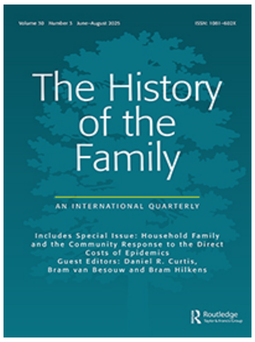

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Epidemics and urban growth: the impact of cholera in Nineteenth-century Prussia

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ABSTRACT

The literature has long studied the economic consequences of epidemics. While plague and influenza episodes have received substantial attention by researchers, the same does not apply to cholera outbreaks. We examine the impact of cholera in urban Prussia during the 19th century with two novel datasets containing detailed information on cholera mortality and population growth for almost one thousand cities. Our results show that cities experiencing an additional one-percentage-point increase in cholera mortality grew ca. 0.5% less right after an epidemic. This size effect is representative of the three pandemic periods we consider, namely 1831–1837, 1848–1859 and 1865–1874. In addition, we find that post-epidemic growth recovery was rather fast during the second and fourth pandemics, but somewhat sluggish during the third one. We consider three factors that can account for post-epidemic trajectories – market potential, prevalence of rural serfdom and degree of industrialization – through their influence on labor supply and demand. Our results suggest that the flow of unskilled short-distance migration to urban areas during the second pandemic possibly reduced the labor supply shock induced by cholera. In subsequent pandemics, however, a mixture of labor supply and demand constraints created a context where relative recovery after the epidemic outbreaks happened in some places but not others. In particular, peaks in Transatlantic migration could have led to increased competition for migrants and therefore lower overall labor supply. Also, depressed labor demand could have reduced economic opportunities in shocked cities characterized by increasing returns.

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1. Introduction

The literature has long studied the economic consequences of epidemics. Two diseases, in particular, have received substantial attention by researchers: plague and influenza.[1] This is perhaps unsurprising, given the exceptional mortality rates of bubonic plague and the unprecedentedly fast diffusion of the 1918 Influenza pandemic. The economic impact of cholera, on the other hand, has remained understudied,[2] even though it also took the lives of millions of people in a series of global pandemics starting in the early 19th century

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and thus caused widespread societal disruptions (Harper, 2021; McNeill, 1976). This gap in our knowledge is even more surprising, if one considers the vast literature documenting the broader social and demographic effects of this disease (Baldwin, 2004; Hamlin, 2009; Rosen, 1958/1993).

The lack of quantitative work on the economic impact of cholera is a missed opportunity to learn about the relationship between demographic shocks and the economy. This illness thrived in dense and unhealthy city environments and was therefore closely connected to industrial and economic development (Evans, 1988). Improved transportation, growing market integration and expanding commercial exchange facilitated the spread of cholera (Vögele et al., 2021). In urban labor markets, the demographic shock caused sudden and substantial declines in the availability of workers, while leaving capital largely untouched, which provides an appropriate setting to study how local economies reacted to unforeseen labor scarcity issues.[3] While this mechanism has been studied for the Black Death and other pre-industrial epidemics (e.g., Alfani, 2022; Jedwab et al., 2024; van Bavel et al., 2020), two distinct aspects of cholera can shed new light into how European societies suffered, mitigated and recovered from demographic shocks: cholera emerged repeatedly in a series of epidemic waves rather than as a single major shock; and local economies were much more integrated during the 19th century in regional and international markets. In this context, it is unclear whether we should expect lower or greater rates of post-epidemic recovery. On the one hand, cities affected by the labor *supply* shock had greater opportunities to grow due to increased mobility, market integration and economic potential. On the other hand, post-epidemic weak *demand* for skilled labor could have depressed urban markets relying on economies of scale. In sum, more evidence is needed to understand the net economic impact of cholera.

The present article contributes to the literature with an analysis of the economic impact of cholera in 19th-century urban Prussia. This case is interesting for various reasons. First, the country suffered greatly from multiple outbreaks of this disease in the context of three pandemics: 1831–1837, 1848–1859 and 1865–1874.[4] These outbreaks are well documented with high-quality historical records, which allow overcoming some pitfalls associated with the study of pre-industrial epidemics, such as incomplete disease reporting (Roosen & Curtis, 2019). The data indicate that epidemic years drove overall mortality rates up to 35 per 1,000, ca. 23% higher deaths than in 'normal' years; some locations lost more than 10% of their population in a single year. Second, the vast geographic extent of Prussia and its marked regional heterogeneity result in a rich set of experiences that we can analyze to obtain a representative estimate of the economic impact of cholera and post-epidemic growth paths. And third, various developments after ca. 1820 released powerful equalizing forces via migration with potential to alleviate urban labor scarcity, namely the abolition of serfdom, the expansion of railways and industrialization (Pierenkemper & Tilly, 2004). In addition, our setting has two advantages when compared to other epidemic contexts. Military conflicts impacting the economy do not explain the regional diffusion of cholera in 19th-century Prussia, with the exception of the 1866 outbreak, as common with other pre-industrial epidemics (van Besouw & Curtis, 2022). Also, unlike more modern disease outbreaks, controlling the diffusion of cholera was challenging due to imperfect knowledge of its aetiology and lack of efficient public health infrastructures before the sanitary revolution (Gallardo-Albarrán, 2025; Kappner, 2024b). This resulted in a diverse set of epidemiological experiences, with a wide range of mortality rates.

We have constructed two new datasets for our analyses. The first is one of the most comprehensive and detailed spatiotemporal accounts of the mortality impact of cholera within an industrializing economy. Our sample contains almost one thousand cities with complete information on all epidemics that ravaged the country from the 1830s to the 1870s. This allows us to capture a broad set of local experiences across various dimensions, such as population size or the structure of the economy. We then relate cholera deaths to post-epidemic growth trajectories using information on population, a widely-used metric in the literature to proxy for economic development in the absence of highly-disaggregated indicators of production, such as gross domestic product.[5] Our population figures refer to multiple benchmarks during the 19th century and therefore offer substantial information to study growth dynamics after the epidemic shocks.

Our results show that cities experiencing a one percentage point higher cholera mortality grew ca. 0.5% less right after an epidemic than their less affected counterparts. This size effect is representative of the three pandemic periods we consider, namely 1831–1837, 1848–1859 and 1865–1874. Given that average cholera mortality during the second pandemic (1831–1837) was 2.14 per 100, excluding unaffected places, our results imply that the outbreak initially brought down city growth by 0.93%. This represents eight percent of the total growth that this group of cities experienced during the pre-epidemic period. For the third and fourth pandemics, this figure becomes 30% and 19%, respectively. In addition, our results show that post-epidemic growth recovery was rather fast during the second and fourth pandemics. It did not take longer than three years since the last cholera outbreak for cities to return to 'normal' growth paths. The exception is the third pandemic in the 1850s, when growth rates remained persistently low in shocked cities for almost ten years.

Our estimates of the effect of cholera on population dynamics are correlational, though we try to rule out a number of potentially important confounders, namely: city-specific invariant factors, such as long-run climate; the impact of previous cholera pandemics; and economic characteristics, such as initial population levels, industrialization and market potential. Importantly, our analyses focus on towns' trajectories *within* provinces, so that (unobserved) differences in, say, economic development or demography *between* these geographic units do not drive our results.

The second part of our analysis considers three factors that influenced the ability of cities to recover after an epidemic in the short- to medium-term: market potential, prevalence of serfdom in the countryside and degree of industrialization. The first two influence the capacity of cities to attract workers from labor surplus areas, while the latter refers to the type of labor in demand that will tend to be higher skilled in more sophisticated local economies.

Our results show that the flow of unskilled short-distance migration to urban areas during the second pandemic reduced the labor supply shock induced by cholera. Indeed, we find that less-industrialized cities with higher levels of market potential and serf emancipation recovered quicker. In subsequent pandemics, however, a mixture of labor supply and demand constraints created a context where relative recovery after the epidemic outbreaks happened in some places but not others. In particular, peaks in Transatlantic migration during the 1840s and 1850s could have led to increased competition for migrants and therefore lower available labor supply. On the other hand, depressed labor demand could have reduced economic opportunities in shocked cities characterized by increasing returns.

Our research adds to the literature on the economic impact of historical epidemics, such as plague (Alfani, 2022; Voigtländer & Voth, 2013); or the 1918 Influenza (Correia et al., 2022; Gallardo-Albarrán & de Zwart, 2021; Noy et al., 2023). Our city-level empirical setting is close to that by Jedwab et al. (2024), who find large population declines following the Black Death and faster recovery in places with greater access to trade networks. Our results do not show such a long-run dramatic demographic collapse because both cholera was less deadly than plague and Prussian cities grew at high rates during the 19th century. However, even in an expansive demographic context, we find noticeable and persistent effects among cholera shocked cities, particularly during the 1840s and 1850s.

Our work also relates to a vast literature exploring different aspects of the demographic impact of epidemics in a variety of settings (e.g., Alfani et al., 2024; Biraben, 1975; Curtis, 2016; Murray et al., 2006). In the German context, Franke (2022) argues that poverty and pollution exacerbated the mortality impact of the 1918 Influenza in the Kingdom of Württemberg. With regards to cholera, the work by Davenport et al. (2019) on the 1832 and 1849 outbreaks in England is comparable to ours, in that they employ town-level data to model their spatial diffusion. We add to this body of work by presenting a novel dataset on cholera deaths for about a thousand cities during the most deadly outbreaks of the 19th century.

Finally, our work contributes to studies looking at drivers of long-run economic development in Germany. This literature has emphasized (among others) labor reform, factor endowments, technological change, human capital accumulation, transport infrastructures or trade (Ashraf et al., 2025; Becker & Woessmann, 2009; Gutberlet, 2014; Hornung, 2015; Keller & Shiue, 2014; Uebele & Gallardo-Albarrán, 2014). We add cholera to the picture and argue that although the impact we find is temporary, this was large enough to provoke medium-term economic disruptions, particularly during the third and fourth pandemics. In addition, our empirical exercise can be seen as a 'stress' test of German labor markets. Supporting the idea that migration flows responded to market mechanisms (Grant, 2005), we find that temporary urban labor scarcity was compensated with additional workers, though at different speeds throughout the 19th century.

2. Historical context

2.1. The mortality impact of cholera during the 19th century

Cholera entered Central Europe in the 1830s causing widespread fear. Baldwin (2004, pp. 56–57) describes how just the sight of patients, doctors or hearse were perceived as dangerous to the extent that cases caused by fear, *Angst-Cholera*, were reported. The feeling of imminent death after the onset of its grossly physical symptoms and the absence of effective treatments left a lasting imprint on the population and authorities. Cholera typically decided the fate of a victim within 6 days, with an incubation period of 18 hours to 5 days and a fatality rate of about 50% in pre-modern periods for the most severe cases (Clemens et al., 2017, p. 1543), and an estimated overall case fatality rate of ca. 15% (Ewald, 1991, p. 86).

