	0	0
Nabelentzündung	0	0	0	2
Nierenleiden	0	0	0	1
Operation	0	0	0	1
Rachenbräune	13	0	0	0
Rippenfellentzündung	1	0	0	0
Rose	0	0	0	7
Rotlauf	0	0	0	1
Rückenleiden	0	0	0	1
Rückenmarksleiden	0	0	0	2
Ruhr	0	11	0	0
Scharlach	0	0	0	7
Scharlachfrieseln	0	0	0	3
Schlag	0	0	0	9
Schlag und Zahnen	0	0	0	1
Schlagfluss	0	0	0	4
Schleimfieber	0	0	0	2
Schwäche	0	0	439	0
Schwamm	0	0	0	16
Schwamm und Brustkrankheit	0	0	0	1
Schwindsucht	4	0	0	0
Syphilis	0	0	0	5
Typhus	0	0	0	1
Unterleibsentzündung	0	1	0	0
Unterleibsleiden	0	1	0	0
venerisches Gift der Amme	0	1	0	0

Table 8 *continued*

Cause of death	Respiratory	Gastro-intestinal	Weakness/atrophy	Other disease
Verblutung und Mord	0	0	0	1
Wassersucht	0	1	0	0
Wurmfieber	0	1	0	0
Zahnen	84	0	0	0
Zahnen und Krampf	0	0	0	2
Zahnfieber	0	0	0	1
Zahnhusten	1	0	0	0
Zahnkrampf	0	0	0	106
Zellgewebeeiterung	0	0	0	1
Zellgewebekrankheit	0	0	0	1
Total	427	1,363	500	399

9.3 Study 3

Michael Mühlichen (2019):

Avoidable Mortality in the German Baltic Sea Region Since Reunification: Convergence or Persistent Disparities?

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Avoidable Mortality in the German Baltic Sea Region Since Reunification: Convergence or Persistent Disparities?

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Abstract
The consequences of political reunification for health and mortality have the unique character of a 'natural experiment'. This is particularly true for the formerly divided German Baltic Sea region due to its cultural and geographic commonalities. This paper ascertains the changes and differences in premature mortality at ages 0–74 in urban and rural areas of the German states of Mecklenburg–Vorpommern (MV) and Schleswig–Holstein (SH) since reunification and the contribution made by 'avoidable' mortality. Using official cause-of-death data, the effectiveness of health care and health policies was measured based on the concept of avoidable mortality in terms of both amenable and preventable conditions. Methods of decomposition and standardisation were employed in order to erase the compositional effect from the mortality trend. As a result, mortality differences relate primarily to men and the rural areas of the German Baltic Sea region. Whereas the mortality levels in the urban areas of MV and SH have converged, the rural areas of MV still show higher levels of preventable and amenable mortality. The results show that the accessibility and quality of medical care in the thinly populated areas of MV and the effectiveness of inter-sectoral health policies through primary prevention, particularly with regard to men, have room for improvement.

Keywords Avoidable mortality · Urban–rural differences · East and West Germany · Decomposition analysis · Direct standardisation · Natural experiment

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1 Background

Since the fall of the Iron Curtain, political transitions have taken place in Eastern Europe. However, measuring the contribution made by these transitions to improvements in health and life expectancy in country comparisons is difficult due to cultural differences which are barely quantifiable. Since these differences are assumed to be comparatively small between Western and Eastern Germany, the consequences of German reunification for mortality have the unique character of a 'natural experiment' in demographic research (Vaupel et al. 2003; Vogt and Vaupel 2015). Twenty-eight years after reunification, the average life expectancy is still lower in the eastern part of the country, at least among men. However, this east–west gap is partly a result of a north–south divide: life expectancy is highest in the south of Germany, which was part of West Germany, politically (Kibele 2012; Kibele et al. 2015; DESTATIS 2016).

Consequently, the 'natural experiment' attribution applies even more to the formerly divided German Baltic Sea region because of the geographic, cultural, historical and structural commonalities that cannot be found to the same extent in overall east–west comparisons. The two federal states that are located at the Baltic Sea—namely Mecklenburg–Vorpommern (MV) as part of the former German Democratic Republic (GDR) and Schleswig–Holstein (SH) as part of the former Federal Republic—are characterised by agriculture, tourism and lacking economic development and share a similar mentality, culture and language shaped by the Hanseatic era and centuries of Protestant tradition. These commonalities were among the driving factors for the long-time cooperation and, finally, the merger of the Evangelical Lutheran churches of Mecklenburg, Vorpommern and Schleswig–Holstein/Hamburg in 2012, which is the only east–west spanning church merger to date (Ahme et al. 2016). Today, the two states also share a common administrative unit within the framework of several federal institutions (Eltges 2014). From a historical perspective, the cooperation between the two regions in economic, cultural and political terms stretches back as far as the middle of the thirteenth century with the Wendish City League of Lübeck, Stralsund, Wismar, Kiel and Rostock marking an important milestone in the development of the Hanseatic League (Dollinger 1998).

In MV, Germany's most north-easterly state, the average life expectancy is lower than in most other German states, including its western neighbour SH, even though it is a popular recreational and holiday destination and actually possesses a number of factors which are conducive to living a long life, e.g. good air quality, seaside location, many lakes and forests (LUNG 2017). Possible reasons for the lower life expectancy include socio-economic, structural and risk-relevant characteristics as well as selective migration following reunification and poorer living conditions during the GDR era.

As early life circumstances influence adult mortality (Doblhammer 2004), political, socio-economic and health conditions during the GDR are still likely to have an influence—albeit a decreasing one—on the mortality of people who grew up in MV in that time (Dinkel 2003; Gjonça et al. 2000). Generally, socio-economic factors like employment, income, working conditions or education have a considerable impact on regional mortality differences in Germany, at least among men (Klein et al. 2001; Grobe and Schwartz 2003; von Gaudecker and Scholz 2007; Scholz and Schulz 2009; Scholz et al. 2010; Latzitis et al. 2011; Kibele 2012; Luy et al. 2015). The distribution of socio-economic characteristics, in turn, is influenced by selective migration. The emigration of 'good risks' has had a negative impact on average life expectancy in Eastern Germany (Luy and Caselli 2007). As concluded by Westphal (2016): "Leaving behind a population who has a greater susceptibility to chronic conditions, selective migration is likely to reinforce the consequences of population ageing and healthcare demand, in particular in regions characterised by outmigration".

Structural factors involve, for instance, accessibility and quality of health care, which differ between regions. Aside from political, economic and social differences, two different health systems developed during the period of German partition (1949–1990), with the GDR's system becoming increasingly antiquated in comparison with the FRG's as far as medical technology was concerned (Dinkel 2003; Gjonça et al. 2000; Luy 2004a, b). As a consequence, the difference in life expectancy between East and West Germany grew until reunification, to the detriment of the east, but has been decreasing ever since. The remaining east–west gap is connected with causes of death that can be considered avoidable (Nolte et al. 2002; Kibele and Scholz 2009; Sundmacher et al. 2011; Kibele 2012). In addition, there are reverse urban–rural gaps in Eastern and Western Germany: in the west, overall mortality in urban districts is higher than in rural districts, but the opposite is true for the east (Kibele 2012). This contrast also applies to the German Baltic Sea region: In MV, the rural districts accordingly exhibit a higher level of mortality than the urban ones, especially in connection with cardiovascular diseases, whereas in SH the urban districts show a higher mortality level than the rural ones, particularly regarding neoplasms (Müller and Kück 1998; Heitmann et al. 2001; Kibele 2012; Mühlichen 2014). This contrast was implemented during the period of German partition. Whereas West Germany was committed to achieving regional equality of living conditions in accordance with its constitution, spatial planning in East Germany concentrated on the central cities, which consequently benefited from selective immigration (Werner 1985). Thus, the accessibility of medical care was, in comparison, limited in the neglected peripheral regions of the east (Bucher 2002; Mai 2004). As a long-term consequence, most urban districts in Eastern Germany still show better working and structural conditions and therefore attract internal migrants from the rural areas, which even further enhances the urban–rural contrast (Sander 2014).

Risk-relevant factors include smoking, alcohol abuse, unhealthy nutrition, low levels of physical activity and dangerous driving, for instance. Despite a considerable decline in traffic accident mortality in MV since 1990, it is still significantly higher here than in SH and most other German states. This is most likely a consequence of the many narrow tree-lined roads in the rural areas of MV which make dangerous driving even more dangerous (Dinkel 2003; DESTATIS 2017). Furthermore, according to a study by the Robert Koch Institute (RKI 2011), there is a high percentage of obesity among men and women in MV and a low level of sporting activity in comparison with other federal states. In this same study, men in MV also exhibited considerably high rates of smoking and alcohol abuse and stated most often that they suffered from unhealthy working conditions. In SH and Hamburg, women showed relatively high percentages for smoking and alcohol abuse, whereas the values for men were below the German average. As a result, alcohol and tobacco-related mortality are relatively high among men in MV and among women in SH (Kibele 2012; Mons 2011).

