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# The Unification of Germany and Regional Economic Convergence:

Evidence from Real Wage Data, 1850-1889

by

Johan David Vesterager Husfeldt,

[jo2738hu-s@student.lu.se](mailto:jo2738hu-s@student.lu.se)

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Supervisor: Jonas Ljungberg

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# Abstract

This thesis studies the regional development of Germany in the 19<sup>th</sup> century, examining whether there was an increased tendency toward economic convergence between the German states following the country's unification. Through a quantitative analysis using real wage data on various German cities and regions covering the period 1850-1889, the study looks for evidence of beta-convergence both before and after the unification of 1871, as well as evidence for sigma-convergence during the whole period. The empirical study finds very weak evidence for beta-convergence at either the state- or city-level following the unification, and even finds signs of sigma-divergence rather than convergence, with economic differences seemingly having been somewhat smaller before the unification. However, the data are determined to not be sufficiently wide-reaching to support many definitive conclusions.

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# List of Abbreviations

FRG – Federal Republic of Germany

GDP – Gross Domestic Product

GDR – German Democratic Republic

HRE – Holy Roman Empire

NGC – North German Confederation

OLS – Ordinary Least Squares

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# 1. Introduction

Large economic differences persist between nations, and these remain the primary focus of much of the literature on economic growth and convergence. Here, economic convergence refers to the process by which the income and/or productivity levels of economies approach more similar levels over time, generally by poorer economies growing faster than richer ones on average, thereby reducing the gap. Regional differences are also significant within many countries, and they are often—and perhaps counterintuitively—just as persistent. History is littered with examples of economies either diverging or converging economically, and questions naturally arise as to why. Why do these differences exist, and what are the factors that can counteract them, leading states and regions to converge to more similar income levels? There are many such potential factors that could affect the outcome, such as increased trade between regions, technology spillovers, and closer institutional, legal, and political interconnections. This thesis aims specifically to examine the latter of these mentioned factors, using the example of 19<sup>th</sup> century Germany as a case study on regional economic convergence. The study is conducted using local wage data at the city and regional level, the findings of which are proven to be difficult to interpret.

Note that this thesis is largely based on a previous research proposal written for a previous course, and many of its elements will have been derived therefrom (Husfeldt, 2022).

## 1.1 Historical Context

Germany as a nation has been unified and divided multiple times throughout its history. The most recent and well-studied of these instances has been the reunification of the German Democratic Republic with its western counterpart, the Federal Republic of Germany, at the end of the Cold War in 1990. As a satellite state of the Soviet Union, the GDR had a socialist planned economy led by a one-party dictatorship, while the US-aligned FRG followed the western model of a liberal democracy with a market-based economy. The reunification brought an end to 45 years of division of the German nation, as the GDR was abolished, and its territories brought into the political and economic fold of the FRG (Turner and Sheehan, 2022). These two culturally similar yet economically and politically divergent states suddenly unifying into one has served as a very informative and recent natural experiment, with its



economic effects still being felt to this day, and there is by now an abundance of literature covering the economic development and convergence (or lack thereof) of the eastern and western regions of Germany.

By contrast, the German unification of 1871 and its economic consequences on the regional level has received comparatively less attention. The formation of the German Empire in 1871 was the culmination of a more than half-century long political transformation of the nation, which had begun with the dissolution of the Holy Roman Empire in 1806 as a consequence of the Napoleonic Wars. This ended a nearly thousand year-long legacy, and though the HRE had long been internally fragmented to the point that its constituent entities were de facto independent states, its demise paved the way for the following developments. Following Napoleon's defeat, it was replaced by the German Confederation in 1815, which included most of the German-speaking lands. The Confederation was little more than an association of states and, much like its imperial predecessor, it didn't exert any sovereign influence on its members (Hamerow and Sheehan, 2022). But as nationalist tendencies began sweeping throughout Europe, and the bitter memory of Napoleon's domination remained, calls for further integration of the German nation became ever louder. One of the early signs of this was the establishment of the *Zollverein* ("Customs Union") in 1834, which gradually came to include more and more members of the German Confederation, removing toll barriers and tying their economies closer together. Later, the national revolution of 1848 was a popular uprising that culminated in the first serious push toward unifying Germany into one country, yet the attempt was ultimately unsuccessful. It would take several more decades before another attempt at unification was made, though this time it would be successful. By 1867, the German Confederation had been abolished, and the states of northern Germany were unified by the North German Confederation, complete with a federal government and constitution. The blueprint of the NGC was kept when the southern German states also joined in to form the German Empire a few short years later, finally completing the process of German unification in 1871 (Hamerow and Sheehan, 2022).

The formation of the German Empire saw some two dozen states of the former German Confederation unify into a modern nation-state. Foremost among these was the Kingdom of Prussia, whose king also became the head of state as German Emperor of this new federal monarchy. Other important states were the Kingdom of Bavaria, Kingdom of Saxony, and Kingdom of Württemberg, while the remaining states with a lower rank ranged from the Grand Duchy of Baden to the Free and Hanseatic City of Lübeck. Famously, Austria was

excluded from the union, as was Luxembourg, despite both of these having been part of the German Confederation (Wawro, 2004, p. 18). Note that for this thesis, unless otherwise specified, the term “state” will be used to refer to the constituent states that made up the German Confederation and later the German Empire, such as Prussia, Bavaria, Saxony, etc. The term “region” will also be used instead of “state” in certain contexts, as the distinction between these two terms can get blurry, especially in the case of 19<sup>th</sup> century Germany, as the states varied greatly in size and had numerous exclaves (to get a feel for the complexity of Germany’s internal borders, see the maps in Figure 3.1 and Figure 3.2). Germany as a whole, both before and after its unification, will be described using terms such as “country”, “nation”, or “nation-state” depending on the context.

In the following decades after unification, the new Germany experienced rapid economic growth and industrialization, seeing its income levels catching up with the likes of Britain, whose growth was relatively slower at the time (Bolt and van Zanden, 2020). This became known as the Second Industrial Revolution (Mokyr, 1998), said to have begun around 1870 and thereby roughly coinciding with Germany’s unification, though the phenomenon was not unique to that country, as it brought with it significant increases in productivity for most North Atlantic economies until the First World War. This was in spite of a serious global depression in the 1870s induced by the financial panic of 1873 originating in Vienna (Nitschke, 2018), which impacted both North America and Western Europe. The late 19<sup>th</sup>-century to early 20<sup>th</sup>-century economic convergence between Germany and other industrial newcomers with Britain is well-known among economic historians, but what is far less known is to which extent there was an internal convergence between the newly politically integrated regions of Germany.

## 1.2 Motivation and Research Problem

Compared to the divided Germany of the Cold War, its reunification in 1990, and the subsequent regional developments of East and West until today, the German regional convergence of the previous century is quite understudied. This is somewhat understandable, given the scarcity of available economic data from the 19<sup>th</sup> century, and the fact that the internal borders of Germany’s states were quite complex at the time. Relatively little is known about regional GDP figures or wages in Germany before its political unification, and even in the initial decades after unification data are somewhat scarce. It is also difficult to say

whether the economic differences within larger states such as Prussia or Bavaria were less or more important than the differences between them, as these likely also had significant internal regional inequalities. Interestingly, many important parallels regarding the question of regional inequality and convergence can also be drawn between Germany and Italy in the same time period. Italy was an equally divided nation until the 1860s, when it too unified into one nation-state. The significant economic disparity between the northern and southern parts of Italy is well-known and was not solved by the unification, as the unequal levels of income between north and south persist to this day (Felice and Vasta, 2015). This was not lost on the people of the time; in fact, Bismarck himself, the man largely responsible for Germany's unification, expressed his worry that the inclusion of Bavaria in a political union would provide "*the same element of weakness that Southern Italy has created for that state*" (Erfurth, 2021, p. 20). This speaks to the perceived differences between the various regions of Germany at the time, and while Bavaria today is among the wealthier areas of the country (Statistisches Bundesamt, 2020), it becomes clear that gaining a greater understanding of the regional income differences is important to contextualizing much of 19<sup>th</sup> century European affairs.

The unification of Germany exists in a critical time period, when some countries were transforming into modern and industrialized economic powerhouses, while others began lagging behind significantly, and understanding the exact reasons for this has become one of the foundational questions of economic history. Germany's unification coincided with an unprecedented economic transformation of the country, and how this played out in the regional or state-level is well-worth studying, as it relates to many questions regarding when and why regional convergence occurs. Note that a key difference between the unification of 1871 and the reunification of 1990 is that the former was almost purely a political unification. The *Zollverein* had already linked many of the politically divided Germany closer together economically as early as the 1830s, meaning that trade could already move relatively freely between most German states even before unification. However, the opposite was also the case for a small number of German states that rejected the customs union even *after* being politically unified, with Hamburg and Bremen only joining the *Zollverein* as late as 1888 (Dedinger, 2015). This is all in stark contrast to the divide between East and West Germany during the Cold War, which was both a political *and* an economic one. Moreover, while evidence of economic convergence between eastern and western Germany since 1990 has been shaky at best, and all but non-existent at worst (Hall and Ludwig, 2006), this was under

conditions of one part—East Germany—having a fundamentally different economic system, and being forced to transform itself to comply with the now dominant West Germany. The institutional differences between the German states in the 19<sup>th</sup> century may not have been as pronounced, and here the unification happened more gradually. These factors distinguish the unification of 1871 from that of 1990, making it a unique case that may enable us to examine the isolated economic effects of a political unification, independent from economic unification.

As such, the purpose of this study is to examine the economic convergence between the German states (excluding those that did not become part of the Empire, such as Austria) and seeing if the unification of 1871 had an impact on this development. The research question can thus be stated in the following way: did the political unification of Germany lead to a greater economic convergence between the German states? The study aims to further contribute to our understanding of economic convergence and to which extent it is affected by political unification, as well as provide a clearer picture of the 19<sup>th</sup> century German economic situation at the regional level, regarding which states and/or regions were wealthier or poorer, and how these developed around the time of unification and industrialization.

The occurrence of convergence would require there to be a significant regional difference in initial income levels for Germany; a difference we don't know for sure was even present to begin with it. With this in mind, two hypotheses are formulated:

1. Different regions and/or states in Germany had significantly differing income levels at the time of unification in 1871.
2. Income levels began to converge after the unification in 1871. If convergence was already occurring before then, the convergence rate began to grow faster afterwards.

The first hypothesis needs to have been fulfilled for the second one to be meaningful in any way. The findings and conclusions of this thesis will therefore be dependent on the first hypothesis, despite the second hypothesis being the main point of study.

### 1.3 Outline of the Thesis

The rest of this thesis will set out to find evidence for and answer the research question. The second chapter presents and discusses the theories and previous literature on the topic of

regional economic convergence, especially as they relate to the context of Germany. The third chapter discusses potential data sources and present the wage data that have been chosen to study the research question, along with explanations on how these data have been processed to fit the study and discussion on some potential limitations of the data. The fourth chapter explains the methodological approach of the study chosen to answer the research question empirically, presenting the quantitative econometrics and variables being used along with robustness tests. The fifth chapter presents the results of the study, along with discussions and analysis on how to interpret the results and how they relate to the wider literature on the topic. The sixth and final chapter presents and discusses the conclusions of the study, summarizing the results and their implications, while making suggestions for future research on the topic.

## 2. Theory

This chapter aims to provide a theoretical framework to the thesis. The main framework is presented, starting with an explanation of the main theories on economic convergence and their background, followed by some brief contextualization of the topic as it relates to the research question. The literature on regional convergence and the economic history of Germany is quite extensive, so the following section also provides a summary of the general findings, both as they relate to the topic in general and to Germany more specifically.

### 2.1 Theoretical Approach

Economic convergence, as stated previously, is the phenomenon of economies approaching more similar levels of income. To be more precise, economic theory has given two general definitions of convergence that are important to distinguish: sigma( $\sigma$ )-convergence and beta ( $\beta$ )-convergence. Sigma-convergence refers to the reduction in the dispersion of incomes across economies, whereas beta-convergence is defined as the tendency for initially poorer economies to have a faster income growth than richer ones (Barro and Sala-i-Martin, 1991). Intuitively, the two concepts are related, as sigma-convergence is conditional on the existence of beta-convergence, meaning there must be beta-convergence for sigma-convergence to also occur, while the presence of beta-convergence often leads to sigma-convergence as well in the long run. But the occurrence of beta-convergence does not necessarily imply sigma-convergence, as the absolute income gap can still increase significantly even when a poorer country has a relatively higher growth rate. Moreover, in cases where the initially poorer economy overtakes the richer economy and continues to grow to the point where the income gap (now inversed) is as wide as it was initially or wider, beta-convergence does *not* lead to sigma-convergence (Sala-i-Martin, 1996a). Either way, some criticize the beta-convergence model as a useful measure of convergence, such as Quah (1996), arguing that even when poorer economies have a faster growth rate, the direct gap between economies can still grow quite significantly.

The typical conceptualization of economic convergence is closely interrelated to the neo-classical growth model based on the theories of Solow (1956) and others. The neoclassical model, which holds up capital, labour, and technology as the primary productivity factors

upon which economic growth is based, meaning that growth occurs when the productivity of any these factors increases. Inherent to the model is also the assumption of diminishing returns on capital accumulation. Diminishing returns on capital implies a higher rate of return when the capital stock is small, thus inducing higher growth for economies with less capital and lower growth for those with more (Sala-i-Martin, 1996a). It also means that the closer the income levels for the two economies are, the lower the rate of convergence should be as well, as they should have more similar growth levels, while the convergence rate should be greater when the gap is wider. The intuition is relatively straightforward, and it implies both beta- and sigma-convergence, as a growing economy would be unable to overtake another economy, as it too would eventually face diminishing returns. However, here emerge two other important categories to distinguish: *absolute* and *conditional* beta-convergence. Absolute beta-convergence refers to the phenomenon as previously described, when a poorer economy grows faster than a richer one, and the underlying assumption here is that the two economies have the same steady state. Conditional beta-convergence, on the other hand, occurs when an economy grows in a specific factor, such as capital. This way, if economies have different steady states, a richer country with a smaller capital stock can grow faster than a poorer country with a larger capital stock, and it will still be considered a convergence at the level of the specific productivity factor (capital in this example). In other words, conditional beta-convergence refers to the phenomenon of an economy's growth rate being positively related to the distance from its steady state. As such, the existence of beta-convergence does not necessarily mean that a poorer economy is growing faster than a richer one if these have different steady state levels; it will only lead to a reduction in the gap of overall income levels if economies are assumed to have the same steady state (Sala-i-Martin, 1996a).

Besides the seemingly “natural” or “automatic” laws of the neoclassical model, what are other factors that can lead to economic convergence? Many argue that increased integration, (meaning, among other things, reduced trade barriers, common currency, etc.) between economies is conducive to economic convergence, with the EU being cited as a common example of this (Yin et al., 2003), as its member states have seen significant convergence coinciding with increased economic and political integration. Moreover, Sachs and Warner (1995) list certain policies as being good for economic growth and therefore convergence, primarily trade liberalization and protection of private property rights. The authors state that “Poorly managed economies — such as those with the absence of secure property rights,

autarkic trade policies, inconvertible currencies, and so forth — are unlikely to experience convergence no matter what the underlying production technology or initial level of human capital” (Sachs and Warner, 1995, p. 5). In their view, policies and institutions thus become the variable that affect the rate of convergence between developing and developed economies, as it is explicitly stated that these can be changed independently of an economy’s income level. Other factors, such as geography may also play a role, but these are not variables that can be easily changed by humans. The points made by these authors make it clear that the discussion on convergence very often approaches the standard discussion of economic growth. Developing economies cannot converge with developed economies without themselves growing, and it is therefore inevitable that any question on how to affect convergence rates is adjacent to the question of how to achieve economic growth.