Historical sources are in a very good position to reliably trace the diffusion of cholera in Prussia. Early on, heads of families were obliged to report all cases of illness or unexpected death (Baldwin, 2004, p. 46). The obligation to report cases of infectious disease was extended to other groups (e.g., the clergy or innkeepers), though in the 1840s medical personnel assumed this responsibility entirely. Doctors were acquainted with the disease because they had either witnessed it in person or read detailed descriptions of its symptoms and consequences for the body (Schmitz-Cliever, 1952, p. 269). Also, autopsies were used in some cases to certify if someone had died from cholera. Another reason why the historical record contains rich information about this disease is that it attracted substantial attention. Authorities and medical experts often published local and regional accounts about the spread of the disease and its correlates, using local death registers (e.g., Müller, 1867). As epidemics broke out multiple times, reports often contained detailed comparisons between epidemics along various spatial, temporal and socioeconomic dimensions (e.g., Liévin, 1868). Also, some doctors published accounts of their experience with the disease, as exemplified by the work of Hartung (1833) in Aachen.

Various distinct epidemics hit Prussia between 1831 and 1874, when the last substantial outbreak ended. This is illustrated in Figure 1, where we present aggregate data on cholera deaths (vertical bars) and crude death rates per 1,000 (vertical axis). For the latter we highlight years in which cholera accounted for at least 1% of all deaths ('cholera years') with a '+' marker. Finally, the dashed line depicts long-run trends by smoothing annual variation with a local polynomial filter.

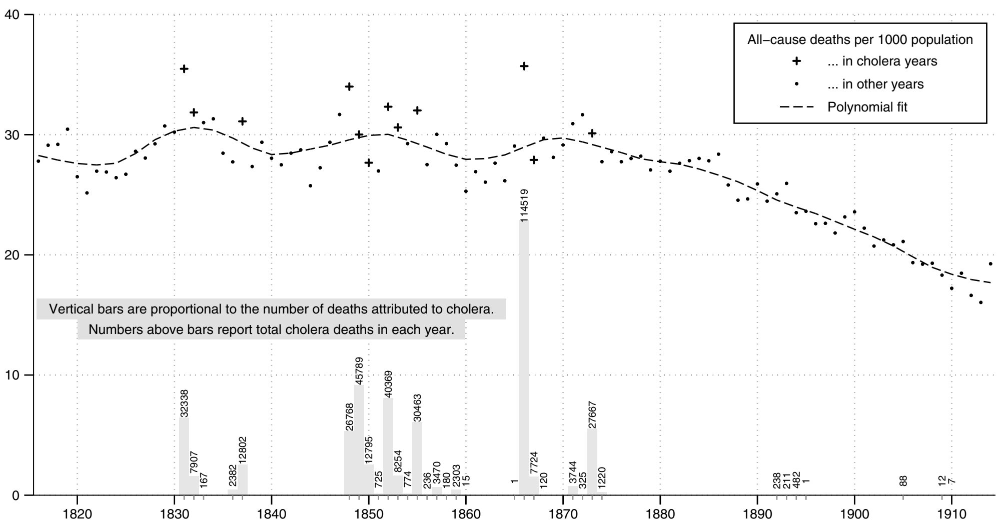


Figure 1. All-cause and cholera deaths in Prussia, 1816–1914. Note: The figure shows annual all-cause deaths per 1,000 for Prussia in its pre-1866 borders from 1816 to 1914. Years in which cholera deaths account for at least 1% of all deaths ('cholera years') are depicted with a '+' marker. The dashed line is obtained with a local polynomial regression, using the plotted annual figures. The vertical bars in the lower part of the figure are proportional to the number of registered cholera deaths in each year and the associated labels provide the number of deaths attributed to this disease. Source: Cholera deaths from Kappner (2025); All-cause deaths and population from Königlich Statistisches Bureau in Berlin (1879, 8–9, 34–37) and Galloway (2007). Population counts after 1910 have been extrapolated based on pre-1910 growth rates.

The first epidemic in 1831 took place within the so-called second pandemic starting in 1826 (Evans, 1988, p. 125). In Prussia, it began in large sea ports along the Baltic coast, such as Danzig (Gdańsk). Soon, cases were registered in the East Prussian provinces, close to the Russian Empire that had been subject to cholera outbreaks by 1830. While Prussia's Western provinces were spared in 1831, a secondary outbreak in 1832 also affected the Rhineland due to its close commercial ties to France, Belgium and the Netherlands. By 1838, Prussian medical authorities had attributed almost 56,000 deaths to cholera Kappner (2025). The second pandemic was a significant mortality event: The Prussian crude death rate in 1831 reached 35.5 per 1,000, only to be matched by the 1866 rate: 35.7 per 1,000 (see Figure 1).

Prussian authorities did not stand still upon the arrival of cholera, as they implemented a number of strategies to halt its spread. Baldwin (2004, pp. 43–48), documents how the initial reaction in the 1830s was informed by previous experiences with other infectious outbreaks. Certainly, authorities tried to learn more about the epidemiological nature of the disease, for instance, by sending a commission to study the disease in Russia. There was little consensus about its spreading mechanisms (Ross, 2015, p. 18) and, in the end, strict sanitary measures were pursued by deploying military cordons along the Polish and Russian borders, setting up quarantine stations to enter Prussia from Poland, and using health certificates to prove that travelers had passed through uninfected areas.

After a decade of absence, cholera came back with full force during the third pandemic (1841–1859). Major demographic crises happened in 1848, 1849, 1850, 1852 and 1855. Most of these were imported either via the Eastern and Southern land connections to Russia, Poland, Bohemia and Austrian Galicia, or via the Baltic sea ports. By the 1840s, the most strict interventions had to be retracted due to population resistance, lack of state and fiscal capacity to sustain them for a long period of time, and the recognition that they could not fully contain the epidemic (Baldwin, 2004). In Düsseldorf, for instance, the practice of placing large warning signs on the houses of infected individuals was abolished in 1848 and quarantine regulations became significantly more relaxed (Fliescher, 1977, p. 16).

The most violent outbreak happened in the context of the fourth pandemic (1863–1875), aggravated by the troop movements during the Austro-Prussian war in 1866. As we can see in Figure 1, that year exhibited the highest crude death rate over the whole 19th century (35.71 per 1,000), comparable only to the 1831 outbreak. Further local epidemics followed in the early 1870s and 1873 saw Prussia's last major outbreak, when cholera once again entered from the East and moved westwards through rivers and the, by now, extensive railroad network. After 1874, Prussian authorities remained sensitive to the threat of cholera, but the kingdom was spared from any further substantial outbreaks.[6] This development coincides with Prussia's sustained mortality transition caused by greater access to sanitary infrastructures and health care (Bauernschuster et al., 2020; Gallardo-Albarrán, 2020, 2024). At that time, knowledge about the epidemiology of cholera accumulated and there was wider appreciation for public health measures that took into account the link between cholera and contaminated water (Gallardo-Albarrán, 2025; Kappner, 2024b). The 1866 epidemic in Aachen is a good example, as sewage discharges from the cholera hospital were separated from those of the rest of the city and waterproof cesspools were constructed (Schmitz-Cliever, 1952, p. 275), while little had been done during the third cholera pandemic.

2.2. An economy in transition

The German economy went through three phases during the 19th century. The first began around 1820 and lasted until 1850, which can be characterized as post-Malthusian. During these decades, population growth did not lead to declines in material welfare, real wages remained stationary and Malthusian positive checks disappeared (Pfister, 2023). This was the result of Smithian growth coming from increasing market size, labor division and market integration; and Boserupian growth stemming from innovation in agriculture, such as all-year-round stall-feeding or the cultivation of fodder crops and harvest diversification. The second phase, early industrialization, comprises the period ca. 1850–1880 with a faster growth rate of net national product per capita at 0.6–1.1% annually (Pfister, 2020, p. 517) During this period, some sectors expanded rapidly, such as heavy industry and the railway, while agriculture did so at a slower pace. The third phase, after 1880, was characterized by modern economic growth. Industrialization accelerated and productivity improved across the economy.

Demographic developments also indicate considerable economic dynamism during the 19th century. According to Reuleke (1977), between 1825 and 1871 Prussia experienced the second fastest population growth (ca. 1% annually) among major German States, only surpassed by Saxony (1.4%) and followed by Baden (0.6%). These differences were due to domestic and overseas migration, rather than disparities in natural growth rates. Within Prussia, the western industrializing provinces and Berlin stand out. If we consider demographic growth in urban centers, Matzerath (1985) distinguishes phases that are largely in line with the periodization above: transition (1815 to 1840), acceleration (1840–1871), and rapid growth (post 1871). Throughout our analyzed period, migration played an important role in city growth, particularly after the mid-19th century (Matzerath, 1985, pp. 78–80; 180). We elaborate on region-specific patterns below.

2.3. Cholera and the economy

2.3.1. Impact on labor

Cholera epidemics caused a sudden and sharp decline in the labor force, particularly over the short and medium term. Two elements contributed to this: the lethality of the disease and the demographic and socioeconomic profile of the victims. Concerning the first, cholera had a high case fatality rate throughout the 19th century. Treatments were largely ineffective – ranging from harmless procedures (e.g., steambaths) to life-threatening techniques (e.g., bloodletting) – and they barely changed between epidemics (Schmitz-Cliever, 1952, p. 272). Consequently, it is unsurprising to observe in Figure 1 that the highest death rates (ca. 35 per 1,000) were observed in three cholera years: 1831, 1848 and 1866. They represent a mortality increase of about 25%, relative to the average crude death rate during 1815–1873. The same picture emerges, and sometimes in a much more dramatic form, if we consider local figures. For instance, Kappner (2024b, pp. 4–5) estimates that the 1849 epidemic in Berlin increased mortality by almost 40%, when about 3,500 people lost their lives. An even more striking account is provided by Haselberg (1853, p. 6), who reports that 21 out of 24 workers died on a farm during one night in the district of Stralsund.

The socioeconomic and demographic profiles of cholera victims suggest that the workforce was largely affected by the epidemics. To be sure, mortality *rates* were typically higher for infants and the elderly,[7] but most deaths consisted of working-age persons. For instance, individuals between 15 and 70 account for about 60–70% of overall cholera mortality during the 1866 epidemic in Leipzig (Schmieder, 1867, p. 3) and Berlin (Hirsch, 1867, p. 307), and the 1892 epidemic in Hamburg (Evans, 1988, p. 445).

