IZA Institute of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 11628

Bismarck's Health Insurance and the Mortality Decline

Stefan Bauernschuster
Anastasia Driva
Erik Hornung

JUNE 2018

I Z A Institute
of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 11628

Bismarck's Health Insurance and the Mortality Decline

Stefan Bauernschuster
University of Passau and IZA

Anastasia Driva
LMU Munich

Erik Hornung
University of Cologne

JUNE 2018

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Bismarck's Health Insurance and the Mortality Decline*

We study the impact of social health insurance on mortality. Using the introduction of compulsory health insurance in the German Empire in 1884 as a natural experiment, we estimate flexible difference-in-differences models exploiting variation in eligibility for insurance across occupations. Our findings suggest that Bismarck's health insurance generated a significant mortality reduction. Despite the absence of antibiotics and most vaccines, we find the results to be largely driven by a decline of deaths from infectious diseases. We present evidence suggesting that the decline is associated with access to health services but not sick pay. This finding may be explained by insurance fund physicians transmitting new knowledge on infectious disease prevention.

JEL Classification: I13, I18, N33, J11

Keywords: health insurance, mortality, demographic transition, Prussia

Corresponding author:
Stefan Bauernschuster
University of Passau
Innstr. 27
94032 Passau
Germany

E-mail: stefan.bauernschuster@uni-passau.de

* We thank Andrew Goodman-Bacon, Leah Platt Boustan, Davide Cantoni, Francesco Cinnirella, Greg Clark, Dora Costa, Carl-Johan Dalgaard, Katherine Eriksson, Oliver Falck, James Fenske, Price Fishback, Michael Grimm, Casper Worm Hansen, Walker Hanlon, Timo Hener, Adriana Lleras-Muney, Chris Meissner, John E. Murray, Jochen Streb, Uwe Sunde, Joachim Voth, Till vonWachter, Joachim Winter, Ludger Wößmann and seminar participants at Arizona, Bayreuth, Copenhagen, Deutsche Bundesbank, DIW Berlin, Frankfurt, Göttingen, Hohenheim, Innsbruck, the Ifo Institute, ISER, IZA, Lausanne, Linz, LMU Munich, Maastricht, MPI for Tax Law and Public Finance, Southern California Population Research Center, Passau, Potsdam, Trier, UC Davis, UC Berkeley, UCLA, Zurich, the 2015 FRESH Meeting in Barcelona, the 2016 Workshop Culture, Institutions and Development in Galatina, the 2016 Workshop Markets and States in History at Warwick, the 2016 meeting of the EHA in Boulder, the 2017 Congress of Economic and Social History in Bonn, and the 2017 Workshop on Health Economics and Health Policy in Heidelberg. This work was financially supported by an Arthur H. Cole Grant awarded by the Economic History Association in 2015. Driva gratefully acknowledges the hospitality provided during a research visit at UCLA as well as the funding through the International Doctoral Program "Evidence- Based Economics" of the Elite Network of Bavaria. We are grateful to our research assistants Tamara Bogatzki, Carolin Fries, Leonie Kirchhoff, Sigfried Klein, Hannah Lachenmaier, Max Neumann, Philipp Nickol, and Markus Urbauer.

"Rarely, if ever, in modern history has a single piece of legislation had such a profound worldwide impact as the German Sickness Insurance Law of 1883 - the cornerstone of German health care policy for almost one century."

– Leichter (1979)

1 Introduction

From the mid of the 19th century, the industrializing world experienced an unprecedented decline in mortality rates. This mortality reduction is central to the demographic transition and had arguably fundamental consequences for long-run growth and productivity.[1] An ongoing debate is concerned with the forces contributing to the mortality decline. Most major advances in medicine such as antibiotics and vaccines did not occur before the 1930s and were not decisive for the considerable reduction of infectious disease mortality during the early phase of the health transition. A large literature discusses the influence of improvements in income and nutrition, directed investments in public sanitation, and scientific advances in health knowledge.[2] Yet, this literature has mostly neglected the emergence of social health insurance at the end of the 19th century.

This paper investigates the impact of Bismarck's health insurance on mortality in Prussia. As Chancellor of the German Empire, Otto von Bismarck introduced the first-ever widely-implemented compulsory health insurance in the world in 1884. Covering large parts of the working population, Bismarck's health insurance (henceforth BHI) was a first move toward democratized access to health care. Subsequently, it acted as a blueprint for Germany's current health system and served as a model for many social insurance systems across the world. Surprisingly however, econometric studies on the health effects of BHI have been missing so far.

Our main empirical approach exploits the fact that BHI became compulsory only for the blue collar worker population while other occupations' access to health care remained unchanged. Newly digitized administrative data from Prussia, the largest of the German states when BHI was introduced, allow us to compute annual occupation-specific mortality rates at the district level for the period 1877 to 1900. We bring these unique panel data to a generalized difference-in-differences model that compares the mortality trend of blue collar workers (treatment group) to the mortality trend of public servants (control group) while allowing for heterogenous reform effects over time.

Difference-in-differences estimates indicate that, from its introduction in 1884 to the turn of the century, BHI reduced blue collar workers' mortality by 8.9 percent. Thus, the insurance accounts for roughly a third of the total mortality decline of blue-collar workers during this period. The results are robust to allowing for heterogeneous effects of urbanization, the establishment of waterworks, and the roll-out of sewerage.

[1] While microeconomic evidence typically confirms the existence of health-induced productivity gains, the relationship between improvements in health and aggregate productivity is subject to ongoing debate. Many studies focus on specific periods of major improvements in health and life expectancy to test this relationship (for some important contributions, see Acemoglu and Johnson, 2007; Ashraf et al., 2008; Bleakley, 2007; Hansen and Lønstrup, 2015; Jayachandran and Lleras-Muney, 2009; Lorentzen et al., 2008; Murtin, 2013; Weil, 2007, 2014).

[2] Seminal contributions include, e.g. Cutler and Miller (2005), Deaton (2013), McKeown (1979), Fogel (2004), and Preston (1975). For recent surveys see Costa (2015) and Cutler et al. (2006).

Common pre-treatment mortality trends across occupations corroborate the validity of the identification strategy. Additionally, we find that BHI created substantial spillovers from the insured to their uninsured family members. The results are neither confounded by contemporaneous social reforms nor by improved working conditions or increasing wages for blue-collar workers.

A range of additional econometric approaches provide corroborating evidence for the effects of Bismarck's health insurance. These various approaches yield a consistent pattern suggesting negative effects of BHI on mortality. To address concerns regarding potential selection into the industrial sector after the introduction of BHI, we employ county- and district-fixed effects models that exploit regional differences in the blue-collar workers share fixed at a point in time *before* the introduction of BHI. The fixed effects models also allow us to rigorously control for changes in the population age structure, to account for the strength of unions, and to perform a specification test using a placebo treatment group. To understand whether Prussia's mortality reduction was particularly pronounced, we employ country-level time series data that allow analyzing the decline in international comparison. While mortality decreased in all Western European countries toward the end of the 19th century, we find that the introduction of BHI indeed coincides with the beginning of a more accentuated drop in Prussian mortality.

We shed light on the channels through which BHI contributed to the mortality decline by inspecting heterogeneity in the causes of death and by comparing the effectiveness of insurance benefits. Using newly digitized data on causes of death in a district fixed effects framework, we show that a large part of the decline results from a reduction of mortality due to airborne infectious diseases. Especially tuberculosis, a disease for which a cure was not developed until 1946, declined in response to BHI. Further results, based on insurance benefits, indicate that a substantial share of deaths were avoided due to individual interactions with physicians and medical treatment but not via sick pay, the main expense of insurance funds. This finding lends support to the view that diffusion of new health knowledge became relevant for public health before the turn of the 20th century.

We interpret the findings to imply that BHI was instrumental in extending access to doctors who acted as transmitters of health knowledge to poor working class families, a group formerly unable or unwilling to afford health care. This hypothesis complements earlier conjectures in the historical literature arguing that the insurance provided its members with access to new knowledge regarding hygiene and transmission of infectious diseases (see Condrau, 2000; Koch, 1901; Vögele, 1998). Our claim resonates with the approach of Mokyr and Stein (1996) who build a model of consumer behavior in which households produce health for its members based on the existing priors on the causes of disease. These priors were radically altered by the germ theory of disease at the end of the 19th century when inputs to the health production function substantially changed. In order for scientific knowledge to affect household priors, a vehicle of transmission is crucial. Indeed, sickness funds encouraged their licensed physicians to disseminate the newly gained knowledge of infectious disease transmission and launched information campaigns to facilitate the application of hygiene knowledge. We provide support for this interpretation by presenting evidence on heterogenous effects of insurance benefits. While fund's expenditures for doctor visits and medication are negatively related to mortality in a district fixed effects model, expenditures for sick pay are not. These findings lend *prima facie* support to the view that the insurance improved health by providing access to health care rather than by providing sick pay.

More recent expansions of compulsory health insurance have been highly effective in increasing access to health care and reducing mortality, at least for specific subgroups of the population. In this respect, our findings are in line with studies on major expansions in health insurance coverage in the U.S., such as Medicare for the elderly (see Card et al., 2008, 2009; Finkelstein, 2007; Finkelstein and McKnight, 2008) and Medicaid for the poor (see Currie and Gruber, 1996; Goodman-Bacon, 2017). Yet, there are some key differences between these 20th century expansions and the introduction of BHI. Present-day health insurance schemes work in an environment of chronic diseases and benefit from the ability to provide health care by medical treatment. In contrast, BHI was established in an environment of infectious diseases whose treatment had not sufficiently developed. As such, our setting might be more readily comparable to the situation in developing countries, where an increasing number of compulsory health insurance schemes are currently introduced (Lagomarsino et al., 2012; Malik, 2014). These schemes are introduced in an environment with a high prevalence of infectious diseases with large parts of the population lacking adequate knowledge on hygiene and disease transmission.

The remainder of the paper is organized as follows. Chapter 2 discusses the literature on the causes of 19th century's mortality decline and provides background information on Bismarck's health insurance. Chapter 3 introduces the historical Prussian district-level data that we use in the empirical analysis. Chapter 4 presents the multiple empirical approaches, presents the results and provides a set of robustness and validity checks. Chapter 5 concludes.

2 Literature and institutional background

2.1 Literature on the causes of the mortality decline

Germany's mortality and fertility decline at the end of the 19th century is considered to be fairly representative of the demographic transition in many European countries (Guinnane, 2011). Yet, Germany experienced higher levels of mortality and fertility than most other European countries at the beginning of the 19th century. With respect to mortality, Leonard and Ljungberg (2010) depict a 'German penalty' which was evident in 1870, but vanished by 1900 when Germany's mortality had declined to the levels of other countries. In the period 1875 to 1905, life expectancy of a German child below the age of one increased from 38.4 to 45.5; for individuals between the age of 20 and 25 it increased from 43.2 to 47.8 (Imhof, 1994). Life expectancy in rural areas of Europe was considerably higher than in urban areas until the beginning of the 20th century (e.g., Kesztenbaum and Rosenthal, 2011). At birth, the average Prussian boy living in the countryside expected to outlive his urban counterpart by five years (Vögele, 1998).

The precise factors that contributed to the mortality decline remain disputed. The empirical literature has attempted to provide various explanations, ranging from nutritional improvements and public investments in sanitation infrastructure to the diffusion of knowledge as a tool to prevent disease transmission. Seminal contributions by McKeown (1979) and Fogel (2004) argue that improvements in living standards and nutrition were responsible for the mortality decline in 19th century Europe, ruling out many other factors. The role of public health measures was first revised by Szreter (1988). In contrast to the views of McKeown (1979) and Fogel (2004), the literature broadly agrees that especially the 'urban penalty' was gradually removed through a range of investments in public sanitation infrastructure during the second half of the 19th century. Many recent studies provide evidence for major reductions in infant and adult mortality which are associated with improvements in sanitation infrastructure (Hennock, 2000; Meeker, 1974). More specifically, improvements in the water supply (Brown, 1988; Ferrie and Troesken, 2008; Beach et al., 2016), water purification (Cutler and Miller, 2005), and sewerage systems (Alsan and Goldin, 2015; Kesztenbaum and Rosenthal, 2017) strongly reduced mortality from waterborne diseases.

Cutler et al. (2006) and Leonard and Ljungberg (2010) argue that medical treatments hardly contributed to the mortality decline before 1914. However, effective medication was not entirely absent at that time. Indeed, smallpox vaccination became available already in 1796 and largely reduced infant mortality (Ager et al., 2017; Hennock, 1998). In the first decades of the 19th century, many German states introduced compulsory vaccination against smallpox. While this was not true for Prussia, smallpox vaccination and re-vaccination were a widespread practice and eventually became compulsory for all children as part of the Imperial German Vaccination Law in 1874. In 1885, rabies vaccine became available. In 1891, the first drugs against diphtheria emerged. A range of antiseptics and anesthetics were widely used. More generally, the end of the 19th century saw a significant progress in chemistry that allowed identifying effective ingredients of medicinal plants and producing new chemical drugs.

The medical sector expanded substantially at the end of the 19th century. From 1870 to 1890, the number of medical students in Prussian universities more than tripled (from 2,600 to 8,724), whereas the number of students of all other faculties roughly doubled. As a result, by 1890, the medical faculty boasted the largest number of students of all faculties. Similarly, data from the Prussian occupation censuses show that the share of people working in the health sector grew by about 40 percent from 1882 to 1907.

Overall, scientific medical knowledge deepened considerably towards the turn of the century (Mokyr and Stein, 1996). The widely held belief, prevalent since medieval times, that diseases were transmitted through bad smells (*miasmas*) gradually faded out during the course of the 19th century. It was replaced by scientific findings identifying the role of bacteria as crucial transmitters of diseases. Major breakthroughs in epidemiology and bacteriology occurred during the second half of the 19th century (for details see Easterlin, 1999). These included the well-known discoveries of water as a transmitter of Cholera by John Snow and William Budd as well as numerous discoveries in bacteriology by Robert Koch, Louis Pasteur, Ignaz Semmelweis and others.[3] Advances in bacteriology had an impact on established knowledge across all types of infections related to

[3]The role of hygiene, as an important tool to prevent infectious diseases in hospitals, became generally appreciated in the 1880s, twenty years after the death of Ignaz Semmelweis, the pioneer of modern antisepsis (Murken, 1983). Yet, it was not before Alexander Fleming discovered penicillin in 1928 that antibiotics became widely known as drugs that could fight bacteria.

waterborne and airborne diseases. In fact, Mokyr (2000, p. 15) recognizes germ theory to be "one of the most significant technological breakthroughs in history." However, mere identification of the root cause of infections was insufficient to cure the sick, especially when no remedies were available. All that physicians could do was to "educate patients on hygiene" (Thomasson, 2013, p. 177).

The role of knowledge diffusion in improving health has recently gained the attention of economists. Deaton (2013), for instance, argues that upward shifts of the Preston curve are driven by the *application* of new knowledge. In the first half of the 20th century, knowledge regarding hygiene was disseminated via health care centers, congresses and public information events around the developed world. Nordic countries were particularly progressive in diffusing knowledge through well-child visits and health care centers. Wüst (2012) finds that Danish infant mortality was reduced due to home visiting programs which helped towards diffusing knowledge on nutrition as well as highlighting the positive health effects of breastfeeding. Bhalotra et al. (2017) show that a similar Swedish program managed to reduce chronic diseases of infants by providing nutritional information, non-financial support and monitoring. According to findings by Bütikofer et al. (forthcoming), Norwegian mother-child health care centers also contributed to better long-term economic outcomes by granting universal and free access to well-child visits during the first year of life. Ogasawara and Kobayashi (2015) find similar effects when evaluating a program for inter-war Tokyo. Hansen et al. (2016) investigate the introduction of tuberculosis dispensaries in Denmark in the early 20th century. In the absence of a cure, these dispensaries disseminated knowledge related to the transmission of tuberculosis to patients and their families as well as to the general public significantly decreasing tuberculosis mortality.[4]

Public interventions also include the introduction of health insurance across European countries at the turn of the 20th century. According to Vögele (1998), health insurance funds might have contributed to the penetration of new knowledge and health education in the German Empire.[5] Guinnane (2003, p. 45) supports this hypothesis by noting that the insurance sickness funds played a major role in strengthening the role of physicians as advocates of hygiene. Kintner (1985) argues that physicians and midwives represented a major source for disseminating information on the health effects of breastfeeding to pregnant women.[6] In addition, Tennstedt (1983, p. 461) suggests that insurance funds fostered prevention of illness transmission by introducing new rules and benefits for workers' families, workers' hygiene and lifestyle, the workplace, and the employers' responsibilities. Yet, empirical evidence for the role of early health insurance programs for the mortality decline is still scarce.

[4]Condran and Crimmins-Gardner (1978) argue that 'similar' information campaigns in U.S. cities at the end of the 19th century played a minor role in reducing tuberculosis-driven mortality.

[5]Vögele (1998, p. 199-208) lists a range of potential channels through which BHI might have been able to increase health, including preventing families to fall into poverty due to sick pay, increasing access to doctors and hospitals, or by allowing the state to systematically educate and control the covered population with respect to their attention to health issues.

[6]According to Kintner (1985) and Kintner (1987), breastfeeding was more widespread in Prussia compared to the south of Germany; whereas some cities such as Baden or Munich saw an increase in breastfeeding, breastfeeding in the capital Berlin massively declined between 1885 and 1910. However, unfortunately, comprehensive data on breastfeeding are missing before 1910. It has been argued that improvements in the quality and supply of cow milk were only marginal in improving infant mortality conditions (Vögele, 1998). Legal regulations regarding the quality of milk did not become an issue in the German Empire until 1901.

Winegarden and Murray (1998) provide empirical evidence that health insurance coverage across five European countries was associated with mortality reductions in the periods before World War I. They find that a ten percentage point increase in the insured population results in a mortality reduction of 0.9 to 1.6 per 1,000 people. Bowblis (2010) extends this study to eleven countries and studies the effect of health insurance on infant mortality. He speculates that health insurance reduced mortality by "educating people about the benefits of clean houses, not re-using dirty bath water, washing hands, and isolation of sick family members from the rest of the household" (Bowblis, 2010, p. 223). Finally, Strittmatter and Sunde (2013) show that the reduction in mortality due to the introduction of public health care systems across Europe translates into positive effects on growth in income per capita and aggregate income. Their cross-country analysis is based on data from twelve European countries; due to a lack of data availability, they exclude Germany, the country which introduced the first public health insurance system and boasts the largest share of insured at the turn of the 19th century. These studies provide an interesting yardstick for our findings. Yet, while all three studies exploit across-country, over-time variation, our empirical setup exploits *within*-country, over-time, across-occupation variation. This setup allows us to flexibly control for general mortality trends within the country and time-invariant factors that are specific to subregions. Moreover, we contribute to this literature by taking several steps to explore the potential channels of the mortality effects using newly digitized administrative data from Prussia.

2.2 Bismarck's health insurance

The Compulsory Health Insurance Act of 1883 constituted the birth of Germany's social security system. Bismarck's health insurance was the first of the three main branches of the German Social Insurance System, followed by the Accident Insurance Act (1884) and the Disability/Old-age Pension System Act (1891).[7]

Chancellor Otto von Bismarck's decision to introduce the compulsory health insurance was a reluctant reaction to mounting upheavals among the working class. The Industrial Revolution led to increasing social tension between the rising working class and the political and economic elite. The new Socialist Workers Party of Germany gained support among the lower strata of the population and became a threat to the political stability of conservative dominance in the German Reich Parliament. Against this backdrop, the health insurance reform was a *mass bribery* for Bismarck to win over votes from the socialist party and the worker unions (Rosenberg, 1967). Furthermore, it disburdened public funds by shifting the cost of poor relief to workers and employers. The Reichstag approved the law on May 31, 1883, against the votes of the Social Democrats who argued that this social reform would not really improve the workers' situation (Tennstedt, 1983).

From December 1st, 1884, BHI was "compulsory for all industrial wage earners (i.e. manual laborers) in factories, ironworks, mines, ship-building yards and similar workplaces" (Act of June 15, 1883, see Leichter, 1979). Contributions were earnings-

[7] Scheubel (2013) provides an excellent overview of Bismarck's social security system. Fenge and Scheubel (2017) show that the introduction of the disability and old age pension system reduced fertility, while Guinnane and Streb (2011) provide evidence for moral hazard effects of the accidence insurance. Lehmann-Hasemeyer and Streb (2016) find that Bismarck's social security system as a whole crowded out private savings.

related, amounted to an average of 1.5 percent of the wage[8] and were paid jointly by employers (one-third) and employees (two-thirds). Other occupations, including public servants, farmers, domestic servants, day-laborers or self-employed were not eligible for BHI.

In case of sickness, the insured were eligible to receive sick pay amounting to at least 50 percent of the average local wage for 13 weeks. Moreover, funds were allowed to extend free health care to family members. Note that the Act only specified maximum contributions and minimum benefits. Thus, the individual sickness funds had "considerable discretion to set specific benefits and contribution levels" (Leichter, 1979, p. 123). Further benefits included free routine medical and dental care, prescribed medicine, incidental care for up to 13 weeks and treatment in hospitals for up to 26 weeks. In addition, the insurance provided maternity benefits encompassing free medical attention and a cash benefit (*Wochenhilfe*) for three weeks after giving birth. In case of death of an insured worker, the insurance paid a death grant to the worker's family.

The health insurance system was administered in a decentralized manner by local sickness funds (*Krankenkassen*). Generally, we can distinguish between six types of sickness funds. Where possible, Bismarck built upon previously existing organizations such as the building trade, the miners (*Knappschaften*), the guild and various industrial sickness funds.[9] This saved both time and state resources and was sensible from a political perspective because it respected the guilds' and unions' position as insurance providers for their members. In addition to these four types of funds, two new types were established: these included the local funds (*Ortskrankenkassen*) and the parish funds (*Gemeindekrankenkassen*) whose task was to insure all eligible workers not covered by other funds. These two new funds attracted the lion's share of the newly insured workers after the 1884 reform. Indeed, 59 percent of all insured individuals were insured in either local or parish funds by 1905.