Economic convergence, as with much of economic theory, is a concept that has become especially meaningful since the 19<sup>th</sup> century and the Industrial Revolution, when differences in income levels across the world started to become truly significant. As stated previously, the period of 1870-1914 is considered a particularly important period, when the Second Industrial Revolution brought with it a convergence of living standards for the economies of the North Atlantic (Godley, 2001). Germany was among the countries affected by this convergence, and part of this was also a significant factor price convergence associated with increased trade and migration, as the labour scarce countries of the New World experienced significant migrations from Europe, significantly altering the ratios of labour and capital on both sides of the Atlantic (Williamson and O’Rourke, 1999). This further strengthens the ideas of Sachs and Warner (1995) that economic openness and convergence are linked together, as this connection certainly seems to have been in play in the late 19<sup>th</sup> century. If Germany experienced convergence with other nations, it is very possible that the same processes that caused this very convergence were also occurring at the regional level, especially when one considers the rapid industrialization that the country was experiencing at the time.

## 2.2 Literature Review

Economic convergence is a widely-studied topic among economists, both at the global and regional level, though the global development tends to receive more of the attention. A comprehensive review and study by Sala-i-Martin (1996b) summarizes much of the literature



on regional convergence, serving as a solid framework for the topic. Looking at the United States, Japan, and the five largest Western European economies, the author concludes that intranational regional convergence is a consistently occurring phenomenon, usually staying at an annual rate of about two percent, citing the neoclassical growth model and technological diffusion as the primary explanation. This is consistent with other findings on convergence, and the two percent convergence rate has become an oft-cited number in the literature (Barro and Sala-i-Martin, 1991; Abreu et al., 2005).

As stated previously, regional convergence in Germany has been extensively studied as part of the growth literature, but the vast majority of this has focused on the period following the Cold War. Barro and Sala-i-Martin (1991) predicted that the poorer eastern Germany would converge with the richer western Germany in accordance with the neoclassical model, but hindsight seems to have proven otherwise. As was previously touched upon, Quah (1996) was one of the early critics of this prediction, stating that even if beta-convergence were to occur, the distance between their income levels (as it relates to sigma-convergence) might still remain the same. In the following decade, Hall and Ludwig (2006) studied the regional economic growth of Germany since reunification and found that, despite significant improvements in its capital stock and labour productivity, eastern Germany had failed to catch up to the western part of the country in terms of income levels. The authors provided strong criticism of the neoclassical framework on economic convergence, calling into question the assumptions made by the likes of Barro and Sala-i-Martin (1991) and their predictions that eastern Germany would converge with the west. The sentiment is shared by others who have studied modern Germany, such as Brück and Peters (2009), who concluded that the regional income gap between east and west had actually increased in recent years, despite initial convergence in the early years of reunification. Furthermore, Busch and Müller (2004) have criticized the policies pursued by the country, arguing that the institutionalized wealth transfers from western Germany actually backfired and hurt the long-term development of eastern Germany, as it undermined the conditions that would've been necessary to transform the economy in the direction that it needed to. Overall, the consensus is generally clear when it comes to modern Germany: the eastern part of the country has seen significant improvements in income levels, but has generally failed to catch up to the income levels of western Germany, especially after the 1990s. However, there is still room for considerable debate as to why this might be.

By contrast, and as has been mentioned previously, the literature on the 1871 unification is not nearly as extensive. Although there is a fairly large body of literature and data on the economic development of 19<sup>th</sup> century Germany, almost none of it focuses on the internal variations of this development between the various states and regions of the nation, either before, during, or after the country's unification. For example, Pierenkemper and Tilly (2004, p. 15) in their book about the German economy in the 19<sup>th</sup> century constructed estimates for GDP per capita and real wages, but they did not account for the differences between the states and regions of the country. They did show that GDP per capita grew from the 1840s and onward, while real wages stagnated in the middle of the century, only beginning to increase steadily as late as the 1880s, a decade after Germany's unification. The initial disparity between growth in GDP and real wages was not unique to Germany in this time period, but is worth noting. The authors claim that the figures indicated and were linked to structural changes and industrialization, and that the process was nation-wide. Very little is said about specific regional developments, aside from a case study on the agrarian reforms of Prussia, and there is not comparison made with any other state.

To provide some perspective, one country that *has* seen research on the exact topic of economic convergence since the 19<sup>th</sup> century is Sweden. Research by Enflo et al. (2018) constructed regional GDP per capita figures since 1860 with the help of a method developed by Geary and Stark (2002), using these to study the convergence between the various regions of Sweden. The Geary and Stark method uses a mix of employment and wage data from the past to construct estimates for GDP per capita, and it's used quite extensively in works adjacent to Enflo et al. (2018). The study was part of a greater project studying various European countries' regional development over the past century, compiled in the book *The Economic Development of Europe's Regions*, edited by Rosés and Wolf (2018). Janisse et al. (2018) also contributed to this work, writing about regional developments in Denmark since 1850. But to bring the focus back to Germany, Wolf's own contribution to the book, a chapter named *Regional economic growth in Germany, 1895-2010* (Wolf, 2018), comes close to covering the time period of interest, but still doesn't quite reach as far back as the unification of 1871.

Wolf is among the foremost economic historians on Germany in the industrial period, but as of now he has not extended the analysis of regional convergence further back. In another study, looking at data of intranational trade flows in Germany between 1885 and 1933, Wolf (2009) examined the economic integration of the country before the Nazi period. By dividing

the country into several trade districts that roughly corresponded with the states and provinces of Germany, Wolf concluded that the German Empire prior to World War I was still a partially fragmented economy, despite the *Zollverein* and the recent political unification, and that many border regions were better integrated with their neighbouring countries than with other regions of Germany itself. Geographic realities, such as river-flows or mountains still played an important role in determining the direction of trade, although railroads had begun to increasingly connect Germany's regions since the mid-19<sup>th</sup> century (Wolf, 2018). This says very little about income levels at the regional level, and indeed there is no mention of economic convergence or divergence in the study, but Wolf's findings do provide some context to Germany's regional development. If the political unification of 1871 had relatively little impact on the economic integration of the country compared to earlier political and infrastructure developments, it also seems intuitively less likely that Germany's unification would have had much effect on the rate of economic convergence in the country. Keeping the prescriptions of Sachs and Warner (1995) in mind, it would not be unreasonable to suggest that Germany's own internal convergence would be contingent on its internal trade (or lack thereof). Given these assumptions, and the knowledge that modern eastern Germany has lagged behind as well, the prospects for convergence within Germany in the late 19<sup>th</sup> century seem quite dubious at face value, even as real knowledge on the subject remains limited.

That being said, some literature on the regional developments of 19<sup>th</sup> century Germany does exist, especially in more recent times. A new study by Erfurth (2021) examined the development of economic inequality of both Italy and Germany within the context of their respective unifications. For Germany, Prussia and Bavaria were chosen as the two main states for comparison, not only because they were the two largest states at the time, but also since they could be considered each other's cultural and geographic counterpoints, which was previously touched upon. By constructing social tables, Erfurth found that Bavaria and Prussia had only small differences in mean incomes before unification, while the main finding showed only a minimal difference in economic inequality between the two. One could suggest that this meant that the economies of both states were similarly structured, which may not be surprising, as the possibility of this was mentioned previously in this thesis. Nevertheless, despite Erfurth (2021) being one of the few studies focusing on the economic differences between specific states, there is once again very little to be said about absolute income levels or economic convergence.

Furthermore, research by Ploeckl (2010), specifically on the southern state of Baden and the impact of the *Zollverein*, found that the customs union had a positive impact on the economic development and growth of the state. One of the reasons for this was that neighbouring foreign regions in Switzerland and France set up business there to access the larger German market. As such, Baden served as an important bridge between these countries and the rest of Germany. The author argues further that the removal of trade barriers had a significant effect on all member states of the *Zollverein*, and he goes as far as to state that it was “the most important institutional development for the economic unification of Germany during the 19th century” (Ploeckl, 2010). Thus, as has been previously speculated, Germany’s political unification may by implication have been less important in comparison, as any economic effect of closer cooperation between the states would’ve been linked to the *Zollverein* instead.

Another, more recent study by Pfister (2018) studied the development of real wages 19<sup>th</sup> century Germany, constructing a wage dataset on various industries in a number of cities and regions. While very little focus was put on the differences between these cities and regions, the study found that the average real wages of Germans fluctuated and stagnated before unification, before beginning a steady increase afterwards. This is more or less in line with other, previously cited findings on real wages in the 19<sup>th</sup> century (Pierenkemper and Tilly, p. 15), which don’t find a stable growth in real wages before the Second Industrial Revolution after 1870 (Mokyr, 1998). Even though Pfister (2018) uses data from different cities and regions, which is a rare find when it comes to this particular topic, the overall analysis remains confined to the national level, and no inquiries are made into the different regional outcomes in real wages.

On the other hand, something that *has* been studied at the regional level is the development of biological and demographic determinants of living standards in the 19<sup>th</sup> century. Gehrman (2011) studied infant mortality rates in Germany during the period of 1825-1900, examining the rates by individual regions. The findings showed significant differences in infant mortality rates between the states at the start of the period, with south German states like Württemberg and Bavaria having the highest at around 0.30, and the northern areas of Schleswig-Holstein and Mecklenburg at less than 0.15. However, starting around 1870, there was a significant decrease in infant mortality rates for those at the higher end, with Württemberg seeing the most drastic decline to just above 0.20 by 1900. Most regions at the lower end did not decline, and the result was a narrowing of the gap, a convergence, of infant mortality rates. The correlation between infant mortality rates and income levels is hardly

one-to-one, but they both are generally indicative of the prosperity and living standards of a region. However, studies on the relationship between wages and mortality rates, such as Ljungberg (2013), have not found any strong link between the two, arguing that education was the primary driver of the decline in infant mortality rates. With this in mind, the findings do not prove that there was a convergence in income levels, but they do suggest that there may have been significant socioeconomic differences between the states of Germany, and that these conditions may have changed over time. Especially interesting is the fact that the decline in infant mortality rates began right around 1870, at the same time as both the unification and the Second Industrial Revolution. Whatever the true cause may have been, the time around Germany's unification brought with it dramatic changes in mortality rates, and the differences were clearly felt most strongly in the least prosperous areas (at least by this particular metric).

In summary, there is an abundance of literature on economic convergence, German economic history, and even regional convergence for Germany during the last century. But a disappointingly small amount of that literature—practically none of it, in fact—is dedicated to the convergence of the German states and/or regions in the 19<sup>th</sup> century. The time period is undeniably one of great importance to the history of the country, both politically and economically, but it has been largely overlooked compared to other, more recent developments. The literature that does exist seems to point in the direction that income levels increased across the country following unification, while the internal differences between states may not have been very large in the first place. However, the literature on infant mortality rates seems to suggest the opposite, as these varied significantly between the various regions of the country in the beginning of the 19<sup>th</sup> century, before rapidly converging after 1870. Nevertheless, nothing on the subject of region-specific income levels can be said with great confidence based on the literature review, as the available evidence remains limited. Some of the literature is adjacent to the question of regional income levels, such as studies on intranational trade flows, regional inequality, or case studies of specific states and their economic development, but practically none address this specific issue. The importance of finding and analysing reliable data on income levels at the regional or state level becomes immediately clear if one is to answer the research question.

## 3. Data

This chapter presents and discusses the data used for the econometric analysis. The first section discusses potential sources and what would constitute ideal data for answering the research question. The following section presents the raw dataset on wages that has been chosen and discusses its strengths and weaknesses. Thirdly, a section is dedicated to explaining the steps taken to normalise the data, as they are insufficient for comparison in their raw form. The fourth section presents the normalised data, providing some graphs of the development real wages and making some observing comments. The final section presents and discusses the control variables that have also been included for the empirical analysis.

### 3.1 Potential Material

To answer the research question, data on income levels at the regional and/or state level of Germany in the 19<sup>th</sup> will be used. The data would have to cover the time period surrounding the unification of Germany in 1871, so that convergence rates can be measured both before and after that point. A good and commonly used measure in economics would be figures for the gross domestic product (or “gross regional domestic product” to be more precise, but the “GDP” abbreviation will be used for simplicity’s sake) of the states over time.

The previous chapter mentioned research done by Enflo et al. (2018) and Janisse et al. (2018), both of whom used the Geary and Stark method (2002) to construct regional GDP figures for Sweden and Denmark, going as far back as 1860 and 1850 respectively. The Scandinavians are among the most well-documented countries when it comes to these types of data, but even so, these figures have been estimated relatively recently, so it is likely not surprising that estimates going back equally far for other countries, such as Germany, have not yet become widespread. While there are many data from Germany in the 19<sup>th</sup> century archived in the GESIS archive for historical statistics (Rahlf et al., 2012), GDP levels at the regional level are not among these. This is unfortunate, as GDP is the most common intuitive way to measure the economic prosperity of a country or region, and would ideally serve well to answer the research question. Constructing regional GDP levels independently would also be too time-consuming for the purposes of this thesis, so an alternative will have to be found.

One option would be to make use of biodemographic indicators, such as life expectancy or infant mortality rates, as has been done before by Gehrman (2011), for example. This was mentioned in the previous chapter as well, but what was also mentioned was that biodemographic indicators usually do not correspond exactly with economic indicators of living standards, so using these instead would undermine the purpose of the thesis. Though data might be more easily available, it would likely also not yield very new or interesting results, as studies on biodemographic indicators have already been done by the likes of Gehrman, and conclusions on the economic developments would have to be based on guesswork and dubious inferences.

So, this leaves the option of finding already existing data on economic indicators other than GDP. There exist some few data sources on regional economic figures for the time period of interest. The Ifo Prussian Economic History Database (iPEHD) contains data for wages and income taxes at the county level in the Kingdom of Prussia during the 19<sup>th</sup> century (Becker et al., 2014). However, the data only cover a handful of years, and they are limited to Prussia alone, omitting any other states of Germany. Prussia, much like Scandinavia, had a tradition of record-keeping that surpassed the rest of Germany, and so one would expect that state to have the most available economic data, and indeed this seems to be the case. But the flipside of this is that other states—even larger ones, like Bavaria—are far less well-documented, and consequently economic data are far more scarce, as no similar dataset to the iPEHD exists for these other states. Since the goal of this thesis is primarily to examine the convergence between the states, and not within the states themselves, the iPEHD dataset is insufficient for such a purpose. Nevertheless, wage data is likely the best option besides GDP, as it gives a good indication of income levels in a given region. Though wages are usually not recorded at the state level, but tend to be on the more local city-level, they can at least give some indication of the income levels of various regions.

Moreover, the empirical model, which will measure beta-convergence, requires data for control variables, as it is in the interest of the study to control for other variances between states that could potentially have affected the growth in wages. Chapter 4 also clarifies how including control variables will help distinguish between conditional and unconditional beta-convergence. In the context of the 19<sup>th</sup> century, control variables in an economic model can range from level of urbanisation, schooling, number of railways, and many others, and these will have to be at the regional level as well, much like the main wage data.

## 3.2 Source Material

Ultimately, the dataset by Pfister (2018) was chosen for this study, with the citation for the dataset being Pfister (2019). It contains panel data for nominal wages for various urban industries and trades in a number of German cities and regions over time. The extent of the data varies depending on the city and industry, but it covers the period of about 1840 to 1889, though data for some cities go back as far as 1818. While having the data extend all the way to 1914 would be ideal, as it would allow us to see how the states developed until World War I, the covered time period should still be sufficient enough to answer the research question. The industries which are covered by the data are heavy iron goods, mechanical engineering, mining, printing, textiles, and urban construction. The wage data for textiles are not at the city level, so the textile industry has been excluded completely from the analysis. Some cities with insufficient data have also been excluded. Along with nominal wage data, the set includes consumer price indices and weights for industries to enable the calculation of real wages as well. The dataset is heavily based on an older set by Kuczynski (1962), which is among the first compilations of wage series in Germany from this period. But Pfister (2018) makes significant additions to the data as well, updating it to be more suitable to modern times.