Since German mortality statistics offer no insight into socio-economic background, migration biography or early life circumstances, and given that linkages to other data sources are not possible to date, the influence of these variables at an individual level cannot be estimated.[1] Structural and risk-relevant factors can, however, be addressed in the official cause-of-death statistics by the concept of 'avoidable mortality', which encompasses causes of death that can be either avoided through timely and effective health care ('amenable mortality') or can be reduced through primary prevention by means of effective inter-sectoral health policies ('preventable mortality') (Nolte et al. 2002; ONS 2011). A comparatively high number of causes of death that are considered amenable to health care indicates unfavourable structural conditions with regard to the accessibility and quality of health care, whereas a high level of preventable mortality points to deficits in the effectiveness of health policies in reducing risk-relevant behaviour, e.g. smoking, alcohol abuse and dangerous driving. Studies examining avoidable mortality in Germany focused on east–west differences (Nolte et al. 2002; Kibele and Scholz 2009) or on cross-sectional differences at the district level (Sundmacher et al. 2011; Kibele 2012). Long-term trends have not been examined for Germany at a regional level yet, not to mention the German Baltic Sea region.

The objective of this paper is therefore to explore the development of the adaptation process in mortality for MV compared to SH since reunification, taking particular account of amenable and preventable mortality. Due to urban–rural gradients in cause-specific mortality, which are in some cases diametrically opposed in Eastern and Western Germany (Kibele 2012), both states were divided into urban and rural districts. Specifically, the following four hypotheses were examined:

1. On the one hand, trends in cause-specific death rates in MV and SH are influenced by compositional changes in the age structure. Selective migration accelerated population ageing in MV but slowed it in SH. On the other hand, the trends are influenced by the general decline in mortality. Exploring the extent of these two components, it is our expectation that the trends in death rates and their differ-

[1] The only study that tried to estimate the connection between selective migration and mortality in Germany used the Billeter index as an indicator of selective migration (Luy and Caselli 2007). Surveys that include other explanatory variables, e.g. the German Life Expectancy Survey (LES) and the Socio-Economic Panel (SOEP), do not offer a sufficient number of cases for regional mortality analyses, whereas the Study of Health in Pomerania (SHIP) focuses on a very limited regional context. Data of the German Statutory Pension Insurance Scheme (FDZ-RV) only work sufficiently for elderly men who were not employed as officials in the civil service. Moreover, these datasets do not only allow for cause-specific mortality analyses. Multi-level studies that combine individual and macro-data are problematic from a causality point of view, particularly when the number of regional units is low.

ences across the study regions are mainly driven by changes in the direct mortality component and that the extent of the compositional component differs between urban and rural regions and is of greater importance in the latter.

2. As is typical for Western Germany, an urban–rural divide in mortality to the detriment of the urban areas is expected for SH, whereas the opposite scenario, as is typical for Eastern Germany, is expected for MV.
3. The difference in age-standardised mortality between urban MV and urban SH is expected to have been widely eliminated since reunification, whereas mortality in rural MV is expected to be significantly higher than in the other regions.
4. The anticipated remaining difference between rural MV and rural SH is expected to be due mainly to higher amenable and preventable mortality rates in rural MV.

Decomposition analysis is used to explore the contribution of compositional changes and survival improvements to the changes in the regional mortality differentials in MV and SH. Direct standardisation is used to examine the trend in cause-specific mortality, adjusted for compositional distortions. To control for regional bias, the economically strong city of Hamburg, its surrounding districts in SH and the structurally weak Vorpommern region were studied separately as a sensitivity analysis (see supplementary material online).

2 Data and Methods

2.1 Data Sets and Aggregation

In the following analyses, we used the official German year-end population numbers by sex, age and district for the period 1989–2011, and the official cause-of-death statistics, including all deaths according to sex, age, district and cause of death from 1990–2011. Whereas the population statistics were obtained directly from the statistical offices of MV and SH/Hamburg on request, the cause-of-death statistics were accessed and prepared in the period from mid-2013 to mid-2016 at the Wiesbaden location for guest researchers of the *Forschungsdatenzentrum der Statistischen Ämter der Länder* (research data centre of the statistical offices of the federal states), since these data are not freely available for the district or municipal level. Pre-1990 data on causes of death were not used because they are barely available for small regions and are not suitable for east–west comparisons due to different coding practices (Dinkel 2003).

Whereas the annual population statistics are aggregated by age and sex at the district level, the annual cause-of-death statistics are individual data that first had to be merged into one data set and then aggregated by age, sex, region and cause of death. In the original data sets, cause of death is registered according to the International Classification of Diseases (ICD), with ICD-9 codes up to 1997 and ICD-10 codes from 1998 onwards.

Due to the data protection regulations of the research data centre, the data selection was limited to age groups instead of single years of age (except for infant deaths) and to three-digit ICD codes. In addition, any aggregated number of deaths per region, sex, cause of death, age group and calendar year had to exceed the number of two to not be deleted. Thus, considering the number of cases, we merged age groups with a similar cause-of-death structure into the following seven age groups: 0–14, 15–34, 35–49, 50–59, 60–64, 65–69 and 70–74. We excluded the 75+age group, and analysed it separately (see Figure S.6 in the supplementary material online) "as 'avoidability' of death and reliability of death certification become increasingly questionable at older ages" (Nolte and McKee 2004: 65). Because of the low numbers of cases in the first two age groups in particular, and in order to avoid random variation over time, we used 5-year values for all rates. Thus, the analyses refer to the period from 1992 to 2009.

The regional division is based on the administrative distinction between *kreisfreie Stadt* (urban district) and *Landkreis* (rural district) prior to 4 September 2011. The following four regions were therefore generated: urban districts of MV (Urban MV), rural districts of MV (Rural MV), urban districts of SH (Urban SH) and rural districts of SH (Rural SH). In the sensitivity analysis (see Figures S.2–S.5 in the supplementary material online), we added for comparison the neighbouring city of Hamburg and analysed separately the surrounding *Landkreise* of Hamburg in SH and the eastern *Landkreise* of MV due to structural and socio-economic differences. As some changes in the regional administrative structure of MV took place in the early 1990s and in 2011, the district borders as of 4 September 2011 had to be updated retrospectively for all years prior to 2011 using additional municipal-level data on population and causes of death. Table 1 and a map in Figure S.1 in the supplementary material online illustrate the composition of the chosen regions.

Table 1 Composition of the study regions

Region	Administrative districts (according to current territorial status as from 4 September 2011)	Population size on 31 December 2011
Urban MV	Urban districts of Rostock and Schwerin; former urban districts of Greifswald, Neubrandenburg, Stralsund and Wismar	521,525
Rural MV	Landkreis Rostock, Ludwigslust-Parchim, Mecklenburgische Seenplatte (excl. Neubrandenburg), Nordwestmecklenburg (excl. Wismar), Vorpommern-Greifswald (excl. Greifswald) and Vorpommern-Rügen (excl. Stralsund)[a]	1,113,209
Urban SH	All urban districts: Flensburg, Kiel, Lübeck and Neumünster	618,914
Rural SH	Dithmarschen, Nordfriesland, Ostholstein, Plön, Rendsburg-Eckernförde, Schleswig-Flensburg, Steinburg, Herzogtum Lauenburg, Pinneberg, Segeberg, Stormarn[b]	2,218,727

[a]Vorpommern-Greifswald (excl. Greifswald) and Vorpommern-Rügen (excl. Stralsund) were analysed separately as 'Rural Vorpommern' (360,634 inhabitants), the rest as 'Rural Mecklenburg' (752,575 inhabitants) in the online supplementary material

[b]Herzogtum Lauenburg, Pinneberg, Segeberg and Stormarn are the surrounding districts of Hamburg and were analysed separately as 'Rural Southern Schleswig-Holstein' (983,709 inhabitants), the rest as 'Rural Northern Schleswig-Holstein' (1,235,018 inhabitants) in the online supplementary material

2.2 Selection of Causes of Death

We selected causes of death on the basis of the avoidable mortality concept, first developed by Rutstein et al. (1976).[2] 'Avoidable' deaths can be divided into causes amenable to medical or health care (amenable mortality) and causes avoidable through primary prevention (preventable mortality). Whereas amenable mortality can be considered as an indicator of the effectiveness of health care through secondary prevention or medical treatment, preventable mortality can be considered as an indicator of the effectiveness of inter-sectoral health policies in the broad sense and largely reflects risk-relevant behaviour of the population (Nolte et al. 2002).