After issuing the Act in 1883, municipalities and other institutions had more than a year of preparatory time to set up the insurance funds. Yet, the very early period of BHI did not pass without frictions. Employers did not report their workers to the funds, workers opted to remain in pre-existing funds with lower benefits, and collectors of insurance premia returned drunk and lost their lists.[10] The literature typically argues that workers were unenthusiastic about the insurance and concerned about employer's resentments regarding their share of contributions. As a result, some workers preferred to buy insurance from voluntary funds (*Hilfskassen*) that did not require employer contributions and employers preferred to hire workers with such insurances (Tennstedt, 1983, pp. 318-322). Initially, around 40 percent of the targeted workers took up insurance. In the following years, this share gradually increased, also due to more rigorous inspection.

[8] Contributions were confined to a maximum range of 3 to 6 percent of the wage.

[9] Only few workers from minor industries were covered by these particular insurance funds; most of them were members of the *Knappschaften* which provided insurance against accident, illness, and old age from 1854 (see also Guinnane and Streb, 2011).

[10] Based on the occupation census of 1882, officials in Dresden were expecting 45,000 workers from 8,665 firms to be liable for compulsory insurance. By mid 1885, only 30,000 workers were registered and 3,000 employers had yet to report their workers. Similar compliance rates were reported from Leipzig (Tennstedt, 1983, p.319).

Figure 1 depicts the development of health insurance coverage over time.[11] Pre-1885 insured are either voluntarily insured or clustered in very few small industries providing compulsory health insurance such as mining. The data suggest only slight increases in the insured population until 1876, the latest available pre-BHI data point, after which the insured population surged from 3 percent to 8 percent in 1885. The subsequent increase in insured population is likely due to several reasons, including the increased uptake after initial frictions in recording the eligible workers, an expansion in the blue collar worker population due to ongoing industrialization, and a stepwise extension of BHI towards white collar groups (*Angestellte*). The steady increase in the share of insured after 1885 suggests that any effects of BHI are likely to become stronger over time.

Historical accounts suggest that being covered by BHI increased the demand for health goods and services. The insured consulted physicians far earlier and more frequently than the uninsured and it is argued that a large share of the newly insured would not have been able to afford consulting a physician in the absence of BHI (Huerkamp, 1985, p. 202).[12] The insured were in fact legally required to consult a licensed physician to receive a sick note and become eligible for sick pay. Fund physicians often received a lump sum payment of 2 Marks per insured from the insurance funds, irrespective of the treatment frequency. Since the insured did not bear the immediate costs, they increasingly made use of consultation hours. The stereotypical doctor's complaint that patients came for consultation only when it was too late turned into complaints that patients came in for petty indispositions (Huerkamp, 1985, p. 201).[13] Moreover, BHI became a key driver of the increased utilization of hospital capacity in the 1890s (Spree, 1996). Vögele et al. (1996) find that half of the patients in Düsseldorf hospitals were compulsory insured by 1901. The majority of inpatients were treated for non-communicable skin, eye and surgical diseases, i.e. treatment of injuries and wounds. Technological progress in antiseptics and improved sterilizing of wounds was highly supportive for successful treatment.

Contemporary complaints typically criticized the insurance's main benefit – sick pay. In principle, sick pay constitutes an improvement to the previous situation in which workers received no income while being sick at home. However, workers were hardly able to subsist on half of the local daily wage and the historical accounts suggest that they preferred returning to work as soon as possible (Ellerkamp, 1991). From a political perspective, contemporary supporters of BHI argued that the reform was costly but "bought social peace for Germany" (Leichter, 1979, p. 124).

3 Data

To quantify the impact of BHI on mortality, we draw on unique administrative data from Prussia, the largest state of the German Empire. In 1885, Prussia's territory covered roughly two thirds of the total area and population of the German Empire. The Royal Prussian Statistical Office is unique in having published annual death statistics by occupa-

[11] Table A1 in the Appendix shows the exact numbers of insured and total population of Prussia over the years.

[12] The chairman of the Imperial Insurance Agency Tonio Bödiker argued that less than half of the worker's families would have consulted a doctor before the introduction of the compulsory insurance (Huerkamp, 1985, pp.207-208).

[13] This notion is supported by contemporary sources suggesting that only half of the consultations justified a period of sick leave (Huerkamp, 1985, pp.202).

tional group. We combine these data with Prussian population and occupation censuses. The resulting data set is additionally extended to include information on public sanitation infrastructure such as waterworks and sewerage. When further refining our analysis, we draw on heterogeneity in the causes of death and in sickfunds' expenditures to provide evidence on potential channels through which the reform affected mortality. The period of observation for the main analysis covers the years from 1875 to 1905.

3.1 Data on mortality by occupation

The *Preussische Statistik* (KSBB, 1861-1934), a series of statistical volumes published by the Royal Prussian Statistical Office, annually reports the number of deaths by occupation for all 36 Prussian districts.[14] This information is reported for 28 occupational groups from 1877. Deaths are reported for adult men and women, as well as for male and female children below fourteen years of age. Children and non-employed females are classified by the occupation of their father or husband, respectively. We extract eighteen occupations that are consistently reported over time, following the classification of the Prussian Statistical Office into blue collar sector and public sector.[15] This categorization is particularly helpful for our analysis since it allows to compare mortality across occupational groups that differ in their eligibility for Bismarck's health insurance.

The death statistics are supplemented by occupation censuses that were exclusively conducted in the years 1882, 1895, and 1907 under the supervision of the Imperial Statistical Office (KSA, 1884-1942). The period under analysis is a period of rapid industrialization in Germany.[16] Accordingly, the occupational groups experienced differences in the growth of the working population leading to differences in the growth of the population at risk (see Table 1 for details). To take this into account, we generate occupation-specific mortality rates by combining the occupation-specific death statistics and the occupation-specific population data from the occupation censuses. We were able to consistently match the eighteen occupations extracted from the death statistics to those reported in the occupation census. Gaps between census years were filled by linear interpolation and extrapolation to obtain estimates of the respective size of each occupational group.[17]

[14] In the Prussian administrative hierarchy the district (*Regierungsbezirk*) ranks above the county (*Landkreis*).

[15] Blue collar worker industries encompass thirteen groups listed as sector B in the statistics: mining and turf, minerals, metals, machinery, chemicals, fossil fuels, textiles, paper and leather, wood, food, apparel and cleaning, construction, and printing. Public servant groups encompass five categories listed as sector E in the statistics: public administration, military, church and education, health, and arts and entertainment.

[16] Note that this period is not a period of substantial warfare. The Franco-Prussian war of 1871 did not affect Prussian territory and civilians. The war created 30,000 veterans suffering from long-term disabilities and/or diseases. Even so, there is no evidence for the year 1884 constituting a crucial turning point in veteran's mortality.

[17] Different from the death statistics, the occupation censuses report occupation-specific numbers of working males and females but aggregate non-working family members into a single category. Thus, when calculating occupation-specific mortality rates we rely on the total occupational population (excluding servants). We tested the robustness of our results to replacing this denominator by the occupation- and gender-specific working population. The results are qualitatively similar. We further tested interpolation based on urban population growth, which does not require linear extrapolation to years prior 1882. Again, the results are qualitatively similar.

3.2 Data on aggregate mortality, causes of death, and health insurance contributors

In a range of specifications we draw on aggregate mortality rates for the period from 1875 to 1904 instead of using occupation specific mortality rates. These mortality rates are provided by Galloway (2007) for all Prussian counties. Due to the fact that several counties were split during administrative reforms, we aggregate the data to consistently reflect the borders of 1875, resulting in a constant set of 441 counties. When necessary, the data are aggregated to reflect the district level with 36 observations. Next to total mortality, the data include gender-specific mortality and infant mortality by legitimacy status.[18]

To gain insights into potential mechanisms through which BHI affected health, we digitized rich data on the causes of death from the *Preussische Statistik* (KSBB, 1861-1934). In particular, we draw on district-level information reporting the full universe of fatalities by the thirty distinct causes of death that were reported annually from 1875 to 1904. This wealth of data allows us, for example, to distinguish between deaths from waterborne infectious diseases such as typhus, typhoid fever, or diarrhea, and deaths from airborne infectious diseases such as smallpox, scarlet fever, measles, diphtheria, pertussis, scrofula, tuberculosis, tracheitis, or pneumonia. Besides, the data provides us with information on the number of deaths due to accidents, maternal deaths and deaths from non-infectious diseases such as cancer, edema, stroke, heart disease, brain disease, and kidney disease.[19]

In specifications with aggregate or cause-specific mortality as dependent variables we use the aggregate pre-BHI blue collar worker share as main explanatory variable. We calculate the county- and district-specific population share employed in blue collar occupations using the above mentioned occupation census of 1882. In an alternative specification, we draw on data recording the actual take-up of health insurance. KSA, 1884-1942 provides annual district-level records on the number of health insurance contributors, which allows us to calculate the share of insured in the total population.[20]

3.3 Data on sanitation infrastructure, urbanization, age structure, and SPD vote shares

We address concerns regarding changes specific to the urban environment coinciding with the introduction of the health insurance by supplementing our dataset with information

[18]We follow the standard approach to calculate crude death rates as the total number of deaths per year per 1,000 people. Infant mortality is defined as the number of deaths of children below the age of one per year per 1,000 live births. This applies for legitimate and illegitimate deaths and live-births respectively.

[19]Concerns regarding the quality of causes of death data from this period have been raised in the literature (Kintner, 1999; Lee et al., 2007). Note that it is possible that improved knowledge about diseases allowed registrars to better identify the accurate cause of death over the course of our period of observation. If regions with a higher share of insured were also regions were physicians or registrars were better able to identify the cause of death, we expect the residual category 'unknown cause of death' to show a stronger decline. Using 'unknown cause of death' as an outcome in a district fixed effects model similar to Equation 2, we do not find evidence of such a pattern (see also Table 6 below). This finding indicates that there were no systematic improvements in the ability to identify the correct cause of death related to the introduction of BHI that could drive our findings on causes of death.

[20]Although this data is available for the entire German Empire, we confine our analysis to Prussia since our detailed mortality data are only available for the Prussian territory.

on sanitation infrastructure as well as urbanization rates. The literature discusses two drivers of change in urban mortality occurring at the end of the 19th century which are related to the provision of public sanitation infrastructure — waterworks and sewerage. We draw on Grahn (1898-1902) and Salomon (1906-1907) who report city level dates of the establishment of public water supply and sewerage systems respectively. Assuming that the entire city population benefited from the introduction of sanitation infrastructure, we calculate the county/district level share of the total urban population with access to waterworks and sewerage. The Prussian Statistical Office conducted population censuses including urban population counts every five years. These data, available from (Galloway, 2007), are linearly interpolated to generate annual estimates of the urban population and urbanization rates.[21] Depending on the specification, we are able to use county level data or aggregate the data to the district level.

Moreover, we digitized district-level data from population censuses reported in KSBB, 1861-1934 to generate variables that depict the age structure of the population during the period 1875 to 1904. In particular, we calculate the average age and the size of age cohorts (ages: 1-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70 plus) as a fraction of the total population. These variables should capture changes in a district's age composition over time. Additional robustness checks rely on data from Galloway (2007) to calculate the district-level vote share of the workers party SPD (and its predecessors) in the general elections of 1874, 1878, 1884, 1890, 1893 and 1898 to proxy changes in the regional strength of workers' movements and unions.[22]

3.4 Data on health insurance fund expenditures, hospitalizations and licensed physicians

In an attempt to present further *prima facie* evidence on the mechanisms at work, we draw on newly digitized annual data on the expenditures of insurance funds for the period from 1885 to 1904. KSA, 1884-1942 reports district-level data from insurance funds balance sheets. Expenditures include categories such as sick pay, medication, hospitalizations, doctor visits, death benefits, maternity benefits and administration reported in German Mark, as well as the number of sick days. Combining these data with the annual number of insured in a district, we calculate per capita expenditures by type.

To conduct complimentary analyses of the demand for health services, we digitized district level hospitalization rates based on the annual number of treated patients and individual cases, reported in KSBB, 1861-1934 for the period from 1880 to 1904. To capture the development of the supply side, we digitized district-level information on the number of licensed physicians (*approbierte Ärzte*) for the years 1879, 1882, 1887, 1898, and 1901 (KSB HB, 1903).

[21] The waterworks data is additionally extrapolated to cover the post 1898 period.

[22] These elections were chosen because they precede the first year of each five year interval to which we aggregate.

4 Empirical evidence

This section analyzes the impact of BHI on mortality using multiple empirical approaches. Bringing together evidence from various data sets with varying degrees of aggregation, we sequentially address a range of concerns regarding a causal interpretation of our findings of BHI on mortality. The sequence of specifications starts with a comparison of mortality trends across countries. To avoid problems of unobserved time-varying heterogeneity across countries, we proceed with a disaggregated intention-to-treat difference-in-differences approach that focuses on Prussia. This approach exploits the fact that BHI was compulsory for blue collar workers but not for other occupations and compares occupation-specific changes in mortality rates over time. In regional fixed effects analyses, we address selection issues exploiting pre-BHI variation in treatment eligibility at the district and county level, and provide further support against confounding factors. Finally, to explore the potential channels through which BHI affected mortality, we draw on causes of death statistics and sickness funds' expenditures data. Each subsection is structured to first establish the econometric specification, then present the results and finally discuss advantages, concerns and drawbacks particular to the respective approach.

4.1 Time-series and cross-country statistics

We start our empirical analysis by inspecting the long-run development of mortality in Prussia from the early 19th to the early 20th century. Figure 2 plots the crude death rate, defined as the number of deaths per 1,000 inhabitants of Prussia over the period from 1815 to 1913. Mortality was rather volatile, due to higher prevalence of epidemics and war, until the early 1870s when the fluctuations notably ceased. However, it is not before the mid-1880s that we observe a distinct break in the long-run mortality trend. From 1885 to 1913, the crude death rate in Prussia declined from about 27 to about 17 deaths per 1,000 population, corresponding to a substantial drop of almost 40 percent. Thus, we observe a remarkable coincidence of the introduction of BHI in December 1884 with the timing of the mortality decline.

At the end of the 19th century, mortality rates declined across all industrializing countries. Yet, the drop of German mortality rates from 1884 onwards was noticeably more accentuated than in other Western countries, which might be related to the introduction of BHI. Appendix Figure A.1 shows the crude death rates for Prussia and various European countries against years from 1875 to 1913.[23] To highlight the comparatively steeper mortality decline in Prussia, we plot the difference in the mortality rate of Prussia and every other country by year, while normalizing the respective mortality difference in 1884 to zero. To smooth the trends, we apply country-pair-specific local regressions using a tricube weighting function (Cleveland, 1979) and bandwidths of 0.8 to the left and 0.2 to the right of the cut-off year 1884. Figure 3 shows that the mortality decline for Prussia

[23]The data come from a range of national sources that are collected and made available by the team of the Human Mortality Database, a joint project of the University of California, Berkeley (USA) and the Max Planck Institute for Demographic Research (Germany). For details, please visit http://www.mortality.org or www.humanmortality.de

was indeed considerably stronger than the mortality decline in all other countries during this period.[24]

Although remarkable, these findings from simple time-series and cross-country statistics should not be interpreted as evidence for a causal effect of BHI on mortality. If Prussia experienced structural changes that other countries did not experience simultaneously and if these changes affect mortality and happen to coincide with the introduction of BHI, this might explain Prussia's comparatively strong mortality decline at the end of the 19th century. Therefore, in the remainder of this chapter, we will put together additional pieces of evidence to plausibly separate the effect of Bismarck's health insurance from that of other determinants of mortality.

4.2 Difference-in-differences: eligibility by occupation

4.2.1 Econometric specification

To investigate the role of Bismarck's health insurance for mortality within Prussia, we proceed by exploiting the fact that BHI, introduced in December 1884, was mandatory for blue collar workers but not for other occupations. This constitutes a natural setting for a reduced form difference-in-differences model, in which we compare the mortality trend of blue collar workers (treatment group) to the mortality trend of a control group.

Two characteristics qualify public servants as our preferred control group. First, similar to blue-collar workers, public servants are likely to live in urban areas and thus experience the same structural changes to their living environment. Second, public servants did not become eligible for compulsory health insurance before 1914. Prussian civil servants were however eligible for continuation of salary payment during illness and a pension in case of disability or old age. These benefits were confirmed after German unification by the Imperial Law on the Legal Relationship with Public Servants of 1873. Yet, public servants did not receive benefits such as free doctor visits and medication. Most importantly for our identification assumption, their benefits were not subject to change in the period 1873 to 1914.

Our main specification is based on data aggregated over all blue collar and public servant subgroups and over four year periods.[25] Subsequently, we relax each respective type of aggregation. Exploiting differences in eligibility, we estimate a difference-in-differences model that can be expressed by the following Equation 1:

$$Death_{iot} = \alpha_{io} + \theta_{it} + \sum_{t=1877-1880}^{1897-1900} \beta_t (BlueCollar_{io} * T_t) + X'_{it} BlueCollar_{io} \gamma_+ \varepsilon_{iot} \quad (1)$$

$Death_{iot}$ is the average death rate of people with occupation $o \in (BlueCollar, PublicServant)$, measured in district i at period $t \in (1877 - 1880, 1881 - 1884, 1885 -$

[24]The comparison also suggests a *less* pronounced mortality decline prior to 1884 in Prussia than in most other countries.

[25]The use of four year periods is owed to the fact that the occupation-specific mortality was published from 1877 — eight years before BHI. We are thus able to create two pre-treatment periods and four post treatment periods. Results are robust to the choice of other period lengths and the use of annual data (see Section 4.2.4).

1888, 1889 − 1892, 1893 − 1896, 1897 − 1900). α_{io} are occupation by district fixed effects accounting for any time-constant occupation-specific mortality differences between districts. θ_{it} are district by period fixed effects that flexibly allow mortality trends to differ across districts. These fixed effects pick up a range of shocks affecting the district-level health environment relevant for both occupational groups, such as overall improvements in nutrition due to variation in harvests and food prices, or differences in temperature especially affecting infant mortality. $BlueCollar_{io}$ is a dichotomous variable that is unity for blue collar workers and zero for public servants. We interact this occupation indicator with period indicators T_t to flexibly allow the mortality difference between occupations to vary over time. The β_t coefficients measure an unbiased reduced form effect of BHI in the absence of time-varying unobservables differentially affecting blue collar workers' mortality and public servants' mortality. ε_{iot} is a mean zero error term. Standard errors are clustered at the occupation by district level to allow for serial occupation-specific autocorrelation within districts.

By letting β vary over time, we generalize the standard difference-in-differences model to allow for heterogeneous intention-to-treat effects over time. This makes particular sense in our setting in which we expect the mortality effects of BHI to expand gradually. At the same time, this specification allows us to perform a placebo treatment test. In particular, using the period from 1881-1884 as the reference period, we expect β_t to be zero in the pre-treatment years, suggesting that blue-collar workers and public servants followed the same mortality trend before BHI was introduced. Thus, this placebo treatment test would corroborate the validity of our identifying assumption, namely that the mortality of blue-collar workers and public servants follows the same time trend in absence of the treatment.

To further validate the empirical approach, in an extended specification, we introduce an interaction of the blue-collar worker dummy $BlueCollar_{io}$ with a vector of time-varying district-level control variables X'_{it}. Public health interventions such as the construction of waterworks and sewerage in cities are among the most frequently cited explanations for decreased mortality in 19th century Europe and the U.S. (see Alsan and Goldin, 2015; Beach et al., 2016; Ferrie and Troesken, 2008; Kesztenbaum and Rosenthal, 2017). Accordingly, X'_{it} includes the district's urbanization rate, the share of a district's urban population with access to public waterworks and the share of a district's urban population with access to public sewerage. Note that such time-varying district-level characteristics are already captured by the θ_{it} in our basic specification as long as they affect both occupational groups equally. Now, introducing the interactions $X'_{it}BlueCollar_{io}$, we explicitly allow these measures of public health infrastructure to have differential effects for blue-collar workers and public servants. Furthermore, by allowing urbanization rates to differentially affect occupational groups, we account for the fact that city quarters with occupational clustering could be differentially affected by changes in population density due to city growth at the intensive margin.

4.2.2 Main results

A first graphical depiction of the difference-in-differences results is provided in Figure 4. Here, we plot the crude death rate of blue collar workers (treatment group, black solid line) and the crude death rate of public servants (control group, black dotted line) against years. The vertical line marks the introduction of BHI in 1884. In addition, the grey solid line depicts the counterfactual mortality trend of blue collar workers, i.e., the mortality trend followed in the absence of BHI, assuming that the actual mortality trend of public servants resembles an untreated mortality trend of blue collar workers. Throughout the entire period of observation, the level of blue-collar workers' mortality lies above the level of mortality of public servants. Prior to BHI, both groups follow approximately the same mortality trend. If at all, public servants' mortality declines faster than blue-collar workers' mortality, which would bias the difference-in-differences estimate downward. Only after the introduction of BHI, the mortality of blue collar workers falls more steeply than the mortality of public servants. This can most clearly be seen in the considerable departure of blue collar workers' actual mortality trend from the counterfactual trend. Blue collar workers' mortality declines more substantially than what we would expect in absence of BHI. We interpret this graphic pattern as suggestive of a negative treatment effect of BHI on the mortality of blue collar workers.

In a next step, we bring the data to a regression framework and estimate the generalized difference-in-differences model of Equation 1. Column 1 of Table 2 reports the results from a basic specification, where we regress the crude death rate on the interactions of the blue-collar worker dummy and period fixed effects while controlling for occupation by district fixed effects and district by period fixed effects. The period immediately preceding Bismarck's reform, i.e., the period 1881-1884, constitutes the reference period. We find that blue-collar workers and public servants indeed followed a similar mortality trend in the years preceding BHI. This result provides evidence supporting the common trend assumption of the difference-in-differences framework and thus corroborates the validity of the empirical approach. A short-lived significant deterioration of blue collar workers' health after 1884 is not robust across specifications and depends on the choice of the omitted period. For all subsequent periods, we observe significant negative effects that gradually increase in size.