The set of included cities and regions is diverse, covering Berlin, Hamburg, Munich, Leipzig, and many others, each with their own series of wages over time. Many states, certainly the largest and most important ones, are represented by these cities. While Prussia accounts for a large number of the cities, this is not surprising given the size of that state. On the other hand, a weakness would be the lack of consistency in which cities are represented by which industry and what time period they cover, and the fact that not *all* states are represented by the included cities. Data for some cities don't even cover the years before or after 1871. Moreover, the wages are not always recorded in the same currency or timeframe. While most are written in German mark, some are valued in US dollars or even grams of silver, and while some wages are recorded annually, some are weekly, biweekly, or even daily, which makes the series difficult to compare to each other. The wages for the printing industry is also divided into two types: before 1872, wages are recorded per 1000 words written and afterwards they are recorded weekly. These limitations and inconsistencies largely have their root in the fact that the data were not originally compiled for the purpose of comparing cities or regions to each other. Rather, Pfister (2018) and Kuczynski (1962) before him studied the



development of real wages nationally. The German mark didn't even really exist prior to the unification of the country, so it's also somewhat understandable that not all wage series are recorded in that currency. Nevertheless, the lack of normalisation of the dataset necessitates careful extra work to process it, which will be described the following section.

Another potential concern is one inherent to wage data: they more than likely do not correspond one-to-one with GDP per capita in most cases, and previous research, such as Pierenkemper and Tilly (2004, p. 15), shows that they certainly didn't in the 19<sup>th</sup> century. The increases in real wages lagged behind increases in GDP per capita for many decades before beginning to catch up, and we can be reasonably certain that whatever the wage data show us will not necessarily be completely indicative of the more general productivity of any given state. If GDP per capita were used instead, it's very possible that the data would tell a different story. Nevertheless, real wages are a commonly used indicator of income levels and living standards, and some ways it measures living standards better than GDP, so this concern does not necessarily imply a weakness. It is, however, something the reader should keep in mind.

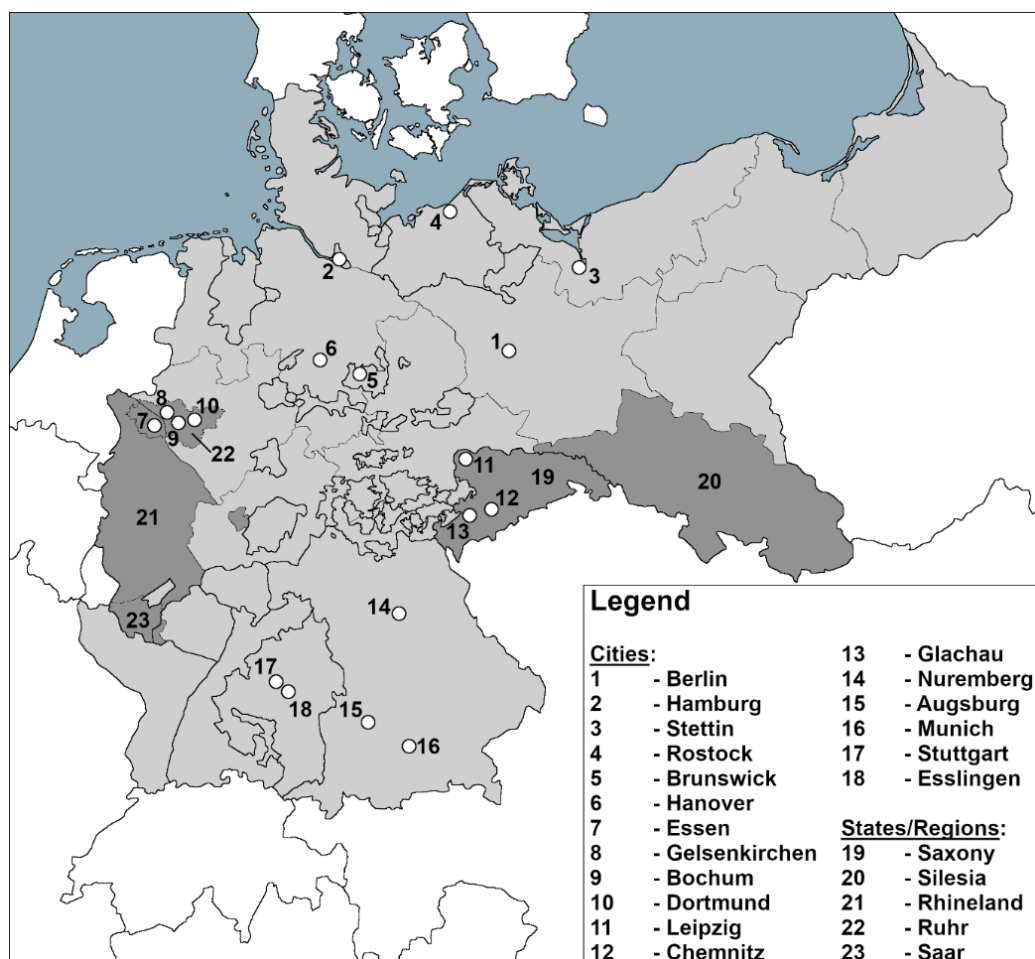
The inconsistencies in the data make them difficult to present in a simple overview. Shown below is a table and two maps of the German Empire with its internal state borders. Table 3.1 presents all cities and regions included in the dataset in table form, showing which states they belong to, which industries they are represented in, and which time period their respective wage series cover respectively. For example, Berlin has wage data in the printing industry for the period 1830-1889 and data in the urban construction industry for the period 1868-1889. However, the CPIs don't start before 1850, so no real wages can be calculated before that year, and the analysis will therefore be limited to 1850-1889. Also note that the city and state of Hanover did not belong to Prussia before 1866, but since the data for Hanover do not extend further back than 1875, this does not need to be taken into consideration. See the Appendix (Table A.1) for descriptive statistics of the raw wage data within the various industries, excluding the aforementioned textile industry.

*Table 3.1 Cities and Regions Represented by the Dataset*

| <b>City/State/Region</b> | <b>State</b>         | <b>Industry</b>                               | <b>Time period</b>      |
|--------------------------|----------------------|---|-------------------------|
| <b>Berlin</b>            | Prussia              | Printing,<br>Urban construction               | 1830-1889,<br>1868-1889 |
| <b>Hamburg</b>           | Hamburg              | Urban construction                            | 1840-1889               |
| <b>Stettin</b>           | Prussia              | Mechanical engineering                        | 1870-1887               |
| <b>Rostock</b>           | Mecklenburg-Schwerin | Urban construction                            | 1840-1886               |
| <b>Brunswick</b>         | Brunswick            | Urban construction                            | 1840-1877               |
| <b>Hanover</b>           | Prussia              | Mechanical engineering                        | 1875-1889               |
| <b>Essen</b>             | Prussia              | Heavy iron goods                              | 1848-1889               |
| <b>Gelsenkirchen</b>     | Prussia              | Urban construction                            | 1871-1885               |
| <b>Bochum</b>            | Prussia              | Heavy iron goods,<br>Urban construction       | 1869-1889,<br>1871-1885 |
| <b>Dortmund</b>          | Prussia              | Mining  | 1818-1889               |
| <b>Leipzig</b>           | Saxony               | Printing,<br>Urban construction               | 1830-1889,<br>1840-1860 |
| <b>Chemnitz</b>          | Saxony               | Mechanical engineering,<br>Urban construction | 1860-1887,<br>1841-1885 |
| <b>Glachau</b>           | Saxony               | Urban construction                            | 1865-1885               |
| <b>Nuremberg</b>         | Bavaria              | Mechanical engineering,<br>Urban construction | 1851-1889,<br>1840-1889 |
| <b>Augsburg</b>          | Bavaria              | Mechanical engineering                        | 1851-1889               |
| <b>Munich</b>            | Bavaria              | Mechanical engineering,<br>Printing           | 1867-1889,<br>1848-1889 |
| <b>Stuttgart</b>         | Württemberg          | Printing                                      | 1830-1889               |
| <b>Esslingen</b>         | Württemberg          | Mechanical engineering                        | 1848-1889               |
| <b>Saxony</b>            | Saxony               | Mining  | 1869-1885               |
| <b>Silesia</b>           | Prussia              | Heavy iron goods                              | 1869-1889               |
| <b>Rhineland</b>         | Prussia              | Urban construction                            | 1855-1870               |
| <b>Ruhr</b>              | Prussia              | Heavy iron goods                              | 1855-1889               |
| <b>Saar</b>              | Prussia              | Heavy iron goods,<br>Mining                   | 1869-1889,<br>1824-1889 |

Source: Pfister (2018) data

For a more visual representation, Figure 3.1 illustrates which German cities and regions are represented in the dataset on a map. States and regions are highlighted in dark grey, and include the state of Saxony, the Prussian provinces of Silesia and the Rhineland, and the informal Ruhr and Saar areas. The latter two of these, defined on the map by their later formalised borders, also have territories within the Rhineland, though the majority of the Ruhr is within the neighbouring province of Westphalia, which is otherwise not represented in the data, while a small piece of the Saar (at least as defined by its later gotten official borders) is part of the Palatinate exclave of Bavaria (though since the data for the Saar are based on areas within Prussia it will entirely be counted as part of Prussia). Note that, as previously mentioned, no single one of these cities or regions is represented by all industries; the map merely shows which cities are represented at any point in the dataset.

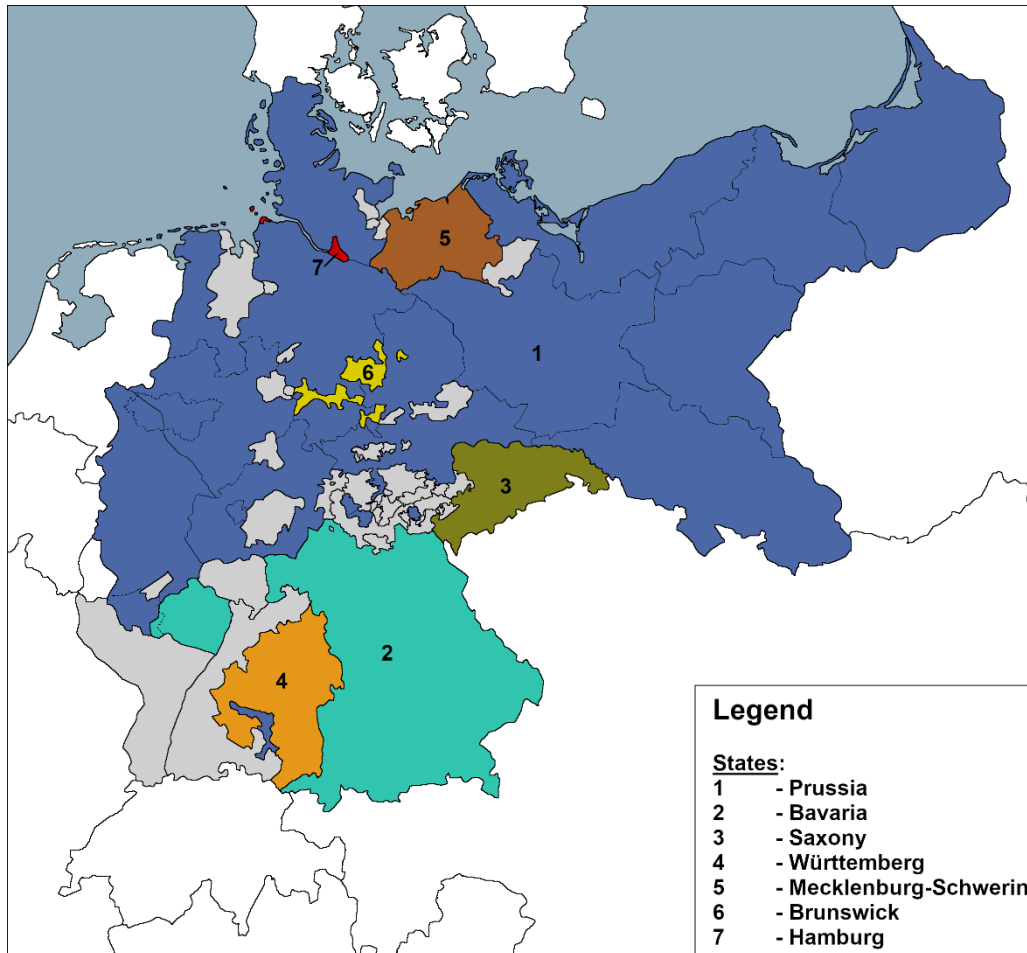


*Figure 3.1 Map of Cities Represented by the Data*

Source: Author's own map based on Wikimedia Commons (2021)

Figure 3.2 shows another map, this time highlighting in colour the states that are represented by the cities and regions included in the data, while the rest remains in grey. For example, Munich is a city in Bavaria, so Bavaria is colourised and labelled, while no city or region in

Baden is included in the data, so Baden is not highlighted (coloured light grey). Naturally, the coloured states are not represented in all industries either.



*Figure 3.2 Map of States Covered by the Cities*

Source: Author's own map based on Wikimedia Commons (2021)

The two maps are meant to provide an intuitive idea of which states are examined for this thesis, and which parts of Germany are completely excluded by the data. As can be observed, most of the country is accounted for on some level or another, though there are also some significant and unfortunate holes, the most glaring ones being mid-sized states such as Oldenburg, Hesse, and Baden not seeing any representation. Most of the smaller states are also missing, and in the end, this means that only seven states in total are covered by the data. This will result in a very small number of observation if one chooses to only look at the state level, which will likely lead to econometrically dubious results.

### 3.3 Normalising the Data

To resolve the issue of exchange rates, converting the currencies in this time period is not quite straightforward. Though Pfister (2018) provides a steady exchange rate of silver in his study, which enables the conversion of these values to German mark (5.5556 grams for 1 mark), he does not do so for the US dollar, and since there is no easily available record of the direct exchange rate between the mark and dollar, converting the values to make them comparable cannot be done directly. Instead, we use exchange rates for other currencies that *are* available to indirectly convert dollars to mark. The underlying data from Ljungberg (2019) provides century exchange rates for the British pound sterling to the US dollar as well as to the Swedish krona between the years 1840 and 1900. Lobell (2009) in turn provides exchange rates for the Swedish krona to German mark between 1804 and 1914, which enables a roundabout conversion from dollars to mark, by converting the values of the wage data from USD to GBP, then GBP to SEK, and finally from SEK to German mark to finally give us a normalised series of wages. Additionally, Pfister's exchange rate for silver does not account for the changes in the price of silver after 1872, caused by Germany's adoption of the gold standard (Meissner, 2002). The converted silver wages after 1872 are therefore also deflated according to the silver price index by Allen (n.d.).

Resolving the timeframe of the wages requires some assumptions to be made regarding the time spent working in these industries. The author behind the data states himself that employment was often seasonal, and so the normalisation of wages from daily or weekly to the annual level should "be interpreted as a convention rather than an effort to determine effective annual earnings" (Pfister, 2018, p. 572). With this in mind, the work week is assumed to be six days long (Giattino et al., 2020) and the work year 52 weeks long. Daily, weekly, and biweekly wages are thusly converted to annual wages with the use of these assumptions. Moreover, the printing wage data is resolved by linking the weekly wage to the wage per 1000 words at the point where they meet (the year 1872) and extrapolating the wages before 1872 based on the rate of that year. By these methods, much of the data will likely not reflect the exact levels of income of workers, but rather what they would have earned given a certain amount of work.