Within the labor force, cholera took a disproportionate number of lives from the poorest segment. To be sure, the epidemics affected broad sections of the population including the better-off (Reulecke & Gräfin zu Castell-Rüdenhausen, 1991, p. 12). But evidence from Germany and England shows that the poor were particularly at risk, as a result of their unsanitary and overcrowded living conditions (Evans, 1988, p. 130). This was something that contemporaries were aware of, as accounts of cholera epidemics often considered the demographic toll on individuals with varying occupational backgrounds. For Königsberg (Kaliningrad), Schiefferdecker (1873, pp. 23–25) showed that workers made up more than 40% of the deaths among (male) individuals over the age of 10 during the fourth pandemic. Though our data does not allow us to look at gender patterns, this dimension could be important in understanding the varying impact of mortality throughout municipalities. For instance, workers in some predominantly-female occupations, such as domestic service or health care, performed water-related activities and were more likely to get infected with cholera (Liczbińska & Vögele, 2023).

Public health responses to cholera could potentially influence the impact of the epidemics,[8] though it is hard to assess their actual effectiveness. Cities had a great deal of political independence and they responded differently to the same crisis. On top of this, we lack systematic information on the type of non-pharmaceutical measures taken. Nonetheless, we can examine a few experiences to get a sense of the 'typical' policies enacted. The city of Düsseldorf, for example, undertook public health preparations already in 1830, before the actual outbreak in Prussia. Among other initiatives, a health commission was established to monitor sanitary conditions and set up temporary health care institutions (Fliescher, 1977, p. 10). In Aachen, local health official Dr. Hartung favored a number of initiatives to stop the contagion of cholera in 1832, such as the establishment of a temporary cholera hospital and a quarantine station, but the appointment of a new medical expert led to a passive response in the next epidemic (Schmitz-Cliever, 1952). The city of Berlin exhibited a more energetic approach to curbing cholera up to 1866, when the last major epidemic took place. Numerous regulations were issued concerning the cleaning of streets, disinfection, market inspections, etcetera (Müller, 1867, pp. 60–63).[9]

In sum, cholera caused sudden and substantial disruptions to urban labor markets in the short term. Our goal is to understand whether and how epidemic-induced labor force shortages impacted city growth. For this, we need to consider which factors may influence recovery, or lack thereof.

2.3.2. Post-epidemic growth paths: some conceptual considerations

After an epidemic, a population can recover in three ways from a demographic point of view, namely via reduced mortality, increased fertility and heightened migration. In an exercise performed in appendix D, we show that the first two did not systematically respond to cholera mortality in Prussia in the short- and medium-term.[10] Migration, instead, was the prime driver of 19th-century urban growth, particularly after the mid-19th century, in line with Reuleke (1977, p. 25) and Matzerath (1985, pp. 402–435). For this reason, in the following we focus on it as a prime *proximate* driver of post-epidemic growth paths.

Cholera epidemics could simultaneously affect labor supply and demand in urban markets, leading to ambiguous outcomes with respect to population recovery. Beginning with labor supply, at the most basic level a sudden reduction in the workforce, *ceteris paribus*, leads to a rise in the capital-labor ratio, productivity and wages. This, in turn, increases the returns to migration to places affected by cholera relative to less affected ones, thus driving recovery and catch up in the former group. Fixed factors of production (e.g., land) and geographic characteristics (e.g., access to water transport) ensure continued labor demand and can therefore mitigate the economic impact of an epidemic. Jedwab et al. (2024) show that city growth after the Black Death was stronger in places with better land quality and trade potential.

This scenario considers a recovery path under the assumption that labor demand remains constant during a demographic shock. However, this assumption– implying absolute or relative recovery of the labor supply – is not necessarily realistic. Increasing returns to production, stemming from market size or labor specialization, could result in a vicious cycle where locations hit hard continue to decline, as labor flows to less-affected areas. Drawing on evidence from the 1629–30 plague in northern Italy, Alfani and Percoco (2019) argue that a widespread shortage of skilled labor crippled industrial activity, lowered productivity and set Italian economies on a path of relative decline with respect to their counterparts in northern Europe.

We identify three factors that could help us make sense of varying post-epidemic demographic paths, in relation to urban labor supply and demand shocks. The first is market potential, which we interpret in our setting as the capacity of an economy to attract and employ migrants. Following Harris (1954), this measure reflects the size of markets accessible to a place and how far such markets are from that place. Market size relates to differences in demographic growth and regional population densities (we elaborate on these below), while distance to other markets depends on the state of the transport network. On the one hand, market potential improvements derived from better transport lowered migration costs, particularly over land, with the diffusion of paved roads and railways (Hornung, 2015; Uebele & Gallardo-Albarrán, 2014). This would lead to faster recovery in better-connected markets. On the other hand, locations with more market potential may suffer from a greater loss in human capital that tends to be more sophisticated in higher-potential areas. It is therefore unclear *a priori* which of these labor supply and demand mechanisms would be stronger.

The second factor we consider is more directly tied to alleviating labor (supply) scarcity in urban settings: the prevalence of serfdom in the countryside. This institution ensured that rural workers provided forced labor to landlords in exchange for their ability to work their land. The situation was particularly onerous in regions to the east of the Elbe, where the peasantry was largely attached to the land of the local landlord and their ability to move was extremely limited. A process of labor emancipation began in 1807 when Prussia was defeated by Napoleon (Ogilvie, 2014). Though the actual scope of the reform was partially reduced after the return of the nobility to power in 1816, many workers became free during the first half of the 19th century (Ashraf et al., 2025). The consequences of this process for urban growth, however, are ambiguous. On the one hand, the lifting of mobility restrictions meant that a larger pool of labor in the countryside could move to places where they had greater economic opportunities. Surely, the extent of the reform could have been greater by including smallholders and lowering redemption costs. But still, many farmers and their descendants became free to migrate, which contributed to a greater supply of unskilled labor in urban areas. On the other hand, Grant (2005, pp. 215–252) argues that the abolition of serfdom may have led to improved economic opportunities in the east and labor absorption, due to a significant increase in the amount of cultivated area. Indeed, mass migration from eastern Prussia becomes noticeable around 1860 when demographic growth outpaced the rate of output growth. Consequently, we expect that labor emancipation correlates either positively with nearby urban growth or it does not correlate at all.

The third and final factor we consider is the level of industrialization in a given location. From a supply side perspective, the presence of physical capital, unaffected by the epidemic, keeps demand for labor relatively high. On the other hand, the type of labor demanded by industrial activities tends to be more sophisticated and scarce than that employed in agriculture. Particularly after the mid-19th century, new modes of production required workers with more sophisticated skills that were complementary to industrial capital (Becker et al., 2011; Semrad, 2015). A labour shock in this setting may have had a greater impact, as workers with critical skills declined sharply. Therefore, as with market potential, it is unclear *a priori* which of the two will be empirically more relevant.[11]

3. Data

Our main sample consists of 986 municipalities with a town charter (*Stadtordnung*) within Prussia. Some of these were fairly large at the time, though our data also contains places that were small (see table A1 in the appendix). This variation was due to the criteria employed to assign legal city rights, which often referred to factors relevant in medieval times (e.g., relevance of trade and industry) rather than population size at the beginning of the 19th century (Dawson, 1914, p. 30).

The focus on cities is not limiting for the purposes of our analyses, for various reasons. First, it ensures a high-degree of comparability between epidemics by considering the same set of administrative units. In addition, cities with legal rights enjoyed a set of privileges that could influence economic dynamics in particular ways when compared to their 'rural' counterparts (*Landgemeinde*), such as greater political autonomy, more fiscal independence and freer labor markets (Dawson, 1914). Third, the consideration of places with different size provides significant variation to explore different dimensions of the relationship between epidemic shocks and subsequent development. Lastly, the wide range of population size within the sample makes our analyses representative of a large number of places, and not just rural communities or major urban agglomerations.

We further ensure the comparability of outcomes between epidemics in both cities and regions where they were located, by restricting the spatial scope of our sample to pre-1866 Prussian borders.[12] Unlike other regions, the 'old' provinces were part of the same administrative and political unit before major institutional reorganizations took place after the Austro-Prussian War in 1866[13] and the founding of the German Empire in 1871.

Our dataset consists of three main elements: population growth, cholera death rates and various factors that could influence post-epidemic development. We elaborate on these in the following.

3.1. City growth

We use population data to proxy for broader economic development. This approach is in line with earlier studies on Germany that, in the absence of disaggregated indicators of production, have used population to look at the impact of transport infrastructures (Hornung, 2015), the Protestant Reformation (Cantoni, 2015) or public goods provision in the aftermath of plagues (Dittmar & Meisenzahl, 2020). At the same time, using this type of demographic information in analyses of the impact of epidemics may lead to mechanical short-term effects. We discuss this issue in greater detail below when we present the empirical model, but we do not find this concerning in our case, for two main reasons. We study short- and medium-term population dynamics within and between pandemic periods. This allows us to identify whether a purely mechanical effect is driving the impact of cholera outbreaks, or whether we observe recovery paths with different timing or intensity. Also, the second part of our analyses considers heterogeneities in short- and medium-term population trajectories after an epidemic episode. We find plenty of variety in these trajectories, indicating that a mechanical effect that would be common to all towns is not driving our results. In addition, as we explain below, our regression framework filters these out.

In the absence of original counting sheets or other disaggregated archival material, the official Prussian census reports provide the most consistent source of demographic information since censuses were regularly carried out in 1816.[14] While enumeration techniques were far from perfect, they improved substantially over time, e.g., when house-to-house counts were carried out since the 1840s (Pfister & Fertig, 2024, p. 3). The starting point for our city-level population dataset is Hornung (2015), who improves on Matzerath (1985) and provides information for 978 Prussian cities equipped with a town charter between 1816 and 1885. Annual demographic information is unfortunately unavailable. Instead, population counts are extracted from official Prussian census summary reports for the years 1816, 1822, 1831, 1837; every three years until 1867; and 1871, 1880, and 1885. We then extend this basic sample in three directions. First, we obtain population counts for 1875 and 1890 drawing on official census reports (Königliches Statistisches Bureau in Berlin, 1877, 1893), to cover demographic developments more comprehensively after the fourth cholera pandemic. Second, we obtain population counts for 1810 (available for 393 cities) from Mützell (1823/5), which we use to study population trends before the second pandemic.[15] Also, we add cities to the sample that received a town charter after 1831, which Hornung (2015) excluded. This is appropriate in our setting, given the extended time frame we look at. Finally, we corrected a few transcription errors. In the end, we arrive at a set of 986 cities with consistent civil population counts between 1816 and 1890 (see table A1 in the appendix for some descriptive statistics).