The list of amenable causes (Table 4 in the "Appendix") is primarily based on Nolte and McKee (2003, 2004, 2008, 2012), which is the most widespread classification and suitable for international and regional comparisons as it is mostly based on three-digit codes and wider cause-of-death groups (instead of single 4-digit-code causes). Thus, it provides sufficient numbers and reduces incompatibilities because of different coding practices over time or across regions.[3] The list of preventable causes (Table 5 in the "Appendix") is primarily based on Page et al. (2006), which is the most comprehensive classification of causes avoidable through primary prevention. We added some conditions to both lists to keep in line with current research (see the notes of Tables 4 and 5 for detailed information) and made further minor adjustments to improve the compatibility between ICD-9 and ICD-10, especially when access is limited to three-digit codes. Moreover, we did not set an arbitrary threshold (i.e. a minimum number of cases or recent interventions) for excluding cases, as distinct from Tobias et al. (2010) and Plug et al. (2011). Apparently, an exclusion of rare causes like measles or whooping cough was unnecessary as all causes were aggregated into groups (amenable, preventable and other causes) and are not shown individually.

2.3 Methods

There are different ways of showing cause-specific mortality differences and dealing with compositional changes. The compositional component is particularly significant in this context because the composition of the population developed completely differently in the two federal states after reunification: while selective immigration had a rejuvenating effect on the age structure of SH, selective emigration accelerated population ageing in MV. To show cause-specific mortality differences over time and between regions and sex, without being distorted by compositional effects, the most suitable practice involves using standardised death rates. The direct standardisation of death rates was first introduced by Neison (1844) and has the advantage

[2] See Nolte and McKee (2004) for a detailed comparative description of all important works on the concept of avoidable mortality published prior to 2004.

[3] See Mackenbach et al. (2013) for the limitations of amenable mortality analysis in international comparisons.

of being additive: "the sum of death rates by cause equals the death rate from all causes" (Meslé 2006: 36). Based on textbooks like Preston et al. (2000), we computed death rates with a directly standardised age and sex structure for each region according to sex and cause of death group. However, we adjusted the death rates for the use of 5-year periods and year-end population statistics:

$$\mathrm{SDR}_t = \sum_x \left(\frac{D_{x;t-2} + D_{x;t-1} + D_{x,t} + D_{x,t+1} + D_{x,t+2}}{0,5 \cdot N_{x;t-3} + N_{x;t-2} + N_{x;t-1} + N_{x;t} + N_{x;t+1} + 0,5 \cdot N_{x;t+2}} \cdot C_x \right), \tag{1}$$

with SDR_t being the standardised death rate at time t (in years); D_x being the number of deaths at age x, N_x being the age-specific year-end population size and C_x being the age-specific standard population. In accordance with Preston et al. (2000: 26), the average of the age structures of MV and SH in 2000 was chosen as a standard population without disaggregation by sex (see Table S.1 in the supplementary material online). As a statistical test for the standardised death rates, we calculated 95% confidence intervals according to Chiang (1984), with the age-specific probability of death computed according to Farr (1859). If the confidence intervals of two regions did not overlap, the differences at the respective time t were interpreted as being statistically significant.

Another practice to measure mortality differences is the decomposition method, first introduced by Kitagawa (1955). Whereas the standardisation method eliminates the compositional impact on death rates by using an arbitrary standard population, the purpose of decomposition analysis is to measure the difference between the true, observed death rates both in terms of differences in mortality (direct component) and differences in age structure (compositional component).

We conducted two different decompositions. First, the difference in the (cause-specific or crude) death rate of each study region between 1990/1994 and 2007/2011 was decomposed into a direct and compositional component according to Kitagawa (1955). Second, we applied the 'difference of differences' approach of Rau et al. (2008) to the formula of Kitagawa to measure the direct and the compositional impact on the changes in mortality between regions over time:

1. the difference in mortality between 1990/1994 and 2007/2011 for urban districts in MV **minus** the difference in mortality between 1990/1994 and 2007/2011 for rural districts in MV,
2. the difference in mortality between 1990/1994 and 2007/2011 for rural districts in SH **minus** the difference in mortality between 1990/1994 and 2007/2011 for urban districts in SH,
3. the difference in mortality between 1990/1994 and 2007/2011 for urban districts in SH **minus** the difference in mortality between 1990/1994 and 2007/2011 for urban districts in MV and
4. the difference in mortality between 1990/1994 and 2007/2011 for rural districts in SH **minus** the difference in mortality between 1990/1994 and 2007/2011 for rural districts in MV.

This decomposition of the difference of the changes in the death rate Δd over time t_k (with $k=1{,}2$ for the periods of 1990/1994 and 2007/2011) between regions r_1 and r_2 was calculated in the following way[4]:

$$\Delta d(r_1,t_k)-\Delta d(r_2,t_k)=\sum_x \frac{\frac{\bar{N}_x(r_1,t_2)}{\bar{N}(r_1,t_2)}+\frac{\bar{N}_x(r_1,t_1)}{\bar{N}(r_1,t_1)}}{2}\cdot\left(d_x(r_1,t_2)-d_x(r_1,t_1)\right)$$
$$-\sum_x \frac{\frac{\bar{N}_x(r_2,t_2)}{\bar{N}(r_2,t_2)}+\frac{\bar{N}_x(r_2,t_1)}{\bar{N}(r_2,t_1)}}{2}\cdot\left(d_x(r_2,t_2)-d_x(r_2,t_1)\right)$$
$$+\sum_x \frac{d_x(r_1,t_2)+d_x(r_1,t_1)}{2}\cdot\left(\frac{\bar{N}_x(r_1,t_2)}{\bar{N}(r_1,t_2)}-\frac{\bar{N}_x(r_1,t_1)}{\bar{N}(r_1,t_1)}\right)$$
$$-\sum_x \frac{d_x(r_2,t_2)+d_x(r_2,t_1)}{2}\cdot\left(\frac{\bar{N}_x(r_2,t_2)}{\bar{N}(r_2,t_2)}-\frac{\bar{N}_x(r_2,t_1)}{\bar{N}(r_2,t_1)}\right), \tag{2}$$

where the first two lines on the right side constitute the direct component, which shows the "contribution of survival improvement to the difference of differences of the death rates", whereas the last two lines constitute the compositional component, which shows the "contribution of compositional changes over time on the difference of differences of the death rates" (Rau et al. 2008: 273). The annual average population size $\bar{N}$ was calculated based on the average of 2 year-end population numbers N. All statistical analyses were conducted in Excel.

3 Results

3.1 Decomposition of Trends in Death Rates

The results of the decomposition analysis are presented in Tables 2 and 3 for men and women, respectively. All in all, we find that the observed cause-specific death rates did not change drastically between 1990/1994 and 2007/2011 because of diametrically opposed developments in the direct and the compositional component. The direct component, without the compositional distortions, shows an immense decrease in amenable and preventable mortality, particularly in Mecklenburg–Vorpommern (MV). Survival improvements in other causes were comparatively small over time, especially in Schleswig–Holstein (SH). The direct effect was stronger than the compositional effect in the trend in amenable and preventable mortality rates in all regions and regarding both sexes. For women, this is also true for other causes, except for rural SH. Referring to the lower parts of both tables, the direct effect was stronger than the compositional one in terms of the change of the

[4] The notation of the equations in this paper is based on Canudas-Romo (2003).

difference in observed death rates between urban and rural MV as well as between rural SH and rural MV. However, the change over time in the difference between rural and urban SH and between urban SH and urban MV was driven more by compositional changes. This is true for both sexes.

In more detail, with regard to men (Table 2), the observed cause-specific death rates decreased between 1990/1994 and 2007/2011, except for other causes of death, which increased in all regions. If the age structure had not changed between the two periods, however, all death rates would have fallen, as the direct component is negative in all regions. On the contrary, as a result of an ageing population, the compositional component is positive in all regions, especially in MV. In the urban areas of MV, the compositional impact in total premature mortality (33 per 10,000) is even stronger than the direct effect of mortality reduction (−32), which is, however, due to the impact of other causes of death. In all regions, the biggest improvements in terms of survival were found in preventable causes followed by amenable causes, whereas the reduction in other causes was comparatively small, especially in SH. Generally, the reduction in mortality was strongest in rural MV (−50 in total) followed by urban MV. Both urban and rural SH exhibited a decline in mortality of −21 per 10,000.