The nominal wage data, once normalised to the same currency (mark) and timeframe (annual), are converted to real wages using the CPIs, weights, and instructions provided by Pfister (2018). The real wages of Munich, Nuremberg, and cities and areas within Prussia

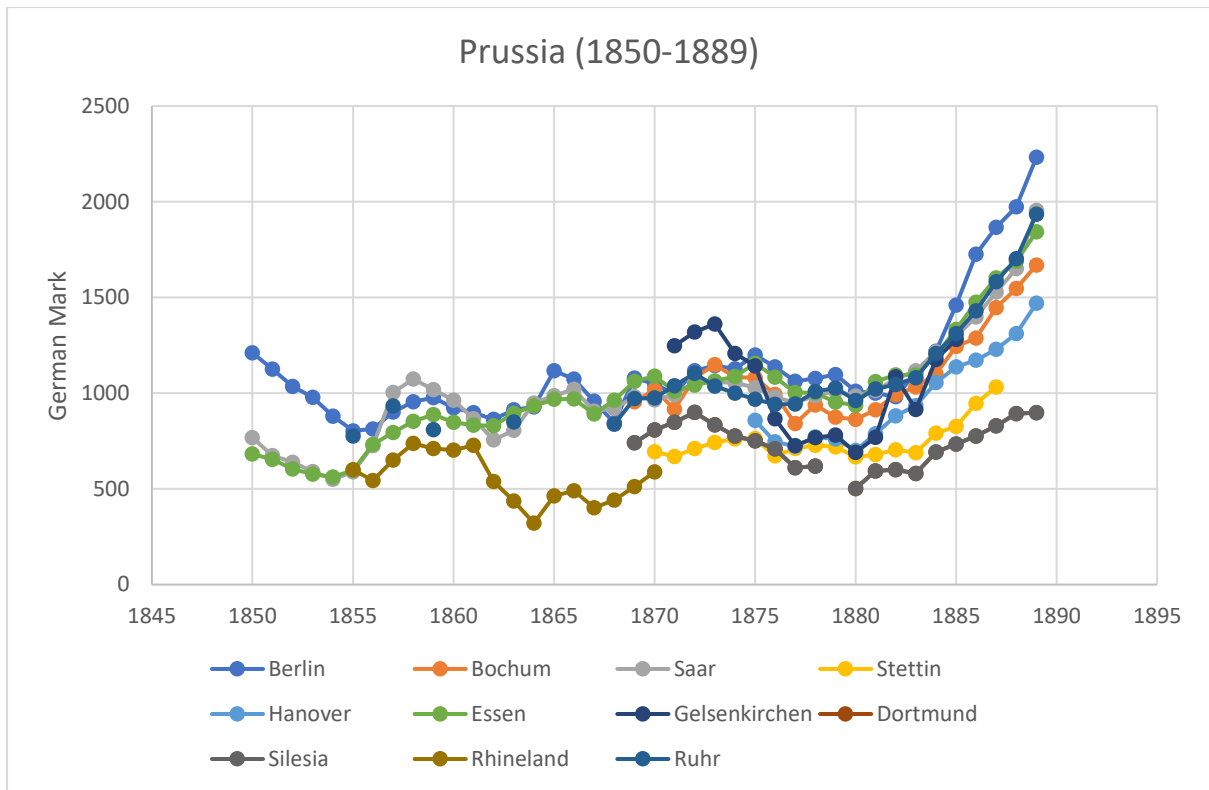
(including the Saar) are calculated using their respective food price indices, while the rest are calculated with the generalized food price index. The generalized food index is for the whole of the country, and does not account for regional variations, which should be acknowledged. However, the differences in food prices between the generalized index and the more specific indices are generally quite small, so this is not suspected to cause too much of a problem, especially as only a handful of cities are used for it.

Finally, to account for the variations in wages across industries, the wages in the varying industries are indexed with the urban construction industry as a numeraire. This means that the relationship between wages across industries for cities that are represented both in urban construction and some other industry is extrapolated to the other cities with that other industry. If two cities in the urban construction industry are both present in another industry (such as Berlin and Leipzig, both represented by printing), then the index for that industry is derived from the average index of these two. The mining industry, which has no cities in the urban construction industry, is indexed by two steps via the Saar region (which has data for heavy iron goods and mining) through the heavy iron goods index and finally to urban construction.

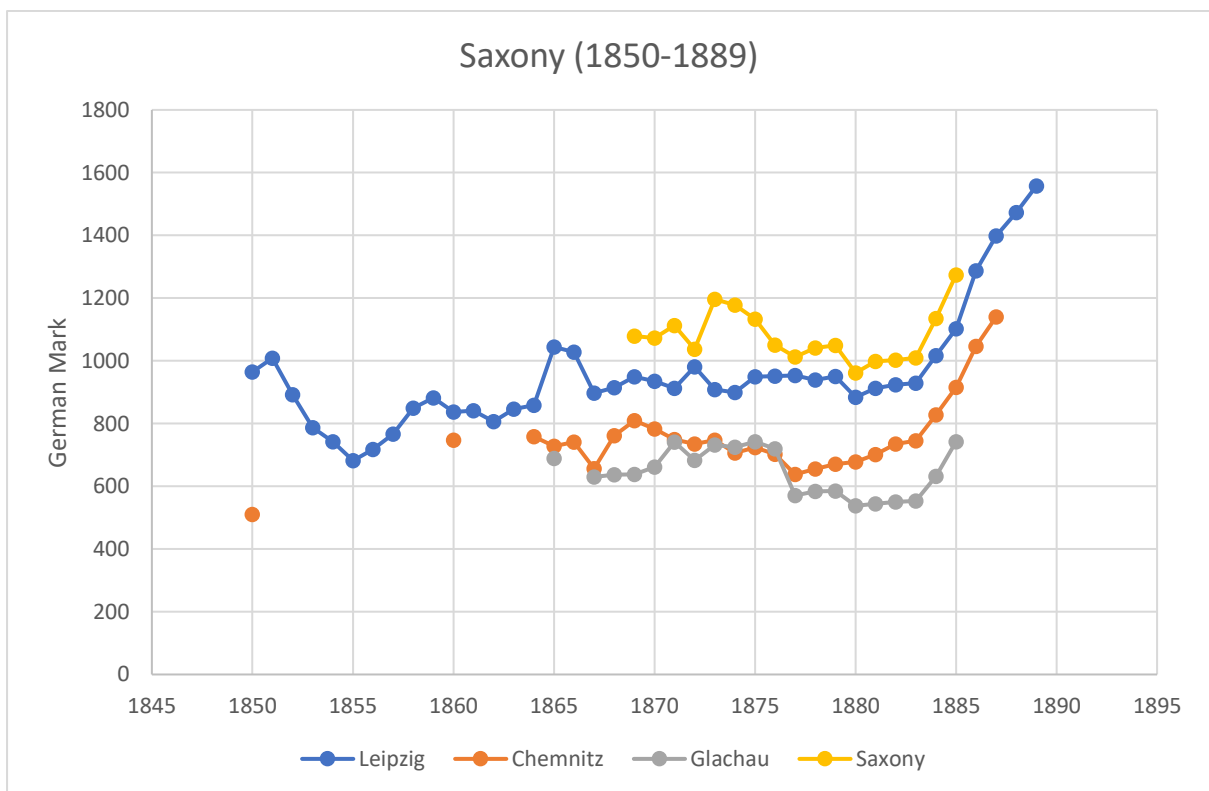
By indexing the data this way, wages across cities are arguably more comparable to each other than if one just took the average wages of each city without accounting for the variation in industry. However, it also means that the data for cities outside of the urban construction industry are not the actual wages, but rather an estimate based on the relationship of wages across industries.

### 3.4 Basic Observations

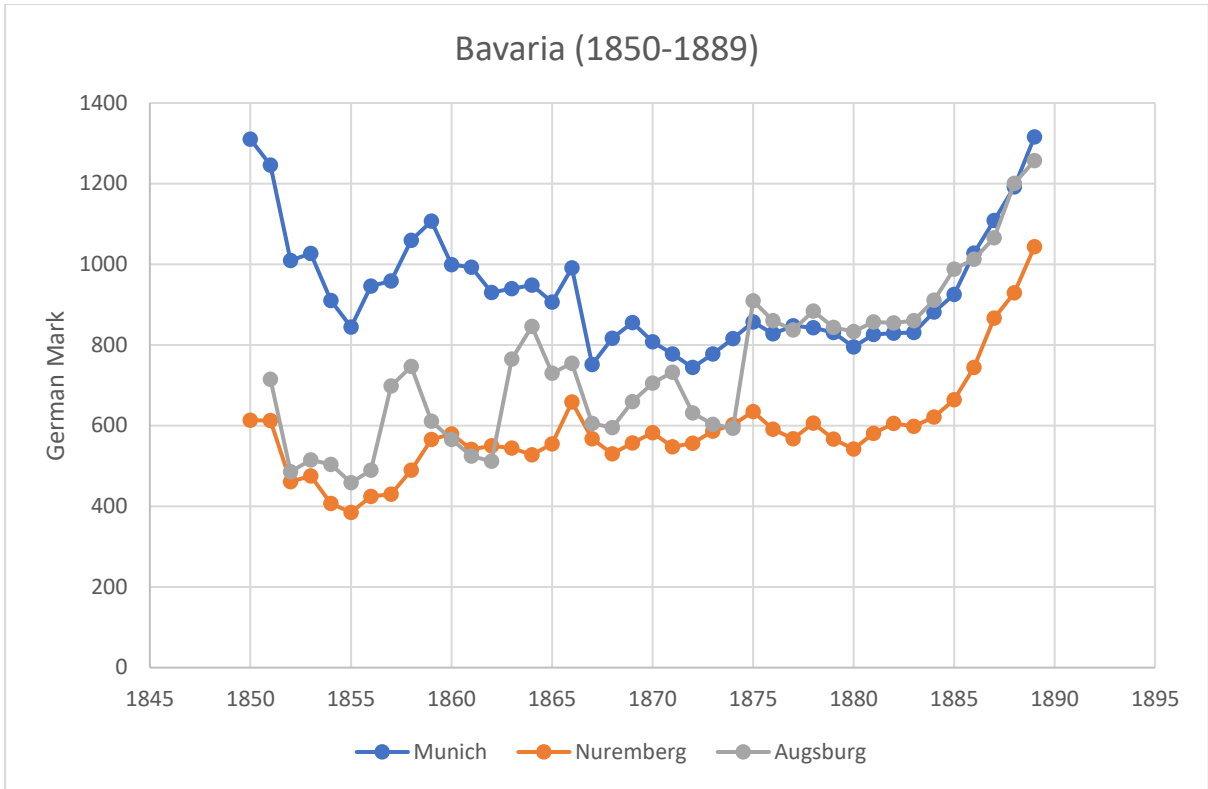
The development of real wages that can be observed in the data is largely consistent with what has been found by previous studies on the topic (Pierenkemper and Tilly, 2004, p. 15). The graphs in Figures 3.3-3.9 show that the average real wages saw a sharp increase around the 1880s for practically all cities. However, a clear and significant inequality in wage levels can also be observed at the end of the period between cities, with Hamburg pulling far ahead of the rest of the country.



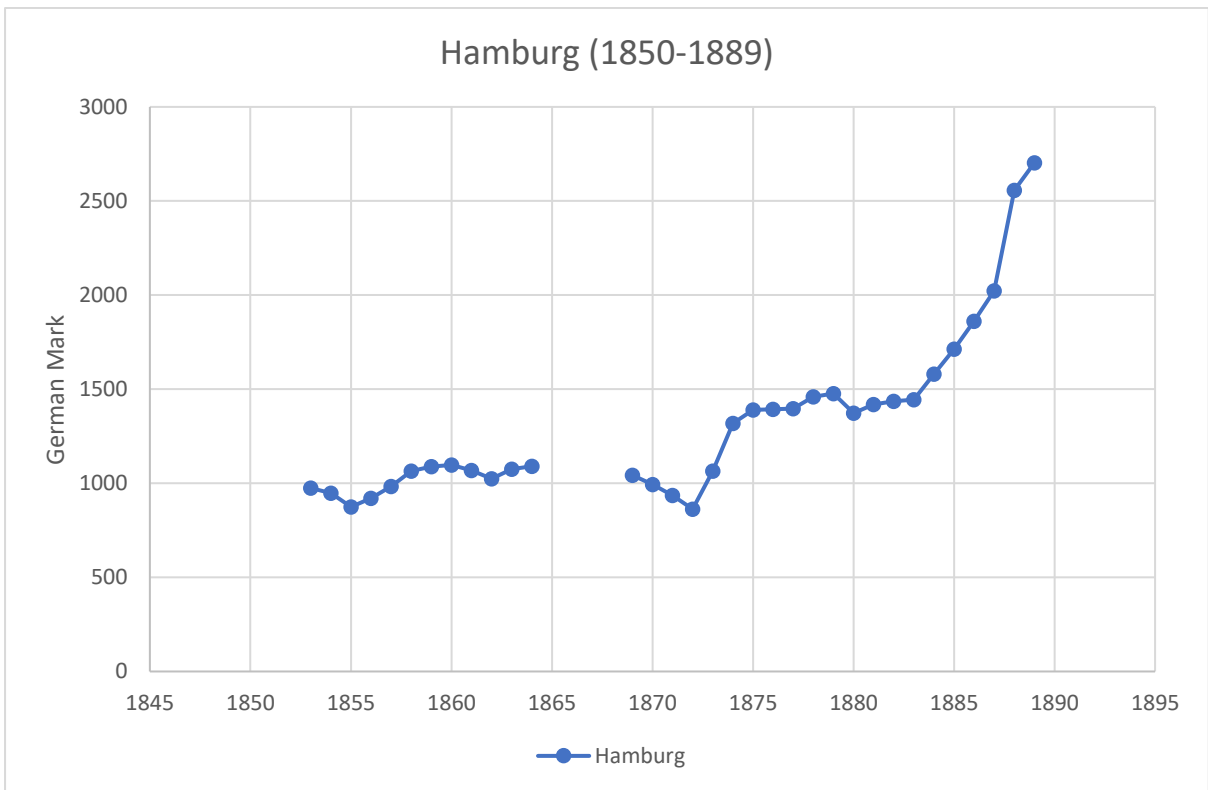
**Figure 3.3** Real Wages of Cities/Regions in Prussia  
 Source: author's own elaboration from Pfister (2018) data