Three elements are important to consider when interpreting our population figures. First, they include persons present at census day.[16] This implies that factors such as seasonal migration may drive up or down certain counts. Our analyses try to account for this and similar regional factors influencing population dynamics. Second, until 1837 figures only refer to the civil population, thus excluding military personnel and their families. Therefore, we use the former in our analyses for consistency. In any case, we show that this choice does not alter our findings, since we conduct robustness checks with full population counts (i.e.

including individuals associated to the military) after 1840, when such information was reported. The last element to consider is that census counts were conducted at the end of the year, typically at the beginning of December. As we will discuss below, this has implications for our 1831 benchmark, the first epidemic year in Prussia.

Figure 2 presents a visual depiction of our main sample containing 986 cities. The Prussian Kingdom is well represented with a fair number of localities in the western, central and eastern regions. Table 1 provides annual population growth rates across provinces and pandemics, for our sample. Two patterns are worth highlighting. First, annual population growth was the fastest during the period 1822–1846 (1.37%) when compared to subsequent decades (0.85 and 0.77%). At the same time, these aggregate figures mask substantial regional variation. The Rhineland, Westphalia and Brandenburg (which includes Berlin) took the lead after the mid-19th century, while initially fast-growing regions fell behind (e.g., Pomerania or Silesia). This point, as we will discuss below, is important for our analyses because it highlights marked between-province differences in population growth. More specifically, structural conditions throughout Prussia make city-level comparisons across provinces challenging, such that within-province comparisons are more meaningful.

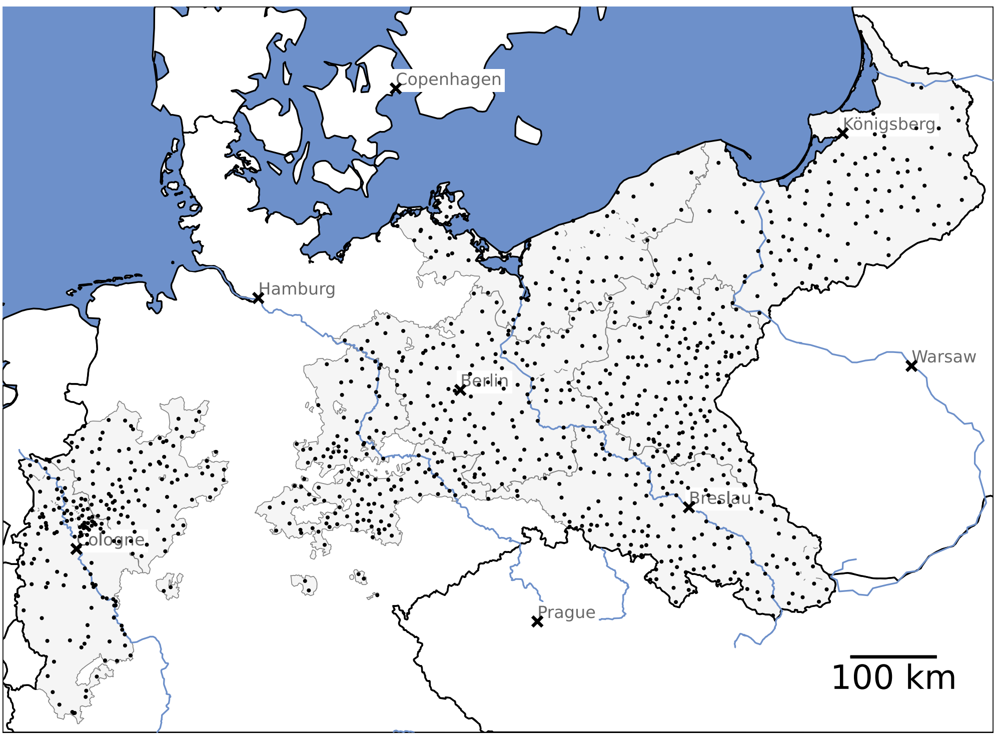


Figure 2. Study area and location of sample cities. Note: Each dot depicts a city in our main sample (986 towns). The light gray area is the State of Prussia in its pre-1866 borders. Gray lines follow the boundaries of Prussia's provinces. Black lines show national borders. Blue lines show the rivers Rhine, Elbe, Oder, Vistula and Neman (West to East). Major cities and foreign capitals are labeled and marked with a cross. See section 3.1 for details on the construction of the sample.

Table 1. Annual population growth by province (in percent), 1822–1890.

Province	1822–1846	1846–1864	1864–1890
Prussia	1.43	1.02	0.39
Posen	1.53	0.60	0.48
Silesia	1.39	0.67	0.55
Pomerania	1.69	1.15	0.17
Brandenburg	1.65	1.26	1.37
Saxony	1.25	0.85	0.79
Westphalia	0.99	0.58	1.10
Rhineland	1.17	0.76	1.07
Total	1.37	0.85	0.77

Note: The table shows annualized population growth rates per province for different periods. Provinces are ordered from east to west. See section 3.1 for the sources.

3.2. Cholera

The starting point to create our cholera dataset is Kappner (2025), who provides the annual deaths for each of our 986 cities.[17] This information is taken from multiple tabulation sheets present in the Prussian state archive, which were sent to inform the central government about the state of the epidemic. Kappner (2025) describes how these documents were traced across various dossiers and were compiled into a harmonized database.

For the purpose of our article, it is important to note that the data are complete and comprehensive due to administrative efforts to monitor cholera developments. With its first appearance in Europe in 1830, the Prussian government ordered its provincial administrations to produce regular reports on the epidemic situation throughout the country.[18] Provincial bodies were urged to present the information in standardized tabulation sheets. Their format and content changed little over time, reflecting their value to the central government.

While we consider the overall quality of the data as high, we are aware of some uncertainties that can introduce measurement error. Provincial bodies' means and methods to collect information within their territory varied. Usually, county physicians (*Kreisphysikusse*) were tasked with collecting and tabulating cholera numbers for their respective county. They then sent the data to the provincial administration, which compiled the province-level reports that were submitted to the central government in Berlin. This means that county physicians played a crucial role in identifying, reporting and submitting cholera deaths. We have *a priori* no reason to believe that a particular region presented better or worse statistics, since we lack information for such an assessment. In our analyses, however, we account for regional idiosyncrasies by focusing on within-province comparisons.

An additional issue with any epidemic is the identification of an individual's cause of death. This is challenging in a historical context because of the presence of comorbidities coupled with imperfect epidemiological knowledge in the absence of modern tools of disease identification. We have tried to minimize this problem by focusing on cholera deaths, rather than cases, since its characteristic symptoms, particularly when it led to a fatal ending, made it easier to identify it.

We validate our dataset by comparing cholera death counts with excess mortality estimates. The aim of this exercise is to use two independent sources to see whether epidemic deaths are predictive of 'additional' deaths relative to non-epidemic years. We collect annual all-cause death counts for Prussia's 26 districts between 1816 and 1914. These counts, while only available at the district-level, are highly reliable as they stem from regular death registrations from civil registry procedures that were already fairly established since the 1820s. We then regress annual district-level deaths on the population at risk, and a district-specific linear time trend.[19] Reassuringly, we find that almost all district-years with substantial cholera mortality are predictive of excess mortality.[20]

3.3. Factors influencing post-epidemic trajectories

We focus on three factors, as explained in the previous section, that could impact post-epidemic trajectories: market potential, the prevalence of serfdom in the countryside and industrialization (figure B4 presents a correlation matrix).

We construct a measure of local market potential (Harris, 1954) for each city at the beginning of each pandemic (1831, 1848 and 1866). It uses information on the distribution of the urban and rural populations, and the long-distance transport network in Prussia and all its German neighbor states.[21] To begin, we calculate the minimum travel time between each city pair, based on contemporary average speeds for each transport mode. In the absence of reliable, city-pair-specific information on actual transport costs, we believe that our estimated minimum travel times are the best available proxy. They capture relative differences in the opportunity costs of migration that workers across Prussia faced as a result of their proximity to faster or slower modes of transport.[22] In appendix section C.7, we provide further details on our modal speed assumptions and show that our results are robust to varying these.

The second step in the creation of the market potential measure consists of calculating, for each city *i*, the sum over all other locations *j*'s populations, each weighted by the inverse of the pairwise travel time via the least-cost path. Figure B5 shows the spatial distribution of this measure. We note that market potential is strongly correlated with longitude, reflecting the East-West population gradient across Germany, though this relationship changed over time as the transport network expanded.[23]

We measure the lifting of institutional constraints on labor mobility at the county level drawing on Ashraf et al. (2025), who report serfs emancipation rates for the period 1821–1848, excluding the Rhineland province and the Stralsund area. Based on Meitzen (1868), who documented progress of the emancipation process, the authors compute the ratio of settled emancipation cases to the eligible rural population. One limitation of this dataset is that we cannot observe whether recently-emancipated workers actually migrated. The initial ambitious scope of the reform was considerably toned down when the nobility came back to power after the Napoleonic Wars by excluding smallholders from emancipation and setting high labor redemption prices. The laborers that remained serfs were therefore more vulnerable and may have been more likely to migrate, if they had had that option. At the same time, the descendants of emancipated workers who may have initially stayed may have chosen to migrate some years later, as population growth put pressure on economic resources. These issues introduce some uncertainties as to the extent we can capture rural-urban migration potential, but unfortunately we do not have additional sources to correct for this.

We compute a city-level measure of exposure to labor emancipation by calculating the area-weighted average of county-level emancipation rates within a 25-kilometer radius around each city.[24] Figure B6 shows the spatial distribution of this variable. It is worth noting that though our indicator measures the *change* in free labor, our regressions include province-fixed effects. In this way, we account for the potential varying impact of labor emancipation across regions, as serfdom was more onerous in the eastern provinces.