These DiD estimates depict reduced form intention-to-treat (ITT) effects. Provided that full insurance take-up of blue-collar workers was delayed due to initial frictions, the increasing magnitude of effects may exclusively be driven by increasing coverage. Yet, if we rescale the ITT estimates by the corresponding share of insured among blue-collar workers (computed from Tables 1 and A1), we find that roughly a third of the increase in the coefficients can be attributed to the expansion of coverage. The remaining two thirds can be attributed to increases in the intensive margin of the insurance effect. If we take both effects into account, BHI had reduced the mortality of blue collar workers by 1.907 deaths per 1,000 individuals, i.e. by 8.9 percent (-1.907/21.519), by the end of the 19th century. In other words, BHI accounts for roughly a third (-1.907/-5.652) of the total mortality decline of blue collar workers in this period.

The estimated effects are robust to occupation-specific urbanization and sanitation infrastructure effects. To account for occupation-specific urbanization effects, i.e., the crowding of factory workers into city quarters due to rapid city growth, we include an interaction of the time-varying urbanization rate with the blue-collar worker dummy as a covariate. The results from column 2 show a slight reduction of the point coefficients. Yet, the effects stay negative, statistically significant and economically meaningful. The same is true if we include occupation-specific interactions of access to waterworks (column 3) or access to sewerage (column 4) to make sure that the results are not confounded by occupation-specific heterogeneity in the effects of the roll-out of sanitation infrastructure.[26] Across all specifications, the results point to a considerable negative effect of BHI on blue-collar workers' mortality, which increases over time.

4.2.3 Effect heterogeneity: men, women, and children

So far, we have estimated an average reduced form effect of BHI eligibility on blue-collar workers' crude death rate. In order to obtain more information on the underlying components of this effect, we disaggregate the occupation-specific death rates to obtain separate death rates for men, women, and children. Mortality rates of children and non-employed females are classified by the occupation of their father or husband respectively. Table 3 presents the results of this analysis. We find a considerable part of the mortality decline to be driven by male blue-collar workers (column 2). At the same time, we observe a substantial decrease of child mortality (column 4), while the effect on females is somewhat smaller but also significantly different from zero (column 3).[27] For all three groups, the effects gradually increase over time.

Declining child mortality is one of the dominant features in the Demographic Transition and may be explained by changes in both nutritional and non-nutritional factors. Our findings indicate that children benefited massively from changes inflicted by the health insurance. There are three core channels that may explain such findings but remain undistinguishable with the data at hand. First, since some funds extended treatment and medication to all family members, children might directly benefit from health care. Second, sick pay obtained by the insured parent might result in intra-family spillovers of insurance benefits. If sick pay stabilizes income, therefore facilitating continuous calorie intake and nutritional prospects of the household, infants may benefit (see Subramanian and Deaton, 1996; Case and Paxson, 2008). Third, treatment and medication obtained by the insured parent might affect health of uninsured family members. Next to the possibility to share medication, patients could share knowledge on hygiene matters received during treatment by insurance physicians with all members of the household. In addition to behavioral changes of the insured, intra-family knowledge diffusion likely led to prevention of infectious disease transmission. Given the economic literature on early human capital development and the fetal origin hypothesis (Douglas and Currie, 2011; Deaton, 2007), we expect children to respond stronger than spouses to such changes in the health environment, even if they are not themselves targeted by the reform.[28]

[26]Figures A.2 and A.3 in the Appendix provide further visual support against the concern that the roll-out of waterworks and sewerage confounds the health insurance effect. We plot the number of waterworks and sewerages established in Prussian cities per year as well as their cumulative distribution functions. Both waterworks and sewerage coverage in Prussian cities clearly increase in the second half of the 19th century. However, we do not observe any conspicuous jumps in the roll-out around the introduction of Bismarck's health insurance in 1884 which could explain the absolute and relative mortality decline for blue-collar workers in the aftermath of the reform.

[27]Note that results are qualitatively similar when using the occupation-specific population size by working males and females as denominator. Especially for the male population, this is arguably very close to capturing the insured population in the treatment group.

[28]Until the end of the 19th century, hygiene education was not part of schools' curricula, teachers were not particularly trained to educate students in hygiene issues, and doctors were not systematically integrated in the school system to examine pupils and inform parents (e.g., Krei, 1995; Leuhuscher, 1914; Umehar, 2013). Therefore, positive knowledge and health spillovers from students to their parents are rather unlikely.

4.2.4 Robustness checks

We proceed by presenting results from a difference-in-differences model based on disaggregated annual mortality rates.[29] In this model, we also include occupation specific linear time trends to mitigate concerns related to potentially diverging pre-treatment trends between treatment and control group. Figure 5 plots the annual difference-in-differences estimates using 1884 as the reference year. The slight increase in mortality right after the reform remains insignificant in this specification. From 1886, we observe a mortality decline that gradually accumulates over time. Thus, this more fine-grained model with annual intention-to-treat estimates complements our previous findings. In fact, allowing for diverging pre-treatment trends increases the point estimates compared to those presented in Table 2.

Achieving an accentuated drop in mortality is easier if the pre-existing level is high. Even if the absolute decline is much larger for the group with initially higher mortality rates, the relative decline might be similar for both occupations. To rule out this concern, we measure death rates on a logarithmic scale and run a log linear difference-in-differences model. The results confirm the established pattern (see Figure A.4 in the Appendix). The mortality decline for blue collar workers is steeper than the mortality decline for public servants both in absolute terms and in percent terms. Thus, this exercise corroborates the robustness of the findings with respect to changes in the specification.

4.2.5 Threats to identification

Bismarck's disability insurance and old age pension system

Bismarck's disability insurance and old age pension system, the third pillar of his welfare system, was introduced in 1891, i.e., seven years after BHI. Using 1891 as the baseline year in the annual difference-in-differences model, we investigate whether the introduction of the third pillar constitutes a considerable trend break. The estimates show that blue-collar workers' relative mortality starts to decline well before 1891 and proceeds to do so thereafter (see Figure A.5 in the Appendix). Indeed, there is no particular pattern in the data suggesting that the year 1891 changed blue-collar workers' relative mortality in a meaningful way. This finding suggests that the disability insurance and the old age pension system do not confound the effects of Bismarck's health insurance.

Working conditions and factory regulation

If the introduction of BHI coincides with improvements in industrial working conditions, leading to a stronger mortality decline for blue collar workers than for public servants, our estimates may be biased. Such a scenario is rather unlikely, as the period under analysis is a period of ongoing, rapid industrialization. The typical industrial job was physically demanding, workers were remunerated via piece rate schemes, working hours were extensive, breaks were irregular and food intake during working hours insufficient (see, e.g., Berg et al., 1989; Paul, 1987; Pietsch, 1985). What is more, the relationship

[29] This basic version of the model excludes additional covariates.

between workers and their employers was characterized by an authoritarian style, where employers disciplined employees using harsh measures (see, e.g., Frevert, 1981).

Prussian legislation prohibited employment of children in industry until the age of thirteen in 1855. The Trade, Commerce and Industry Regulation Act (*Gewerbeordnung*) of 1878 adopted the Prussian industrial code into an imperial law, barring all children from any work in factories, mines, foundries and stamping mills until the age of thirteen. According to Hennock (2007, p.83), this marked "the end of the development of factory legislation in Germany for the next thirteen years." Bismarck strongly opposed any further attempts aimed at improving working conditions since he considered new factory regulations to be detrimental to economic development.[30] Hennock (2007) argues that Bismarck's health insurance might even have delayed any major safety and health regulations in factories. Indeed, the 1880s saw only few improvements in workplace regulation. Federal regulatory reforms were minor and restricted to very specific industries.[31] It seems highly unlikely that such improvements have the ability to generate the aggregate BHI effects. Almost immediately after Bismarck resigned from office in 1890, regulations were passed to reduce maximum working hours for women. Similar legal restrictions in working hours for men were introduced only in 1919 (e.g. Hennock, 2007, pp.125-128). In 1891, an amendment of the Trade, Commerce and Industry Regulation Act (*Gewerbeordnung*) formally tightened regulations regarding safety at work. In line with earlier considerations regarding the introduction of the old age pension system, the absence of a particular trend break in mortality in 1891 mollifies concerns of confounding safety regulations (see Figure A.5 of the Appendix).

The absence of formal improvements in workplace regulation does not exclude the presence of informal improvements driven by changing incentives of employers to voluntarily improve working conditions.[32] The benefits of a healthy workforce increase in the task-specific human capital of incumbent workers. We argue that the ratio of skilled to unskilled workers with little task specific human capital was likely relatively low at the end of the 19th century. Employers thus had little incentives to incur the marginal costs of improving working conditions to gain the marginal benefits of a more healthy but less disposable workforce. Due to the lack of employment protection, employers were legally unrestricted to substitute workers at any time. The historical narrative is mostly supportive of this view. Even by 1912, a metal workers' union reported the typical factory air condition to be extremely hot, dusty and toxic due to insufficient ventilation. Yet, employers refused to provide workers with free protective masks and goggles (see, e.g., Deutscher Metallarbeiter-Verband, 1912, p.545).[33] Next to such complaints, the metal workers' union reports the number of work-related accidents per 1,000 metal workers. This

[30] An anecdotal account is characteristic of Bismarck's position: as the Pomerian factory inspector R. Hertel admonished Bismarck that there was a risk of explosion at his own paper factory in Varzin, he grumpily countered: "Where is danger ever completely ruled out?" (Lerman, 2004, p.182).

[31] In particular, these improvements consist of a regulation of the use of white phosphorus in the manufacture of matches (1884), a regulation for the manufacture of lead paints and lead acetate (1886) and for the manufacture of hand-rolled cigars (1888).

[32] Similarly, improvements in working conditions may have been a byproduct of technological progress, for example if steam power is replaced by electricity. However, the widespread use of electricity developed much later than BHI (a mere 2.7 percent of steam engines produced electricity in 1891). Furthermore, by 1900 approximately eighty percent of electrical energy was used for lighting.

[33] Even if inspectors criticized employers for providing insufficient safety for their workers, employers had no incentives to comply because they could hardly be prosecuted (Bocks, 1978).

quantitative evidence clearly shows that the number of non-fatal accidents per worker in the workplace increased considerably from 1886 until 1909.[34]

We can gain additional insights regarding improved working conditions as a potential confounder by exploiting the heterogeneity of our occupation-specific mortality data. Presume that workers in some industries were more successful in improving working conditions and/or employers in some industries improved working conditions voluntarily (further assuming no related reductions in work-related accidents). As a result of such uncoordinated, local activity, we would expect working conditions to improve in different industries and regions at different points in time. To analyze whether this is the case, we resort to the difference-in-differences model as introduced in Equation 1 based on annual data. Yet, instead of the aggregate blue-collar worker mortality rate, we draw on disaggregated mortality rates for all the individual thirteen blue-collar occupations. The results of this exercise are displayed in Figure 6.[35] Three findings are noteworthy: First, the negative mortality effect is not driven by one single (large) industry but systematically occurs across many industries. Second, the mortality decline occurs at the same point in time across industries, namely shortly after the introduction of BHI. Third, we do not find a substantial post-1884 mortality decline in the mining industry, the only sector that introduced *compulsory* health insurance prior to BHI in 1854 and therefore did not experience a fundamental change in health benefits during the period of observation. We consider these findings to be convincing evidence against a substantial role of working conditions in confounding the mortality decline for blue collar workers.

Wages and income

If blue collar workers' wages grew more rapidly than public servants' wages, the BHI effects might be confounded by income increases and related improvements in nutritional status. To be precise, a relative increase of blue-collar workers' wages would prevent the clean identification of an insurance effect only if the reason for the income change is unrelated to BHI.[36] Unfortunately, there are no administrative data available that systematically report annual wages by occupation *and* district. However, based on an individual-level dataset of household accounts by Fischer (2011), we identify approximately 2,500 blue collar workers reporting income and consumption during a year in the period 1870-1910. We find no sign of a trend break in mean disposable income or food consumption around 1884 that would explain the sudden decline in mortality rates (see Figure A.7 in the Appendix).

Time series wage data for nineteenth-century Germany, reported by Hoffmann (1965), suggest the largest wage growth between 1884 and 1900 occurred in the construction (43%) and the wood (39%) industries, whereas metals (23%) and textiles (23%) experienced considerably lower wage growth. If our findings were indeed driven by an income effect, we would expect the mortality decline to be more salient in industries with

[34] Below, we provide evidence from causes of death data confirming that the mortality decline is not driven by a reduction of workplace accidents.

[35] Similarly, difference-in-differences analyses by eleven individual provinces presented in Figure A.6 show the decline to be uniformly occurring across regions. Note that in this figure the province of Brandenburg contains the imperial city of Berlin and the province Rheinland contains Sigmaringen due to the external administration of the health sector.

[36] A related but countervailing concern is that employers passed on their part of insurance contribution by decreasing wages.

the largest increases in wages. Again drawing on the heterogeneity across individual industries displayed in Figure 6, we find the mortality decline in low wage-growth industries such as metals (5.2 deaths per 1,000) and textiles (3.4) to be similar or even significantly larger than in high wage growth industries such as wood (3.6) and construction (1.6) by 1900. Based on these, admittedly limited, comparisons, we find no indication of income as a confounder of the BHI effect.

Spillovers and selection

As indicated above, positive spillovers within the family of the insured are very likely. Yet, since families do not live in isolation, we might in addition observe spillovers to untreated individuals outside the family. This might be particularly relevant in our setting. On the one hand, we prefer members of our control group to be as similar as possible to members of our treatment group, i.e., they should for example live in the same area. On the other hand, this implies that members of the control group potentially benefit from an improved disease environment. Spillovers from blue-collar workers to public servants due to reduced risk of disease transmission imply that our estimates constitute a lower bound of the BHI effects on mortality.

Moreover, the data at hand do not allow a clear distinction between insured and uninsured people, neither in the treatment nor in the control group. We cannot exclude the possibility that public servants voluntary bought additional health insurance. At the same time, compliance of blue-collar workers is incomplete due to frictions in particular during the early years of BHI. Consequently, there might be people in the treatment group who are uninsured and people in the control group who are insured.[37] Therefore, we interpret our approach as an intention-to-treat design that identifies reduced form effects of BHI eligibility on mortality. On the positive side, this approach rules out any issues arising from the endogenous nature of actual insurance take up.

While the intention-to-treat design rules out selection into insurance take-up, selection into occupations after BHI might be a problem. If there is systematic selection into treatment, i.e. people selecting into blue collar occupations whose health characteristics are systematically different from those in the treatment group prior to the introduction of BHI, this would bias the results. If an increasing amount of young and healthy people from rural areas migrate to cities to pick up an industrial occupation, the average age structure of blue collar workers might change, leading to lower aggregate mortality in the treatment group, which results in an upward bias of the BHI effect. On the other hand, it might be the case that necessity drives poor and unhealthy rural agricultural workers into blue-collar occupations, which would downward-bias the BHI estimates. A similar downward bias occurs if the new workers from rural areas are prone to suffering under the dismal living conditions of urban working-class quarters and fall sick leading to higher mortality in the treatment group. Thus, the direction of the bias arising from selection into the industrial sector is a priori unclear. The root cause of the problem is that the data do not allow us to fix assignment to treatment to a date before the introduction of BHI.

[37] Moreover, within both occupational groups we cannot distinguish between dependent workers and the self-employed who would not be captured by the mandatory nature of BHI.

4.3 Fixed effects: pre-reform differences at the regional level

In this section, we aim at resolving the discussed spillover and selection issues using an alternative empirical specification. This specification allows us to estimate the effect of BHI on the full population, capturing all potential spillovers. At the same time, this specification enables us to exclude problems from selection into treatment eligibility by holding fixed the treatment group at a point in time before the introduction of BHI.

4.3.1 Econometric specification

To this end, we use a county fixed effects model and compare the mortality trend of counties with a high share of blue-collar workers at the time BHI was introduced to the mortality trends of counties with a lower share.[38] This model can be described by the following Equation 2:

$$Death_{it} = \alpha_i + \theta_t + \sum_{t=1875-1879}^{1900-1904} \beta_t (BlueCollar_{i,1882} * T_t) + X'_{it}\gamma + \varepsilon_{it} \tag{2}$$

$Death_{it}$ is the average death rate of county i in period $t \in (1875-1879, 1880-1884, 1885-1889, 1890-1894, 1895-1899, 1900-1904)$. α_i are county fixed effects capturing unobserved time-invariant heterogeneity between counties, and θ_t are period fixed effects that flexibly account for general time trends. $BlueCollar_{i,1882}$ is the share of blue-collar workers in county i in year 1882. We hold this variable constant at its 1882 level and interact it with period indicators T_t. The omitted reference period is 1880-1884. Thus, β_t captures any period specific associations between the share of blue-collar workers in 1882 and the outcome variable. By holding the share of blue-collar workers constant at the 1882 level, we avoid any issues due to potentially systematic selection into the industrial sector after the introduction of BHI. X'_{it} is a vector of time-varying county-level covariates, including the urbanization rate and the share of population with access to sewerage and waterworks. ε_{it} is a mean-zero error component. Standard errors are clustered at the county level to account for serial autocorrelation within counties.

In order for β_t to identify reduced form intention-to-treat effects of BHI on mortality, we rely on the assumption that there are no time-varying unobserved determinants of mortality that are correlated with the share of blue-collar workers in 1882. In other words, conditional on X'_{it}, counties with a high and counties with a low share of blue-collar workers in 1882 follow the same mortality trend in absence of the treatment. Again, we provide evidence in support of this assumption by performing a placebo treatment test. In particular, we analyze whether β_t is indeed zero in the pre-treatment years. Additionally, we will employ a placebo treatment group to test the validity of this alternative approach.

[38] A county is the administrative unit below the district. In her borders of 1867, Prussia consists of 441 counties with an average area of less than 800 square kilometers.

4.3.2 Main results

In column 1 of Table 4, we document that the established pattern of results can also be found using a basic version of the county fixed effects model described in Equation 2. Again, the reduced form effect of Bismarck's health insurance increases over time. In the average county (with a blue-collar share of 7.4 percent in 1882), BHI reduced mortality by roughly 0.9 deaths per 1,000 inhabitants, or 3.4 percent, measured at the turn of the century. The insignificant placebo treatment effect in the pre-treatment period corroborates the validity of this alternative empirical approach. In column 2, we add the urbanization rate, the share of population with access to waterworks, and the share of population with access to sewerage to control for changes in urbanization patterns and the roll-out of public health infrastructure. Adding these controls does not change the findings qualitatively.[39] Yet, the reduced form effects become slightly smaller as waterworks and sewerage pick up part of the reduction in mortality over time.

In columns 3 to 7 of Table 4, we disaggregate the outcome variable to analyze the effects of BHI on males, females, and infants separately. We find statistically significant negative effects for males and females after 1885. Infant mortality is defined as deaths of children during their first year of life per 1,000 births. For such infants, the post-BHI coefficients are large and negative but only marginally significant. Yet, there is considerable heterogeneity related to the legitimacy of infants. Once we distinguish between legitimate infants (column 6) and illegitimate infants (column 7), we find highly significant negative effects for the former but not for the latter. In the average county (with a blue-collar share of 7.4 percent in 1882), BHI reduced mortality of legitimate children by roughly 5.5 deaths per 1,000, or 2.4 percent, measured at the turn of the century.[40] Thus, mortality reductions due to BHI are only found for infants that most likely live in households with both parents present. The lack of BHI-induced reductions for illegitimate infants might be explained by the lack of intra-family diffusion of insurance benefits for this group of infants: if a single mother is not a blue collar worker, the absence of a father leaves the family without access to insurance benefits. Finally, note that in those cases where the pre-treatment interaction is significant, the sign is always negative, implying increasing mortality in counties with a high blue collar workers' share. Consequently, if we accounted for these deviating trends in the pre-treatment period, the treatment effects would become even larger.[41]

Column 8 reports the results of a placebo treatment group test. We investigate whether differences in a counties' pre-BHI share of public servants create a similar pattern of results as the blue-collar workers share. We reject this hypothesis finding only very small and insignificant coefficients for the relationship between the 1882 public servants share and changes in mortality. Consequently, we can rule out that our treatment indicator picks up mortality trends common to other occupational groups.[42]

[39] Findings are qualitatively similar if we interact the urbanization and public infrastructure variables with time dummies to allow for differential effects of these covariates over time (results available upon request).

[40] From 1880 to 1884, the average death rate of legitimate children across all counties was 228.2, while it was 368.5 for illegitimate children. Deaths of illegitimate children accounted for 11.5 percent of all deaths of children below age one.

[41] In further unreported regressions, we observe significant negative effects of BHI on the mortality of individuals younger than 15, and of individuals aged between 15 and 44.

[42] Note that running a horse race regression between the share of blue collar workers and the share of public servants yields similar results (available upon request).

4.3.3 Robustness checks

In Table 5, we move our analysis from the county level to the district level. This allows us to address a range of concerns with additional data that are only available at this higher level of aggregation. We start by showing that results from a baseline regression using the standard control variables in column 1 are in line with our findings using county level information but are estimated with less precision.[43]

Changes in the age structure

We can now address the concern that changes in the age composition of the population, for example due to selective migration, confound the BHI effect. In particular, if changes in a region's age composition are correlated with its share of blue-collar worker in 1882, the BHI estimates might be biased — at least as long as the changes in the age composition do not arise due to the mortality effect of BHI. Rosenbaum and Rubin (1984) show that using age-adjusted mortality rates does not resolve this issue unless all explanatory variables are adjusted in the same way. Unfortunately, constructing age-adjusted controls is not feasible due to a lack of adequate data. In the absence of such data, Rosenbaum and Rubin (1984) suggest to include age composition variables on the right-hand side of the regression equation instead of using age-adjusted outcome variables. We follow their suggestion and run regressions controlling for changes in the age composition in two ways. We either include the mean age of the population or more fine-grained changes in the population share captured by the size of age cohorts of ten years (1-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70 plus) in columns 2 and 3. Our findings are virtually unaffected when controlling for such changes in the age structure.