**Figure 3.4** Real Wages of Cities/Regions in Saxony  
 Source: author's own elaboration from Pfister (2018) data

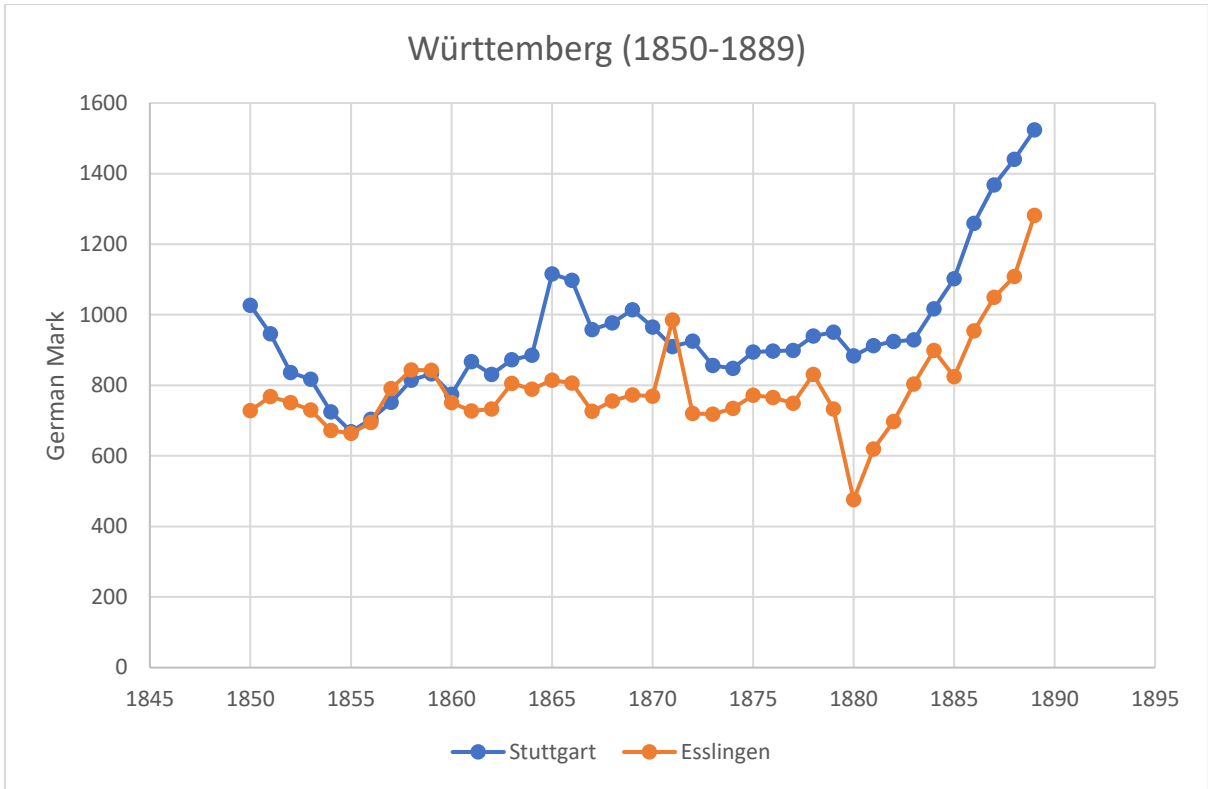


**Figure 3.5** Real Wages of Cities/Regions in Bavaria  
 Source: author's own elaboration from Pfister (2018) data

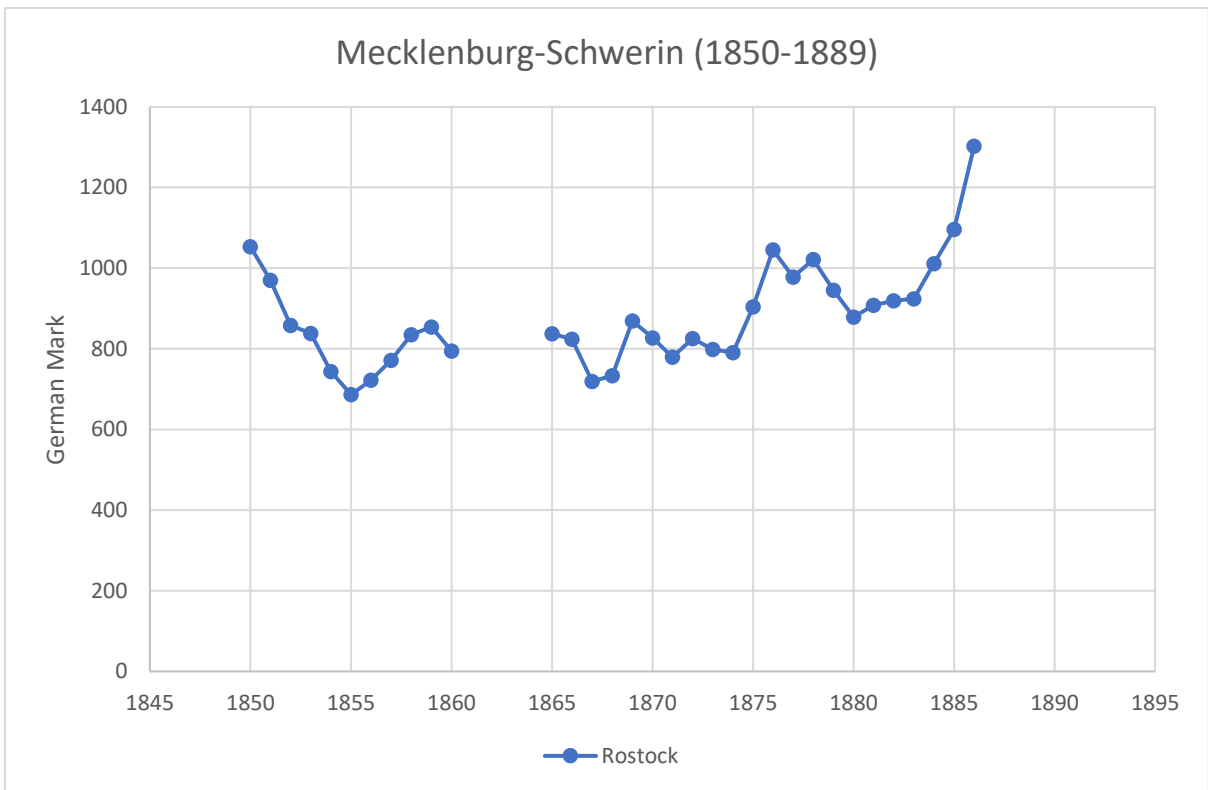


**Figure 3.6** Real Wages of Cities/Regions in Hamburg  
 Source: author's own elaboration from Pfister (2018) data

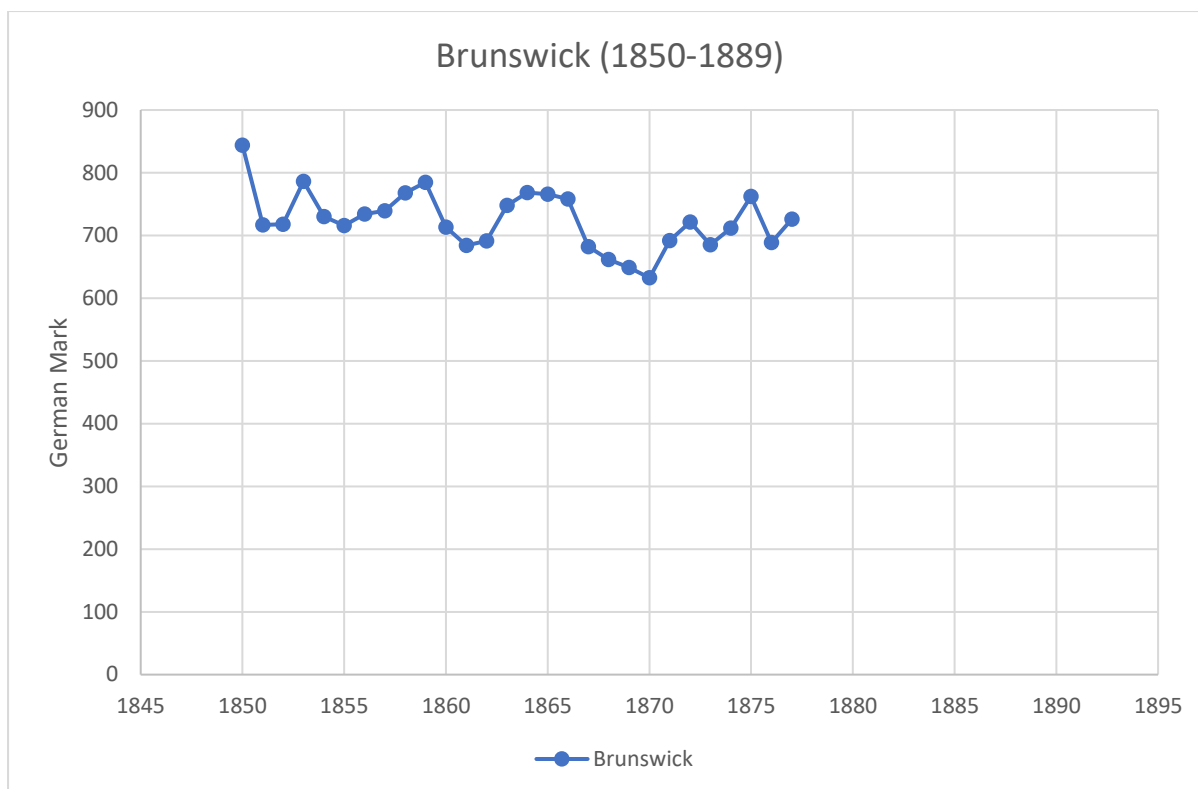




**Figure 3.7** Real Wages of Cities/Regions in Württemberg  
 Source: author's own elaboration from Pfister (2018) data



**Figure 3.8** Real Wages of Cities/Regions in Mecklenburg-Schwerin  
 Source: author's own elaboration from Pfister (2018) data

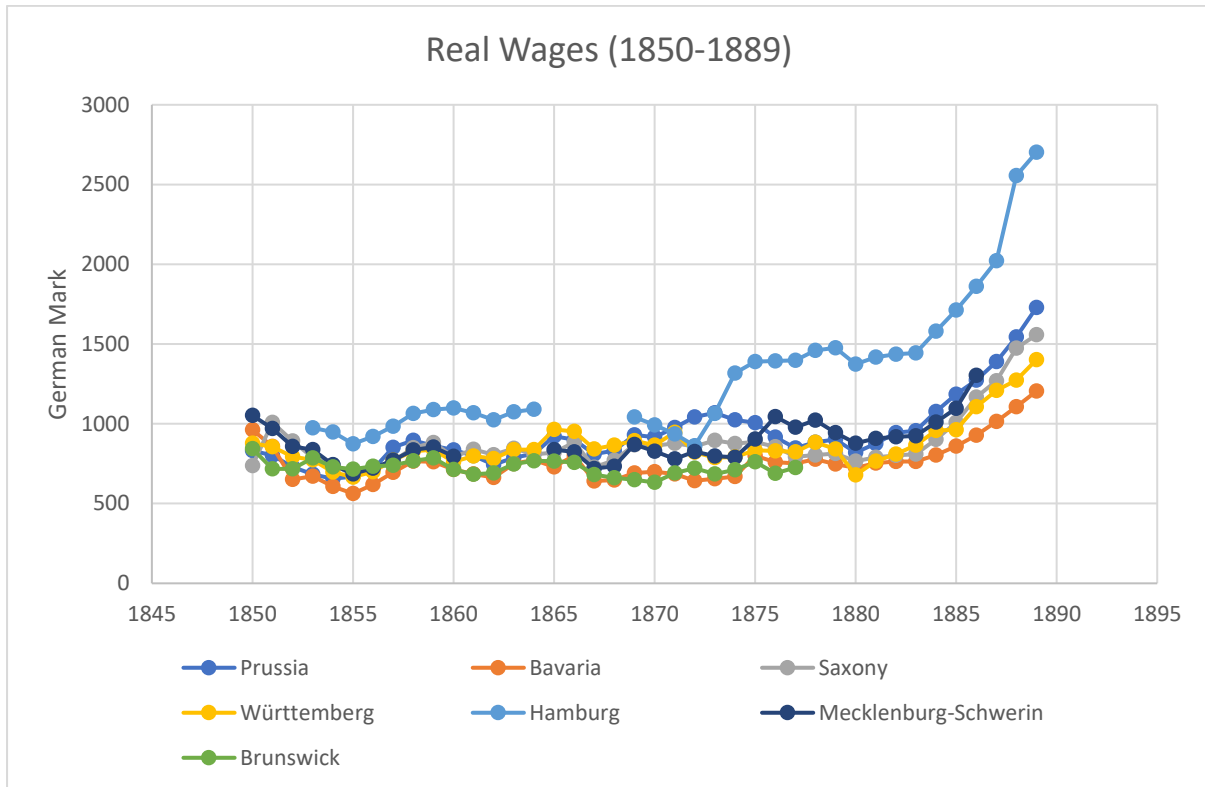


**Figure 3.9** Real Wages of Cities/Regions in Brunswick

Source: author's own elaboration from Pfister (2018) data

Looking at the state level instead, Figure 3.10 shows the average wage of each state based on the cities within that state that are included in the data. Hamburg retains its top spot, though this not surprising given its status as a city-state. Prussia and Saxony are far behind Hamburg, but still pull ahead of the south German states in the end of the period. While Württemberg stays at a relatively similar real wage level compared to Prussia, Bavaria lags a bit further behind, seemingly confirming the view that southern Germany, Bavaria in particular, was economically less prosperous compared to the north at the time. However, this must be stated with the caveat that the Figure 3.3 also shows that Silesia was the poorest area in the whole dataset, suggesting that Prussia, especially with regard to its eastern provinces, may have had large internal regional inequalities that were at least as significant as those between the states themselves, if not more so. Though this can also be nuanced by the fact that an entire region like Silesia with multiple cities and a wide countryside is quite unfair to compare to a single city like Berlin. There is no indication in the data what the exact wages in Silesian cities like Breslau or Kattowice may have been. Moreover, the province of the Rhineland as a whole, the traditional industrial heartland of Germany, was also shown to have a lower wage than cities, though data from before 1870 is a bit harder to interpret, given that real wages tended to fluctuate more before the Second Industrial Revolution. From this, it may be reasonable to

conclude that comparing the wages of cities to those of regions that include more rural areas can lead to problems in interpreting the data.



**Figure 3.10** Real Wages of States

Source: author’s own elaboration from Pfister (2018) data

### 3.5 Control Variables

As stated previously, the empirical analysis will also include control variables, which are meant to strengthen the internal validity of the results, further isolating the effect that the political unification had on Germany’s internal convergence and ensuring that any potential increase in convergence wasn’t due to other factors. Regional data for other indicators besides economic growth are equally difficult to come by in the 19<sup>th</sup> century, but digging through the sources provides us with some data that may be relevant. The most important years to get data for these controls are 1850 and 1871 (see Chapter 4 for explanation), and some of the data are not for these exact years, but rather one or two years before or after, though this is close enough that they can still be used. Three indicators have been chosen: population density, railway networks, and human capital.

*Population density* is meant to capture some of the factors associated with population growth, urbanization, supply of available labour, and the general structure of a state's economic conditions (Yegorov, 2015). A state like Hamburg, for example, will have a much higher population density on account of it being a city-state. The variable is constructed by dividing the population of a state with its surface area. The data on population for each state are retrieved from historical statistics by Müller and Zymek (2006) and Kraus (2007), while the data on surface area are retrieved partly from Ziegler (2011) and partly from Statista (2019). Both the population and area data are based on the states' borders at the time of unification (meaning that, e.g., Prussia includes the province of Hanover even before 1866).

*Railway network* is a variable meant to control for various factors associated with increased industrialisation and lower transport costs. An increase in railway transportation has been shown to have increased employment in the tertiary sector away from agriculture and magnify a region's natural resources and ability to take advantage of economic agglomeration (Bogart et al. 2022). This variable also uses data from Ziegler (2011), specifically on total length of all railways for each German state in the 19<sup>th</sup> century. These figures are in turn divided by the land area of each state in square kilometres to get data for the density of railway networks.

*Human capital* is meant to control for the effects of an increasingly educated population on economic growth. Human capital is an essential part of any standard model for economic growth (Todaro and Smith, 2015, p. 382). While there are many potential proxies for human capital, such as literacy rates, this study will be using number of students in so-called higher schools ("*höhere Schulen*") as its measure. Data for these figures are retrieved from Müller and Zymek (2006), and the number of students also is divided by the population of each state. Unfortunately, the only data that go back all the way to 1850 for this variable are those for Prussia and Bavaria. The first period therefore only has human capital indicators for the two largest and most important states.

See Tables A.2-A.6 in the Appendix for descriptive statistics of all independent variables used in the study, both at the city and state level (note here that the observations for the control variables at the city-level are the same as at the state-level, just applied on each city depending on its respective state).

## 4. Method

This chapter presents and discusses the empirical method used for the data analysis. The first section presents the main regression model and its variations for studying beta-convergence, while the second section presents and explains the robustness tests, including the method for examining sigma-convergence.

### 4.1 Methodological Approach

The overall goal is to determine whether the convergence rate was greater as a result of the states joining together in a political union. Convergence will here be defined as beta-convergence, meaning higher growth rate for initially poorer states. The model for beta-convergence can be expressed as an equation in the following way:

$$\ln(\Delta y_{i,0-t}) = \alpha + \beta \ln(y_{i,0}) + \varepsilon_{i,t}$$

where  $(\Delta y_{0-t})$  is the annual growth of income levels (real wages in this case) for region  $i$  during the period covering the years 0 to  $t$  (with 0 being the first year of the period),  $y_{i,0}$  is the initial level of income at year 0,  $\beta$  is the coefficient to be estimated, and  $\varepsilon_{i,t}$  is the error term (Barro et al., 1991; Monfort, 2020). The natural log is implemented to reduce the skew toward large values. A negative value for  $\beta$  would imply that beta-convergence is occurring, as a higher level of initial real wages would be negatively correlated with growth, meaning that regions with an initially lower real wage would have a higher growth rate.