Finally, we measure industrialization with the per-capita share of workers employed in the industrial sector, using information from three censuses reporting relevant information at dates close to the onset of each pandemic. The first refers to the year 1819 and lists the number of independent craftsmen, which we divide by the 1822 civil population (Mützell, 1823/5). The second is a detailed census conducted in 1849 by the Statistisches Bureau zu Berlin (1851–1855), also listing the number of independent craftsmen per city (which we divide by the 1849 civil population). Data from this census has been used earlier in the literature (Hornung, 2015). Finally, we calculate the share of workers in industry (including mining) per county in 1867 using data reported for the 1867 census (Königlich Preussisches Statistisches Landesamt in Berlin, 1871, pp. 38ff.). We then scale our 1849 city-level industrial worker shares by the 1849-to-1867 county-level changes to approximate 1867 city-level industrial shares.[25]

One limitation of our data is that we created a measure of industrialization over time with different occupational categories, namely independent craftsmen for 1819 and 1849, and the share of workers in industry including mining for 1867. We argue, however, that our post-1850 indicators are comparable in that they capture a similar phenomenon during early industrialization. Our numbers for 1819, however, should be seen as an indicator of proto-industrialization, since we gathered occupational figures for the so-called mechanical arts, 'mechanische Künste'. Another potential issue with our sources is that rates of industrialization seem unrealistically high (i.e. 100%), in a handful of cities.[26] This likely reflects that most workers in these locations were registered somewhere else. For our analyses, this has no impact because we create tertiles out of our industrialization variable and these cities would belong to the top tertile anyways. The spatial distribution of our industrialization metrics can be seen in figure B7.

4. Method

We assess the short- and medium-term impact of cholera epidemics with a similar empirical setting to that by Correia et al. (2022). We estimate:

$$\ln \text{Pop}_{it} = \sum_{\tau \in T} \beta_\tau C_i \mathbf{1}_{t=\tau} + \sum_{\tau \in T} \mathbf{X}_i{}' \alpha_\tau \mathbf{1}_{t=\tau} + I_{it} + \gamma_i + \delta_{t \times p(i)} + \varepsilon_{it}, \tag{1}$$

where $\ln \text{Pop}_{it}$ is log-transformed population in city i and year t. We estimate the previous equation separately for distinct periods (T) that include a few years before and after each pandemic. We consider the time frame 1821–1846 for the second pandemic (1831–1837); 1846–1864 for the third pandemic (1848–1859); and 1864–1890 for the fourth pandemic (1865–1874). C_i refers to the total cholera deaths during a given pandemic, over the mean population.[27] Our coefficients of interest (β_τ's) refer to the interaction between C_i and the time dummies ($\mathbf{1}_{t=\tau}$) and measure the percentage difference in population growth between places exposed to cholera relative to less exposed ones, for various years. This is our metric of the extent to which the cholera shock influenced post-epidemic growth paths. Importantly, our regression filters out any short-term mechanical effects of cholera on population, since these are exactly proportional across control (less affected) and treatment (more affected) cities.

Our estimates of the effect of cholera on population dynamics are correlational,[28] though we try to rule out a number of potentially important confounders. For instance, we include city-fixed effects (γ_i) to account for unobserved time constant characteristics at the local level, such as long-run climatic differences. Also, we add province-year-fixed effects ($\delta_{t \times p(i)}$) to account for time-varying factors that are common within provinces, such as differences in regional population growth trends, as discussed earlier, or regional economic crises.[29] In this way, we focus on city comparisons *within* provinces, so that (unobserved) between-province differences in economic development or demography do not drive our results. Finally, we cluster the standard errors at the city level to allow for serial correlation.

We also add a set of pre-determined city-level controls ($\mathbf{X}_i$), interacted with time dummies, to account for their changing effect over time. First, we control for initial (log-transformed) population, as this correlates with both population growth and the likelihood that a city experiences an epidemic. Second, for the third and fourth pandemics, we include cholera death rates in prior epidemics to capture their potential persistent impact. Third, we control for key aspects affecting the local economy that could be correlated with the influence of cholera, such as the market potential and the level of proto- and regular industrialization. At last, we add longitude to account for the fact that cholera was more often imported in the eastern parts of Prussia, also within provinces. This control is also useful to capture the typical east-west gradient in socioeconomic aspects.

Finally, I_{it} is a time-varying city-level control, taken from Hornung (2015), that captures whether a city incorporated nearby settlements and thus experienced a large population change due to administrative reasons.[30] Like Hornung, we notice unusually large population growth rates in a few cases that could be attributed to unobserved incorporations or potential issues with the censuses. Since we are unsure about their nature, as a conservative approach, we exclude from our sample city-years with rates above the top one percent of the distribution.

The second part of our analyses examines the mechanisms influencing post-epidemic recovery, or lack thereof. For this purpose, we interact C_i in Equation 1 with the three factors presented in section 2.3.2– market potential, prevalence of serfdom in the countryside and degree of industrialization – that could impact how workers could flow to labor markets in need of them. Rather than employing continuous measures of these factors, we estimate a separate coefficient for each tertile of the respective factor's distribution, thus allowing for non-linear responses to the labor supply shock. Formally, we estimate the following model separately for each pandemic:[31]

$$\ln \text{Pop}_{it} = \sum_{\tau \in T} \sum_{\mu \in M} \lambda_{\tau \times \mu} C_i \mathbf{1}_{t=\tau} \mathbf{1}_{m=\mu} + \sum_{\tau \in T} \sum_{\mu \in M} \eta_{\tau \times \mu} \mathbf{1}_{t=\tau} \mathbf{1}_{m=\mu} \tag{2}$$

$$+ \sum_{\tau \in T} \beta_\tau C_i \mathbf{1}_{t=\tau} + \sum_{\tau \in T} \mathbf{X}_i{}' \alpha_\tau \mathbf{1}_{t=\tau} + I_{it} + \gamma_i + \delta_{t \times p(i)} + \varepsilon_{it}.$$

The tertiles of the factors we consider to make sense of demographic trajectories – market potential, labor emancipation and industrialization – are $\mu \in M = \{1, 2, 3\}$ and their associated coefficients are $\lambda_{\tau\times\mu}$. Taking cities in the lowest industrialization tertile as an example, our coefficient of interest ($\lambda_{\tau\times\mu=1}$) measures whether there are growth differences in cities afflicted by cholera relative to less-afflicted ones, within those that are least industrialized. The second term, in the first row, in the equation captures the potentially diverging growth trajectories across tertiles (the main effects). The second row is equivalent to Equation 1.

Our tertile-based metrics have two important features. First, we calculate them separately for each pandemic,[32] to abstract from the secular increase in industrialization and market potential over time (see table A1 in the appendix). This procedure, as a result, shifts the focus to relative differences between cities at the onset of each pandemic. An advantage of this approach is that it reflects how cities switch tertiles between pandemics, reflecting the complex spatial and temporal changes in market potential and industrialization.[33] Naturally, this implies that changing patterns in the $\beta_{\tau\times\mu}$ estimates across pandemics partly reflect the changing composition of tertiles.

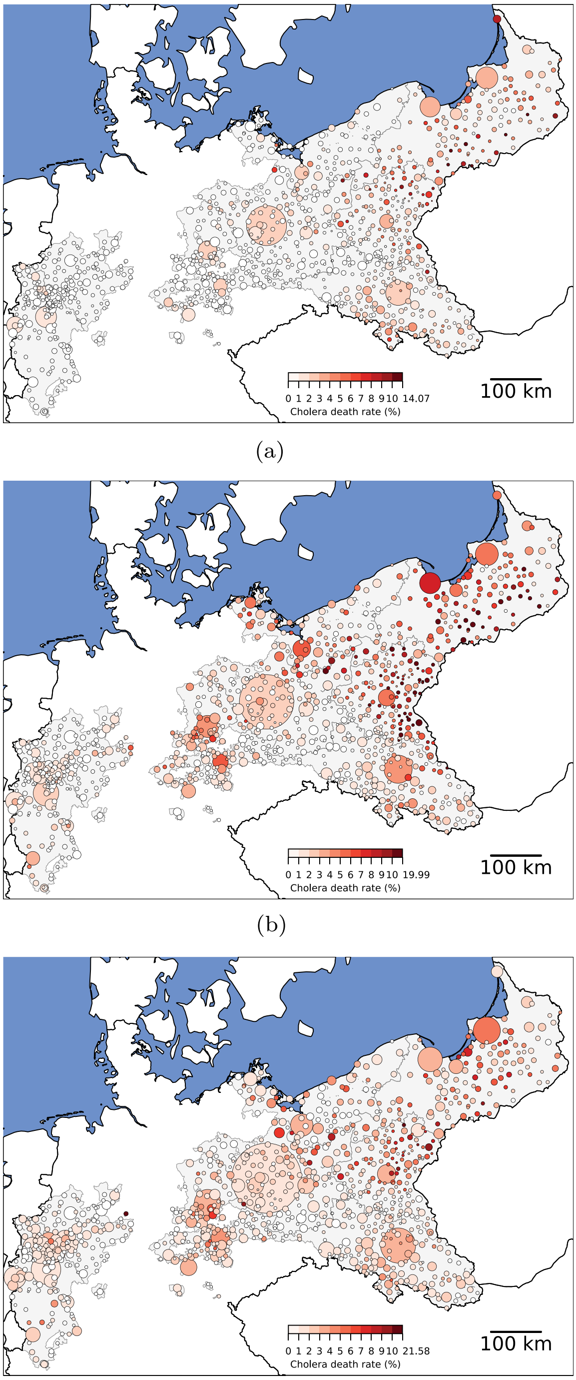
Second, we compute the tertiles separately within each province rather than pooling over all cities for a given pandemic. This choice is consistent with our focus on within-province variation (implied by the province-year fixed effects) and ensures variation within each province. This approach provides more meaningful comparisons in a country that differed vastly along many dimensions. For instance, in this way we allow cities in the east of Prussia that are far away from major transport hubs to exhibit greater levels of market potential by relating them to their less-connected counterparts in the same province.

5. Results

5.1. Spatial and temporal patterns of cholera

Figure 3 presents a detailed spatial reconstruction of the deadliest epidemic crises of the 19th century in Prussia. It includes cholera mortality rates for the 986 cities in our sample, during each of the pandemics we discussed earlier. In line with C_i in Equation 1, mortality rates are calculated as the sum of registered cholera deaths over the mean population in that period.

Figure 3 reveals two noteworthy stylized facts about the spatial spread of cholera. First, all epidemics had a strong eastern component, as a result of the importation of the disease from Russia. In particular, the provinces of Prussia (in the North-East), Posen (in the Central-East) and Silesia (in the South-East) experienced high mortality rates in every decade, while epidemics were less severe across the Western and Central provinces. This is particularly evident during the 1830s when entire regions such as Posen or eastern Prussia were largely affected, while Westphalia and most of the Rhineland were spared. In fact, the Western territories saw their only substantial outbreak in the 1860s. Table A2 in the appendix provides some aggregate mortality figures underpinning this point. Across the three pandemics, mortality rates in the province of Prussia ranged from 1 to 2.2 per 100 people, while the Rhineland experienced rates between 0.02 and 0.28.