As shown in the lower half of Table 2, the regional differences in death rates decreased in most cases, except for the gap between urban SH and urban MV, where the direction changed to the detriment of the latter (from 3 to −5). This is primarily caused by the change in composition (−18.8), whereas the direct component points in the other direction (10.8). Thus, if the age structure had not changed, the death rates in the urban districts of MV would have improved to a greater extent than in the urban districts of SH, thereby narrowing the gap.[5] Decreases in direct mortality differentials were remarkably high between the rural districts of SH and MV (29.4) and between the urban and rural areas of MV (18.3), which is largely attributable to preventable and amenable causes. By contrast, the decline in the difference between the rural and urban districts of SH (4.7) is mainly due to compositional changes (4.3), whereas the direct effect was relatively minor (0.3).

As shown in Table 3, the trend among women is almost identical. The main difference is that most values are substantially lower than those for men. In all regions, the observed death rates declined between 1990/1994 and 2007/2011, except for other causes in rural SH which increased slightly by 0.5 per 10,000. As was the case for men, the direct component shows a considerably higher decrease than the observed rates. In contrast to the trend among men, however, this decline was stronger in amenable mortality than in preventable mortality. Unlike the direct effect, the compositional component is positive in all regions, but has a lower impact on the observed mortality trend. Direct improvement in mortality was highest in rural MV (−26.4), followed by urban MV (−21.8), rural SH (−10.7) and urban SH (−10.5).

As far as the bottom part of Table 3 is concerned, the regional differences in observed mortality decreased between the two periods, with one exception: the

[5] As the following chapter 3.2 will show, age-standardised mortality of men has never been significantly lower in urban MV than in urban SH since reunification.

Table 2 Decomposition of the difference in the cause-specific death rates of MV and SH (per 10,000) into direct and compositional components, men aged 0–74

Region	Cause of death	Death rate 1990/94	Death rate 2007/11	Δ	Direct	Compositional
Urban MV	Amenable causes	14.248	13.889	−0.359	−9.874	9.515
	Preventable causes	29.888	28.306	−1.582	−15.718	14.136
	Other causes	16.175	19.530	3.355	−6.050	9.404
	Total	60.312	61.725	1.414	−31.642	33.055
Rural MV	Amenable causes	19.309	15.590	−3.718	−13.940	10.222
	Preventable causes	42.586	30.709	−11.877	−28.507	16.630
	Other causes	17.927	19.668	1.741	−7.536	9.277
	Total	79.822	65.968	−13.854	−49.983	36.129
Urban SH	Amenable causes	15.757	12.898	−2.859	−6.792	3.933
	Preventable causes	30.065	22.713	−7.352	−13.097	5.745
	Other causes	17.500	21.056	3.556	−0.980	4.536
	Total	63.322	56.667	−6.655	−20.869	14.215
Rural SH	Amenable causes	13.662	11.917	−1.745	−7.039	5.294
	Preventable causes	25.638	20.375	−5.263	−12.619	7.356
	Other causes	14.590	19.595	5.005	−0.881	5.886
	Total	53.890	51.887	−2.003	−20.540	18.537
Urban MV minus rural MV	Amenable causes	−5.060	−1.701	3.359	4.066	−0.707
	Preventable causes	−12.698	−2.403	10.296	12.789	−2.494
	Other causes	−1.752	−0.138	1.613	1.486	0.127
	Total	−19.511	−4.243	15.268	18.341	−3.074
Rural SH minus urban SH	Amenable causes	−2.094	−0.981	1.114	−0.247	1.361
	Preventable causes	−4.427	−2.338	2.088	0.477	1.611
	Other causes	−2.910	−1.461	1.449	0.099	1.350
	Total	−9.431	−4.780	4.651	0.329	4.322
Urban SH minus urban MV	Amenable causes	1.509	−0.991	−2.500	3.082	−5.581
	Preventable causes	0.177	−5.593	−5.770	2.622	−8.392
	Other causes	1.324	1.526	0.202	5.069	−4.868
	Total	3.010	−5.058	−8.068	10.773	−18.841
Rural SH minus rural MV	Amenable causes	−5.646	−3.673	1.973	6.901	−4.927
	Preventable causes	−16.948	−10.334	6.614	15.888	−9.274
	Other causes	−3.338	−0.074	3.264	6.655	−3.391
	Total	−25.932	−14.081	11.851	29.443	−17.592

difference of observed mortality between urban SH and urban MV (−3.7) actually increased, not only among men but also among women. Whereas the direct effect (11.4) points towards a considerably greater improvement in terms of survival in urban MV, this was outweighed by the compositional effect (−15), i.e. the stronger population ageing of urban MV. The contribution of the direct component was strongest in terms of the difference between rural SH and rural MV

Table 3 Decomposition of the difference in the cause-specific death rates of MV and SH (per 10,000) into direct and compositional components, women aged 0–74

Region	Cause of death	Death rate 1990/94	Death rate 2007/11	Δ	Direct	Compositional
Urban MV	Amenable causes	12.386	10.123	−2.263	−8.073	5.809
	Preventable causes	11.689	9.572	−2.117	−7.006	4.890
	Other causes	12.341	11.575	−0.766	−6.760	5.994
	Total	36.415	31.269	−5.146	−21.839	16.693
Rural MV	Amenable causes	16.379	10.538	−5.841	−10.749	4.909
	Preventable causes	14.234	9.552	−4.682	−8.692	4.010
	Other causes	14.536	12.214	−2.323	−7.001	4.679
	Total	45.149	32.304	−12.845	−26.443	13.598
Urban SH	Amenable causes	14.319	9.527	−4.793	−5.366	0.573
	Preventable causes	12.544	9.755	−2.789	−3.299	0.510
	Other causes	13.302	12.055	−1.247	−1.810	0.562
	Total	40.165	31.337	−8.828	−10.474	1.646
Rural SH	Amenable causes	12.883	9.724	−3.160	−5.354	2.194
	Preventable causes	10.400	8.504	−1.896	−3.586	1.690
	Other causes	11.562	12.062	0.500	−1.754	2.255
	Total	34.846	30.290	−4.556	−10.694	6.139
Urban MV minus rural MV	Amenable causes	−3.993	−0.416	3.577	2.676	0.901
	Preventable causes	−2.545	0.020	2.565	1.686	0.879
	Other causes	−2.195	−0.639	1.556	0.241	1.316
	Total	−8.733	−1.034	7.699	4.603	3.096
Rural SH minus urban SH	Amenable causes	−1.436	0.197	1.633	0.011	1.621
	Preventable causes	−2.143	−1.251	0.892	−0.287	1.179
	Other causes	−1.740	0.007	1.747	0.055	1.692
	Total	−5.319	−1.047	4.272	−0.220	4.493
Urban SH minus urban MV	Amenable causes	1.934	−0.596	−2.529	2.707	−5.236
	Preventable causes	0.855	0.183	−0.672	3.707	−4.379
	Other causes	0.961	0.480	−0.481	4.951	−5.432
	Total	3.749	0.067	−3.682	11.365	−15.047
Rural SH minus rural MV	Amenable causes	−3.496	−0.815	2.681	5.395	−2.714
	Preventable causes	−3.833	−1.048	2.786	5.106	−2.321
	Other causes	−2.974	−0.152	2.823	5.247	−2.424
	Total	−10.303	−2.014	8.289	15.748	−7.459

(15.7). Regarding the change in the difference between urban and rural MV, both the direct (4.6) and the compositional effect (3.1) showed the same direction, whereas the observed change between rural and urban SH is almost entirely attributable to changes in the age structure (4.5).

The direct component in other causes is relatively high for the change in the differences between urban SH and urban MV (about 5 per 10,000 for both men and women) and between rural SH and rural MV (6.7 in men, 5.2 in women), compared to the inner-state regional differences in other causes. This is due to stronger decreases in other premature mortality in MV than in SH, even though these are still minor in comparison with the decreases in amenable and preventable causes.