Strength of unions

The earlier concern of confounding improvements in working conditions and wages is addressed again in column 4 – this time by controlling for a proxy for the strength of workers' movements and unions. In particular, we add the district-level vote share of the workers' party SPD (and its predecessors) as a control variable. This variable is expected to be highly correlated with spatial and intertemporal heterogeneity in the power of unions.[44] Again, our findings remain virtually unaffected by the inclusion of this variable.

Share of insured individuals

The district level aggregation also allows us to use new data on the share of individuals registered with health insurance funds. Columns 5-8 of Table 5 repeat columns 1-4 but substitute the share of blue-collar workers with the share of insured as the treatment variable of interest. Similar to the previous specifications, we hold the share of health

[43] For a full replication of Table 4 at the district-level see Table A2 in the Appendix.

[44] From 1878 to 1890, the Anti-Socialist Law prohibited assemblies of social democratic groups, in particular of the Socialist Worker Party and related organizations such as unions. Consequently, the strength of unions was curbed until the ban was lifted and organized strikes were suspended. Due to the lack of information on union activity, we resort to using information on the election of social democratic politicians who were still allowed to run as individuals without party affiliation. The vote share of social democratic politicians (during and after the ban) is probably the single available and best proxy for the strength of worker movements and unions during this period.

insured constant at the earliest possible year in 1885, right after the introduction of BHI, and interact it with year dummies.[45] The fact that results from both treatment variables are qualitatively similar (comparing columns 1-4 and 5-8) corroborates our interpretation that the blue collar worker mortality decline is in fact related to the health insurance. Comparing the estimates in more detail, we find that the point coefficients for the share of health insured (columns 5-8) are consistently larger than the point coefficients for the share of blue-collar workers (columns 1-4). This is exactly what we expect if the share of insured is a more direct measure for the treatment than the share of blue-collar workers.

4.4 Exploiting data on causes of death and sick funds' expenditures

In this section, we use panel data on thirty different causes of death to provide further evidence against contemporaneous reforms and public health improvements biasing the results. Moreover, these causes of death data allow us to better understand the channels via which BHI reduced mortality rates. Since the causes of death data are not recorded by occupation, we cannot exploit heterogeneity across occupations along the lines of Equation 1. Therefore, we employ a regional fixed effects model as described by Equation 2.[46] Finally, we will present regression results using data on sick funds' expenditures that provide further insights into the mechanisms through which BHI affected mortality.

4.4.1 Further evidence against confounding factors

In 1885, shortly after the introduction of BHI, Otto von Bismarck introduced the second pillar of the German welfare system, namely the accident insurance. If the aggregate mortality reduction was driven by a reduction of work accidents, this could raise suspicions regarding a confounding effect of Bismarck's accident insurance. The results when using deaths by accident as the outcome variable in a district fixed effects model are depicted in column 1 of Table 6. We do not find any negative association between the share of blue-collar workers in 1882 and changes in mortality due to accidents implying that the overall mortality effect is unlikely to be driven by improvements related to the accident insurance.[47]

Despite controlling for the spread of waterworks and sewerage, there might be remaining concerns that nonlinearities in the improvements of public sanitation infrastructure confound the estimates. As indicated by the literature (i.e. see Cutler and Miller, 2005) we expect waterborne disease mortality to react to the introduction of water supply and sewerage. If our effects were driven by a reduction of waterborne-disease mortality, this would leave room for the BHI estimates being confounded by improvements of water supply. Yet, column 2 of Table 6 shows that there is no association between

[45] The choice of the first year is admittedly arbitrary to some degree. Since results are qualitatively similar when using other years, we decided to use 1885 to exclude the most pressing concerns of reverse causation and selection.

[46] Note that, due to changes in the original reporting of the causes of death after 1902, the last period only contains three years of data from the period 1900-1902.

[47] In fact, most post-reform coefficients are positive and significant. Such results are in line with Hennock (2007) who argues that BHI delayed any major safety and health regulations in factories and with Guinnane and Streb (2015) who show that the accident insurance compensated workers for their losses due to accidents but did not result in a decline in work-related accidents. Note however, that, similar to the health insurance, the accident insurance provided sick pay and disability pensions to casualties of work accidents that likely improved living standards.

the share of blue collar workers in 1882 and deaths by waterborne diseases. Indeed, the coefficients are far from any conventional significance levels and even positive in all of the four post-treatment periods.

4.4.2 Understanding the channels

Below, we will argue that one of the most important channels through which BHI affected the mortality of insured was through the diffusion of knowledge about disease transmission and avoidance of infection. Note that there is an important difference in the transmission of waterborne and airborne diseases. While avoiding airborne diseases only requires knowledge about transmission channels, avoiding infection with waterborne diseases requires both knowledge about transmission and access to infrastructure. If individuals learned about the risk of contaminated water, they might boil drinking water, yet remain at higher risk of contact with contaminated water until proper infrastructure were installed. Consequently, investment in infrastructure is a necessary condition for the reduction of waterborne diseases. In contrast, knowledge transmission channels are sufficient for reducing the risk of infection with airborne diseases.

Evidence from causes of death

While BHI had no effects on waterborne disease mortality, we find considerable negative effects on airborne disease mortality (column 3 of Table 6). Among airborne infectious diseases, tuberculosis was the most prominent at that time. Tuberculosis (TB) was responsible for 12% of overall mortality in Prussia in 1884 and 30% of deaths among males in the age group 20-70 were attributed to this disease. A major breakthrough in fighting TB was achieved in 1882, when Robert Koch identified the bacterium causing tuberculosis.[48] Since TB was widespread among the working age population, the sickness insurance funds were particularly interested in reducing its incidence. Yet, as the cure was not developed until 1946, the focus was set on preventing infections.[49] Robert Koch (1901, p. 575) himself argued that only preventive action could reduce tuberculosis mortality, including the diffusion of knowledge about its contagiousness to increasingly larger circles.[50] As worker's access to such information was fundamentally improved with the introduction of BHI, they gained a head start in TB prevention over other groups that did not have free access to doctors, such as public servants.

The hygienic situation of workers' housing became the center of attention of funds' interventions. A characteristic excerpt from Tennstedt (1983, p.458) mentions that *research by Preysing and Schütz found tuberculosis germs underneath 21.2% of 66 toddler's fingernails, which they picked up when crawling on the floors of worker dwellings contaminated by sputum.* Such deficits in the hygienic situation were detected by sickness inspectors (*Krankenkontrolleure/Krankenbesucher*) who became instrumental in educating workers on hygiene. Initially hired to detect malingering via unannounced home visits,

[48] Initially, tuberculosis was typically assumed to be hereditary since usually the entire family suffered from its symptoms.

[49] Once a vaccine was found in 1921, it had a major impact on infection rates and longevity (see Bütikofer and Salvanes, 2015).

[50] For recovery, physicians sent infected patients to TB sanatoria. The very first sanatorium, the "Genesungshaus Königsberg" near Goslar, was opened by Hannover's province insurance on May 1st, 1895.

sickness inspectors eventually became mandated to monitor the curfew and medication intake of patients.[51] Moreover, physicians and inspectors specifically aimed at triggering changes in the hygienic behavior of all members of the household through particularly addressing women, who were typically in charge of care and food (Frevert, 1981).[52] The literature further indicates that insurance funds initiated publicly well-attended educational talks by insurance doctors (see Ewald, 1914). Indeed, the success of these measures crucially depended on the organization by the health insurance funds. Tennstedt (1983, p. 462) argues that this gave the talks a self-administrative working-class appearance so that they were not condemned as bourgeois-elitist events patronizing workers.

Our results suggest that these measures were successful. As can be seen from columns 4 and 5 of Table 6, the share of blue-collar workers in 1882 is associated with a decline in the number of deaths by lung diseases and especially tuberculosis (and the related scrofula). These effects are meaningful in size, statistically significant and become gradually stronger over time.[53] In column 6 of Table 6, we see that BHI also reduced deaths due to non-infectious diseases although coefficients are smaller in magnitude than for infectious airborne diseases. This result suggests that BHI did not exclusively affect communicable disease mortality and leaves room for explanations related to improved access to medication such as antiseptics and the provision of sick pay. However, to the degree that cardiovascular diseases can ultimately be triggered by infectious diseases such as simple influenza, we cannot exclude a certain overlap. Indeed, identification of the ultimate cause of death is a complex task. We find some evidence for a reduction in maternal deaths (column 7), which may be related to several channels including doctor visits, medical treatment, and sick pay.

If changes in the ability to correctly specify causes of death are systematically related to a districts' share of blue-collar workers, our results may be biased and the direction of the bias is ambiguous. To investigate this issue, in column 8, we turn to the category 'unknown' cause of death. The results reveal that there is hardly any evidence for a systematic change of 'unknown' cause of death. Only after the turn of the century, the treatment coefficient becomes marginally significant suggesting that, if anything, districts with a high blue collar workers share became worse in understanding the cause of death. On a cautionary note, such a regression cannot exclude systematic shifts in misspecified categories of known causes of death.

Evidence from the supply and demand for health services

Additional district fixed effects regressions along the lines of Equation 2 show the impact of BHI on the number of physicians and hospital inpatients (Table A3 in the Appendix). We do not find that the number of licensed physicians per capita increases by more in regions with a larger share of blue collar workers in 1882 (column 1). This suggests that BHI's negative mortality effects are not just the result of changes on the

[51] In 1896, the municipality fund of Leipzig conducted 79,332 visits by voluntary inspectors and 149,899 visits by professional inspectors (Tennstedt, 1983, p. 451).

[52] According to Tennstedt (1983, p. 458) funds specifically considered to deploy female inspectors to give advice to *their uneducated sisters* on *how to ventilate and clean the apartment, curtains and other dust catchers.*

[53] As technology to detect the actual cause of death was limited, deaths classified as unspecified lung diseases may in fact have been tuberculosis and vice versa.

supply side. In column 2, we find that the demand for hospital treatment increased post-BHI introduction. Since insurance benefits covered treatment in hospitals, this result does not come as a surprise. Both findings seem to support Huerkamp (1985) who argues that BHI increased the demand for health services and Spree (1996) who argues that BHI increased the utilized capacity of hospitals.

Evidence from insurance benefits

In an attempt to further distinguish between the channels of the mortality effects, the remainder of this section presents *prima facie* evidence based on data about expenditures by health insurance funds. The aggregate district level data from administrative sources distinguishes between expenditures for doctor visits, medication, hospitalization, sick pay, maternity benefits, death benefits, and administration. Figure 7 presents the evolution of sickness funds' expenditures per insured from 1885 to 1905. While we observe a steady increase in expenditures per insured over the full period of observation, the relative importance of the different kinds of expenditures is remarkably stable. Roughly a third – and thus the largest share – of total expenditures is due to sick payments for the insured. Expenditures for doctor visits make up for another 20-25 percent of total expenditures, followed by expenditures for medication, and hospitalization. Expenditures for administration, death benefits, and maternity benefits complete the picture.

If knowledge diffusion by physicians played a crucial role in reducing mortality, we expect mortality to decrease in association with an increase of expenditures on doctor visits. Similarly, if progress in medical treatment was important, we expect mortality to decrease in response to positive changes in medication or hospitalization expenditures. On the other hand, if sick pay helped to avoid temporary malnourishment and thus improve health and reduce mortality rates, expenditures for sick pay should be negatively correlated with mortality. To investigate through which of these channels BHI reduced mortality, we regress district level mortality rates on time-varying measures for the different types of expenditures per insured. Expenditures are lagged by one year to avoid most pressing concerns of reverse causality.[54] District fixed effects account for time-invariant heterogeneity between districts, while time fixed effects flexibly capture mortality trends common to all districts.

Panel A of Table 7 shows results when using overall mortality as the dependent variable, while panel B shows results when using cause specific mortality as the dependent variable. Column 1 in Panel A provides estimation results that support a mechanism of knowledge diffusion through physicians. An increase in expenditures for doctor visits by one standard deviation decreases the mortality rate by 0.11 standard deviations. Similarly, an increase in medication expenditures decreases mortality (column 2) by 0.16 standard deviations, suggesting that advances in medical treatment were a similarly important channel. We do not find a significant response to changes in hospitalization expenditures (column 3).

Interestingly, mortality does not respond to changes in sick pay, the lion's share of sickness funds' expenditures; the point coefficient is small and far from conventional

[54] The results are robust to changes in the lag structure. For reasons of consistency, control variables are lagged by one year as well.

levels of significance (column 4). We interpret this finding to show that the sick pay provided under BHI was not instrumental in reducing (short-run) mortality rates through income smoothing. Sick pay might have been just insufficient to prevent deterioration of health status. In fact, sickness was the reason for requesting poor relief in 27% of cases as late as 1913. However, we find a negative coefficient on maternity benefits that reaches marginal significance (column 5). Paid maternity leave for three weeks could smooth family income after birth and give the mother the opportunity for breastfeeding, which both can have positive effects in particular on infant health. In column 6, we find a positive albeit insignificant relationship between death benefits and the mortality rate. This finding reminds us that in these regressions, we cannot rule out completely the concern of reverse causality even if we lag the explanatory variables.[55] The model yields a negative coefficient of expenditures for administration on mortality in column 7. On the one hand, we expect high administration costs per insured to be a sign of inefficient organization, e.g. related to fund size, resulting in higher mortality. On the other hand, high administration costs might be indicative of an extensive deployment of sickness inspectors monitoring the hygienic situation of the insured, arguably resulting in lower mortality.

An alternative interpretation of results in column 1 is that doctor visits are indicative of periods of sick leave. If infectious-disease mortality is a function of interactions with co-workers, staying at home reduces the probability of disease transmission. In column 8, we test this hypothesis using data on sick days per insured as the explanatory variable.[56] We do not find evidence for a significant relationship between the average length of sick leaves and mortality, refuting the hypothesis that isolation from the public was an important driver of the mortality reduction.

Panel B presents results of regressions of cause-specific mortality on sick funds' expenditures. To avoid problems of multicollinearity, we group expenditures into 'health care' (doctor visits, medication, hospitalization), 'compensation' (sick pay, maternity benefits, death benefits), and administration. The results confirm that mortality reductions are associated with health care but not compensation, especially in the field of airborne lung diseases such as tuberculosis.[57]

In sum, this exercise provides further evidence that providing people with access to physicians and health care played a crucial role for the mortality decline. New knowledge on hygiene provided by physicians and embodied in treatment and medication was thus more easily diffused to a population living under poor hygienic condition.[58] This in turn resulted in the prevention of infections from airborne diseases such as tuberculosis. Furthermore, the admittedly parsimonious regressions provide no evidence in support of a view that sick pay contributed to the BHI-induced mortality decline, despite being responsible for roughly a third of sickness funds' expenditures.

[55] An alternative interpretation is that the death of an insured person is indicative of deterioration of the health prospects of the entire family due to income loss and reduced access to health care.

[56] The data is only available from 1889, hence the lower number of observations.

[57] Including maternity benefits, which were not exclusively pecuniary, into the 'care' category reinforces the findings.

[58] This interpretation is further supported by the fact that the BHI effects tend to be larger in regions with a higher pre-BHI mortality rate.

5 Conclusions

What is role of health insurance during the demographic transition? This is an important question in many respects. First, understanding the impact of public health interventions for demographic change and economic growth is crucial for the design of effective public policies. Second, from a demographic perspective, there has been a lot of work on determinants of the demographic transition. Yet, the role of the early health insurance schemes has been largely neglected so far. Third, from a historical perspective, it is interesting to understand the effects of Bismarck's health insurance as the first national compulsory health insurance scheme in the world.

We use newly digitized Prussian administrative panel data to analyze the effect of health insurance on mortality. In December 1884, Otto von Bismarck, Chancellor of the German Empire, introduced this health insurance as the first pillar of the imperial system of social security. We amassed evidence from time-series data on long-run mortality in Prussia, international comparisons, and several difference-in-differences type frameworks that exploit the compulsory nature of the health insurance scheme for blue-collar workers. These multiple empirical approaches yield a consistent pattern assigning BHI with an important role in Prussia's sharp mortality decline at the end of the 19th century.

In an intention-to-treat design, we find a mortality reduction of 1.91 deaths per 1,000 blue collar workers by the end of the century. In other words, a third of the mortality decline of blue-collar workers until 1900 can be attributed to BHI. The negative mortality effects are robust to an extensive set of robustness and validity checks. The estimates show that a large part of the reduction in mortality is driven by a decline in airborne infectious diseases. Additional evidence suggests that providing unrestricted access to doctors and medication was more important for the mortality decline than paying sick pay. This evidence is supportive of our hypothesis that Bismarck's health insurance provided households at the lower end of the income distribution with access to physicians and new knowledge on hygiene that they were unlikely to buy under a voluntary regime. While we do not find any evidence that sick pay was crucial for the effect of BHI on mortality, it might well be that sick pay affected other outcomes such as workers' long-run morbidity or their political support for Bismarck.

If we draw parallels between our findings and the findings in the literature on modern health insurance, i.e. from the U.S., we see that the reduced form effects under Bismarck were considerably larger compared to extending Medicare or Medicaid eligibility, even though medication was less effective at Bismarck's time. Under the U.S. setting, Card et al. (2008) find that extending Medicare eligibility for the 65+ group led to a mortality reduction between 2 and 4 percent one year later. In another study, Currie and Gruber (1996) find that increasing Medicaid eligibility to low-income children is associated with a 3.4 percent mortality reduction. Yet, in the absence of clean information on insurance take-up, we would like to remain cautious when comparing reduced form intention-to-treat effects across various research designs.

References

Acemoglu, Daron and Simon Johnson, "Disease and Development: The Effect of Life Expectancy on Economic Growth.," *Journal of Political Economy*, 2007, *115* (6), 925–985.

Ager, Philipp, Casper Worm Hansen, and Peter Sandholt Jensen, "Fertility and early-life mortality: Evidence from smallpox vaccination in Sweden," *Journal of the European Economic Association*, 2017, *forthcoming.*

Alsan, Marcella and Claudia Goldin, "Watersheds in Infant Mortality: The Role of Effective Water and Sewerage Infrastructure, 1880 to 1915," *NBER Working Paper Series*, 2015.

Anne, Diana Lee Case and Christina Paxson, "The income gradient in children's health: A comment on Currie, Shields and Wheatley Price," *Journal of Health Economics*, 2008, *27*, 801–807.

Ashraf, Quamrul, Ashley Lester, and David N. Weil, "When Does Improving Health Raise GDP?," *NBER Macroeconomics Annual*, 2008, *23*, 157–204.

Beach, Brian, Joseph Ferrie, Martin Saavedra, and Werner Troesken, "Typhoid Fever, Water Quality, and Human Capital Formation," *Journal of Economic History*, 3 2016, *76*, 41–75.

Berg, Eugenie, Lioba Meyer, and Ulf Steitz, *Moderne Zeiten. Industrie- und Arbeiterkultur in Oldenburg 1845 bis 1945*, Oldenburg: Verlag Isensee, 1989.

Bhalotra, Sonia, Martin Karlsson, and Therese Nilsson, "Infant Health and Longevity: Evidence from a Historical Trial in Sweden," *Journal of the European Economic Association*, 2017, *forthcoming.*

Bleakley, Hoyt, "Disease and Development: Evidence from Hookworm Eradication in the American South.," *Quarterly Journal of Economics*, 2007, *122* (1), 73–117.

Bocks, Wolfgang, *Die badische Fabrikinspektion: Arbeiterschutz, Arbeiterverhältnisse und Arbeiterbewegung in Baden 1879-1914*, Freiburg, Munich: Alber, 1978.

Bowblis, John R., "The Decline in Infant Death Rates, 1878-1913: The Role of Early Sickness Insurance Programs," *Journal of Economic History*, 3 2010, *70*, 221–232.

Brown, John, "Coping with the Crisis? The Diffusion of Waterworks in Late Nineteenth-Century German Towns," *Journal of Economic History*, 1988, *48* (2), 307–318.

Bütikofer, Aline and Kjell G Salvanes, "Disease Control and Inequality Reduction: Evidence from a Tuberculosis Testing and Vaccination Campaign," Technical Report Discussion Paper SAM 28 2015, NHH 2015.

_ , Katrine Vellesen Løken, and Kjell G Salvanes, "Infant Health Care and Long-Term Outcomes," *Review of Economics and Statistics*, forthcoming.

Card, David, Carlos Dobkin, and Nicole Maestas, "The Impact of Nearly Universal Insurance Coverage on Health Care Utilization: Evidence from Medicare," *American Economic Review*, December 2008, *98* (5), 2242–58.

_ , _ , and _ , "Does Medicare Save Lives?," *The Quarterly Journal of Economics*, 2009, *124* (2), 597–636.

Cleveland, William S., "Robust locally weighted regression and smoothing scatterplots," *Journal of the American Statistical Association*, 1979, *74*, 829–836.

Condran, Gretchen and Eileen Crimmins-Gardner, "Public Health Measures and Mortality in U.S. Cities in the Late Nineteenth Century," *Human Ecology*, March 1978, *6* (1), 27–54.

Condrau, Flurin, *Lungenheilanstalt und Patientenschicksal: Sozialgeschichte der Tuberkulose in Deutschland und England im spaeten 19. und fruehen 20. Jahrhundert.*, Vandenhoeck & Ruprecht, 2000.

Costa, Dora, "Health and the Economy in the United States, from 1750 to the Present," *Journal of Economic Literature*, 2015, *53* (3), 503–570.

Currie, Janet and Jonathan Gruber, "Health Insurance Eligibility, Utilization of Medical Care, and Child Health," *The Quarterly Journal of Economics*, 1996, *111* (2), 431–466.

Cutler, David, Angus Deaton, and Adriana Lleras-Muney, "The Determinants of Mortality," *Journal of Economic Perspectives*, 2006, *20* (3), 97 – 120.