(a)

(b)

(c)

Figure 3. The spatial spread of cholera. Note: See section 3 for sources. Each figure shows the 986 cities in our dataset, where the circumference of each dot is proportional to the city's population at the onset of the respective pandemic. Smaller cities are plotted on top of larger cities, such that every city can be seen. City circles are colored according to their cholera death rates (i.e. the sum of cholera deaths over the mean population) per pandemic, as indicated by the scale legend. The light gray area is the state of Prussia in its pre-1866 borders. Gray lines follow the boundaries of Prussia's provinces. Black lines show national borders. (a) 2nd pandemic (1831–1837), (b) 3rd pandemic (1848–1859) and (c) 4th pandemic (1865–1874).

The second noteworthy pattern from Figure 3 is the enormous variation in mortality rates at the local level. Cities close to each other exhibit wildly different experiences. Consider the area of Silesia or Pomerania during the third pandemic, where some places remained free of the disease while others witnessed death rates of up to 15 per 100 individuals. To illustrate this point more systematically, we calculate the R-squared from a simple regression with death rates as dependent variable and province-fixed effects. This exercise implies that only 25%, 33% and 16% of the variation in cholera mortality during the three pandemics can be attributed to between-province variation exclusively.[34]

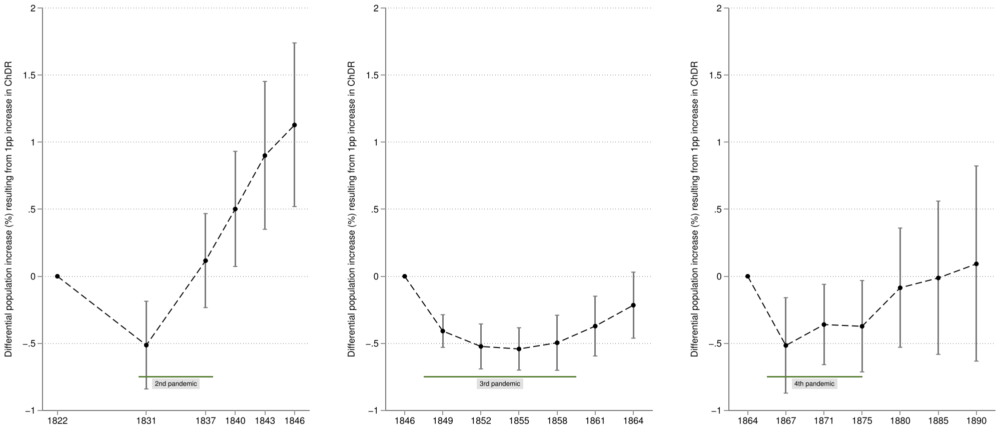
5.2. The impact of cholera on urban growth

We calculate the economic impact of cholera by estimating Equation 1. Figure 4 plots our coefficients of interest (β_τ).[35] Beginning with the second pandemic, panel (a) shows that a one-percentage-point increase in cholera mortality led to 0.44% lower growth in 1831. Given that average cholera mortality during the second pandemic was 2.14 per 100, excluding unaffected places, our results imply that the outbreak initially brought down city growth by 0.93%. This represents eight percent of the population increase that this group of cities experienced between 1816 and 1822. To be sure, this *relative* difference should not be confused with an *absolute* decline in population when the epidemic hit in 1831. In fact, there was an increasing trend in population between the years for which we have data, namely between 1822 and 1831 (see Table 1). From 1837 onward, the coefficients are either statistically insignificant or positive and statistically significant.[36] This is consistent with an expansionary context, and labor, transport and territorial reforms (Albers & Pfister, 2023; Ashraf et al., 2025; Keller & Shiue, 2014; Uebele & Gallardo-Albarrán, 2014).

Our results for the third pandemic in panel (b) suggest a lasting negative impact. Until 1858, the last year in our sample with a cholera outbreak, we find that cities suffering from an additional one-percentage-point increase in cholera death rates experienced 0.5% lower growth. This represents almost a third of total population growth in the affected cities between 1843 and 1846. Clearly, our estimates paint a rather negative picture of this period, which is in line with various other troublesome developments at the time, such as popular unrest leading to the March Revolution (1848–1849), rises in food prices and declines in production and employment (Berger & Spoerer, 2001).

The fourth pandemic (panel c) also led to negative outcomes, but these were less persistent than those unveiled for the 1850s. In 1867, one year after one of the deadliest outbreaks, a one-percentage-point increase in cholera mortality rate was associated with 0.5% lower population growth; this accounts for 20% of population growth between 1861 and 1864 in cities afflicted by this disease. After that, in the 1880s, there are clear signs of recovery as the coefficients are close to zero and statistically insignificant. Indeed, this decade marks the transition of the German economy to a path of modern economic growth (Pfister, 2020, pp. 516–517).

The patterns discussed above remain the same when we consider a standard spatial lag model that takes into account how cholera mortality surrounding a given city may have impacted its trajectory (see appendix E). Interestingly, we find weaker post-epidemic growth during the second pandemic when accounting for the cholera shock of



(a) (b) (c)

Figure 4. The impact of cholera on urban growth. Note: These figures show the estimated β_τ's from Equation 1, transformed into percentage changes. Gray lines indicate 90-percent confidence intervals. See appendix tables C2, C3 and C4 for the underlying regressions with the coefficients expressed in logarithmic points. (a) 2nd pandemic, (b) 3rd pandemic and (c) 4th pandemic.

neighboring locations, possibly due to greater out-migration flows in rural areas affected by the epidemic. During the third and fourth pandemics, we find that neighboring cholera shocks correlated negatively with city growth, though the coefficients are largely insignificant by the 1870s.

We can take the marginal effects just discussed to obtain a sense of how the epidemics brought down pre-epidemic population change across the mortality distribution. The results of this exercise are presented in figure B3 in the appendix. Though the figures are not directly comparable between the second pandemic and those referring to the other two due to differences in the length of the period considered, our calculations show clearly that cholera lowered population growth and in many cases it even led to negative growth rates. Compared with the analyses of Jedwab et al. (2024, Appendix, figure A.8), we find that our estimated average effect is smaller (ca. −0.5% vs ca. −1%). This could be related to the greater mortality impact of the Black Death and the greater dynamism of the Prussian economy during the 19th century relative to pre-industrial Europe.

Finally, we perform a number of tests in appendix C and show that our results are robust to employing i) pre-trends analyses and region-fixed effects at varying levels; ii) alternative shock measures and population-weighted regressions; iii) different subsamples addressing potential data concerns; iv) a cross-sectional setup; v) standard errors accounting for spatial dependence; and vi) a model that takes into account differential timing of exposure to cholera.

5.3. Post-epidemic growth mechanisms

We hypothesized in section 2.3.2 that cities with more market potential possibly had a greater ability to attract labor from surplus areas, though they may have been more vulnerable to a productivity shock. To test which of the two predominates, we estimate

Equation 2 and plot our coefficients of interest ($\lambda_{\tau\times\mu}$) in Figure 5; we refer to the three market potential tertiles as low- (L), medium- (M) and high-potential (H) cities. Each of the lines in the figure represent the estimated association of a one-percentage-point increase in cholera mortality relative to a location *in the same tertile* and with a one-percentage-point lower cholera death rate.[37] Unlike our results shown above, we pool several benchmarks during and after the pandemics to increase the precision of our estimations.

To illustrate the interpretation of the coefficients, consider that referring to the epidemic period 1831–1837 and lowest market potential tertile (L): negative and statistically significant. This implies that cholera mortality in places with low market potential was associated with slower growth, relative to less-affected cities with similar market potential. The same does not apply to cities with medium and high levels of market potential, as the coefficients are either positive and statistically significant or statistically insignificant. In other words, it seems that more attractive locations in terms of population and connectivity did not experience comparatively lower growth rates. In the 1840s, cholera was not associated with lower relative growth in places with low market potential (the coefficient is close to zero and thus statistically insignificant).

The shock of the third pandemic, panel (b), seems more universal. Regardless of market potential, cholera mortality was correlated with slower growth (ca. 0.5% for each one-percentage-point change in the death rate from this disease). In the post-epidemic period (1858–1864), shocked cities in the bottom two tertiles converged with their less-affected counterparts (the coefficients are statistically insignificant), while locations with high market potential did not. This can be explained by city competition in terms of migration at a time when Transatlantic migration reached all-time peaks (Pierenkemper & Tilly, 2004, p. 96), and thus the pool of migrant workers was comparatively smaller. Or, as we

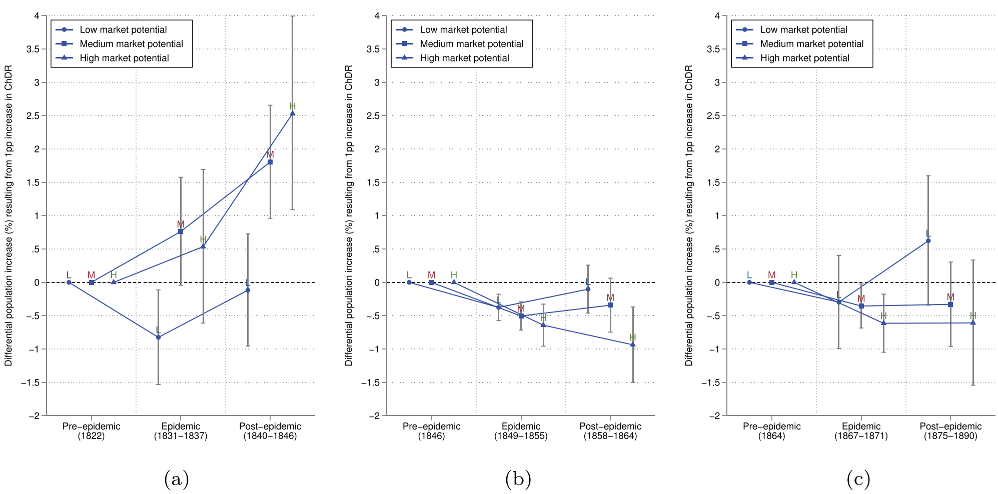


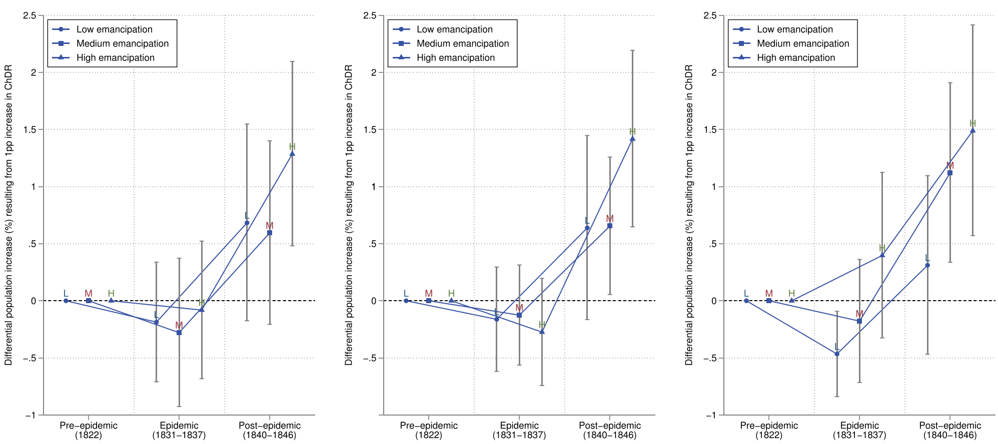
Figure 5. The impact of cholera on urban growth by market potential tertile. Note: Each panel shows the estimated $\lambda_{\tau\times\mu}$'s from Equation 2, transformed into percentage changes, per pandemic. Gray lines show 90% confidence intervals. See appendix table A3 for the underlying regressions with the coefficients expressed in logarithmic points. (a) 2nd pandemic, (b) 3rd pandemic and (c) 4th pandemic.