3.2 Standardised Death Rates

To show the regional mortality trend over time, without distortions due to differences or changes in the age structure, we calculated standardised death rates. Figures 1, 2, 3, 4 display these rates, including confidence intervals (for measuring significance), broken down by causes of death for the population aged 0–74 in the urban and rural districts of MV and SH between 1990/1994 and 2007/2011, with men shown on the left and women on the right. For reasons of simplicity, the 5-year periods were named after the middle year in the figures (e.g. 1992 instead of 1990–1994). As already indicated in Sect. 3.1, the decrease in overall premature mortality (Fig. 1) was greater in MV than in SH, starting from a considerably higher level at the time of reunification. This process of equalisation was especially strong in the 1990s, but eventually slowed down. We find diametrically opposed urban–rural gradients in all-cause premature mortality in MV and SH, to the favour of urban MV and rural SH, respectively. The gap between the rural and urban areas of SH is significant and remained largely constant over time for both sexes. However, the gap between the urban and rural areas of MV decreased and is only still significant for men as it has become very small among women. Among both sexes, the difference in premature mortality between urban MV and urban SH had already been eliminated in the

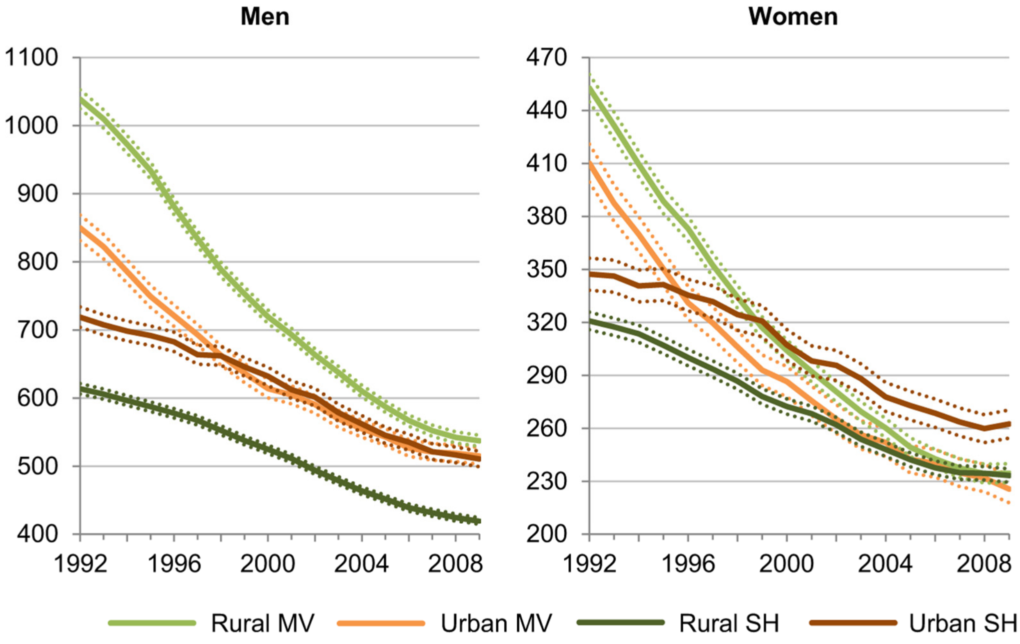

Fig. 1 All-cause mortality in urban and rural regions of Mecklenburg–Vorpommern (MV) and Schleswig–Holstein (SH), standardised death rate (deaths per 100,000), years 1992–2009, ages 0–74

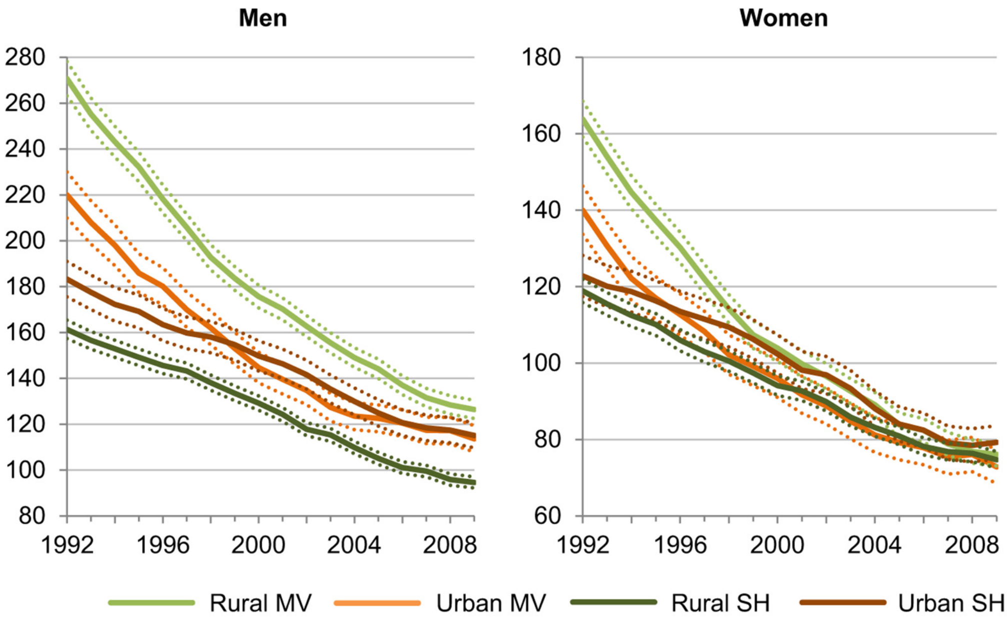

Fig. 2 Amenable mortality in urban and rural regions of Mecklenburg–Vorpommern (MV) and Schleswig–Holstein (SH), standardised death rate (deaths per 100,000), years 1992–2009, ages 0–74

mid-1990s. At the end of the observation period, rural MV still showed a significantly higher mortality level among men, although the difference has declined to a considerable extent. As for women, however, there is no longer any significant difference between rural MV on the one hand and rural SH and urban MV on the other, whereas urban SH lately displayed the highest level of premature mortality.

With regard to Figs. 2, 3, 4, preventable mortality is considerably higher than amenable mortality among men, whereas the opposite is the case for women, albeit to a lesser extent and with the exception of women in urban SH. Although the rate for other premature deaths was comparatively low in the early 1990s, the decrease in amenable and preventable mortality meant that it was higher at the end of the observation period, except for preventable mortality among men. In terms of amenable mortality (Fig. 2), the trend is very similar to overall premature mortality, albeit on a lower level. The main difference is that all significant regional differences have been completely eliminated for women. The preventable mortality trend, shown in Fig. 3, is also similar to that for overall premature mortality. However, the difference between urban MV and urban SH was not eliminated but actually increased in the final years of the observation period. With regard to other causes (Fig. 4), survival improvements were comparatively low, except for rural and urban MV in the early 1990s. In the final years of the observation period, the rate for both men and women was significantly higher in urban SH than in the other three regions, which showed no considerable differences at the end of the period; the only exception was the significantly higher rate for women in rural SH compared to urban MV.

Thus, among men, the remaining difference in premature mortality between MV and SH is primarily caused by higher levels of amenable and preventable mortality in rural MV. However, the urban districts of MV also show significantly higher

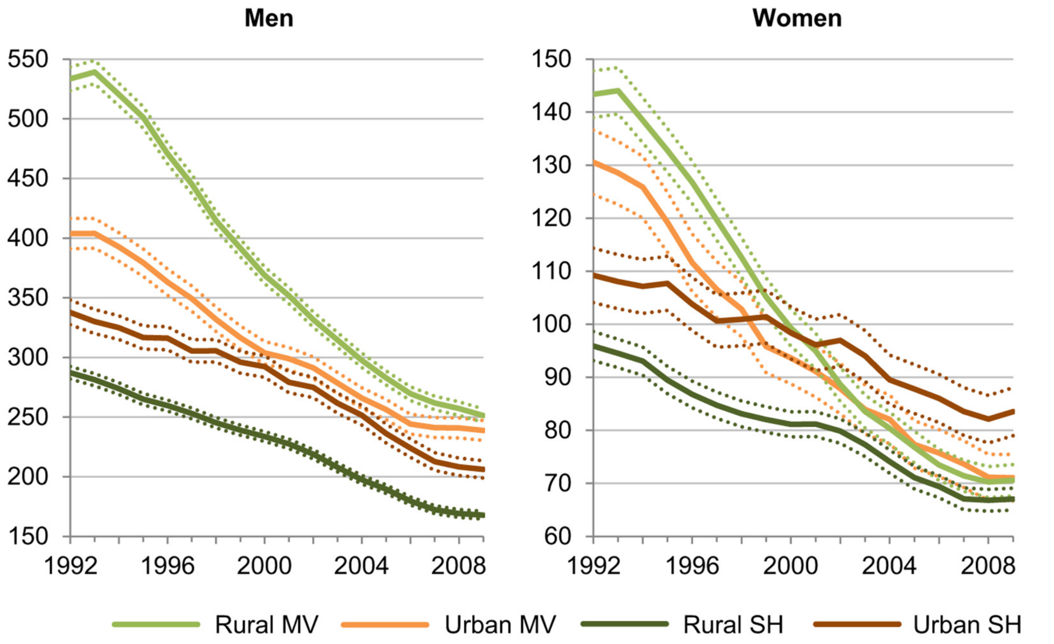

Fig. 3 Preventable mortality in urban and rural regions of Mecklenburg–Vorpommern (MV) and Schleswig–Holstein (SH), standardised death rate (deaths per 100,000), years 1992–2009, ages 0–74