Calculating the dependent variable, *Wagegrowth*, defined as the growth rate of the natural log of real wages, can be done simply by deriving the average annual change in logged real wages between the first year and last year of the given period. However, this may fail to capture the trend properly, as fluctuations in the real wage will not be reflected in individual years. Deriving the growth rate this way may over- or underestimate the average growth in wages, as the starting and end points may skew toward more extreme values, which seems especially likely considering the fluctuating nature of real wages in earlier decades. Instead, the growth rate will be derived from linear OLS correlations of the natural log of real wages for each series, and taking the exponent of these. This way, we will get the annual growth rate

based on the linear trendline, rather than the average growth of the somewhat fickle raw numbers.

The most simple and intuitive way would be to determine the rate of convergence before and after the unification in 1871, with control variables for the beginning of each period included. However, not all states joined together at the same time; the states of the North German Confederation were technically unified with each other in 1867, a few years before the formation of the German Empire in 1871, when the southern states joined as well. This needs to be taken into account for the data analysis.

Tailoring the equation more specifically for the empirical analysis of this study, some simple linear OLS regressions will be estimated as:

$$(Wagegrowth_{i,1850-1871}) = \alpha + \beta_1 \ln(Realwage_{i,1850}) + \beta_2(Popdens_{i,1850}) + \beta_3(Railway_{i,1850}) + \beta_4(HC_{i,1850}) + u_{i,t}$$

and

$$(Wagegrowth_{i,1871-1889}) = \alpha + \beta_1 \ln(Realwage_{i,1871}) + \beta_2(Popdens_{i,1871}) + \beta_3(Railway_{i,1871}) + \beta_4(HC_{i,1871}) + u_{i,t}$$

with the unification of Germany being the cut-off point between the two periods,  $\ln(Realwage)$  being the main dependent variable (natural log of initial real wage in the beginning of each period), and the control variables being *Popdens* (population density), *Railway* (density of railway networks), and *HC* (human capital). The convergence rates in the decades before and after unification will thus be captured this way. Having the control variables derived from the beginning of each period helps alleviate potential endogeneity concerns, as these too may have been affected by the unification of Germany. Since the controls are from 1850 and 1871 respectively, it is highly unlikely that they will be endogenous to the unification at these points in time. Note that for the first period, the initial real wage of Hamburg is from the year 1853, as data from 1850 is missing. Regressions will also be run without the control variables included, which will enable the study to distinguish between conditional and absolute beta-convergence. As per the explanation of conditional and absolute convergence in Chapter 2, the growth of regions may depend on specific factors, which the control variables are meant to capture. Excluding the control variables would show if the beta-convergence is occurring even without accounting for the variations in these

factors. Simply put: including control variables measures conditional beta-convergence, while excluding them measures absolute beta-convergence.

However, as the number of observations for these regressions will be very low, with only 7 states examined, models will also be run using wage data on the city-level. Note that the city-level regressions will include the regions as presented in Figure 3.1. The higher number of observations may make the models econometrically somewhat more sound, though the control variables for each city will still have to be the same as at the state-level, as data for these are unavailable at the city-level. In cases where the initial wage level is missing for the first year of the period, the wage level at the earliest available year will be used instead (such as with the Hamburg example, starting in 1853), unless it's too far in the future (more than 5 years). This may also help provide an image of whether intrastate convergence between poorer and richer cities was occurring as well. If such were the case, it may carry implications regarding at which level regional convergence should be understood for 19<sup>th</sup> century Germany: state, region, or city?

## 4.2 Robustness Tests

To account for the potential effects associated with the formation of the North German Confederation, a regression model of the period 1867-1889 will be run, only including cities that joined the NGC and thereby excluding the cities in Bavaria and Württemberg. Control variables will also be for the year 1867 instead. This can be expressed thusly:

$$(Wagegrowth_{i,1867-1889}) = \alpha + \beta_1 \ln(Realwage_{i,1867}) + \beta_2(Popdens_{i,1867}) + \beta_3(Railway_{i,1867}) + \beta_4(HC_{i,1867}) + u_{i,t}$$

which can help identify whether the unification of 1867 already had an economic effect for those areas that joined the NGC even before the “actual” unification four years later. This period will not be covered at the state level, as excluding two states from the already low number of observations will make the result too unreliable. If the convergence rate is found to be stronger than in the model for the period 1871-1889 (that also includes all cities), this may indicate that the NGC indeed also had some effect.

Moreover, a common problem with regressions that use multiple independent variables is multicollinearity, meaning that the independent variables are correlated with each other. This

can harm the precision of the coefficients, as it means that the included variables will capture similar effects. To test for multicollinearity, the correlations between the variables have been estimated, the results of which are presented by correlation matrices in the Appendix (Tables A.7-A.13). The human capital variable in 1850, likely in part due to the low number of observations, shows perfect collinearity with the other variables, and will therefore unfortunately have to be omitted from the model in the first period. For this reason, another regression for the first period will be run, with control variables set for the earliest possible date for human capital with enough observations, which is the year 1865:

$$(Wagegrowth_{i,1850-1871}) = \alpha + \beta_1 \ln(Realwage_{i,1850}) + \beta_2(Popdens_{i,1865}) + \beta_3(Railway_{i,1865}) + \beta_4(HC_{i,1865}) + u_{i,t}$$

This will yield human capital observations for every state and bypass the collinearity problem, but the control variables in this model will unfortunately not be for the beginning of the period, but rather in the middle of it. Also, for the second period, another model will be run omitting the human capital variable for consistency's sake, along with the model including all control variables.

To examine the change in the dispersion of income levels and further strengthen our understanding of the development of regional wages, sigma-convergence will also be calculated, both for cities and states. This is done by measuring the coefficient variation (Monfort, 2008), first by calculating the standard deviations of wages between regions for every year:

$$\sigma_t = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_{i,t} - \bar{y}_t)^2}$$

and then deriving the coefficient variation:

$$CV = \sigma_t / \bar{y}_t$$

where  $\bar{y}_t$  is the mean wage of every region at a given year. The coefficient variations will be presented over time in graphs, signifying whether sigma-convergence was occurring during the whole period. Sigma-convergence excluding south German cities will also be examined both at the state- and city-level. Sigma-convergence at the state level will also be examined excluding Hamburg, as it is suspected to skew the results significantly given its very high



wage level. Given its status as a city-state, this also makes it less comparable to larger states, but this is also the reason that Hamburg will not be excluded from any analysis at the city-level, since it's more comparable in that context, and excluding it is not expected to impact the overall result nearly as significantly. Nevertheless, coefficient variations at the city-level excluding Hamburg will be shown in the Appendix (see Figure A.1). Moreover, city-level coefficient variations for each state with more than one city represented in the data will also be presented in the Appendix (see Figures A.2-A.5).

## 5. Empirical Analysis

This chapter presents and discusses the results of the empirical study and robustness tests.

The first section presents the empirical results of the applied methodology, the second section discusses the implications of the results and their limitations, while the third and final section discusses the contribution of the study to the literature.

### 5.1 Results

The results of the regressions are presented in table form below. First up are the regressions on the state level. Table 5.1 presents the results of the first period (1850-1871) and Table 5.2 the results of the second period (1871-1889). Significance levels are represented with stars and standard errors in parentheses.

**Table 5.1** *Convergence of States, 1850-1871*

| Dependent variable: Growth in $\ln(\text{Realwage})_{1850-1871}$ |                          |                            |                     |
|--|--------------------------|----------------------------|---------------------|
|  | (1)                      | (2)                        | (3)                 |
| $\ln(\text{Realwage})_{1850}$                                    | -0.0511*<br>(0.0201)     | -0.0824**<br>(0.0188)      | -0.0196<br>(0.0231) |
| $\text{Popdens}_{1850}$  | 0.0000375<br>(0.0000160) |                            |                     |
| $\text{Railway}_{1850}$  | -0.835*<br>(0.325)       |                            |                     |
| $\text{Popdens}_{1865}$  |                          | 0.0000360*<br>(0.00000977) |                     |
| $\text{Railway}_{1865}$  |                          | -0.620*<br>(0.162)         |                     |
| $\text{HC}_{1865}$   |                          | 1.910<br>(1.347)           |                     |
| <i>Constant</i>  | 0.358*<br>(0.138)        | 0.573**<br>(0.130)         | 0.135<br>(0.157)    |
| N  | 7                        | 7                          | 7                   |
| R <sup>2</sup>   | 0.741                    | 0.913                      | 0.127               |

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

**Table 5.2** *Convergence of States, 1871-1889*

| Dependent variable: Growth in $\ln(\text{Realwage})_{1871-1889}$ |                           |                          |                    |
|--|---------------------------|--------------------------|--------------------|
|  | (1)                       | (2)                      | (3)                |
| $\ln(\text{Realwage})_{1871}$                                    | 0.0195<br>(0.0231)        | 0.0265<br>(0.0236)       | 0.0425<br>(0.0310) |
| $\text{Popdens}_{1871}$  | 0.0000383*<br>(0.0000141) | 0.0000368<br>(0.0000139) |                    |
| $\text{Railway}_{1871}$  | -0.217<br>(0.212)         | -0.256<br>(0.212)        |                    |
| $\text{HC}_{1871}$   |                           | -2.992<br>(2.835)        |                    |
| <i>Constant</i>  | -0.103<br>(0.155)         | -0.136<br>(0.155)        | -0.261<br>(0.209)  |
| N  | 7                         | 7                        | 7                  |
| R <sup>2</sup>   | 0.793                     | 0.867                    | 0.273              |

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

As stated in the previous chapter, the human capital variable unfortunately had to be omitted due to collinearity for the regressions of the first period. A weakly significant and negative relationship between the initial level of real wages and growth can be observed for the first period when the control variables for 1850 are included, and the relationship becomes stronger and more significant with control variables for 1865. However, the second period reports no significant values for the main dependent variable, and the sign is even shown to be positive rather than negative. At a glance, evidence for beta-convergence seems significantly stronger for the first period, though it's conditional on the control variables.

For the results of the city-level regressions, see Tables 5.3 and 5.4 for the first and second period respectively. For the period 1867-1889, excluding the south German cities, see Table 5.5.

**Table 5.3** *Convergence of Cities, 1850-1871*

| Dependent variable: Growth in $\ln(\text{Realwage})_{1850-1871}$ |                           |                           |                     |
|--|---------------------------|---------------------------|---------------------|
|  | (1)                       | (2)                       | (3)                 |
| $\ln(\text{Realwage})_{1850}$                                    | -0.0216<br>(0.0150)       | -0.0214<br>(0.0162)       | -0.0210<br>(0.0137) |
| $\text{Popdens}_{1850}$  | 0.00000952<br>(0.0000415) |                           |                     |
| $\text{Railway}_{1850}$  | -0.142<br>(0.582)         |                           |                     |
| $\text{Popdens}_{1865}$  |                           | 0.00000748<br>(0.0000341) |                     |
| $\text{Railway}_{1865}$  |                           | -0.0904<br>(0.382)        |                     |
| $\text{HC}_{1865}$   |                           | -0.398<br>(4.239)         |                     |
| <i>Constant</i>  | 0.152<br>(0.101)          | 0.153<br>(0.108)          | 0.147<br>(0.0921)   |
| N  | 16                        | 16                        | 16                  |
| R <sup>2</sup>   | 0.148                     | 0.148                     | 0.143               |

Standard errors in parentheses

\* p &lt; 0.1, \*\* p &lt; 0.05, \*\*\* p &lt; 0.01

**Table 5.4** *Convergence of Cities, 1871-1889*

| Dependent variable: Growth in $\ln(\text{Realwage})_{1871-1889}$ |                           |                            |                      |
|--|---------------------------|----------------------------|----------------------|
|  | (1)                       | (2)                        | (3)                  |
| $\ln(\text{Realwage})_{1871}$                                    | -0.0130<br>(0.0181)       | -0.0153<br>(0.0190)        | -0.00565<br>(0.0196) |
| $\text{Popdens}_{1871}$  | 0.0000545*<br>(0.0000249) | 0.0000539**<br>(0.0000255) |                      |
| $\text{Railway}_{1871}$  | -0.509*<br>(0.247)        | -0.469*<br>(0.264)         |                      |
| $\text{HC}_{1871}$   |                           | -1.995<br>(3.819)          |                      |
| <i>Constant</i>  | 0.123<br>(0.124)          | 0.130<br>(0.127)           | 0.0584<br>(0.133)    |
| N  | 22                        | 22                         | 22                   |
| R <sup>2</sup>   | 0.253                     | 0.265                      | 0.004                |

Standard errors in parentheses

\* p &lt; 0.1, \*\* p &lt; 0.05, \*\*\* p &lt; 0.01

**Table 5.5** Convergence of North German Cities, 1867-1889

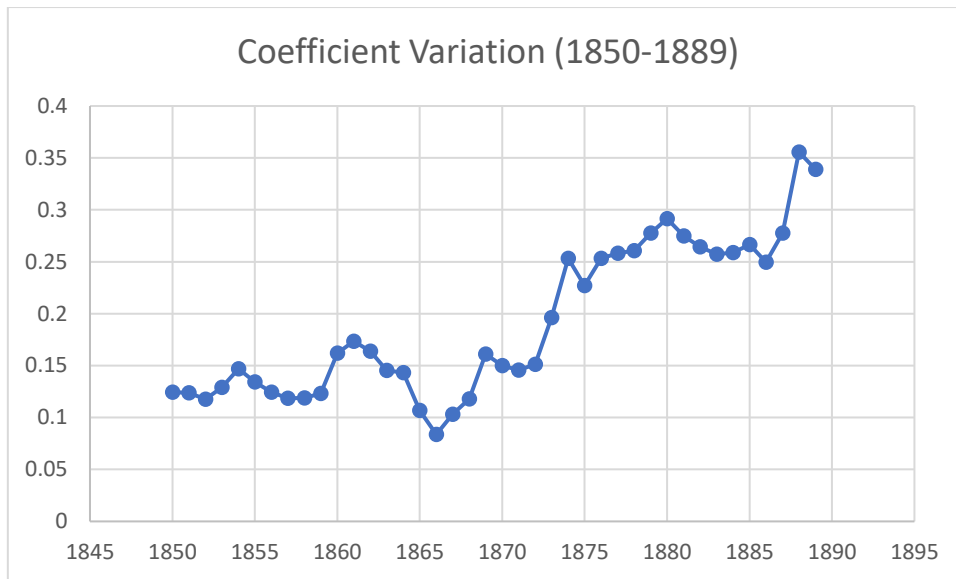
| Dependent variable: Growth in $\ln(\text{Realwage})_{1867-1889}$ |                          |                           |                       |
|--|--------------------------|---------------------------|-----------------------|
|  | (1)                      | (2)                       | (3)                   |
| $\ln(\text{Realwage})_{1867}$                                    | -0.0912***<br>(0.0238)   | -0.0936***<br>(0.0247)    | -0.0758**<br>(0.0265) |
| $\text{Popdens}_{1867}$  | 0.000112*<br>(0.0000471) | 0.000126**<br>(0.0000537) |                       |
| $\text{Railway}_{1867}$  | -0.982**<br>(0.434)      | -1.347*<br>(0.741)        |                       |
| $\text{HC}_{1867}$   |                          | -8.343<br>(13.57)         |                       |
| <i>Constant</i>  | 0.652***<br>(0.160)      | 0.702***<br>(0.184)       | 0.0530***<br>(0.177)  |
| N  | 17                       | 17                        | 17                    |
| R <sup>2</sup>   | 0.581                    | 0.594                     | 0.354                 |

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

At the city level, no significant values can be found for the second or first period for the main dependent variable, regardless of control variables, though the sign remains negative. Using the control variables from 1865 in the first period also doesn't yield any significant results. However, for the period 1867-1889 when excluding cities outside of the North German Confederation, the results show a strongly significantly negative correlation with the initial wage level and the growth rate. The result holds also when excluding control variables, albeit being slightly weaker.