discussed earlier, cholera caused a comparatively greater productivity shock in places with more market potential, leading to lower labor demand.

Finally, our results for the fourth pandemic, panel (c), show that cities experienced declines in relative population growth during the period 1867–1871 regardless of their market potential, although the coefficient for the bottom tertile is imprecisely estimated. By the 1870s, cholera mortality is no longer associated with different growth paths in places with medium and high market potential. The coefficient for the bottom tertile (L) implies a faster recovery rate, potentially suggesting that regional short-distance migration played an important role in their return to 'normal' growth paths, though the coefficient is not statistically significant.

Next, we test whether the lifting of institutional constraints to rural labor mobility was associated with different recovery paths in nearby urban locations. Similar to our results for the market potential mechanism, Figure 6 presents the coefficients for three groups of cities: least-, medium- and most-exposed to emancipation during the period 1821–1848. We report the outcome of constructing three measures by considering that each city inherits the emancipation rate of the county it is located in (panel a), or that it gets the area-weighted average of the emancipation rates of nearby counties within a 10 and 25 kilometer radius (panels b and c, respectively). The area averages take into account that some cities are located at their respective county's border. As there were no restrictions to cross-county migration, the emancipation trends in neighboring counties also mattered.

We find differences in the impact of cholera in cities located in the vicinity of counties with relatively high growth rates of labor emancipation up to 1848, when 10- and 25-kilometer radii are considered. While this result is not fully robust with the 'own county' labor emancipation variable (panel a), cross-county migration makes this measure less



(a) (b) (c)

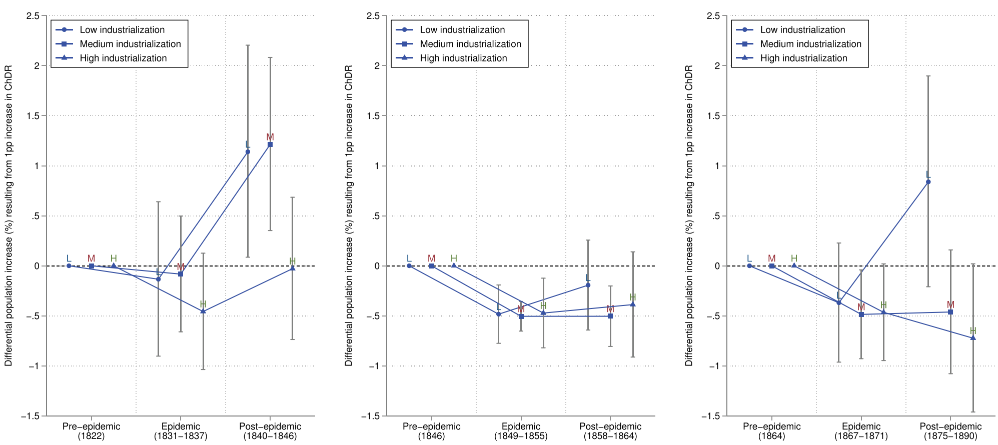
Figure 6. The impact of cholera on urban growth by serfs emancipation tertile (2nd pandemic). Note: Each panel shows the estimated $\lambda_{\tau\times\mu}$'s from Equation 2, transformed into percentage changes, with a variable that considers varying ranges to compute a metric of rural serf emancipation. Gray lines show 90% confidence intervals. See appendix table A5 for the underlying regressions with the coefficients expressed in logarithmic points. (a) 0 km (own county), (b) 10 km radius and (c) 25 km radius.

realistic than the other two. Therefore, we accept the hypothesis that changes in institutional labor mobility in the countryside influenced urban growth dynamics in the aftermath of cholera outbreaks. With regards to the pandemic period (1831–1837), we detect no large differences between less- and more-afflicted cities by cholera across tertiles, since the coefficients are mostly statistically insignificant. Perhaps, two mechanisms may be offsetting each other: the abolition of serfdom increased the ability of rural workers to move out, while also resulting in increases of arable land and productivity that could absorb more workers in the early phase of the emancipation period (Grant, 2005).

Was the labor shortage caused by cholera more persistent in economies relying on worker with more sophisticated skills? Figure 7 presents some evidence supporting this hypothesis, as the most industrialized cities (H) recovered slower after each pandemic than the least industrialized ones (L). This is particularly obvious in the second pandemic (and to some extent in the fourth one, given that the coefficient for the highest tertile is almost significant) when highly-industrialized cities suffering from cholera seemed to have remained below the growth path of similar industrial centers unaffected by the disease. The results for medium-industrialized municipalities are similar to the highly-industrialized ones, except for the second pandemic.

There are two potential explanations for the weak recovery trajectories of industrial cities after epidemic shocks. Though our empirical framework does not shed light on their relative importance, it is worth discussing them qualitatively. The first pertains to the scarcity of skilled labor. Local urban economies built on specialized skilled labor possibly faced more difficulties in restocking their labor force after a cholera shock than cities with a less skill-intensive economy.

Another complementary explanation relates to post-epidemic weak *demand* for skilled labor. To the extent that industrial urban economies exploited increasing returns to scale, an asymmetric labor shock should permanently shrink employment in cholera-struck cities relative to cities that escaped the epidemic and did not experience a short-run



(a) (b) (c)

Figure 7. The impact of cholera on urban growth by industrialization tertile. Note: Each panel shows the estimated $\lambda_{\tau\times\mu}$'s from Equation 2, transformed into percentage changes, per pandemic. Gray lines show 90% confidence intervals. See appendix table A4 for the underlying regressions with the coefficients expressed in logarithmic points. (a) 2nd pandemic, (b) 3rd pandemic and (c) 4th pandemic.

loss of employment. Notably, the more traditional (agricultural and commercial) economies of non-industrial cities would be better characterized by constant returns to scale, suggesting that such a redistribution would not be expected among them. The historical evidence points at the importance of economies of scale in Germany in the growing industrial sector (Fremdling, 1979), particularly in places close to coal-rich regions (Gutberlet, 2014); also trade and increasing export orientation selected firms by size, implying productivity gains from scale in the industrial sector (Biermann, 2021).

We would like to add a final note on the correlational nature of our regressions, and how it affects the interpretation of some of our results. We tried minimizing concerns of omitted variable bias by ruling out a number of potentially important confounders, but some issues (leading to endogeneity) may remain that we cannot tackle quantitatively. For instance, city growth stemming from underlying fundamentals correlated with greater economic development could be associated with greater cholera mortality, industrialization and market potential. In this case, and even in the presence of meaningful control variables, our estimates could be downward biased, because epidemics would tend to target high-potential locations. In addition, cholera exposure between epidemics may related to unmeasured post-epidemic public health policies (e.g., health-related public goods provision) that, in turn, may lead to greater city growth and industrialization (Gallardo-Albarrán, 2025). In this scenario, cities that were not influenced by cholera (our control group) in the later part of our analyzed period may pertain to a sub-set of the sample with high potential, which would in turn lead to a downward bias in our results.

6. Discussion and conclusion

This article examines the economic impact of cholera outbreaks in urban Prussia during the 19th century. For this purpose, we have constructed a dataset containing almost one thousand cities with detailed information on cholera mortality and population growth, which we use to proxy for economic development. Our analyses consider three periods, each covering a major pandemic: 1821–1846 for the 1831–1837 pandemic; 1846–1864 for the 1848–1860 pandemic; and 1864–1890 for the 1865–1874 pandemic.

Our results show that cities experiencing an additional one-percentage-point increase in cholera mortality grew ca. 0.5% less right after an epidemic. The size of our coefficient seems to be constant across pandemics. In relative terms, the coefficient for the second pandemic implies that the decline in population attributed to cholera accounts for eight percent of pre-pandemic population growth. For the third and fourth pandemics, this figure becomes 30% and 19%, respectively. In addition, our results show that post-epidemic growth recovery was rather fast during the second and fourth pandemics. The exception is the third pandemic, when growth rates remained relatively low in shocked cities for almost ten years after the demographic shock.

We examine three factors influencing labor supply and demand in urban areas, to make sense of demographic trajectories following the cholera outbreaks: market potential, labor emancipation in the countryside and degree of industrialization. In the following, we discuss their relevance in explaining the patterns delineated above.

Beginning with the second pandemic, the quick recovery and subsequent city growth in cholera-affected cities after 1837 took place in locations with higher levels of market potential and labor emancipation. Supporting the idea that labor released from the countryside was mostly unskilled, we find that less (proto-)industrialized locations recovered faster. It seems that mechanisms alleviating labor supply scarcity in urban areas could explain differential rates of in the aftermath of cholera.