Cutler, David M and Grant Miller, "The Role of Public Health Improvements in Health Advances: The 20th Century United States," *Demography*, 2005, *42* (1), 1–22.

Deaton, Angus, "Height, Health and Development," *Proceedings of the National Academy of Sciences of the United States of America*, 2007, *104* (33), 13232–13237.

_ , *The Great Escape: Health, Wealth, and the Origins of Inequality.*, Princeton and Oxford: Princeton University Press, 2013.

Deutscher Metallarbeiter-Verband, *Die Schwereisenindustrie im deutschen Zollgebiet: ihre Entwicklung und ihre Arbeiter. Nach vorgenommener Erhebung im Jahre 1910*, Stuttgart: Alexander Schlicke, 1912.

Douglas, Almond and Janet Currie, "Killing Me Softly: The Fetal Origins Hypothesis," *Journal of Economic Perspectives*, 2011, *25* (3), 153–72.

Easterlin, Richard A., "How beneficent is the market? A look at the modern history of mortality," *European Review of Economic History*, 1999, *3* (3), 257–294.

Ellerkamp, Marlene, *Industriearbeit, Krankheit und Geschlecht: Zu den sozialen Kosten der Industrialisierung - Bremer Textilarbeiterinnen 1870-1914*, Göttingen: Vandenhoeck & Ruprecht, 1991.

Ewald, Walther, *Soziale Medizin. Ein Lehrbuch für Ärzte, Studierende, Medizinal- und Verwaltungsbeamte, Sozialpolitiker, Behörden und Kommunen*, Springer Berlin, 1914.

Fenge, Robert and Beatrice Scheubel, "Pensions and Fertility: Back to the Roots–The Introduction of Bismarck's Pension Scheme and the European Fertility Decline.," *Journal of Population Economics*, 2017, *30*, 93–139.

Ferrie, Joseph P. and Werner Troesken, "Water and Chicago's mortality transition, 1850-1925," *Explorations in Economic History*, 2008, *45*, 1–16.

Finkelstein, Amy, "The Aggregate Effects of Health Insurance: Evidence from the Introduction of Medicare," *Quarterly Journal of Economics*, 2007, *122* (1), 1–37.

_ **and Robin McKnight**, "What did Medicare do? The initial impact of Medicare on mortality and out of pocket medical spending," *Journal of Public Economics*, 2008, *92* (7), 1644 – 1668.

Fischer, Hendrik K., *Konsum im Kaiserreich: Eine statistisch-analytische Untersuchung privater Haushalte im wilhelminischen Deutschland*, Akademie Verlag, 2011.

Fogel, Robert William, *The Escape from Hunger and Premature Death, 1700-2100: Europe, America, and the Third World*, Cambridge University Press, 2004.

Frevert, Ute, "Arbeiterkrankheit und Arbeiterkrankenkassen im Industrialisierungsprozess Preussens (1840-1870)," in Werner Conze and Ulrich Engelhardt, eds., *Arbeiterexistenz im 19. Jahrhundert*, Stuttgart: Klett-Cotta, 1981, pp. 293–319.

Galloway, Patrick R., "Galloway Prussia Database 1861 to 1914," 2007. www.patrickgalloway.com.

Goodman-Bacon, Andrew, "Public Insurance and Mortality: Evidence from Medicaid Implementation," *Journal of Political Economy*, 2017, *forthcoming.*

Grahn, Ernst, *Die Städtische Wasserversorgung Im Deutschen Reiche, Sowie in Einigen Nachbarländern*, München: R. Oldenbourg, 1898-1902.

Guinnane, Timothy W., "Population and the Economy in Germany, 1800-1990," in Sheilagh Ogilvie and Richard Overy, eds., *Germany - A New Social and Economic History*, Vol. III, since 1800, London: Hodder Arnold, 2003, pp. 35–70.

_ , "The Historical Fertility Transition: A Guide for Economists," *Journal of Economic Literature*, September 2011, *49* (3), 589–614.

_ **and Jochen Streb**, "Moral Hazard in a Mutual Health Insurance System: German Knappschaften, 1867-1914.," *Journal of Economic History*, 2011, *71* (1), 70 – 104.

_ **and** _ , "Incentives That (Could Have) Saved Lives: Government Regulation of Accident Insurance Associations in Germany, 1884-1914," *The Journal of Economic History*, 2015, *75* (4), 1196–1227.

(Handelsministerium) - Minister für Handel, Gewerbe und öffentliche Arbeiten, *Die unter staatlicher Aufsicht stehenden gewerblichen Hülfskassen für Arbeitnehmer und die Versicherung gewerblicher Arbeitnehmer gegen Unfälle im preussische Staate*, Berlin: Verlag des Königlich Preussischen Staatistischen Bureaus, 1876.

Hansen, Casper Worm and Lars Lønstrup, "The Rise in Life Expectancy and Economic Growth in the 20th Century," *Economic Journal*, 2015, *125*, 838–852.

_ , Peter Sandholt Jensen, and Peter Egedeso Madsen, "Information and Disease Prevention: Tuberculosis Dispensaries," Discussion Paper 16-01, University of Copenhagen 2016.

Hennock, Ernest P., "Vaccination Policy Against Smallpox, 1835-1914: A Comparison of England with Prussia and Imperial Germany," *Social History of Medicine*, 1998, *11* (1), 49–71.

_ , "The Urban Sanitary Movement in England and Germany, 1838-1914: A Comparison," *Continuity and Change*, 9 2000, *15*, 269–296.

_ , *The Origin of the Welfare State in England and Germany 1850 - 1914 - Social Policies Compared*, Cambridge University Press, 2007.

Hoffmann, Walter G., *Das Wachstum der deutschen Wirtschaft seit der Mitte des 19. Jahrhunderts*, Berlin: Springer Verlag, 1965.

Hohorst, Gerd, "Bevölkerungsentwicklung in Preußen und in dem Kreis Hagen von 1816 bis 1914," *GESIS Data Archive*, 1978, *ZA 8049 [2006].*

Huerkamp, Claudia, *Der Aufstieg der Aerzte im 19.Jahrhundert vom gelehrten Stand zum professionellen Experten: Das Beispiel Preussens*, Goettingen: Vandenhoeck and Ruprecht, 1985.

Imhof, Arthur E., "Lebenserwartung in Deutschland, Norwegen und Schweden im 19. und 20. Jahrhundert," ZA 8086 [2005], GESIS Cologne 1994.

Jayachandran, Seema and Adriana Lleras-Muney, "Life Expectancy and Human Capital Investments: Evidence from Maternal Mortality Declines," *Quarterly Journal of Economics*, 2009, *124* (1), 349–397.

Kesztenbaum, Lionel and Jean-Laurent Rosenthal, "The Health Cost of Living in a City: The Case of France at the End of the 19th Century," *Explorations in Economic History*, 2011, *48*, 207–225.

_ **and** _ , "Sewers' diffusion and the decline of mortality: The case of Paris, 1880-1914," *Journal of Urban Economics*, 2017, *98*, 174–186.

Kintner, Hallie J., "Trends and Regional Differences in Breastfeeding in Germany from 1871 to 1937," *Journal of Family History*, 1985, *10* (2), 163–182.

_ , "The Impact of Breastfeeding Patterns on Regional Differences in Infant Mortality in Germany, 1910," *European Journal of Population*, 1987, *3* (2), 233–261.

_ , "Recording the Epidemiologic Transition in Germany, 1816-1934," *Journal of the History of Medicine*, 1999, *54*, 167–189.

Koch, Robert, "Die Bekämpfung der Tuberkulose unter Berücksichtigung der Erfahrungen, welche bei der erfolgreichen Bekämpfung anderer Infektionskrankheiten gemacht sind," *Deutsche Medizinische Wochenschrift*, 1901, *33*, 549–554.

Krei, Thomas, *Gesundheit und Hygiene in der Lehrerbildung: Strukturen und Prozesse im Rheinland seit 1870*, Wien: Böhlau Verlag, 1995.

(KSA) - Kaiserlich Statistisches Amt, *Statistik des Deutschen Reichs, Neue Folge*, Berlin: Puttkammer & Mülbrecht, 1884-1942.

(KSB HB) - Königliches Statistisches Bureau, *Statistisches Handbuch für den Preussischen Staat*, Vol. 1-4, Berlin: Verlag des Königlichen Staatistischen Bureaus, 1888-1903.

(KSBB) - Königliches Statistisches Bureau in Berlin, *Preussische Statistik*, Vol. 1-305, Berlin: Statistisches Bureau zu Berlin, 1861-1934.

Lagomarsino, Gina, Alice Garabrant, Atikah Adyas, Richard Muga, and Nathaniel Otoo., "Moving Towards Universal Health Coverage: Health Insurance Reforms in Nine Developing Countries in Africa and Asia," *The Lancet*, 2012, *380* (9845), 933–943.

Lee, Robert, Michael C. Schneider, and Jörg Vögele, "Zur Entwicklung der Todesursachenstatistik in Preußen im 19. und frühen 20. Jahrhundert," in Josef Ehmer, Ursula Ferdinand, and Jürgen Reulecke, eds., *Herausforderung Bevölkerung: Zu Entwicklungen des modernen Denkens über die Bevölkerung vor, im und nach dem "Dritten Reich"*, Wiesbaden: VS Verlag für Sozialwissenschaften, 2007, pp. 7–16.

Lehmann-Hasemeyer, Sibylle and Jochen Streb, "Does Social Security Crowd Out Private Savings? The Case of Bismarck's System of Social Insurance," Working Paper 1/2016, Priority Programme 1859: Experience and Expectation: Historical Foundations of Economic Behaviour 2016.

Leichter, Howard M., *A comparative approach to policy analysis: Health care policy in four nations*, Cambridge: Cambridge University Press, 1979.

Leonard, Carol and Jonas Ljungberg, "Population and Living Standards, 1870-1914," in Stephen Broadberry and Kevin H. O'Rourke, eds., *The Cambridge Economic History of Modern Europe*, Vol. 2: 1870 to the Present, New York: Cambridge University Press, 2010, pp. 108–129.

Lerman, Katharine A., *Bismarck: Profiles in Power*, London: Routledge, 2004.

Leuhuscher, Georg, "Einleitung: Geschichte der Schulhygiene," in Hugo Selter, ed., *Handbuch der deutschen Schulhygiene*, Dresden, Leipzig: Verlag von Theodor Steinkopff, 1914, pp. 1–18.

Lorentzen, Peter, John McMillan, and Romain Wacziarg, "Death and Development.," *Journal of Economic Growth*, 2008, *13* (2), 81 – 124.

Malik, Khalid, *Human development report 2014: Sustaining human progress: Reducing vulnerabilities and building resilience*, New York: United Nations Development Programme, 2014.

McKeown, Thomas, *The Role of Medicine: Dream, Mirage, or Nemesis?*, Oxford: Basil Blackwell, 1979.

Meeker, Edward, "The Social Rate of Return on Investment in Public Health, 1880-1910.," *Journal of Economic History*, 1974, *34* (2), 392 – 421.

Mokyr, Joel, "Why "More Work for Mother?" Knowledge and Household Behavior, 1870-1945," *Journal of Economic History*, 2000, *60* (1), 1–41.

_ **and Rebecca Stein**, "Science, Health, and Household Technology: The Effect of the Pasteur Revolution on Consumer Demand," in Timothy F. Bresnahan and Robert J. Gordon, eds., *The Economics of New Goods*, Chicago: University of Chicago Press, 1996, pp. 143–206.

Murken, Axel Hinrich, "Aspekte zur Begruendung der klinischen Geburtshilfe und der Entbindungskliniken im 19.Jahrundert," in Hans Schadewaldt and Joern H. Wolf, eds., *Krankenhausmedizin im 19. Jahrhundert*, Munich: Muenchener Vereinigung fuer Geschichte der Medizin, 1983, pp. 70–97.

Murtin, Fabrice, "Long-term Determinants of the Demographic Transition, 1870-2000," *Review of Economics and Statistics*, 2013, *95* (2), 617–631.

Ogasawara, Kota and Genya Kobayashi, "The Impact of Social Workers on Infant Mortality in Inter-war Tokyo: Bayesian Dynamic Panel Quantile Regression with Endogenous Variables," *Cliometrica*, 2015, *9* (1), 97–130.

Paul, Johann, *Alfred Krupp und die Arbeiterbewegung*, Düsseldorf: Schwann, 1987.

Pietsch, Hartmut, "Die Feuerarbeiter. Arbeitsverhältnisse in der Duisburger Grosseisenindustrie vor dem 1. Weltkrieg," in Ludger Heid and Julius Hans Schoeps, eds., *Arbeit und Alltag im Revier. Arbeiterbewegung und Arbeiterkultur im westlichen Ruhrgebiet im Kaiserreich und in der Weimarer Republik*, Duisburg: Walter Braun Verlag, 1985, pp. 166–198.

Preston, Samuel H., "The Changing Relation Between Mortality and Level of Economic Development," *Population Studies*, 1975, *29* (2), 231–48.

Rosenbaum, Paul R. and Donald B. Rubin, "Difficulties with Regression Analyses of Age-Adjusted Rates," *Biometrics*, 1984, *40* (2), 437–43.

Rosenberg, Hans, *Depression und Bismarckzeit: Wirtschaftsablauf, Gesellschaft und Politik in Mitteleuropa*, Veroeffentlichungen der Historischen Kommission zu Berlin, 1967.

Salomon, Hermann, *Die Städtische Abwässerbeseitigung in Deutschland*, Vol. 2, Jena: G. Fischer, 1906-1907.

Scheubel, Beatrice, *Bismarck's Institutions: A Historical Perspective on the Social Security Hypothesis*, Tuebingen: Mohr Siebeck, 2013.

Spree, Reinhard, "Quantitative Aspekte der Entwicklung des Krankenhauswesens im 19. und 20.Jahrhundert: Ein Bild innerer und äusserer Verhältnisse," in Alfons Labisch and Reinhard Spree, eds., *Einem jeden Kranken in einem Hospitale sein eigenes Bett: Zur Sozialgeschichte des Allgemeinen Krankenhauses in Deutschland im 19.Jahrhundert*, Frankfurt: Campus, 1996, pp. 51–90.

Strittmatter, Anthony and Uwe Sunde, "Health and Economic Development–Evidence from the Introduction of Public Health Care," *Journal of Population Economics*, 2013, *26* (4), 1549–1584.

Subramanian, Shankar and Angus Deaton, "The Demand for Food and Calories," *Journal of Political Economy*, 1996, *104* (1), 133–162.

Szreter, Simon, "The Importance of Social Intervention in Britain's Mortality Decline C.1850-1914: A Re-interpretation of the Role of Public Health," *Social History of Medicine*, 1988, *1* (1), 1–38.

Tennstedt, Florian, *Vom Proleten Zum Indusriearbeiter: Abeiterbewegung und Sozialpolitik in Deutschland 1900 bis 1914*, Otto Brenner Stiftung, 1983.

Thomasson, Melissa, "Economic History and the Healthcare Industry," in Robert Whaples and Randall E. Parker, eds., *Routledge Handbook of Modern Economic History*, New York: Routledge, 2013, chapter 16, pp. 177–188.

Umehar, Hideharu, *Gesunde Schule und gesunde Kinder: Schulhygiene in Düsseldorf 1880-1933*, Essen: Klartext, 2013.

Vögele, Jörg, *Urban Mortality Change in England and Germany, 1870-1913.*, Liverpool University Press, 1998.

Vögele, Jörg, Wolfgang Woelk, and Bärbel Schürman, "Städtisches Armenwesen, Krankenkassen und Krankenhauspatienten während des späten 19. und frühen 20. Jahrhunderts in Düsseldorf," in Alfons Labisch and Reinhard Spree, eds., *Krankenhaus-Report 19. Jahrhundert: Krankenhausträger, Krankenhausfinanzierung, Krankenhauspatienten*, Frankfurt: Campus Verlag, 1996, pp. 405–426.

Weil, David N., "Accounting for the Effect of Health on Economic Growth.," *Quarterly Journal of Economics*, 2007, *122* (3), 1265 – 1306.

_ , "Health and Economic Growth," in Philippe Aghion and Steven N. Durlauf, eds., *The Handbook of Economic Growth*, Vol. 2B, Amsterdam: North Holland, 2014, pp. 623–682.

Winegarden, Calman R. and John E. Murray, "The Contributions of Early Health-Insurance Programs to Mortality Declines in Pre-World War I Europe: Evidence from Fixed-Effects Models," *Explorations in Economic History*, 1998, *35* (4), 431–446.

Wüst, Miriam, "Early Interventions and Infant Health: Evidence from the Danish Home Visiting Program," *Labour Economics*, 2012, *19* (4), 484–495.

Figure 1: Expansion of Health Insurance in Prussia. *The figure shows the share of health insured in the total population per year. Data refer to Prussia within its respective borders. Insurance benefits vary pre- and post-1884. The vertical bar indicates the introduction of BHI in 1884. Data source: pre 1884 - Handelsministerium, 1876; post 1884 - KSA, 1884-1942*

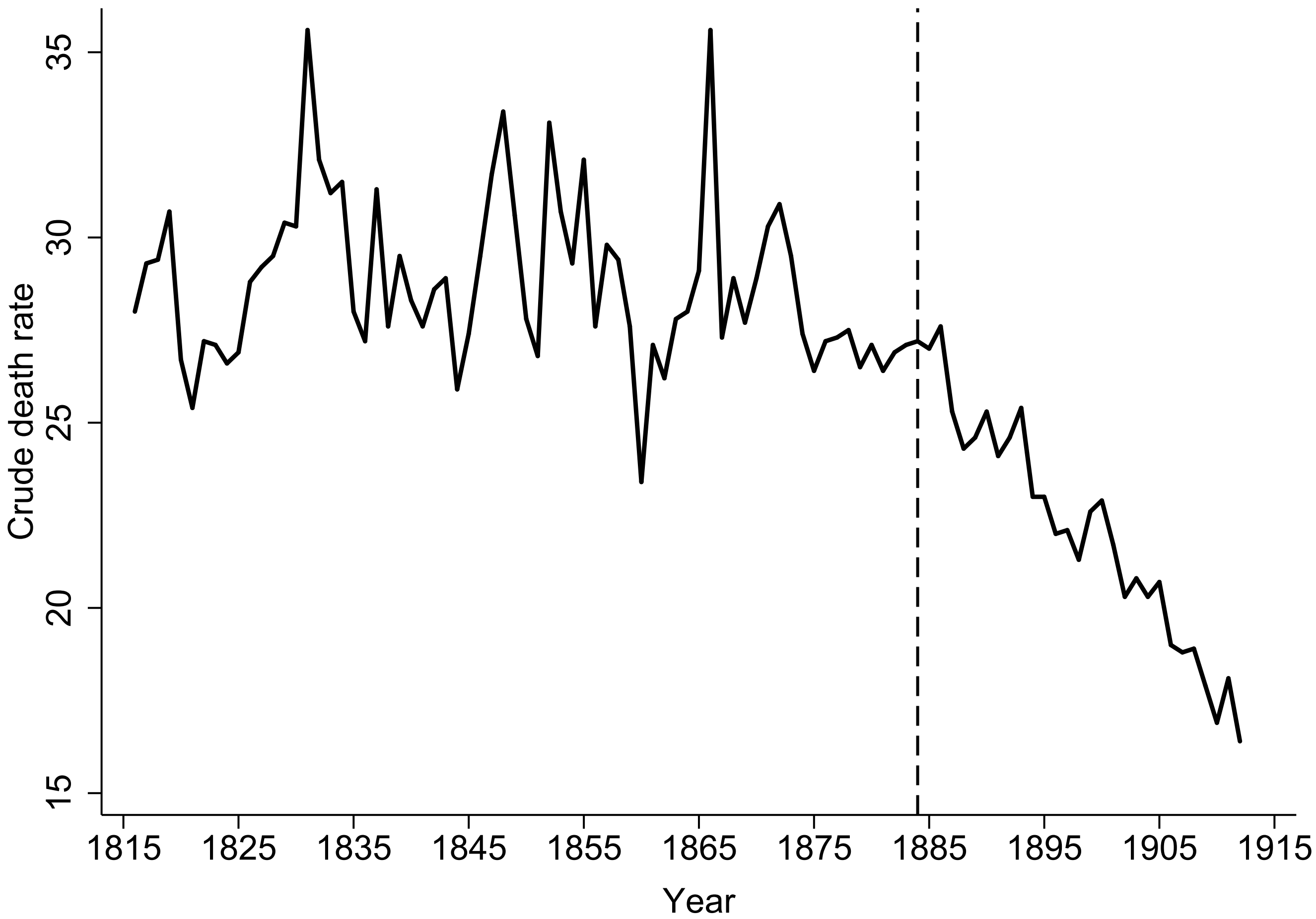

Figure 2: Long-run development of mortality in Prussia. *The figure shows the crude death rate defined as the total number of deaths per year per 1,000 people. The vertical bar indicates the introduction of BHI in 1884. Data source: Hohorst (1978)*