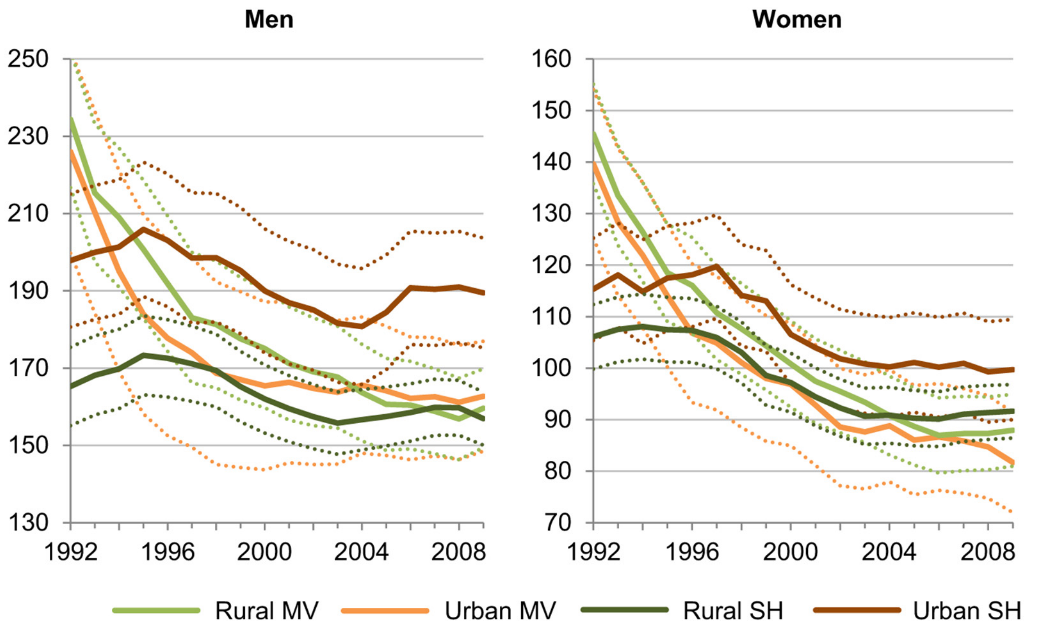

Fig. 4 Other mortality in urban and rural regions of Mecklenburg–Vorpommern (MV) and Schleswig–Holstein (SH), standardised death rate (deaths per 100,000), years 1992–2009, ages 0–74

levels of preventable mortality in comparison with rural and urban SH. For women, the difference in amenable, preventable and other premature mortality between rural MV and both urban MV and rural SH has been completely eliminated, whereas urban SH meanwhile exhibits the highest levels in all three categories. However, only in preventable mortality is the level significantly higher.

4 Discussion

The German Baltic Sea region is an east–west spanning region of two federal states in the north of Germany—Mecklenburg–Vorpommern (MV) and Schleswig–Holstein (SH)—that show strong commonalities in terms of geography, culture and economy and are not affected by the north–south divide of mortality in Germany. As a natural experiment, this paper shows for the first time the trend in premature mortality in MV and SH since reunification, focusing on the contribution made by avoidable mortality, based on a revised classification. Urban–rural differences were studied as well to demonstrate where the levels of mortality have already converged and where this has not been the case.

Methods of decomposition and standardisation were used to eliminate the compositional effect from premature mortality rates. Both methods reveal that premature mortality has decreased rapidly in the German Baltic Sea region since reunification. This is mainly due to a decline of avoidable mortality, i.e. causes considered avoidable through primary prevention or amenable to health care. In the 1990s in particular, survival improvements were stronger in MV than in SH, resulting in a balancing out in levels of mortality between the two neighbouring federal states. The huge difference between both states during the 1990–1994 period can largely be explained by the lack of medical technology in the former GDR (Dinkel 2003). The considerable decrease in amenable mortality in MV in the 1990s therefore reflects the massive improvements in the medical environment after reunification, whereas the decline in preventable mortality mirrors the improved effectiveness of inter-sectoral health policies in reducing risk-relevant behaviour. The regional differences that are still evident primarily concern men. For women, regional mortality differences have been largely eliminated, except in the urban districts of SH where mortality from preventable and other causes has turned to be significantly higher compared to the other three regions.

4.1 Survival Improvements Versus Compositional Changes

The results of the decomposition analysis reveal immense distortions in the observed death rates caused by the compositional component, i.e. changes in the age structure. The direct component, i.e. survival improvements, and the compositional component had a diametrically opposed effect on the observed death rates. Consequently, if the age structure had not changed since 1990, the decrease in mortality rates would have been much greater in all regions, especially in MV. In fact, compared to SH, the population of MV was younger in the early 1990s, whereas it has now become older as a consequence of increasing life expectancy, low fertility and—in particular—selective migration (Dinkel 2004; Grünheid 2015).

Based on the given data, the first hypothesis, according to which the direct component had a stronger impact than the compositional one, has been confirmed in terms of the development of amenable and preventable mortality rates in all regions and both sexes. The direct effect was also stronger as regards the change in the difference in observed death rates between urban and rural MV and between rural SH and rural MV among both sexes. This feature of a strong direct effect is firstly because of the immense reduction in the level of avoidable mortality in rural MV which was, by comparison, high at the time of reunification. Secondly, urban and rural MV had similar age structures and suffered both from selective emigration particularly in the 1990s, albeit to a greater extent in rural MV (Lehmann 2008; Weiß 2006).

However, we established that the change over time in the difference between rural and urban SH and between urban SH and urban MV was driven more by compositional changes, which is also true for both sexes. In the first case, the mortality gap between urban and rural SH remained constant. Thus, the minor changes in the difference over time between these two regions were largely caused by changes in the age structure. In the second case, both effects were considerable, but the compositional one had an even greater impact because the average age in urban MV was lower than in urban SH in the early 1990s but higher in 2007/2011. In addition, the real mortality gap in 1990/1994 between these two regions was not as pronounced as between rural MV and rural SH.

Additional age-specific analyses of the data show that the direct component becomes stronger with growing age. The older age groups benefited to a greater extent from survival improvements than the younger ones. An exception is men in rural MV who showed the highest survival improvements in the 50–59 age group, particularly in connection with preventable mortality. In comparison with the compositional component, all four regions have in common that the direct component was more effective at ages 0–64, whereas the compositional component was more pronounced in the 65–69 and 70–74 age groups.

4.2 Urban–Rural Divides

By means of direct standardisation, we find diametrically opposed urban–rural gradients in all-cause premature mortality in MV and SH to the favour of urban MV and rural SH, thus confirming the second hypothesis, based on the given data. This regional divide in SH, with higher mortality rates in urban than in rural districts, is typical for all of Western Germany (Kibele 2012). This paper shows that the higher premature mortality level in urban SH is due in particular to causes of death that should be avoidable through primary prevention and—with reference to men only—causes that should be amenable to health care. This urban–rural gap is concentrated on men and women aged 35–74, particularly in connection with amenable and preventable neoplasms, whereas rural SH shows a higher mortality level in terms of traffic accidents in the 15–34 age group and cardiovascular diseases in the 75+age group, as profound age- and cause-specific analyses of the data show. In SH, there is also an urban–rural divide in other premature deaths, though this divide is not significant for women. Aside from the varying effectiveness of health policies and health care, different compositions of socio-economic status—as shown by macroeconomic indicators (BBSR 2015)—and thus different compositions of risk-relevant behaviour may contribute to this divide.

By contrast, the rural–urban gap in MV has decreased and is only still significant for men as it has become very small among women. This decrease can be seen in the light of the shifting of mortality to older ages as a consequence of immense improvements in medical infrastructure following reunification, from which rural MV profited more since the need to catch up was greater there (Bucher 2002; Dinkel 2003; Mai 2004). Among men, the rural–urban gap in premature mortality in MV is closely linked to amenable mortality. Profound age- and cause-specific analyses show that cardiovascular diseases in particular play a more prominent role in rural MV than in urban MV, especially at ages 60 and older. Preventable mortality is also lower in urban MV than in rural MV, but to a decreasing extent, and can, for instance, be explained by excess road traffic mortality in rural MV. In the 75 and above age group, however, the rural–urban divide is still very pronounced in both sexes (see Fig. S.6) and applies in particular to cardiovascular diseases. Timely medical treatment of strokes and heart attacks is a challenge in the peripheral regions of the East (Kibele 2012).

4.3 Convergence and Persistent Disparities

With regard to the third hypothesis, we find confirmation for men that mortality differences between the two federal states relate only to the rural areas and no longer to the urban areas. However, this hypothesis does not apply to women as rural MV no longer differs significantly from rural SH and urban MV, whereas urban SH meanwhile exhibits the highest level of premature mortality. The equalisation between women in MV and SH is not only a consequence of the catching-up process in MV, but also of relatively small improvements in survival in SH compared to the rest of Germany.