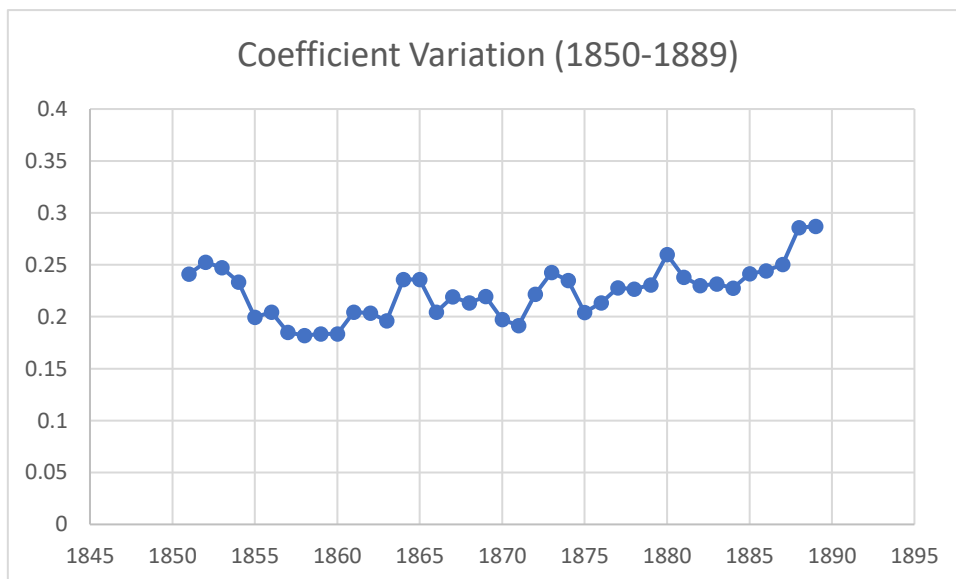
For the main results on sigma-convergence, see the graphs in Figures 5.1 and 5.2 for states and cities respectively.



**Figure 5.1** *Sigma-Convergence Between States*

Source: author's own elaboration from Pfister (2018) data

When looking at the state level, the dispersion of wage levels seems to remain at more or less the same level, albeit with some fluctuations, until the unification in 1871. However, in the following period, the data show a significant increase in regional inequality, suggesting sigma-divergence, meaning the opposite of convergence.

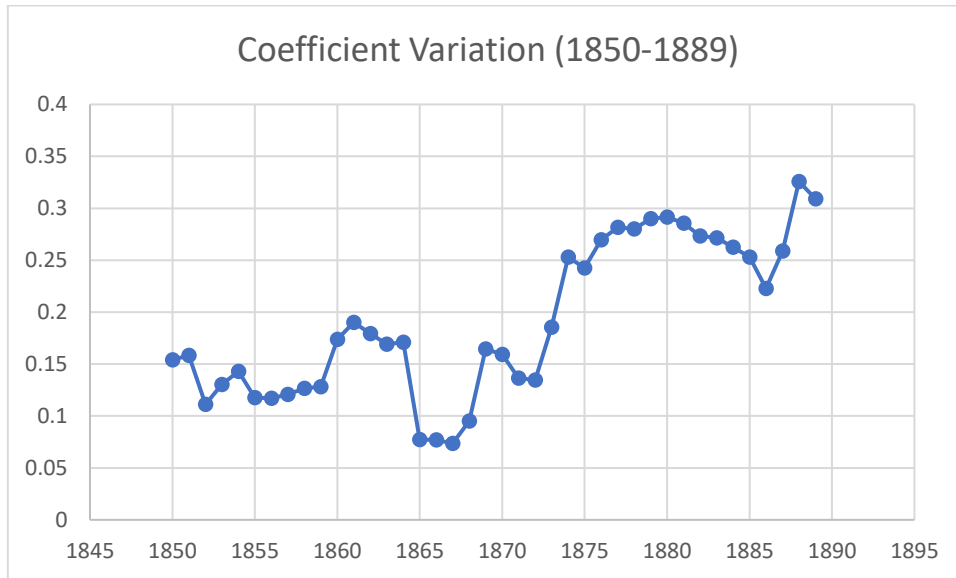


**Figure 5.2** *Sigma-Convergence Between Cities*

Source: author's own elaboration from Pfister (2018) data

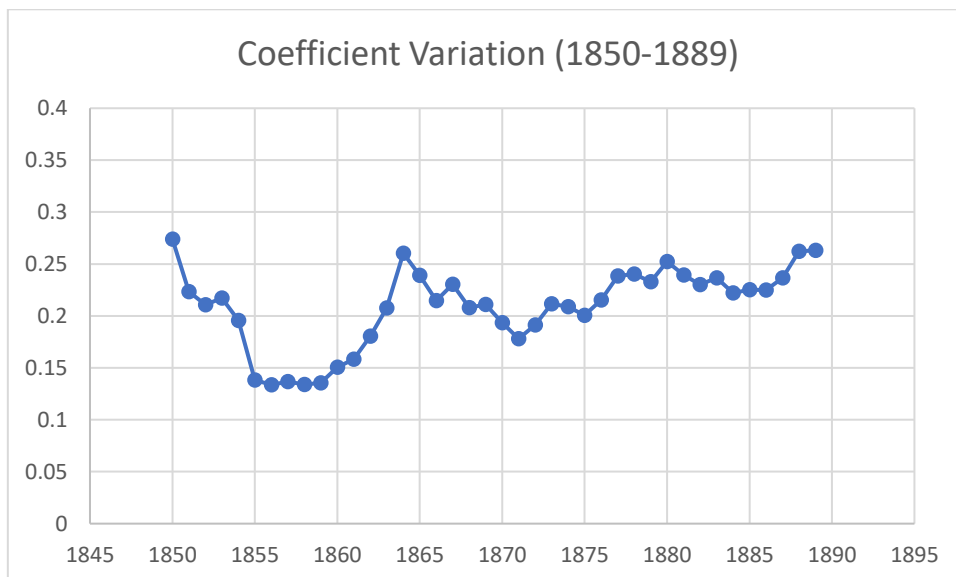
The city-level data also show a slight increase sigma-divergence after 1871, though this increase is far smaller. It could be due to mere fluctuations, but the trendline is nonetheless positive in the second period (see Appendix, Figure A.6). The absolute size of the gap is not necessarily smaller for most of the period, but unlike at the state level, the relative change in

the size of the gap is not nearly as large. The results for sigma-convergence do not differ significantly when looking at only the states or cities of the North German Confederation either (see Figures 5.3 and 5.4), though the coefficient variation is somewhat lower at the end of the period, suggesting that regional wage differences in northern Germany were slightly smaller compared to the whole country, though not by much.



**Figure 5.3** *Sigma-Convergence Between Northern States*

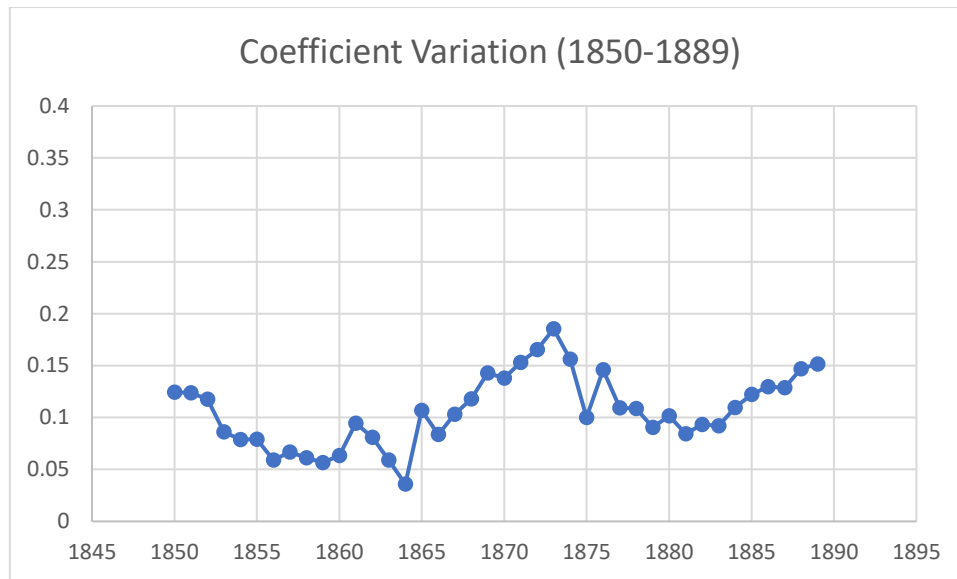
Source: author's own elaboration from Pfister (2018) data



**Figure 5.4** *Sigma-Convergence Between Northern Cities*

Source: author's own elaboration from Pfister (2018) data

However, what does make a difference is excluding Hamburg from the state-level analysis. Figure 5.5 shows the coefficient variations between states excluding Hamburg, which is not only far lower, but also but also displays a much lower overall increase.



**Figure 5.5** *Sigma-Convergence Between States Excluding Hamburg*

Source: author's own elaboration from Pfister (2018) data

This means that Hamburg alone is skewing the results at the state level quite significantly. In fact, one can even observe a fluctuating sigma-convergence during the first decade of unification before the gap starts increasing slightly again in the 1880s. Overall, when excluding Hamburg, the gap between states seems to remain largely fluctuating and stagnant, much like the gap at the city-level.

The implications of these results are ambiguous at first glance when comparing the evidence of sigma-convergence to the evidence of beta-convergence, and they will be discussed further in the following section.

## 5.2 Discussion

When purely examining the dispersion of real wage levels within 19<sup>th</sup> century Germany, it seems as though the unification of the country brought with it a divergence, rather than convergence. However, the strength of this divergence is highly dependent upon the inclusion of Hamburg at the state-level. Moreover, it also does not necessarily mean that initially poorer cities or states grew more slowly than initially wealthier ones following the unification. The regressions show a negative, albeit insignificant relationship between initial level of real wages and the growth rate in the second period. However, what is perhaps more surprising is that evidence for beta-convergence between states in the first period is far stronger than in the second period, as can be seen in Table 5.1. Whatever tendency toward



beta-convergence may have existed seems to have been stronger before unification rather than after, which goes against the hypothesis of this thesis. However, the results of the regressions must not be taken too definitively, as these were done with a very low number of observations.

The city-level regressions, which have more observations, did not display any level of significance for the initial wage variable in either the first or second period. On the other hand, the contrast between the results including all cities and the results excluding southern cities is fascinating and noteworthy, as the evidence for beta-convergence seems far stronger when it comes to the formation of the North German Confederation. There are several potential reasons for this. One may be that the political unification had a delayed effect on convergence, and that joining the NGC indeed gave four extra years for the effect to kick in properly. Another reason may be that northern Germany was already becoming more integrated, and that poorer regions industrialised earlier, compared to the south. However, the most likely option is because of issues related to the data. Fluctuations in the real wages are frequent in the data, and the average wage in 1867 was lower compared to just a few years before or later, meaning that the effect of the initial wage level on the overall growth rate may be overestimated. Running a similar regression beginning in 1871, excluding the southern cities, yields no significant results (see Appendix, Table A.14), which suggests that this is indeed the case. Moreover, control variables for the city-level regressions are at the state level, and so represent the average of the whole state and not the individual cities, which is problematic in and of itself, as the controls are not necessarily representative for all cities.

At the very least, there is little evidence to suggest that poorer areas had a *lower* growth rate in wages than initially wealthier areas, despite the sigma-divergence observed in the later period, which once again is largely dependent on the inclusion of Hamburg. Excluding Hamburg, which is a city-state and perhaps therefore a unique case, tells a different story when it comes to sigma-convergence, which may perhaps be more representative of the overall development between non-city-states. It would be very helpful to have data for other city-states, such as Bremen, to perhaps help determine what the unique role of city-states may have been when it comes to inter-state development.

It's not impossible that a beta-convergence in real wages may have occurred between Germany's states/regions after unification, but the evidence is far from strong enough to be quite convincing. If beta-convergence did occur after unification, it seemingly also coincided

with a sigma-divergence, meaning that absolute wage levels actually diverged in the decades following unification.

Overall, issues related to the data need to be kept in mind for all of the results. Whatever evidence is present for convergence may be highly dependent on the fluctuations in the real wage data. This is exacerbated by the fact that many questions regarding the representativity of the data can be raised. Assumptions were made when converting values into comparable currencies and timeframes, assumptions that could easily be argued against or replaced with different assumptions. Much of the data are for different industries, the wages of which likely do not completely reflect the wages for other industries covered by other cities. Even indexing the wages in the manner that was done in this study does not completely circumvent this problem, as the relationship between wages in different industries may have differed depending on the city. Many states and important cities in Germany are also excluded from the data, which makes the overall picture of the country's regional economic situation incomplete. As has been stated on multiple occasions, data in general are scarce when it comes to this time period, especially at the regional level, which is why making many definitive statements regarding economic convergence is difficult. It becomes clear that better and more economic data on the regional level are needed for a more comprehensive analysis, not just on wages, but on other indicators as well, such as GDP and potential control variables—be they human capital, level of urbanization, or other. Expanding the timeframe may also be necessary. Perhaps the unification had a delayed effect, which could only be observed if one included the regional development in later years as well. As previously mentioned, the ideal would be to study the development until 1914, but these data do not extend that far. As time passes, more data will hopefully and likely become increasingly available on the relevant variables, as study on historical regional development continues.

### 5.3 Contribution to the Literature

The results are not strong enough, nor is the previous literature extensive enough, for this study to be put in a clear context, and the lack of conclusive results reflects the lack of previous research on the topic. The data do confirm what Pierenkemper and Tilly (2004, p. 15) and others have found, that real wages began increasing everywhere in the later decades of the 19<sup>th</sup> century, but once again, the regional variations are not touched upon by these authors. Erfurth's (2021) claims on the differences between Bavarian and Prussian income

levels compared to what the raw data show may be worthy of note, though. The difference in average real wage levels between the two seem indeed not to have been very large before unification, but the gap seems to have widened somewhat in the following decades, with Prussia and northern Germany pulling ahead. Though the divide between north and south doesn't seem to have been as pronounced as in Italy's case, some parallels could potentially be drawn.

Besides Erfurth (2021), there is not much that the findings can be compared to. Nevertheless, some other interesting observations can be made. The points made by Quah (1996) come to mind when seeing the contrast between the evidence for beta- and sigma-convergence. Even if beta-convergence did in fact occur (which remains highly questionable), merely presenting this fact would likely not provide an adequate picture of Germany's regional development in the late 19<sup>th</sup> century, as the dispersion of wage levels between states seems to nonetheless have increased, at least when including Hamburg. Much like in 1990, any effect the unification of 1871 may have had on convergence between the states was likely small if not non-existent. An interesting detail is that when excluding Hamburg from the sigma-convergence analysis, an almost similar pattern cannot be observed of an initial reduction of income gaps in the first decade of unification and a subsequent widening in the second decade (Brück and Peters, 2009). However, this could easily be a mere coincidence, and when Hamburg is included, the sigma-divergence in the 19<sup>th</sup> century begins seemingly immediately after the unification, and steadily continues to widen as time passes.

For now, the research done by the likes of Enflo et al. (2018) and Wolf (2018) seems to be the most promising inspiration for future studies on this topic. The Geary and Stark (2002) method employed by these has potential to be used for constructing regional GDP per capita data on the regional level for periods extending back well beyond the second half of the 19<sup>th</sup> century. This would be very useful for further understanding the economic development of the states and regions of Germany, and should ideally cover the whole of the country.

Thus, among the contributions of this thesis is the careful confirmation that economic differences did exist between Germany's states and regions in the 19<sup>th</sup> century, and that there is little evidence that political unification necessarily induces regional economic convergence, at least in the short- or medium-term. However, the main contribution of this thesis may be the highlighting for the necessity of more data on regional economic indicators

in the 19<sup>th</sup> century and more studies on the topic, with the understanding that we currently know far too little to make many definitive claims.