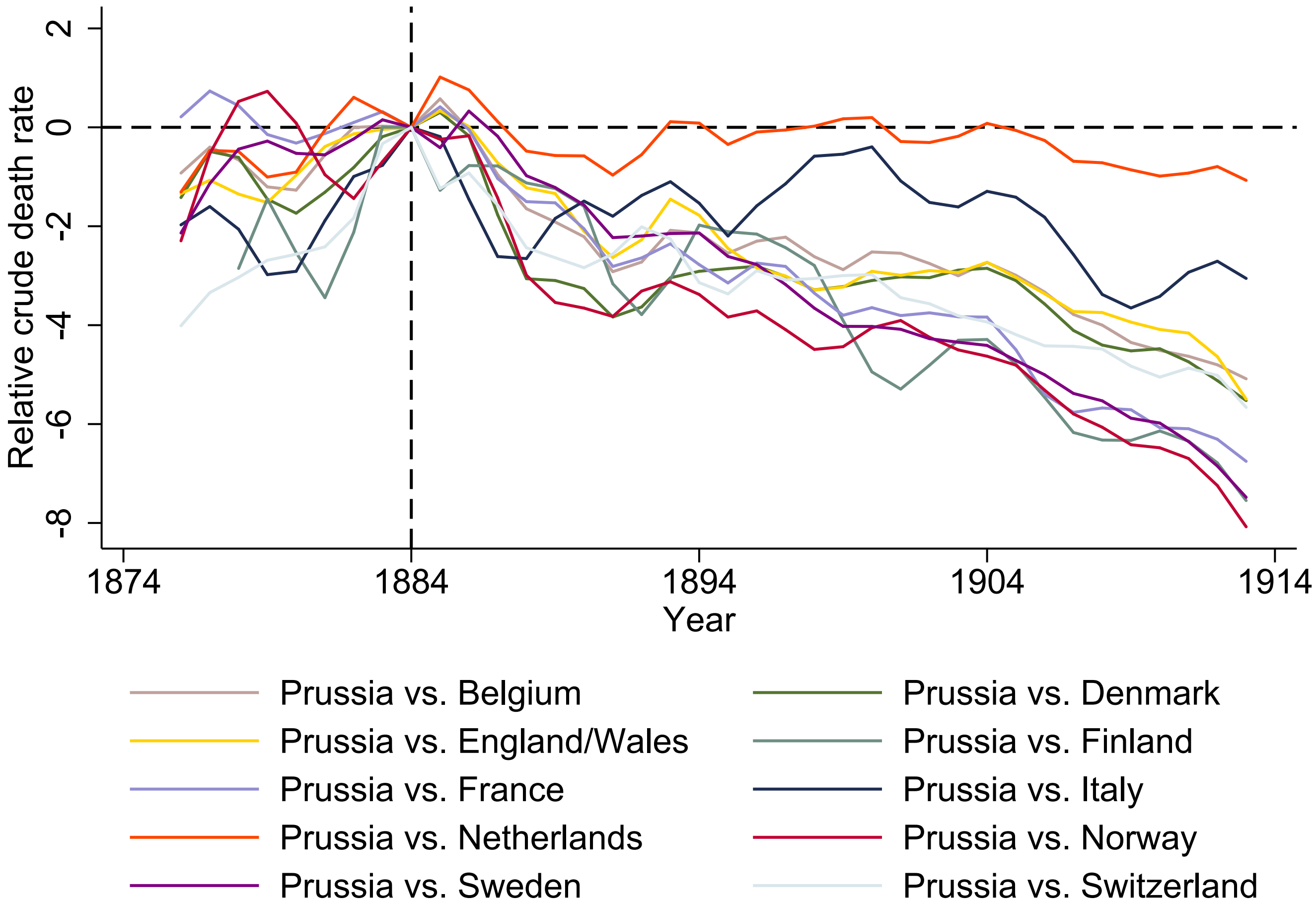

Figure 3: International mortality decline relative to Prussia. *The figure shows the number of deaths per 1,000 people in Prussia minus the number of deaths per 1,000 people in the respective other country over time. The variable is normalized to zero in 1884. The trends are smoothed by applying country-pair-specific local regressions using a tricube weighting function (Cleveland, 1979) and bandwidths 0.8 to the left and 0.2 to the right of the cut-off year 1884. The vertical bar indicates the introduction of BHI in 1884. Data source: Human Mortality Database (http://www.mortality.org)*

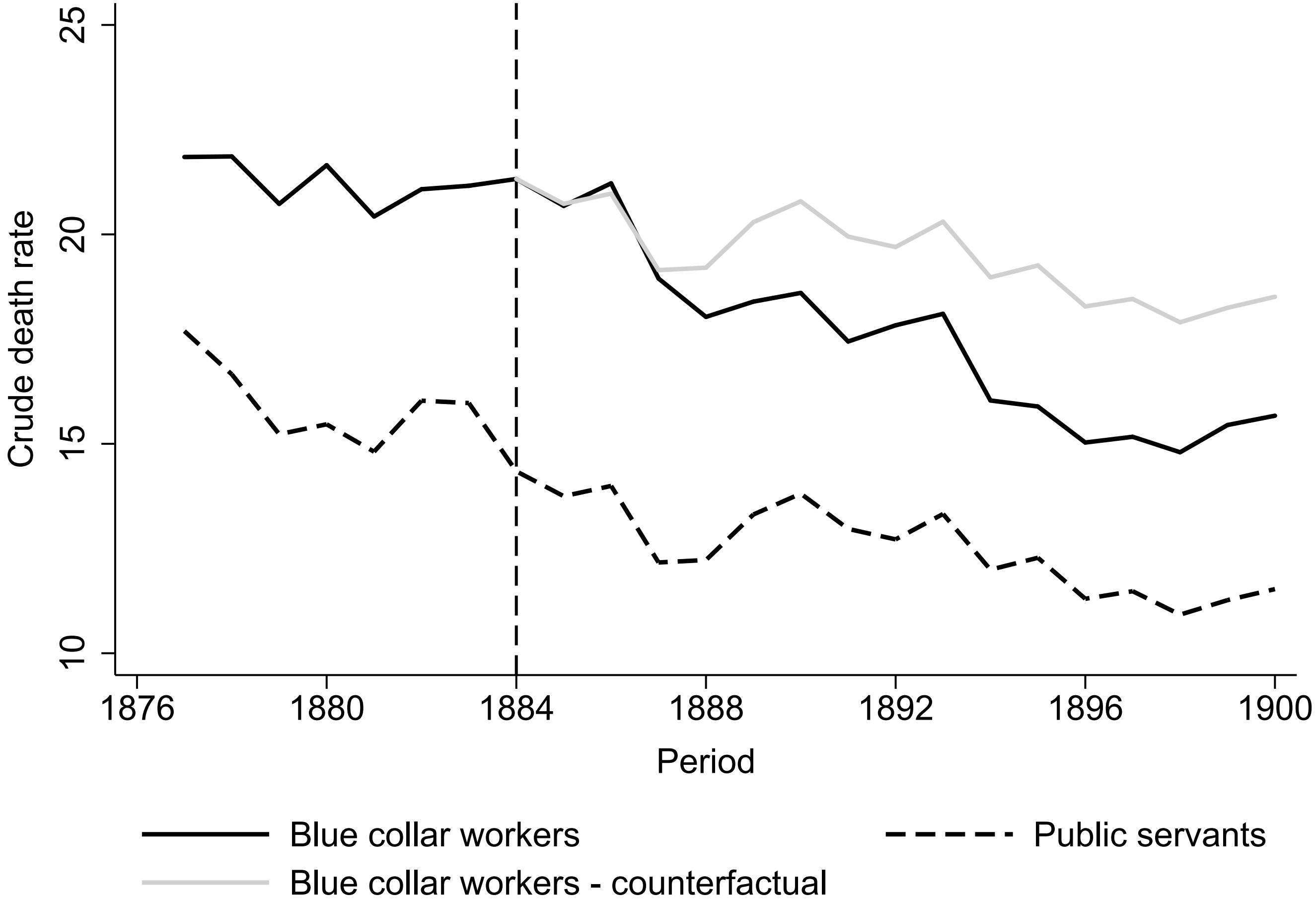

Figure 4: Crude death rates by sector (blue collar workers and public servants). *The figure shows the number of deaths per 1,000 people by sectoral groups of blue-collar workers and public servants. Following a difference-in-differences logic, the counterfactual is computed by parallel-shifting the trend of the public servants up to the blue collar workers level in 1884. The vertical bar indicates the introduction of BHI in 1884.*

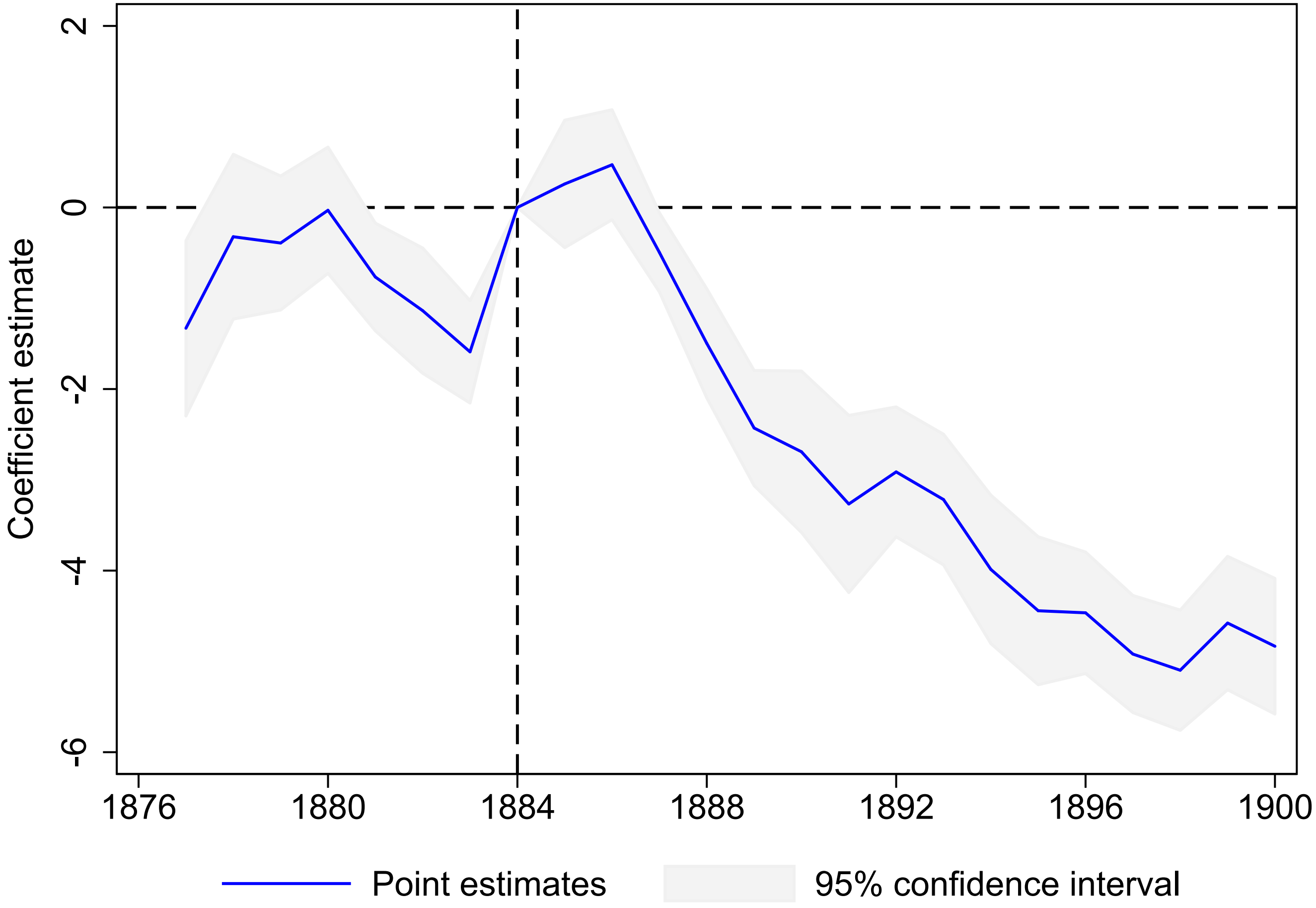

Figure 5: Flexible-DiD estimates. *The figure shows estimated coefficients and 95% confidence intervals from a difference-in-differences model similar to Equation 1 using annual data and accounting for pre-trends. The omitted year 1884 is marked by the vertical line and indicates the introduction of BHI.*

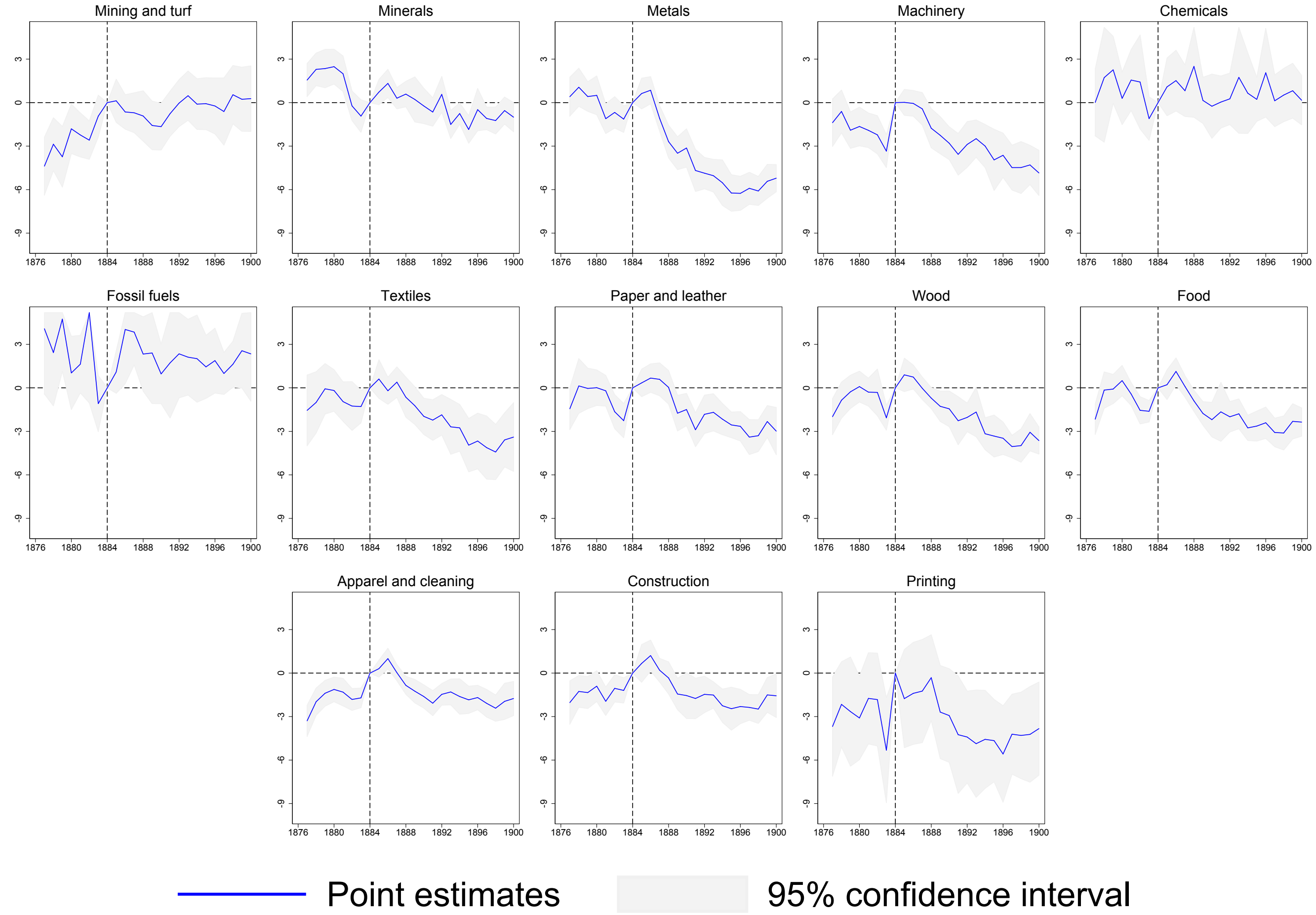

Figure 6: Flexible-DiD estimates by industry. *The figure shows estimated coefficients and 95% confidence intervals from a difference-in-differences model similar to Equation 1 using annual data and individual blue collar industries. The omitted year 1884 is marked by the vertical lines and indicates the introduction of BHI.*

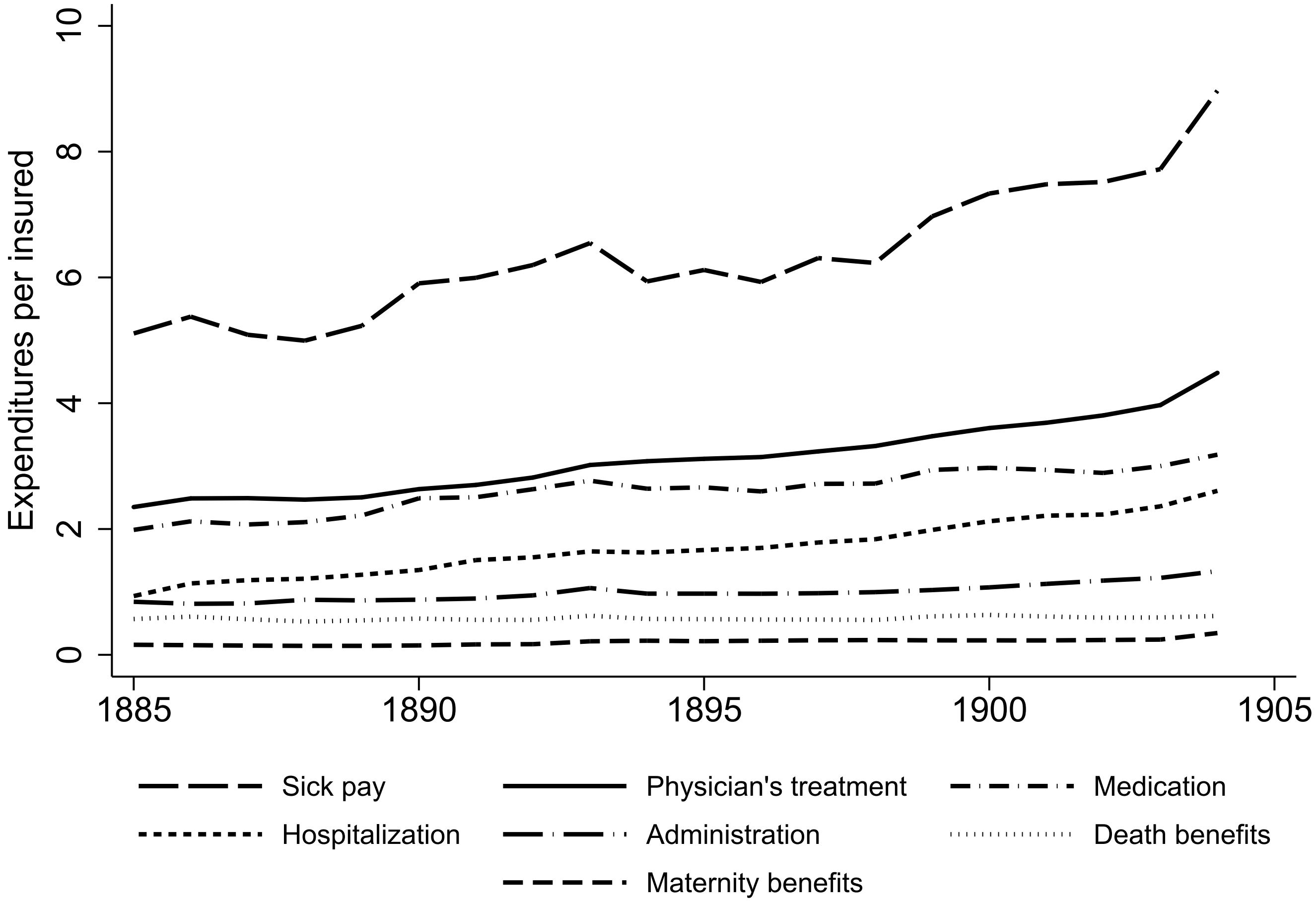

Figure 7: Sickness funds' expenditures per insured in Marks. *The figure shows types of sickness funds' expenditures per insured in Marks over time. Data source: KSA, 1884-1942*

Table 1: Sectoral occupation structure

	Industrial sector			Public sector		
	1882	1895	1907	1882	1895	1907
Total occupational population	9,394	12,196	16,244	1,306	1,672	2,043
Working population	3,651	4,756	6,688	587	823	1,027
Female working population	585	761	1,078	61	97	166
Share in total population	34.4%	38.3%	43.6%	4.8%	5.2%	5.5%
Share in working population	31.2%	35.9%	37.1%	5.0%	6.2%	5.7%
Share in female working population	17.5%	22.3%	18.7%	1.8%	2.8%	2.9%

Notes: The table reports descriptive statistics based on the occupation censuses conducted in the German Empire in 1882, 1895, and 1907. The industrial sector refers to the official sector B (Industry), while the public sector refers to the official sector E (Public). Absolute population numbers are reported in thousands. The *Total Occupational Population* includes children and non-employed family members and assigns to them the occupation of the father or husband, respectively.