With regard to men, the gap between rural MV and rural SH applies to all-cause mortality and amenable mortality. However, as far as preventable causes are concerned, mortality levels among men in both urban and rural MV are still significantly higher than in SH. The difference in amenable mortality points to comparatively worse accessibility to appropriate health care in rural MV, whereas the difference in preventable mortality for MV as a whole is related more to behavioural factors. Among the preventable conditions, levels of smoking- and alcohol-related causes are higher in MV among men, as in-depth analyses show. Moreover, in spite of a considerable decrease, traffic accident mortality is still relatively high in rural MV.

The convergence in life expectancy between women in Eastern and Western Germany can partly be explained by higher smoking rates among middle-aged Western German women (Myrskylä and Scholz 2013). The same is true for the German Baltic Sea region, as profound cause-specific analyses show: Tobacco-attributable mortality, e.g. lung cancer, is comparatively high among women in SH, particularly in urban SH. In MV, women show higher levels of alcohol-related mortality, but this feature is outweighed by the excess smoking-related mortality of women in SH.

In neighbouring Denmark, the high smoking rates (along with alcohol consumption and other factors) among women had a decisive influence on the stagnation in the development of female life expectancy between 1980 and the mid-1990s (Juel 2008; Christensen et al. 2010). But while in Denmark the female cohorts with the highest smoking rates are currently dying out and thus causing an increase in life expectancy (Lindahl-Jacobsen et al. 2016), this is not the case yet for the German Baltic Sea region. As additional analyses based on the German Microcensus show, the cohorts in SH with the highest smoking rates have already reached the mortality-relevant age, in particular with regard to cancer mortality, whereas the respective cohorts are younger in MV.[6] As a result, the example of Denmark may possibly serve as an indicator of the future trend in mortality among women in the German Baltic Sea region. Vogt et al. (2017) forecast that the higher smoking rates of younger Eastern German women will reverse their contemporary mortality advantage in comparison with the West.

In summary, and with reference to the fourth hypothesis, the remaining difference among men in premature mortality between MV and SH is indeed caused by higher levels of amenable and preventable mortality in rural MV. However, also urban MV exhibits a higher preventable mortality rate compared to rural and urban SH. As far as women are concerned, however, the gap between MV (both urban and rural) and rural SH has completely disappeared in amenable, preventable and other premature mortality, whereas the highest rates in these three cause-of-death groups, significantly in preventable mortality, are recorded for urban SH.

4.4 Sex Differences

The considerable differences between men and women justify conducting separate analyses for the two sexes. The sex gap in mortality in favour of women is a typical result for industrial countries (Trovato 2005). It can be explained by biological and non-biological factors, with the latter in turn being influenced by the former: on the one hand, women are biologically/genetically more ‘robust’, whereas, on the other hand, non-biological factors such as unhealthier working conditions and a riskier lifestyle of men compared to women have a decisive impact as well (Luy 2003, 2009; Luy and Gast 2014; RKI 2014). Especially the higher smoking rates of men compared to women were found to be an important explanatory factor in several industrial countries (Valkonen and van Poppel 1997; Trovato 2005). In MV, the sex gap is higher than in any other German federal state (DESTATIS 2016). Health policies and advances in health care applied to both sexes but were obviously less effective among men. “Overall, women are more likely than men to engage in health behaviours associated with primary prevention”, as concluded by Hiller et al. (2017: 348). In comparison with the other federal states, men in MV show relatively high rates of obesity, smoking and alcohol abuse (RKI 2011, 2014; Baumeister et al.

[6] The regional smoking rates as surveyed in the 2005, 2009 and 2013 waves of the German Microcensus were provided by the Federal Statistical Office (DESTATIS) on request.

2005). Salzmann (2012) concluded that an adoption of a less risky lifestyle has only taken place slowly among men in MV.

4.5 Potential Bias and Limitations

The decline in premature mortality is closely linked to a decline in avoidable mortality, which points to the suitability of the used cause-of-death classification. There was a decrease in other 'non-avoidable' premature mortality in MV during the early 1990s, though, that might seem counterintuitive but can be explained by the immense general improvements in living conditions in Eastern Germany following reunification and the consequent shifting of mortality to older ages (Vogt 2013). In both SH and MV, the aggregation of amenable causes of death is dominated by cardiovascular diseases among men, but with decreasing weight and followed by neoplasms. Among women, however, neoplasms were more frequent than cardiovascular diseases. This is mainly due to the fact that women-specific neoplasms like breast, uterine and cervical cancer are outnumbering testicular cancer. In the aggregation of preventable causes of death, neoplasms play the most important part, followed by cardiovascular diseases.

With regard to the different age groups, in-depth analyses of the used data show that the differences among men were rather consistent over age, whereas differences among women mirror different cohort-specific smoking rates. Thus, preventable mortality among women aged 15–49 is higher in MV, especially in urban MV, but among women aged 50–69 it is higher in SH, particularly in urban SH. Among both men and women, excess mortality of rural MV in comparison with the other three regions is strongest in the 15–34 age group, which is linked to fatal traffic accidents, and in the 70–74 age group, which is due mainly to excess cardiovascular mortality.

The regional distinction proved appropriate to show where convergence has already taken place and where it has not. As a common feature, all urban districts in MV and SH are classified as an *Oberzentrum* (high-level urban centre) in regional planning, with the exception of Wismar, which nevertheless does partly fulfil functions of an *Oberzentrum*. Regarding the rural areas, however, population density is considerably higher in rural SH (about 145 inhabitants per square kilometre) than in rural MV (ca. 50). Consequently, there are structural advantages in rural SH which most likely benefit the accessibility of health care. We conducted a sensitivity analysis (see Figures S.2–S.5 in the supplementary material online) that further divides the rural parts of MV and SH to control if the chosen regional division overlays other regional differences in the study area. The analysis shows that there are indeed inner-regional differences to the advantage of the southern districts in SH and of the western districts (Mecklenburg) in MV but they are rather small in comparison with the chosen urban–rural distinction.[7] Furthermore, the urban–rural distinction

[7] Additional district-level analyses confirm that the main gap in rural mortality is between Mecklenburg and Vorpommern in MV and between the south and the north in SH.

delivers a clearer view of where differences still exist (between the rural areas of both states) and where they have widely disappeared (between the urban districts). In comparison with SH and MV, the neighbouring metropolitan city of Hamburg shows a lower level of amenable mortality, thus indicating a comparatively good accessibility of health care. However, the preventable mortality level in Hamburg is very similar to urban SH, which is not surprising since its smoking rates are also very similar to urban SH, as additional analyses of the German Microcensuses 2005, 2009 and 2013 show.

An inclusion of important individual-level variables like socioeconomic conditions and migration biography in a multivariate model would help improve the understanding of the observed differences. However, these variables are not available in this context up to now. Different outcomes of preventable mortality imply that health policies are not equally effective among all population groups, especially in connection with socio-economic conditions. Salzmann (2012) identified unemployment as one of the major drivers of male excess mortality in MV. In fact, MV has been one of Germany's federal states with the highest levels of unemployment since reunification. In January 2018, the unemployment rate in MV stood at 9.3%, compared to 6.3% in SH and 5.8% nationwide (BA 2018). Moreover, the level of education among young men, especially in the eastern peripheral regions of Germany, has much room for improvement compared to young women (Sievert and Kröhnert 2015).

Socioeconomic compositions are influenced by selective migration. Whereas MV has exhibited large losses in net migration since reunification, SH has reported migration gains, particularly from MV (Bucher and Heins 2001a; Dinkel 2004; Fischer and Kück 2004; Heiland 2004; Sander 2014). Furthermore, among young and highly-qualified people, emigration from MV is greater than immigration to MV, especially in its rural areas (Bucher and Heins 2001b; Lehmann 2008; Schultz 2006; Weiß 2006). The metropolitan region of Hamburg plays a special role in this context as the southern districts of SH benefit from suburbanisation-related immigration from Hamburg, whereas only a small number of municipalities in western MV are located close enough to Hamburg (and Lübeck) to benefit from migration gains (Dinkel 2004; Sander 2014). Consequently, it is highly probable that the higher mortality levels in rural MV are influenced to a considerable degree by the outmigration of young and better-educated people, while average life expectancy is highest in the university city of Rostock that has profited from migration gains since the early 2000s (BBSR 2015).

5 Conclusions

In an east–west spanning region that is not affected by the German north–south divide in mortality and where cultural and geographic differences are relatively small, are there still east–west differences that can be considered avoidable? The results of this natural experiment reveal that the accessibility and quality of medical care in the thinly populated rural areas of the east (MV) can still be improved in comparison with the rural areas of the west (SH), whereas this is no longer the case for the urban areas. Furthermore, inter-sectoral health policies aiming at primary prevention also need to become more effective, especially among men in MV (focussing in particular on smoking, alcohol abuse and dangerous driving), but also—to a lesser extent—women in urban SH whose high rate of smoking becomes visible in the rate of preventable mortality.