The persistent negative outcomes during the third pandemic can be explained by various factors. The epidemic outbreaks took place throughout an extended period of time covering the late 1840s and the full decade of the 1850s, though the ones after 1855 were comparatively mild (see Figure 1). Why, then, do we observe little recovery after that? In other words, why did migration not close the gap between surplus labor areas and cities in need of workers? One explanation refers to the broader turbulent economic context of that decade, due to the 1848–1849 Revolution, rises in food prices and declines in production and employment (Berger & Spoerer, 2001). At that time, and particularly between 1846 and 1857, Germany experienced the highest rates of Transatlantic migration (up to about 240,000 individuals annually) during the 19th century (Pierenkemper & Tilly, 2004, p. 96). Therefore, workers that would have migrated to cities in that decade may have chosen a different destination, leaving some urban environments afflicted by cholera at relatively low growth paths. Another explanation relates to a labor demand shock causing lower relative productivity, since locations with higher market potential seem to have taken the strongest hit. At the same time, however, we do not find a similar sluggish pattern for industrial cities employing labor with more sophisticated skills. A mixture of limited labor supply and depressed labor demand, then, can account for comparatively-low urban growth in the 1850s and 1860s.

Lastly, during the fourth pandemic we find the lowest levels of (relative) population growth in the most industrialized places (strictly speaking, however, the coefficient referring to this is barely significant). These results could, as for the third pandemic, be interpreted in light of two mass emigration waves during the periods 1864–1873 and 1880–1893, when skilled labor was relatively scarce. Also, lower labor demand may have hindered recovery in the 1870s and 1880s.

In sum, the labor supply shock induced by cholera in the second pandemic was quickly ameliorated by unskilled migration from nearby cities. In subsequent pandemics, however, a mixture of labor supply and demand constraints ensured that (relative) recovery after the outbreaks happened in some places but not others.

Future work could use a wider range of variables to elucidate the economic impact of cholera in other contexts as well as an empirical setting that leverages exogenous variation. Our study makes it clear that this demographic shock had significant and sometimes persistent consequences and that researchers should devote more attention to understanding the economic effects of the many cholera outbreaks that afflicted 19th-century economies.

Notes

1. On the impact of plague on economic performance and labor markets, see Postan (1972), Voigtländer and Voth (2013) or Alfani and Percoco (2019); Jedwab et al. (2022) provides a recent review. A different, though related, strand of the literature has looked at the distributional consequences of plague (Alfani, 2022). On the 1918 Influenza, see Correia et al. (2022), Gallardo-Albarrán and de Zwart (2021) or Bridgman and Greenaway-McGrevy (2023); Beach et al. (2022) offers a useful review of the literature.
2. There are a few exceptions, such as Ambrus et al. (2020), Franck (2024) or Kappner (2024a).
3. To be sure, cholera could affect the economy in other, sometimes ambiguous, ways. For instance, epidemics could have accelerated public goods provision, and sanitation in

particular, by exposing the deplorable living conditions of the population (Vögele, 2020). We elaborate on other mechanisms in section 2.

4. The usual periodization of the three pandemics is: 1826–1837, 1841–1859 and 1863–1875 (Evans, 1988, p. 125). For simplicity and ease of exposition, however, we refer to the years with cholera epidemics *in* Prussia.
5. See, for instance, Allen (2009), Hornung (2015) or Jedwab et al. (2024).
6. During the fifth pandemic (1881–1896), about 900 deaths from cholera were registered, mostly in the Eastern and Baltic provinces and, to a lesser extent, in industrial Rhineland. The sixth pandemic (1899–1923) led to about 1,800 deaths, of which almost 1,700 occurred among the Eastern army troops during World War I. The last deaths due to cholera ever registered in Prussia occurred among a Königsberg laboratory janitor and her co-lodger in October 1921 (Kappner, 2025).
7. Using life tables for cholera deaths in Ariège (France) during an epidemic in 1854, Bourdelais (1991, p. 127) shows a clear U-shape mortality pattern with respect to age that becomes particularly pronounced at older ages. Age-specific death rates followed a similar pattern in Hamburg during a deadly outbreak in 1892 (Evans, 1988, p. 446).
8. Our review of factors influencing the demographic impact of cholera is not exhaustive. Other factors mattered as well, such as weather fluctuations (e.g., temperature or humidity) or external influences (e.g., military conflicts).
9. It is beyond the scope of this article to establish the trade-offs between the economy and public health measures. Evidence from the 1918 Influenza, however, indicates that non-pharmaceutical interventions did not depress the American economy, while they contributed to better health outcomes (Bridgman & Greenaway-McGrevy, 2023; Correia et al., 2022).
10. Table D-1, panel A shows that fertility is not consistently associated with contemporary and up-to-three-year lags of cholera mortality. Depending on the model specification, the coefficients are either positive or negative, and often statistically insignificant. The same applies to overall mortality, shown in panel B, with the exception of cholera's mechanical immediate effect on crude death rates.
11. There may be long-run dynamics emerging from the complementarities between labor and capital across sectors, which we cannot examine. Franck (2024) finds that a greater number of cholera deaths in 19th-century France resulted in labor-saving technology adoption in agriculture but not in industry. In our setting, lower labor demand in agricultural cities would hamper post-epidemic growth, while the opposite would be true for non-agricultural places.
12. Because of its geographic remoteness, we exclude the small South German district of Hohenzollern, formally a part of Prussia since 1850.
13. Hanover, Hesse-Nassau, the city of Frankfurt/Main and Schleswig-Holstein were annexed into Prussia then.
14. Beyond population counts, these sources contain information on various demographic indicators, such as age and gender distributions, though unfortunately at more aggregated levels.
15. Unfortunately, comprehensive city-level population counts were not published for the 1834 census, as well as most censuses before 1831. Apart from the 1810 and 1822 counts already discussed, the only source we are aware of is Statistisches Büreau zu Berlin (1821), reporting 1819 population counts. In contrast to all other census reports before 1840, these include military personnel and are therefore not comparable to population counts for other years in the 1820s and 1830s.
16. Some census reports, such as the one from 1861, additionally provided population counts based on other definitions, such as the resident population. However, the *factual* population is the only count concept consistently reported throughout the 19th century (Pfister & Fertig, 2024, p. 6).
17. From the same source, we take information for 325 rural counties that we employ in regressions with spatial lags.
18. Most of the time, these updates came biweekly, although it was not uncommon for reports to be assembled at other intervals, such as weekly or triweekly.

19. We employ a Poisson model for crude deaths and include the population at risk as an offset term. Motivated by Prussia's mortality decline after 1873 (see Figure 1), we allow the linear time trends to vary before and after 1873. Figure B1 in the appendix plots predicted deaths against the observed deaths; points below the 45-degree line are district-years with excess mortality.
20. Out of the 41 (15) district-years in which cholera accounted for 10–20% (more than 20%) of all deaths, 37 (15) district-years also experienced excess mortality, i.e. more deaths than predicted by our model. Kappner (2025) presents additional validation exercises, such as cross-checking other sources containing cholera mortality or predicting deaths using reliably measured predictors that correlate with the spread of the disease, such as warm temperatures.
21. We include Prussia's German neighbors because of their increasing economic and political integration through the 19th century (Pierenkemper & Tilly, 2004). All-German population data comes from Kappner (2025). In the absence of census counts for 1848 and 1866, we interpolated population levels using the closest censuses (1846 and 1849, and 1864 and 1867, respectively). We trace all railway lines, train stations, navigable rivers, artificial waterways, and ports that existed in Germany in 1831, 1848, and 1866 using Dumjahn (1984), Kaiserliches Statistisches Amt (1878), Ministerium für Handel, Gewerbe und öffentliche Arbeiten (1874) and Kurs (1898). While we do not directly observe the historical road network, we approximate least-cost travel times through it using Özak (2018)'s *Human Mobility Index* cost layer. This approach is widely used to estimate realistic pre-industrial travel paths and speeds (de la Croix et al., 2024; Fernihough & O'Rourke, 2021; Flückiger et al., 2022). We also use this cost layer to connect cities to railway stations and ports within a 25 km radius.
22. Our framework is not aimed at modeling decisions to migrate out of Germany, but rather between German locations. We think the former are driven by a different set of considerations.
23. The correlation between market potential and longitude is −.82 in 1831, −.60 in 1848, and −.69 in 1866.
24. Our results are robust to employing alternative radii.
25. To our best knowledge, no comprehensive city-level occupational or sectoral data has been published for Prussia after 1849.
26. For 1821, one location exhibits a 100-percent industrialization rate, while for 1849 and 1867 this issue affects four and 14 cities, respectively.
27. We aggregate cholera mortality by each pandemic to proxy for the total labor supply shock. In addition, we lack annual population data to estimate a more flexible model in which both cholera death rates and population change on an annual basis. In appendix section C.2, however, we show that our empirical framework is robust to different ways of operationalizing the epidemic shock. Also, our results remain similar if we employ a distributed-lag model that considers within-pandemic heterogeneity in the timing of annual outbreaks (appendix section C.6).
28. We are aware of various identification strategies from the literature to deal with the potential endogeneous nature of epidemics, but they cannot be applied to our setting. For instance, Franck (2024) instruments cholera shocks with summer temperatures. However, such information is not available at the detailed spatial level we consider in Prussia. Jedwab et al. (2024), on the other hand, instrument plague shocks in two ways: i) taking distance from the original starting outbreak location; ii) considering the timing of an epidemic, arguing that later shocks within a year last less due to the onset of cold weather. This approach is problematic in our context since a given city can experience multiple outbreaks over a single pandemic, implying multiple outbreak points and starting dates of epidemics.
29. Prussia had eight provinces at the time. While Berlin formed its own province in 1881, we incorporate it into the surrounding Brandenburg province.
30. We slightly adjust Hornung (2015)'s original variable as we extend our dataset both in terms of cities and time periods. To trace incorporations, we rely on Wikipedia.
31. We prefer this setting over a model that considers all periods jointly. As explained in section 2, the German economy was in transition during the 19th century so we expect that the coefficients of the recovery mechanism variables change over time. In addition, labor

emancipation only refers to the period up to 1848 and thus cannot be included in the analysis of the fourth pandemic.

32. This does not apply to our labor emancipation variable referring to the period up to 1848, which we only use in our calculations for the second pandemic.
33. Consider our industrialization variable in figure B5. Whereas this variable reflects some well-known clusters in the 1860s, such as the Ruhr valley or Silesia, proto-industrialization in the second quarter of the 19th century was spread more evenly throughout Prussia.
34. Figure B2 shows the right-skewed distribution of mortality rates for each pandemic.
35. Full regression outputs are provided in the appendix in tables C2, C3 and C4.
36. Selection into the epidemic among fast-growing cities could also explain the positive signs of the coefficients after 1837. However, the use of within-province fixed effects as well as our longitude variable should account for the eastern clustering of the second pandemic.
37. Our estimates, do not reflect the different *main* effects, i.e. population growth trajectories across tertiles. Instead, we are interested in relative differences within each tertile.

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