Table 2: Flexible DiD: main results

Dep. var.: Deaths per occ. Pop.	Baseline (1)	Urbanization (2)	Waterworks (3)	Sewerage (4)
Blue Collar x 1877	-0.1617	-0.3161	-0.3335	-0.2319
	(0.2272)	(0.2410)	(0.2146)	(0.2255)
Blue Collar x 1885	1.0627***	1.2011***	1.1798***	1.1250***
	(0.1604)	(0.1499)	(0.1800)	(0.1554)
Blue Collar x 1889	-0.9193***	-0.6621**	-0.5766	-0.7835***
	(0.2761)	(0.2563)	(0.3603)	(0.2811)
Blue Collar x 1893	-1.6119***	-1.2193***	-1.0993**	-1.3931***
	(0.2747)	(0.2856)	(0.4285)	(0.3101)
Blue Collar x 1897	-1.9076***	-1.3332***	-1.2747***	-1.5905***
	(0.2869)	(0.4146)	(0.3831)	(0.3766)
Urbanization x Sector	No	Yes	No	No
Waterworks x Sector	No	No	Yes	No
Sewerage x Sector	No	No	No	Yes
District x Sector FE	Yes	Yes	Yes	Yes
District x Time FE	Yes	Yes	Yes	Yes
Observations	432	432	432	432
R-squared	0.94	0.94	0.94	0.94

Notes: The table reports flexible DiD estimates. All variables are averaged over four year periods from 1877 to 1900. The dependent variable measures crude deaths rates using deaths by occupation of the household head per alive occupational population (including dependents) in thousands. The omitted period is 1881-84. Column (2) adds the urbanization rate as a covariate, column (3) adds waterworks per capita as a covariate, while column (4) adds sewerage per capita as a covariate. Standard errors are clustered at the occupation by district level and given in parentheses. * 10%, **5%, *** 1% confidence level

Table 3: Flexible DiD: heterogeneity

Dep. var.: Deaths per occ. Pop.	Baseline	Male	Female	Children
	(1)	(2)	(3)	(4)
Blue Collar x 1877	-0.1617	0.0573	-0.2390***	0.0200
	(0.2272)	(0.0695)	(0.0584)	(0.1585)
Blue Collar x 1885	1.0627***	0.3741***	0.0663	0.6223***
	(0.1604)	(0.0701)	(0.0425)	(0.1126)
Blue Collar x 1889	-0.9193***	-0.4118***	-0.1578***	-0.3497**
	(0.2761)	(0.1079)	(0.0536)	(0.1738)
Blue Collar x 1893	-1.6119***	-0.5091***	-0.1783***	-0.9244***
	(0.2747)	(0.1011)	(0.0548)	(0.1774)
Blue Collar x 1897	-1.9076***	-0.5659***	-0.2307***	-1.1110***
	(0.2869)	(0.0927)	(0.0669)	(0.2112)
District x Sector FE	Yes	Yes	Yes	Yes
District x Time FE	Yes	Yes	Yes	Yes
Observations	432	432	432	432
R-squared	0.94	0.92	0.91	0.93

Notes: The table reports flexible DiD estimates. All variables are averaged over four year periods from 1877 to 1900. The dependent variable measures crude deaths rates using deaths by occupation of the household head per alive occupational population (including dependents) in thousands. The omitted period is 1881-84. The dependent variable in column (1) is total mortality, the dependent variable in column (2) is adult male mortality, the dependent variable in column (3) is adult female mortality, and the dependent variable in column (4) is child mortality. Standard errors are clustered at the occupation by district level and given in parentheses. * 10%, **5%, *** 1% confidence level

Table 4: County fixed effects using 1882 blue-collar workers' share

Dep. var.: Crude death rate	Base	Controls	Male	Female	Infants	LegInf	IllegInf	Placebo
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment x 1875	1.891	1.606	-5.714***	0.711	-20.264*	-23.030*	10.630	2.946
	(1.623)	(1.621)	(1.713)	(1.764)	(11.363)	(11.948)	(56.422)	(3.650)
Treatment x 1885	-7.768***	-7.417***	-7.433***	-6.690***	4.018	1.761	27.650	1.452
	(1.693)	(1.689)	(1.965)	(1.596)	(11.484)	(11.989)	(47.676)	(3.098)
Treatment x 1890	-4.754**	-3.983*	-6.971***	-6.550***	-19.437	-30.964**	45.986	-1.712
	(2.041)	(2.053)	(2.395)	(2.079)	(15.279)	(15.668)	(55.537)	(3.798)
Treatment x 1895	-8.631***	-7.619***	-5.881**	-8.454***	-34.598*	-55.767***	79.660	-3.007
	(2.080)	(2.092)	(2.570)	(2.153)	(20.049)	(20.287)	(77.044)	(4.627)
Treatment x 1900	-12.330***	-11.380***	-16.123***	-13.119***	-45.863*	-73.912***	103.370	1.023
	(2.399)	(2.372)	(2.813)	(2.500)	(24.973)	(24.832)	(79.473)	(4.984)
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2645	2645	2645	2645	2645	2645	2645	2645
Counties	441	441	441	441	441	441	441	441
Periods	6	6	6	6	6	6	6	6
R-squared	0.75	0.75	0.74	0.74	0.24	0.27	0.03	0.75

Notes: The table reports county-level fixed effects estimates. All variables are averaged over five year periods from 1875 to 1904. The dependent variable measures crude death rates using total deaths per alive population in thousands. The dependent variable in columns (1), (2), and (8) is total mortality, the dependent variable in column (3) is male mortality, the dependent variable in column (4) is female mortality, and the dependent variable in column (5) is infant mortality (< 1 year) per 1,000 births. The dependent variable in column (6) is infant mortality (< 1 year) born in wedlock per 1,000 births in wedlock, while the dependent variable in column (7) is infant mortality (< 1 year) born out of wedlock per 1,000 births out of wedlock. The treatment variable in columns (1) to (7) is the blue collar workers' population share in 1882, interacted with time-period dummies. The treatment variable in column (8) is public servants' population share in 1882, interacted with time-period dummies. The treatment variable in column (8) is public servants' population share in 1882, interacted with time-period dummies. Column (2) adds the urbanization rate, waterworks per capita, and sewerage per capita as covariates. The omitted period is 1880-84. Standard errors are clustered at the county level and given in parentheses. * 10%, **5%, *** 1% confidence level

Table 5: Robustness tests using district-level data

	Initial Blue Collar Workers (1882)				Initial Insured (1885)			
Dep. var.: Crude DR	Controls	Average age	Age groups	SPD vote	Controls	Average age	Age groups	SPD vote
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment x 1875	3.41	3.46	-10.56**	2.88	4.59	4.67	-9.35**	4.48
	(4.47)	(4.40)	(4.57)	(4.28)	(5.13)	(5.12)	(4.34)	(5.00)
Treatment x 1885	-11.14**	-11.77**	-9.19**	-10.91**	-15.21**	-14.96**	-12.45***	-14.85**
	(5.30)	(5.22)	(3.61)	(5.33)	(6.51)	(6.64)	(4.44)	(6.69)
Treatment x 1890	-7.27	-8.49	-8.04	-5.84	-12.53	-11.90	-11.27	-11.11
	(8.55)	(8.57)	(7.34)	(8.38)	(11.02)	(11.13)	(8.86)	(11.22)
Treatment x 1895	-11.97	-12.96*	-11.28*	-10.40	-17.87**	-17.76*	-13.52**	-16.81*
	(7.23)	(6.82)	(5.83)	(7.23)	(8.52)	(9.08)	(6.37)	(9.50)
Treatment x 1900	-14.91**	-16.39**	-17.04**	-13.19*	-22.79***	-22.70***	-21.39***	-21.63**
	(6.80)	(6.31)	(7.10)	(6.85)	(7.40)	(8.17)	(7.84)	(8.67)
Standard controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Average age	No	Yes	No	No	Yes	No	No	No
Age groups	No	No	Yes	No	No	No	Yes	No
SPD vote	No	No	No	Yes	No	No	No	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	216	216	216	216	216	216	216	216
Districts	36	36	36	36	36	36	36	36
Periods	6	6	6	6	6	6	6	6
R-squared	0.88	0.89	0.92	0.88	0.89	0.89	0.92	0.89

Notes: The table reports district-level fixed effects estimates. All variables are averaged over five year periods from 1875 to 1904. The dependent variable is the crude death rate measured as total deaths per alive population in thousands. The treatment variable in columns (1) to (4) is blue collar workers' population share in 1882 interacted with time-period dummies. The treatment variable in columns (5) to (8) is the share of the population covered by health insurance observed in 1885 interacted with time-period dummies. Standard controls include the urbanization rate, waterworks per capita, and sewerage per capita. In columns (2) and (6), the average age of a district's population is included as a covariate. In columns (3) and (7), we add seven time-varying variables capturing the size of age cohorts as a fraction of the total population (cohorts: 1-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70 plus). In columns (4) and (8), the vote share of the workers' party SPD (and its predecessors) measured at the latest general elections is included as a covariate. The omitted period is 1880-84. Standard errors are clustered at the district level and given in parentheses. * 10%, **5%, *** 1% confidence level

Table 6: District fixed effects: causes of death

Dep. var.: Crude DR	Accident	Infectious				Non-infectious	Maternal	Unknown
		Waterborne	Airborne	Lung	TB+Scrofula			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment x 1875	0.162	3.299*	-3.962**	-3.175*	-0.736	-0.571	-0.030	2.087
	(0.155)	(1.749)	(1.707)	(1.627)	(0.791)	(0.873)	(0.101)	(1.273)
Treatment x 1885	-0.090	2.324	-8.606***	-1.493	-0.396	-0.874**	-0.186***	-0.305
	(0.151)	(2.053)	(2.721)	(1.785)	(0.714)	(0.371)	(0.068)	(1.390)
Treatment x 1890	0.271*	1.803	-4.561	-3.911	-3.317***	-1.243**	-0.186**	1.857
	(0.136)	(3.221)	(4.315)	(2.741)	(0.931)	(0.563)	(0.084)	(2.023)
Treatment x 1895	0.290**	0.422	-4.916	-7.272***	-5.842***	-1.891**	-0.183**	3.581
	(0.139)	(4.169)	(3.638)	(2.387)	(1.215)	(0.720)	(0.078)	(2.212)
Treatment x 1900	0.426**	0.602	-8.062***	-11.007***	-8.464***	-3.436***	-0.053	4.412*
	(0.169)	(3.968)	(2.891)	(1.982)	(1.745)	(0.990)	(0.114)	(2.500)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	216	216	216	216	216	216	216	216
Districts	36	36	36	36	36	36	36	36
Periods	6	6	6	6	6	6	6	6
R-squared	0.54	0.27	0.80	0.60	0.86	0.28	0.92	0.79

Notes: The table reports district-level fixed effects estimates. All variables are averaged over five year periods from 1875 to 1904. The dependent variable measures death rates by causes of death using total deaths per alive population in thousands. The treatment variable is blue collar workers' population share observed in 1882 interacted with time-period dummies. *Accident* is death from accidents; *Waterborne* is death from typhus, typhoid fever, and three types of diarrheal diseases; *Airborne* is death from smallpox, scarlet fever, measles, diphtheria, pertussis, scrofula, tuberculosis, tracheitis, pneumonia and other lung diseases; *Lung* is death from pertussis, scrofula, tuberculosis, pneumonia and other lung diseases; *TB+Scrofula* is death from scrofula and tuberculosis; *Non-infectious* is death from cancer, edema, stroke, heart disease, brain disease, and kidney disease; *Maternal* is maternal death related to childbirth; *Unknown* is unknown or unspecified cause of death. Controls include the urbanization rate, waterworks per capita, and sewerage per capita. The omitted period is 1880-84. Standard errors, are clustered at the district level and given in parentheses. * 10%, **5%, *** 1% confidence level.

Table 7: Mortality and health expenditures

Panel A - Dependent variable: Crude death rate; Explanatory variable as indicated in column head

	Health care expenditures			Compensation expenditures			Administration expenditures	Days of sick leave
	Doctor visits	Medication	Hospitalization	Sickpay	Maternity ben.	Death ben.		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.Expenditure(std)	-0.114**	-0.160***	-0.042	-0.013	-0.062*	0.065	-0.081	-0.038
	(0.056)	(0.042)	(0.072)	(0.071)	(0.036)	(0.040)	(0.064)	(0.036)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	684	684	684	684	684	684	684	576
Districts	36	36	36	36	36	36	36	36
Periods	19	19	19	19	19	19	19	16
R-squared	0.81	0.81	0.80	0.80	0.80	0.80	0.80	0.79

Panel B - Dependent variable: Crude death rate by cause of death as indicated in column head; Explanatory variable as indicated

			Infectious					
	All	Accident	Waterborne	Airborne	Lung	TB+Scrofula	Non-infectious	Maternal
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.Health care(std)	-0.139*	0.079	-0.225	-0.043	-0.302***	-0.333***	-0.196*	0.095
	(0.070)	(0.111)	(0.147)	(0.107)	(0.106)	(0.103)	(0.100)	(0.063)
L.Compensation(std)	0.003	0.059	-0.033	0.047	0.019	0.010	-0.080	-0.062
	(0.053)	(0.116)	(0.074)	(0.069)	(0.103)	(0.091)	(0.064)	(0.057)
L.Administration(std)	-0.024	0.092	-0.153	-0.088	-0.182*	-0.079	0.075	0.052
	(0.050)	(0.098)	(0.137)	(0.104)	(0.104)	(0.098)	(0.076)	(0.070)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	612	612	612	612	612	612	612	612
Districts	36	36	36	36	36	36	36	36
Periods	17	17	17	17	17	17	17	17
R-squared	0.75	0.17	0.52	0.69	0.60	0.78	0.26	0.70

Notes: The table reports district-level fixed effects estimates. The dependent variable measures crude death rates using total annual deaths per alive population in thousands (panel A) or annual death rates by cause of death per alive population in thousands (panel B). *Accident* is death from accidents; *Waterborne* is death from typhus, typhoid fever, and three types of diarrheal diseases; *Airborne* is death from smallpox, scarlet fever, measles, diphtheria, pertussis, scrofula, tuberculosis, tracheitis, pneumonia and other lung diseases; *Lung* is death from pertussis, scrofula, tuberculosis, pneumonia and other lung diseases; *TB+Scrofula* is death from scrofula and tuberculosis; *Non-infectious* is death from cancer, edema, stroke, heart disease, brain disease, and kidney disease; *Maternal* is maternal death related to childbirth. Explanatory variables are sickness funds' expenditures per insured or duration of sick leave per insured lagged by one year. All variables are normalized to a mean zero and a standard deviation of one. Controls include the urbanization rate, waterworks per capita, and sewerage per capita, each lagged by one year. Standard errors are clustered at the district level and given in parentheses. * 10%, **5%, *** 1% confidence level.

A Appendix (for online publication only)

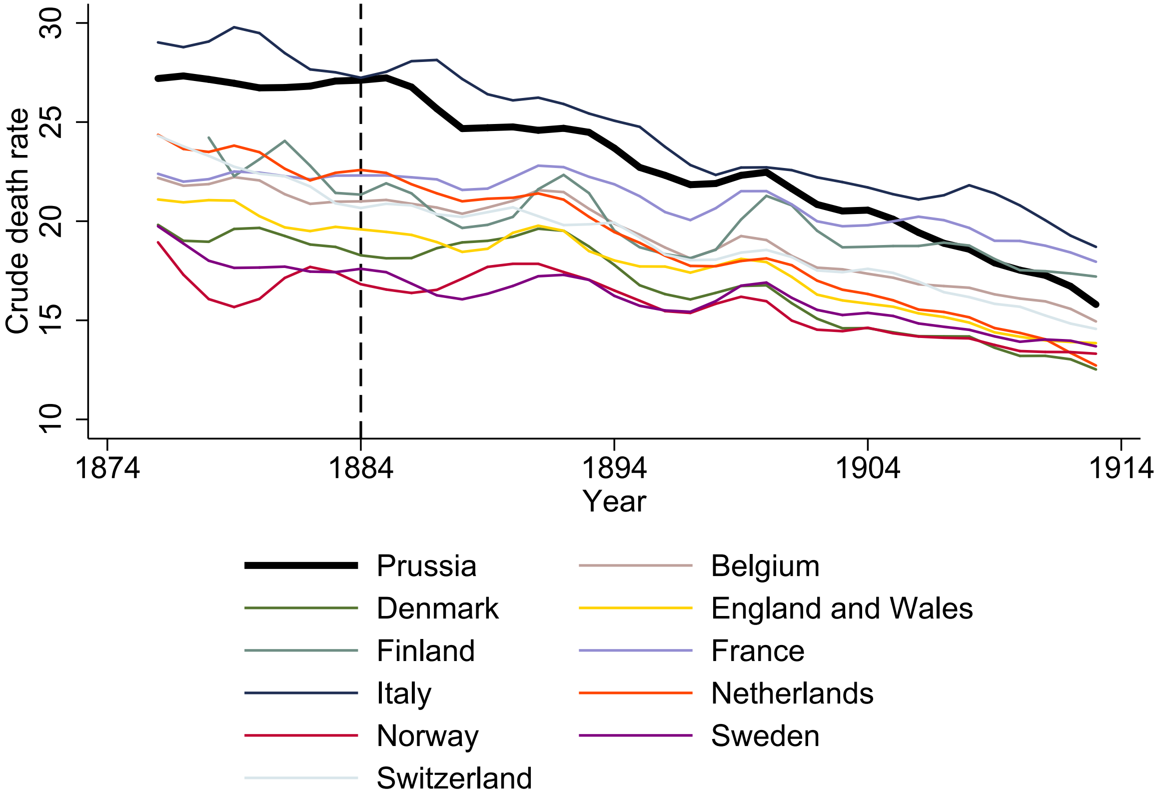

Figure A.1: Mortality decline across Western European countries. *The figure shows the total number of deaths per year per 1,000 people for several countries. The trends are smoothed by applying country-specific local regressions using a tricube weighting function (Cleveland, 1979) and a bandwidth of 0.15. The vertical bar indicates the introduction of BHI in 1884. Data source: Human Mortality Database (http://www.mortality.org)*

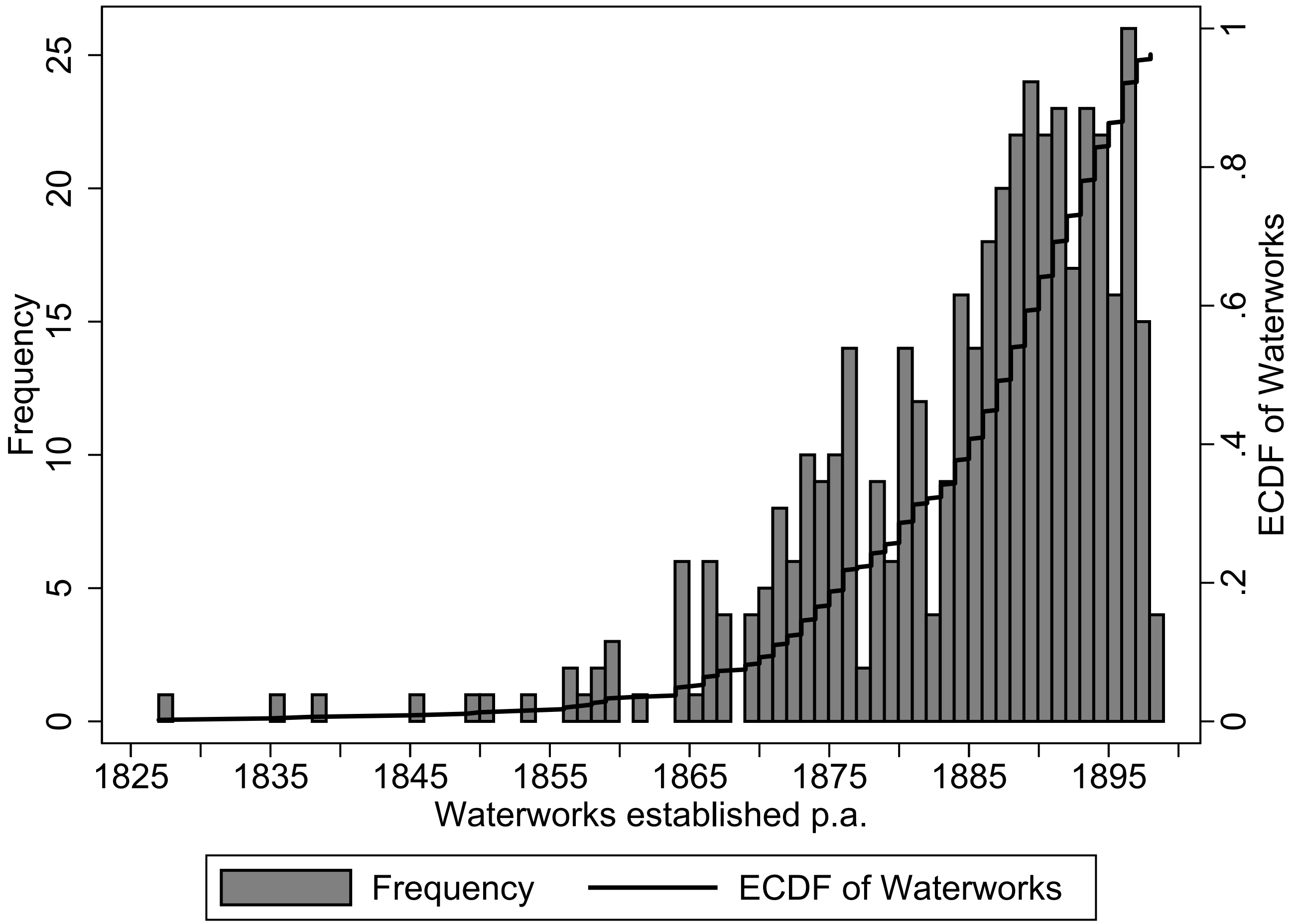

Figure A.2: The roll-out of waterworks in Prussia. *The figure shows the roll-out of waterworks in Prussian cities over time. The bars indicate the annual number of new waterworks put into service. The line indicates the cumulative distribution function. Data source: Grahn (1898-1902)*