All in all, the data reveal that the remaining difference in premature mortality between MV and SH is largely linked to excess avoidable mortality of men in the rural areas of MV. Therefore, German health policies should focus more on the accessibility of medical care in the thinly populated areas of Eastern Germany and men-specific measures of primary prevention in particular. This involves educational policies as well to reduce the educational disadvantage of men since the level of education influences not only the occupational status later in life but also the health-related lifestyle (Klein et al. 2001). Moreover, the creation of adequate opportunities in the labour market, especially for the highly-educated young people, is one of the major current and future challenges for MV.

Further research should focus on the long-term consequences of selective migration and socio-economic differences in this context. But as long as there is no German mortality register that allows for linkages to other data sources, this connection will remain a research gap on the individual level. On the other hand, the analyses of other east–west spanning regions in Germany would be a fruitful addition to research. Since the German reunification is the only worldwide contemporary example of a political unification of a formerly divided nation, an adaptation to other countries could focus on other 'natural experiments' like the contribution of different health care systems on mortality differences between politically divided but ethnically homogenous populations over time.

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Compliance with Ethical Standards

Conflict of interest The author declares that he has no conflict of interest.

Appendix

Tables 4 and 5.

Table 4 Causes considered amenable to health care[a], ages 0–74[b] (unless otherwise stated)

Disease group	Cause of death	Age	ICD-9 code	ICD-10 code
Infectious	Intestinal infections	0–14	001-9	A00-9
	Tuberculosis		010-8, 137	A15-9, B90
	Whooping cough	0–14	033	A37
	Measles	1–14	055	B05
	Other infections		032, 034-8, 045, 084, 381-3, 681-2, 730	A35-6, A38-41, A46, A80, B50-4, H65-70, L03, M86, M89-90
Neoplasm	Colorectal cancer		153-4	C18-21
	Bone cancer		170	C40-1
	Skin cancer		172-3	C43-4
	Breast cancer		174	C50
	Cancer of cervix uteri		180	C53
	Uterus cancer	0–44	179, 182	C54, C55
	Testis cancer		186	C62
	Bladder cancer		188	C67
	Eye cancer		190	C69
	Thyroid cancer		193	C73
	Hodgkin's disease		201	C81
	Leukaemia	0–44	204-8	C91-5
	Benign neoplasm		210-29	D10-36
Endocrine	Diseases of the thyroid		240-6	E00-7
	Diabetes mellitus (50% of deaths)	0–49	250	E10-4
Neurological	Bacterial meningitis		320	G00
	Epilepsy		345	G40-1
Cardiovascular	Rheumatic heart disease		390-8	I00-9
	Hypertensive disease		401-5	I10-3, I15
	Ischemic heart disease (50%)		410-4	I20-5
	Heart failure		428-9	I50-1
	Cerebrovascular disease (50%)		430-8	I60-9
Respiratory	Influenza		487	J10-1
	Pneumonia[c]		480-6	J12-8, A48.1
	Asthma[d]	0–44	493	J45-6
	Other respiratory diseases	1–14	460-79, 488-9, 494-5, 497-519	J00-9, J20-39, J47-99
Digestive	Peptic ulcer disease		531-4	K25-8
	Appendicitis		540-3	K35-8
	Abdominal hernia		550-3	K40-6
	Cholelithiasis and cholecystitis		574-5	K80-2
Genitourinary	Nephritis and nephrosis		580-9	N00-7, N17-9, N25-7
	Hyperplasia of prostate		600	N40

Table 4 (continued)

Disease group	Cause of death	Age	ICD-9 code	ICD-10 code
Maternal/infant	Maternal death		630-76	O00-99
	Perinatal deaths (excl. still-births)		760-79	P00-96, A33
	Congenital anomalies		740-59	Q00-99
External	Treatment complications		E870-9	Y60-84

[a]The list for amenable causes of death is primarily based on Nolte and McKee (2003, 2004, 2008, 2012) but was extended by selected infections for which "early detection and effective intensive support coupled with appropriate antibiotic therapy can massively reduce case fatality rates" (Page et al. 2006: 205). Heart failure was added due to effective treatment (Tobias et al. 2010; Plug et al. 2011), malignant melanoma (listed as part of skin cancer) due to advances in early detection and adjuvant therapy (Page et al. 2006; Tobias et al. 2010). Bladder cancer—although highly connected with smoking—shows moderately effective treatment, "with good 5-year relative survival for early stage disease" (Page et al. 2006: 208) and is thus considered amenable. Bone cancer was added due to advances in adjuvant therapy (Tobias et al. 2010), thyroid cancer because of advances in diagnosis and adjuvant therapy (Page et al. 2006; Tobias et al. 2010). Benign neoplasms and eye cancer were considered amenable due to effective medical and surgical treatment (Tobias and Jackson 2001; Page et al. 2006). In accordance with Page et al. (2006), ischemic heart disease, cerebrovascular disease and diabetes were split equally on a 50:50 basis into amenable and preventable causes (according to age, sex, region and year) as survival improvement in these conditions is about equally split between incidence reduction and improved treatment effectiveness

[b]The general upper age limit is 75 years. Deviating age limits were set for childhood infections, leukaemia, uterus cancer and diabetes in accordance with Nolte and McKee (2004: 64–67). The age limit for asthma was widened in compliance with Tobias et al. (2010: 14)

[c]In ICD-9, the pneumonia group includes Legionnaires' disease (482.84). This condition was shifted, however, to the bacterial diseases group (A48.1) in ICD-10. Due to the limitation to three-digit codes, A48.1 could not be considered for the period from 1998 onwards. However, this is statistically negligible

[d]In the clinical modification of ICD-9, chronic obstructive asthma is listed as 493.2 in the asthma group. Since the introduction of ICD-10, this condition has been registered in the COPD group (chronic obstructive pulmonary disease) under J44.8. This shifting problem is, however, statistically negligible and additionally does not affect this study, as in Germany, chronic obstructive asthma has presumably been registered in the COPD group before (there has never been a 493.2 code in the German modification of ICD-9)

Table 5 Causes considered avoidable through primary prevention[a]; ages 0–74[b] (unless otherwise stated)

Disease group	Cause of death	Age	ICD-9 code	ICD-10 code
Infectious	Hepatitis		070	B15-9
	HIV/AIDS[c]		042-4	B20-4
	Sexually transmitted diseases		090-9	A50-64
Neoplasm	Cancer of lip, oral cavity, pharynx		140-9	C00-14
	Cancer of oesophagus		150	C15
	Cancer of stomach		151	C16
	Cancer of liver		155	C22
	Cancer of larynx		161	C32
	Cancer of trachea, bronchus, lung		162	C33-4
Endocrine/nutritional	Nutritional deficiency anaemia		280-1	D50-3
	Diabetes mellitus (50% of deaths)	0–49	250	E10-4
	Alcohol and drug related diseases		291-2, 303-5	F10-6, F18-9
Cardiovascular	Ischemic heart disease (50%)		410-4	I20-5
	Cerebrovascular disease (50%)		430-8	I60-9
	Aortic aneurysm		441	I71
Respiratory	Chronic obstructive pulmonary disease		490-2, 496	J40-4
Digestive	Cirrhosis of liver		571	K70, K73-4
External	Land transport accidents		E810-29, E846-8	V01-4, V06, V09-80, V82-9, V98-9
	Falls		E880-6, E888	W00-19
	Fires, burns		E890-9	X00-9
	Accidental poisonings		E850-69	X40-9
	Drowning		E910	W65-74
	Suicide		E950-9	X60-84
	Violence		E960-9	X85-Y09

[a]The list for preventable causes of death is primarily based on Page et al. (2006) but was extended by laryngeal cancer as it is highly associated with tobacco and alcohol consumption (Ahrens et al. 1991; Simonato et al. 1998; Tobias and Jackson 2001; Phelan et al. 2004). Both alcohol and tobacco consumption are problematic in the eastern part of the German Baltic region. In accordance with Tobias et al. (2010), self-inflicted injuries were excluded from the suicide group since cause and motivation are not clear and the group of land transport accidents was extended by motor vehicle non-traffic accidents, other road vehicle accidents and vehicle accidents not elsewhere classifiable to avoid differences due to different coding practices

[b]The general upper age limit is 75 years. In accordance with Nolte and McKee (2004: 64–67), the age range for diabetes is shorter. Compared to Page et al. (2006), the age limit for chronic obstructive pulmonary disease was widened in compliance with Tobias et al. (2010: 14)

[c]Since the introduction of HAART (highly active antiretroviral therapy) in 1996, HIV has increasingly become amenable to health care. Studies that focus on amenable mortality only (without preventable conditions) should consider HIV as an amenable condition (Tobias et al. 2010; Plug et al. 2011)

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