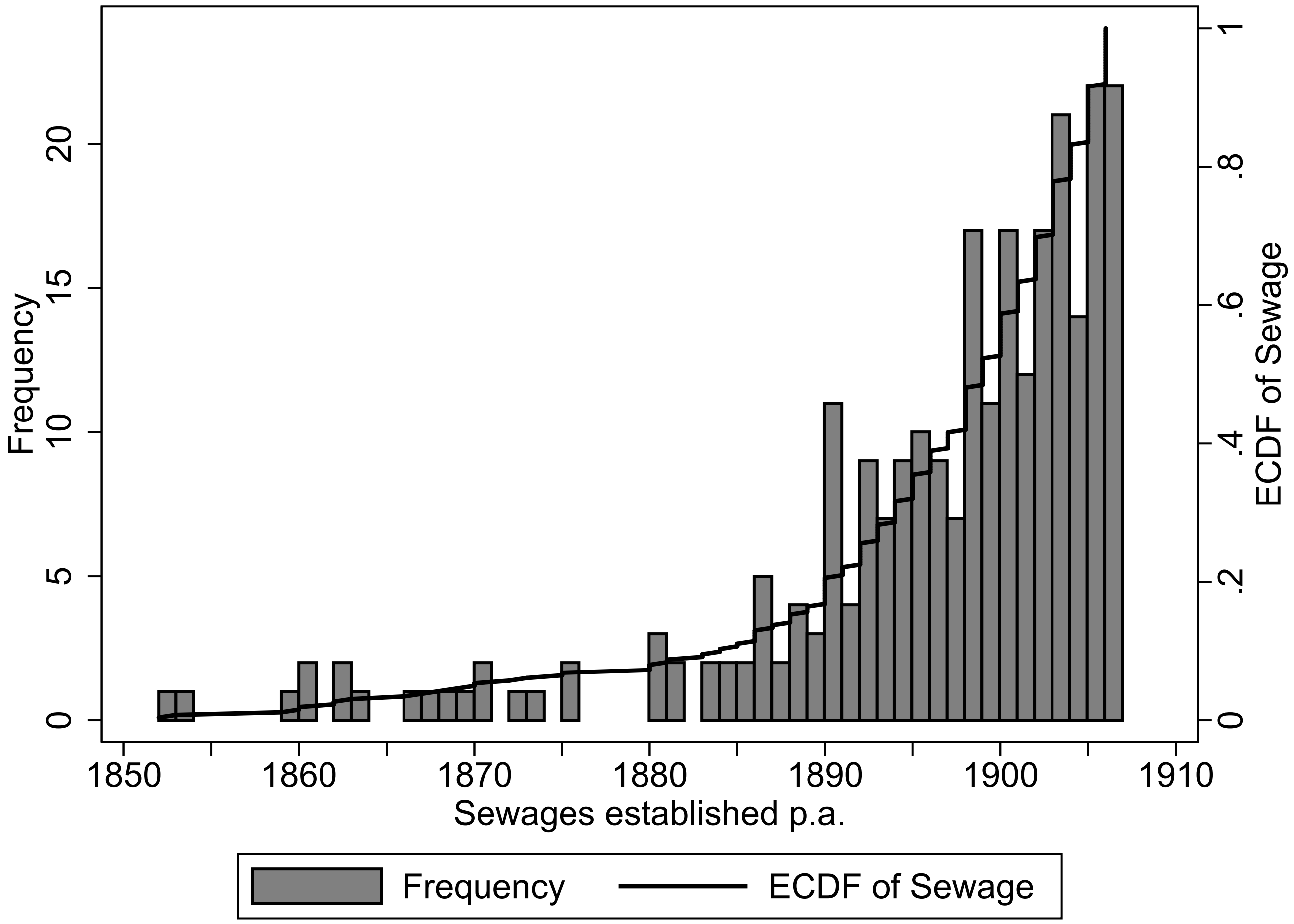

Figure A.3: The roll-out of sewerage in Prussia. *The figure shows the roll-out of sewerage systems in Prussian cities over time. The bars indicate the annual number of new sewerage put into service. The line indicates the cumulative distribution function. Data source: Salomon (1906-1907)*

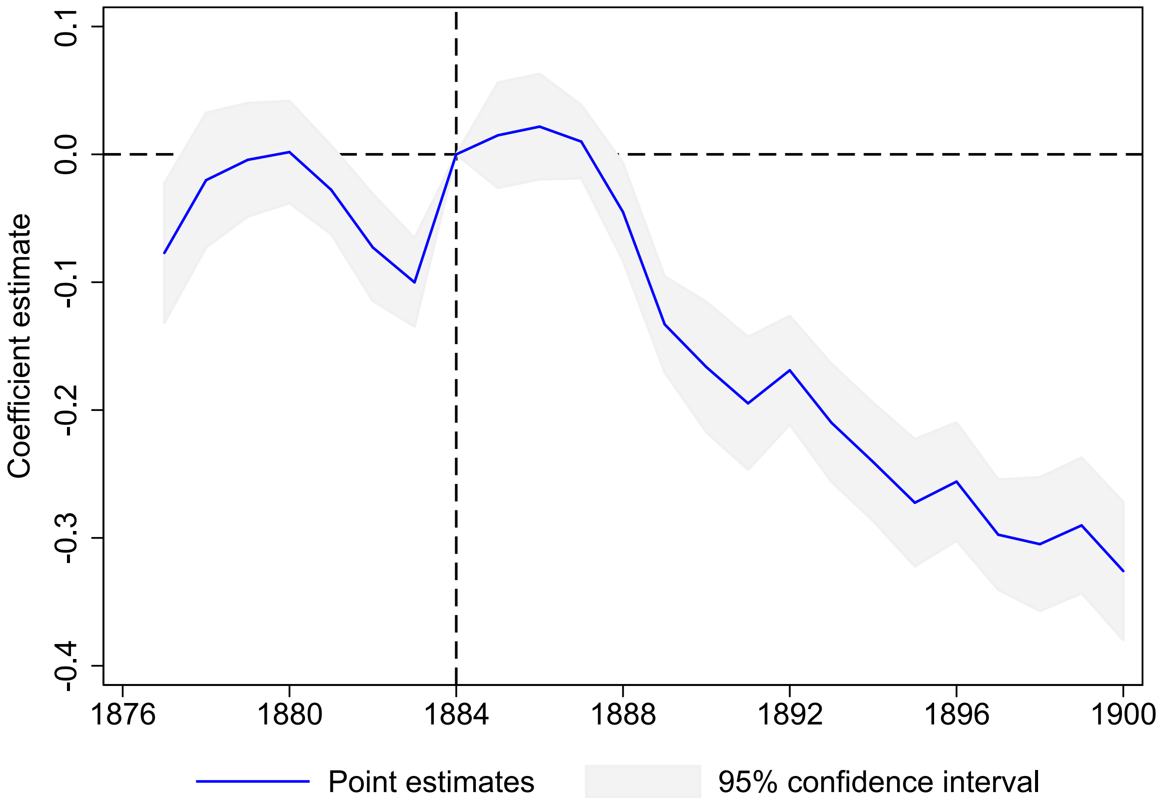

Figure A.4: Flexible-DiD estimates in log-specification. *The figure shows estimated coefficients and 95% confidence intervals from a difference-in-differences model similar to Equation 1 using annual data and accounting for pre-trends. The omitted year 1884 is marked by the vertical bar and indicates the introduction of BHI.*

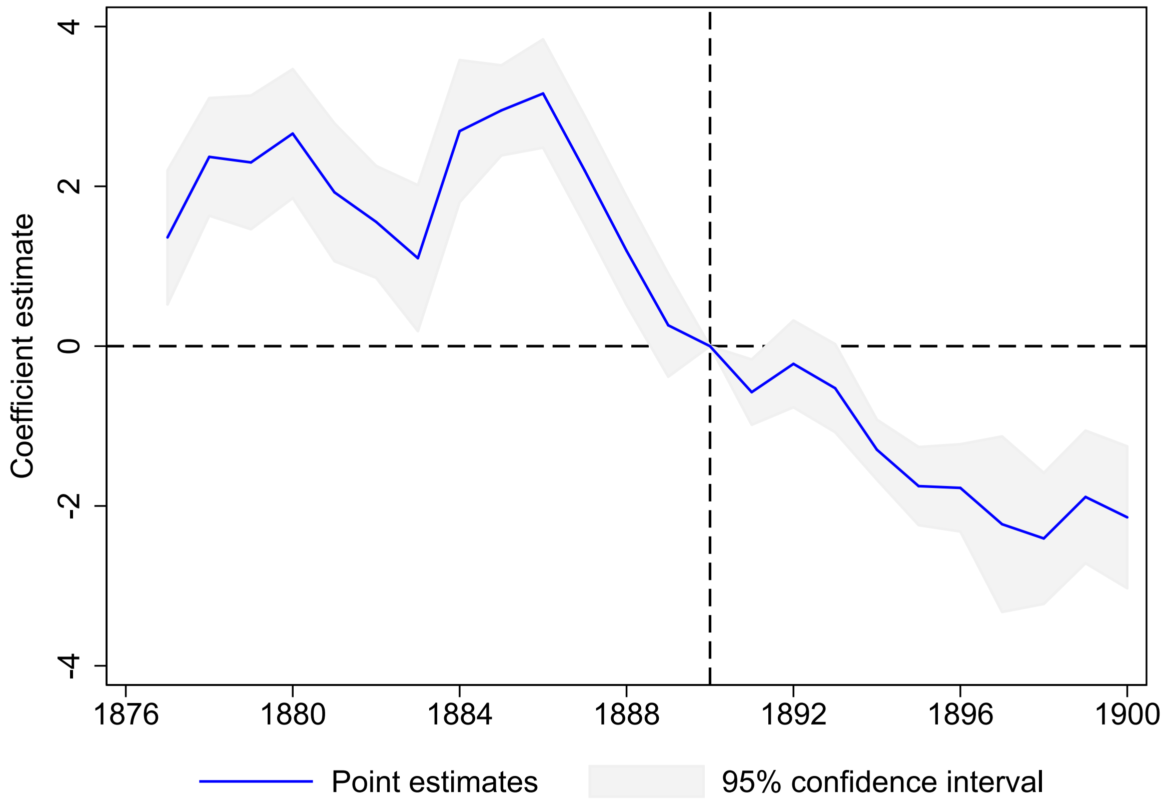

Figure A.5: Flexible-DiD estimates using 1890 as reference. *The figure shows estimated coefficients and 95% confidence intervals from a difference-in-differences model similar to Equation 1 using annual data and accounting for pre-trends. The omitted year 1890 is marked by the vertical bar and indicates the introduction of the old-age pension system.*

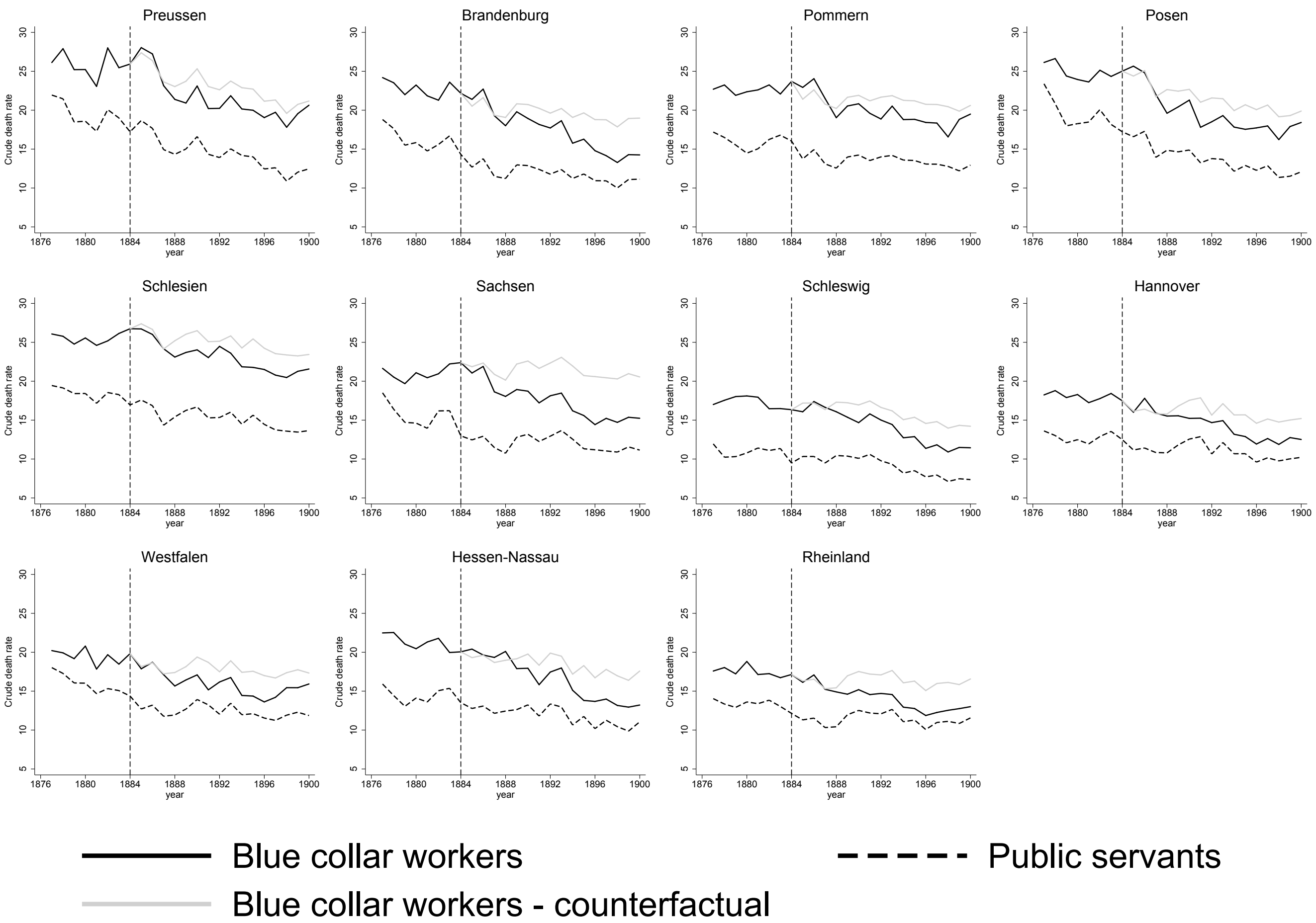

Figure A.6: Crude death rates by sector (blue collar workers and public servants) and province. *The figure shows the number of deaths per 1,000 people by sectoral groups of blue-collar workers and public servants for each Prussian province. Following a difference-in-differences logic, the counterfactual is computed by parallel-shifting the trend of the public servants up to the blue collar workers level in 1884. The vertical bars indicate the introduction of BHI in 1884.*

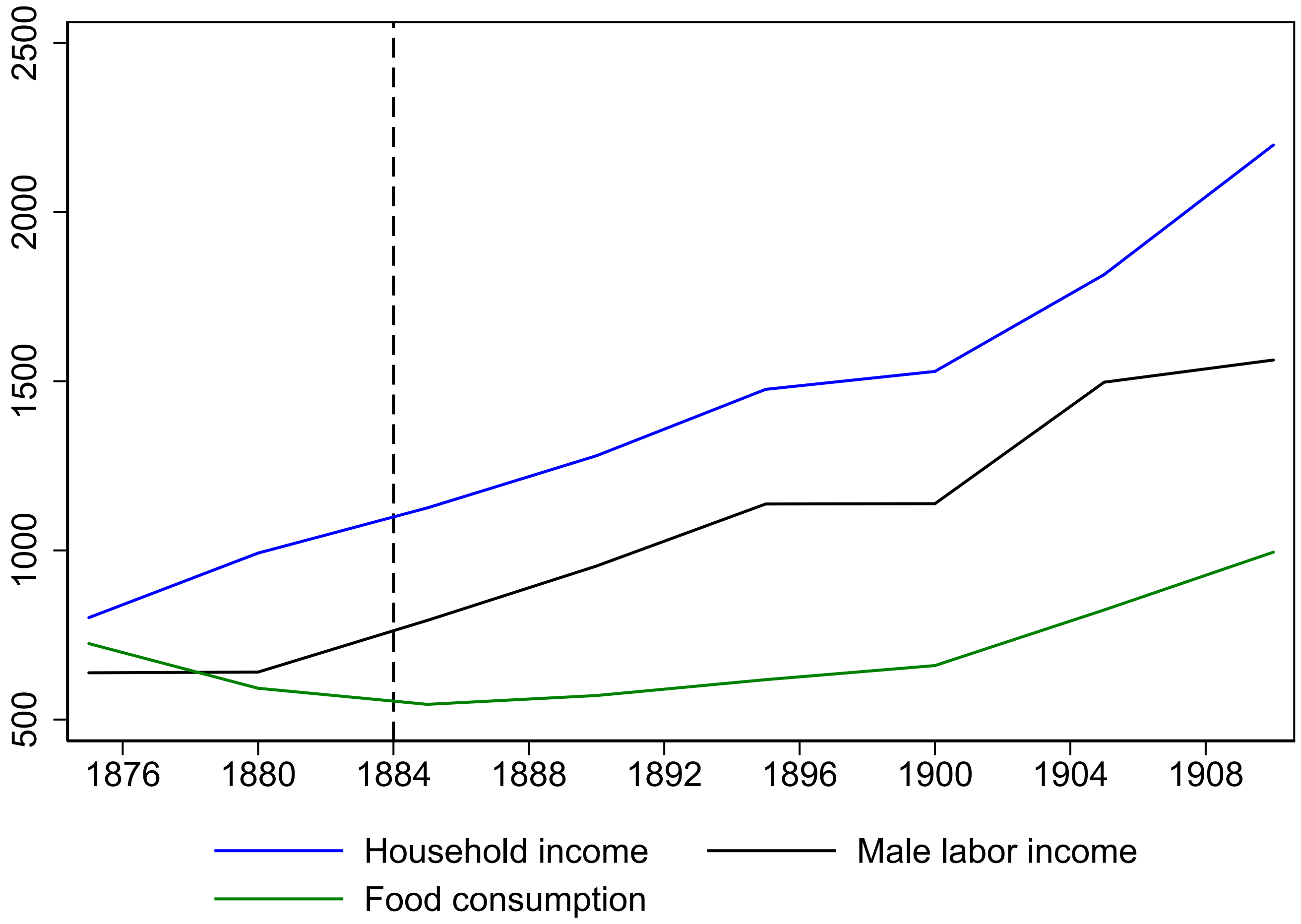

Figure A.7: Worker's Income and Food Consumption *The figure shows the average household income (all sources), male labor income and food consumption (excluding luxury items) of blue-collar workers within five year periods from 1870-1910. The data is based on individual-level data from household accounts as reported by Fischer (2011).*

Table A1: Expansion of health insurance

Year	Population	Health Insured	% Insured Population
1854	17,077	254	1.5%
1860	18,136	329	1.8%
1864	19,149	458	2.4%
1868	24,069	688	2.9%
1870	24,403	632	2.6%
1872	24,801	725	2.9%
1874	25,352	795	3.1%
1876	25,922	785	3.0%
1885	28,232	2,263	8.0%
1890	29,819	3,457	11.6%
1895	31,697	3,998	12.6%
1900	34,254	5,123	15.0%
1905	37,058	6,192	16.7%

Notes: The table shows descriptive statistics on the expansion of health insurance in Prussia within its respective borders. Population and the number of insured are expressed in thousands. Insurance benefits vary pre- and post-1884.

Table A2: District fixed effects using blue collar workers and insured population

	Initial Blue Collar Workers (1882)					Initial Insured (1885)				
Dep. var.: Crude DR	Base	Controls	Male	Female	LegInf	Base	Controls	Male	Female	LegInf
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Treatment x 1875	3.37	3.41	-3.19	2.01	13.30	5.04	4.67	-3.48	3.56	17.71
	(3.35)	(4.47)	(4.41)	(5.40)	(42.84)	(4.30)	(5.12)	(4.70)	(6.44)	(49.36)
Treatment x 1885	-11.19**	-11.14**	-12.34**	-12.20**	-23.87	-15.01**	-14.96**	-15.55**	-15.69**	-54.41
	(4.60)	(5.30)	(5.72)	(5.31)	(41.39)	(6.11)	(6.64)	(7.33)	(6.75)	(47.36)
Treatment x 1890	-7.07	-7.27	-12.25	-12.51	-93.97	-11.27	-11.90	-18.87	-18.04	-153.11*
	(7.90)	(8.55)	(11.15)	(9.37)	(71.55)	(10.65)	(11.13)	(14.44)	(12.21)	(83.26)
Treatment x 1895	-11.64	-11.97	-12.13	-15.64*	-154.22	-16.73*	-17.76*	-19.48	-22.39**	-234.92**
	(6.98)	(7.23)	(9.97)	(7.82)	(93.18)	(9.16)	(9.08)	(12.68)	(9.72)	(105.54)
Treatment x 1900	-15.05**	-14.91**	-19.21**	-19.20**	-162.05*	-21.83**	-22.70***	-28.81**	-28.66***	-242.41**
	(7.27)	(6.80)	(9.42)	(7.18)	(88.70)	(9.00)	(8.17)	(11.68)	(8.52)	(99.95)
Controls	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	216	216	216	216	216	216	216	216	216	216
Districts	36	36	36	36	36	36	36	36	36	36
Periods	6	6	6	6	6	6	6	6	6	6
R-squared	0.88	0.88	0.85	0.86	0.47	0.88	0.89	0.86	0.87	0.49

Notes: The table reports district-level fixed effects estimates. All variables are averaged over five year periods from 1875 to 1904. The dependent variable in columns (1), (2), (6), and (7) is crude death rates measured as total deaths per alive population in thousands. The dependent variable in columns (3) and (8) is male mortality, the dependent variable in columns (4) and (9) is female mortality, and the dependent variable in columns (5) and (10) is infant mortality (< 1 year) born in wedlock per 1,000 births in wedlock. The treatment variable in columns (1)-(5) is blue collar workers' population share observed in 1882 interacted with time-period dummies. The treatment variable in columns (6)-(10) is the share of the population covered by health insurance in 1885 interacted with time-period dummies. The omitted period is 1880-84. Controls include the urbanization rate, waterworks per capita, and sewerage per capita. Standard errors are clustered at the district level and given in parentheses. * 10%, **5%, *** 1% confidence level

Table A3: The supply of health services

Dep. var.:	Initial Blue Collar Workers (1882)	
	Doctors	Hospital Patients
	(1)	(2)
Treatment x 1875	-0.19	
	(0.17)	
Treatment x 1885	-0.06	0.01**
	(0.08)	(0.00)
Treatment x 1890	0.04	0.03***
	(0.09)	(0.01)
Treatment x 1895	0.34	0.04***
	(0.28)	(0.01)
Treatment x 1900	0.43	
	(0.40)	
Controls	Yes	Yes
District FE	Yes	Yes
Time FE	Yes	Yes
Observations	216	144
Districts	36	36
Periods	6	4
R-squared	0.73	0.81

Notes: The table reports district-level fixed effects estimates. The treatment variable is blue collar workers' population share observed in 1882 interacted with time-period dummies. The dependent variable in column (1) is the number of licensed doctors per capita. The dependent variable in column (2) is the number of inpatients in hospitals (unavailable prior to 1880). Controls include the urbanization rate, waterworks per capita, and sewerage per capita. The omitted period is 1880-84. Standard errors are clustered at the district level and given in parentheses. * 10%, **5%, *** 1% confidence level