## 6. Conclusion

This thesis examined the economic convergence between cities and states of 19<sup>th</sup> century Germany, before and after the unification of 1871. The purpose of the thesis was to examine whether the unification led to a greater convergence of income levels between the states and regions of Germany, using data on real wage levels from various German cities during the period of 1850-1889. Regressions for testing beta-convergence at both the state- and city-level were run for the periods 1850-1871 and 1871-1889, and the coefficient variations for cities and states were also calculated to identify sigma-convergence. Regarding the first hypothesis, income levels do seem to have differed between the states and regions of Germany before unification. However, the evidence for beta-convergence was found to be quite dubious if not contradictory to the second hypothesis; while some evidence of conditional beta-convergence could be found for the first period at the state level, no such results were found in the second period, while issues with the data prevent further definitive conclusions. Meanwhile, the evidence on coefficient variation suggests that there was actually a *sigma-divergence* between states in the second period, meaning that the dispersion of regional wage levels increased following the unification, even as this did not seem to be the case *before* 1871. However, this divergence is almost entirely carried by Hamburg, which grew to have an extraordinarily high wage level. On the other hand, the tendency for sigma-divergence at the city level seems to have been far weaker, though still present. Overall, the dispersion of income gaps between states and cities seems to have remained at a very similar level throughout most of the country during the whole period, especially when Hamburg is excluded from the analysis. Even so, a trend toward sigma-divergence in the second period can be observed, certainly when all states in the dataset are included in the analysis. However, since the entirety of the country is not represented by the data, it is difficult to say exactly what the results would have shown if every state of the German Empire were included in the study.

None of this necessarily rules out the possibility of beta-convergence having been present to some extent, but this thesis concludes that there is currently very little evidence of convergence, be it beta or sigma, between the states of Germany following its unification, and that tendency toward convergence (or at least the absence of divergence) seems to have actually been stronger before unification if anything. While seemingly promising results were found for cities in the North German Confederation in the period 1867-1889, this was

determined to likely be due to fluctuations in the wage data. The correlations between initial wage level and growth rate were overall found to be negative, even if mostly insignificant, so it's possible that some beta-convergence did occur, but there is once again very little indication that this was made stronger by Germany's unification.

The idea that significant convergence did not occur following unification is somewhat consistent with the example of Germany's unification a century later in 1990, which also has not been shown to have led to a great convergence between the poorer east and wealthier west of the country in modern times. However, this comes with the caveat that the economic differences between the German states in the 19<sup>th</sup> century were likely not as large as the differences between modern East and West Germany, with perhaps the exception of very wealthy city-states like Hamburg. Having said that, real wages generally seem to have been higher in northern Germany compared to the south by 1889.

As has been mentioned, the necessity for more and better data has become readily apparent throughout the course of this thesis. Future research will likely have to take greater effort to find or construct data on regional wages, GDP per capita, and other economic indicators that cover the entirety of Germany around the time of its unification. This study only covers a limited number of states, and while these are among the largest and most important ones, leaving out the rest of the country renders the study blind to the developments in much of Germany. What must also be repeated is that real wages and GDP do not always match up, and so the findings of this study must be interpreted with that in mind. It is entirely possible that there was in fact a convergence of regional GDP per capita, but not of real wages, but so far there is little evidence to confirm or deny that speculation. Future research would benefit from studying the development of both indicators, and it should also take care to study the differences not just between states, but also within states, as the largest states were likely quite economically diverse.

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May 2022]

# Appendix

**Table A.1** Descriptive Statistics of Raw Wage Data for Industries

| Industry                  | N   | $\mu$    | $\sigma$  | Min   | Max   |
|---------------------------|-----|----------|-----------|-------|-------|
| Heavy iron goods          | 125 | 467.051  | 454.4512  | 1.25  | 1190  |
| Mechanical engineering    | 195 | 541.607  | 380.1641  | 2.32  | 1123  |
| Mining                    | 263 | 313.9089 | 357.0196  | 0.81  | 1111  |
| Printing per 1000 letters | 252 | 0.227619 | 0.0386099 | 0.17  | 0.35  |
| Printing per week         | 104 | 22.39817 | 1.236581  | 18.86 | 26    |
| Urban construction        | 302 | 102.6226 | 198.7976  | 2.25  | 796.3 |

Source: see text

**Table A.2** Descriptive Statistics of State-Level Independent Variables, First Period

| Variable                      | N | $\mu$     | $\sigma$  | Min       | Max       |
|-------------------------------|---|-----------|-----------|-----------|-----------|
| $\ln(\text{Realwage})_{1850}$ | 7 | 6.793261  | 0.119628  | 6.603306  | 6.959854  |
| $\text{Popdens}_{1850}$       | 7 | 141.6922  | 178.9772  | 40.77685  | 542.6537  |
| $\text{Railway}_{1850}$       | 7 | 0.0174669 | 0.0090597 | 0.007604  | 0.0290667 |
| $\text{HC}_{1850}$            | 2 | 0.0021418 | 0.0010036 | 0.0014321 | 0.0028515 |
| $\text{Popdens}_{1865}$       | 7 | 165.3562  | 219.6167  | 42.23153  | 656.6683  |
| $\text{Railway}_{1865}$       | 7 | 0.0381176 | 0.0152223 | 0.0193789 | 0.0576667 |
| $\text{HC}_{1865}$            | 7 | 0.0033115 | 0.0011731 | 0.0015952 | 0.0051518 |

Source: see text

**Table A.3** Descriptive Statistics of State-Level Independent Variables, Second Period

| Variable                      | N | $\mu$     | $\sigma$  | Min       | Max       |
|-------------------------------|---|-----------|-----------|-----------|-----------|
| $\ln(\text{Realwage})_{1871}$ | 7 | 6.726673  | 0.1499981 | 6.530421  | 6.884061  |
| $\text{Popdens}_{1871}$       | 7 | 193.1366  | 282.3051  | 42.47578  | 826.7659  |
| $\text{Railway}_{1871}$       | 7 | 0.0483328 | 0.0175682 | 0.0247205 | 0.0694    |
| $\text{HC}_{1871}$            | 7 | 0.0040771 | 0.0011812 | 0.0024603 | 0.0058877 |

Source: see text

**Table A.4** Descriptive Statistics of City-Level Independent Variables, First Period

| Variable                      | N  | $\mu$     | $\sigma$  | Min       | Max       |
|-------------------------------|----|-----------|-----------|-----------|-----------|
| $\ln(\text{Realwage})_{1850}$ | 16 | 6.69986   | 0.2666416 | 6.235531  | 7.178133  |
| $\text{Popdens}_{1850}$       | 23 | 94.51192  | 101.3697  | 40.77685  | 542.6537  |
| $\text{Railway}_{1850}$       | 23 | 0.0136697 | 0.0088849 | 0.007604  | 0.0290667 |
| $\text{HC}_{1850}$            | 14 | 0.0017363 | 0.0006044 | 0.0014321 | 0.0028515 |
| $\text{Popdens}_{1865}$       | 23 | 110.1242  | 124.1657  | 42.23153  | 656.6683  |
| $\text{Railway}_{1865}$       | 23 | 0.0332092 | 0.0141798 | 0.0193789 | 0.0576667 |
| $\text{HC}_{1865}$            | 23 | 0.0029126 | 0.000958  | 0.0015952 | 0.0051518 |

Source: see text

**Table A.5** Descriptive Statistics of City-Level Independent Variables, Second Period

| Variable                      | N  | $\mu$     | $\sigma$  | Min       | Max       |
|-------------------------------|----|-----------|-----------|-----------|-----------|
| $\ln(\text{Realwage})_{1871}$ | 22 | 6.770761  | 0.193951  | 6.305023  | 7.129298  |
| $\text{Popdens}_{1871}$       | 22 | 123.679   | 162.0978  | 42.47578  | 826.7659  |
| $\text{Railway}_{1871}$       | 22 | 0.0432419 | 0.0163439 | 0.0247205 | 0.0694    |
| $\text{HC}_{1871}$            | 22 | 0.0038047 | 0.0010097 | 0.0024603 | 0.0059286 |

Source: see text

**Table A.6** Descriptive Statistics of City-Level Independent Variables for NGC, 1867-1889

| Variable                      | N  | $\mu$     | $\sigma$  | Min       | Max       |
|-------------------------------|----|-----------|-----------|-----------|-----------|
| $\ln(\text{Realwage})_{1867}$ | 17 | 6.699903  | 0.2631321 | 5.994253  | 7.129298  |
| $\text{Popdens}_{1867}$       | 18 | 124.1373  | 150.8186  | 42.69825  | 706.2902  |
| $\text{Railway}_{1867}$       | 18 | 0.033631  | 0.0160554 | 0.0193789 | 0.0576667 |
| $\text{HC}_{1867}$            | 18 | 0.0028154 | 0.0007461 | 0.0015476 | 0.0041543 |

Source: see text

**Table A.7** Correlations Between State-Level Variables, 1850 Control Variables, First Period

|                               | $\ln(\text{Realwage})_{1850}$ | $\text{Popdens}_{1850}$ | $\text{Railway}_{1850}$ | $\text{HC}_{1850}$ |
|-------------------------------|-------------------------------|-------------------------|-------------------------|--------------------|
| $\ln(\text{Realwage})_{1850}$ | 1.0000                        |                         |                         |                    |
| $\text{Popdens}_{1850}$       | 0.2034                        | 1.0000                  |                         |                    |
| $\text{Railway}_{1850}$       | -0.3169                       | 0.6038                  | 1.0000                  |                    |
| $\text{HC}_{1850}$            | 1.0000                        | 1.0000                  | 1.0000                  | 1.0000             |

Source: see text

**Table A.8** *Correlations Between State-Level Variables, 1865 Control Variables, First Period*

|                               | $\ln(\text{Realwage})_{1850}$ | $\text{Popdens}_{1865}$ | $\text{Railway}_{1865}$ | $\text{HC}_{1865}$ |
|-------------------------------|-------------------------------|-------------------------|-------------------------|--------------------|
| $\ln(\text{Realwage})_{1850}$ | 1.0000                        |                         |                         |                    |
| $\text{Popdens}_{1865}$       | 0.1916                        | 1.0000                  |                         |                    |
| $\text{Railway}_{1865}$       | -0.5257                       | 0.5284                  | 1.0000                  |                    |
| $\text{HC}_{1865}$            | 0.4624                        | -0.0652                 | -0.3627                 | 1.0000             |

Source: see text

**Table A.9** *Correlations Between State-Level Variables, Second Period*

|                               | $\ln(\text{Realwage})_{1871}$ | $\text{Popdens}_{1871}$ | $\text{Railway}_{1871}$ | $\text{HC}_{1871}$ |
|-------------------------------|-------------------------------|-------------------------|-------------------------|--------------------|
| $\ln(\text{Realwage})_{1871}$ | 1.0000                        |                         |                         |                    |
| $\text{Popdens}_{1871}$       | 0.3763                        | 1.0000                  |                         |                    |
| $\text{Railway}_{1871}$       | -0.1639                       | 0.5124                  | 1.0000                  |                    |
| $\text{HC}_{1871}$            | 0.2193                        | -0.1111                 | -0.2064                 | 1.0000             |

Source: see text

**Table A.10** *Correlations Between City-Level Variables, 1850 Control Variables, First Period*

|                               | $\ln(\text{Realwage})_{1850}$ | $\text{Popdens}_{1850}$ | $\text{Railway}_{1850}$ | $\text{HC}_{1850}$ |
|-------------------------------|-------------------------------|-------------------------|-------------------------|--------------------|
| $\ln(\text{Realwage})_{1850}$ | 1.0000                        |                         |                         |                    |
| $\text{Popdens}_{1850}$       | 0.1417                        | 1.0000                  |                         |                    |
| $\text{Railway}_{1850}$       | -0.0114                       | 0.5652                  | 1.0000                  |                    |
| $\text{HC}_{1850}$            | 0.1537                        | 1.0000                  | 1.0000                  | 1.0000             |

Source: see text

**Table A.11** *Correlations Between City-Level Variables, 1865 Control Variables, First Period*

|                               | $\ln(\text{Realwage})_{1850}$ | $\text{Popdens}_{1865}$ | $\text{Railway}_{1865}$ | $\text{HC}_{1865}$ |
|-------------------------------|-------------------------------|-------------------------|-------------------------|--------------------|
| $\ln(\text{Realwage})_{1850}$ | 1.0000                        |                         |                         |                    |
| $\text{Popdens}_{1865}$       | 0.1317                        | 1.0000                  |                         |                    |
| $\text{Railway}_{1865}$       | -0.0517                       | 0.5279                  | 1.0000                  |                    |
| $\text{HC}_{1865}$            | 0.2567                        | -0.0484                 | -0.3859                 | 1.0000             |

Source: see text

**Table A.12** Correlations Between City-Level Variables, Second Period

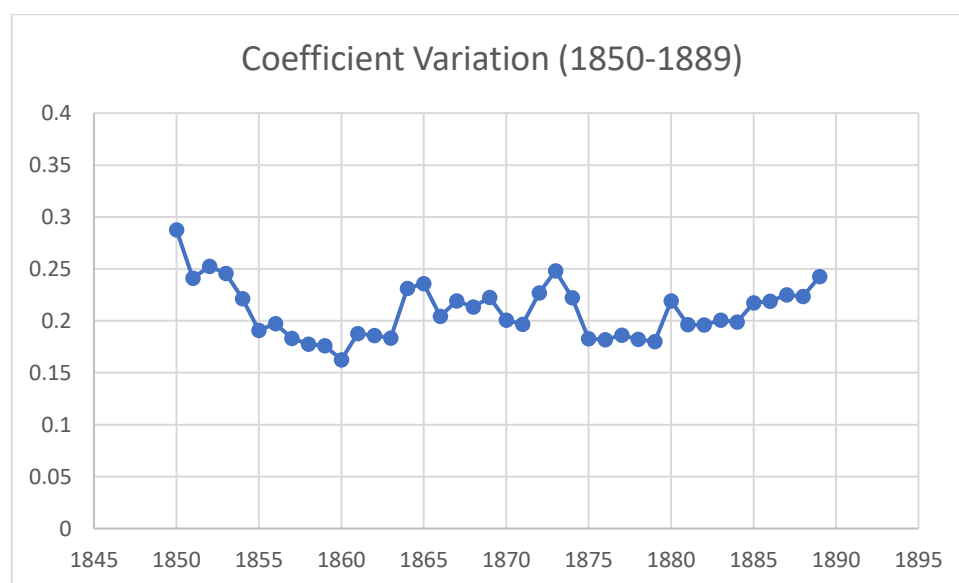
|                               | $\ln(\text{Realwage})_{1871}$ | $\text{Popdens}_{1871}$ | $\text{Railway}_{1871}$ | $\text{HC}_{1871}$ |
|-------------------------------|-------------------------------|-------------------------|-------------------------|--------------------|
| $\ln(\text{Realwage})_{1871}$ | 1.0000                        |                         |                         |                    |
| $\text{Popdens}_{1871}$       | 0.0905                        | 1.0000                  |                         |                    |
| $\text{Railway}_{1871}$       | -0.0744                       | 0.4986                  | 1.0000                  |                    |
| $\text{HC}_{1871}$            | 0.2555                        | -0.0957                 | -0.3203                 | 1.0000             |

Source: see text

**Table A.13** Correlations Between City-Level Variables, 1867-1889

|                               | $\ln(\text{Realwage})_{1867}$ | $\text{Popdens}_{1867}$ | $\text{Railway}_{1867}$ | $\text{HC}_{1867}$ |
|-------------------------------|-------------------------------|-------------------------|-------------------------|--------------------|
| $\ln(\text{Realwage})_{1867}$ | 1.0000                        |                         |                         |                    |
| $\text{Popdens}_{1867}$       | 0.2344                        | 1.0000                  |                         |                    |
| $\text{Railway}_{1867}$       | 0.0010                        | 0.5190                  | 1.0000                  |                    |
| $\text{HC}_{1867}$            | -0.0206                       | -0.1579                 | -0.7519                 | 1.0000             |

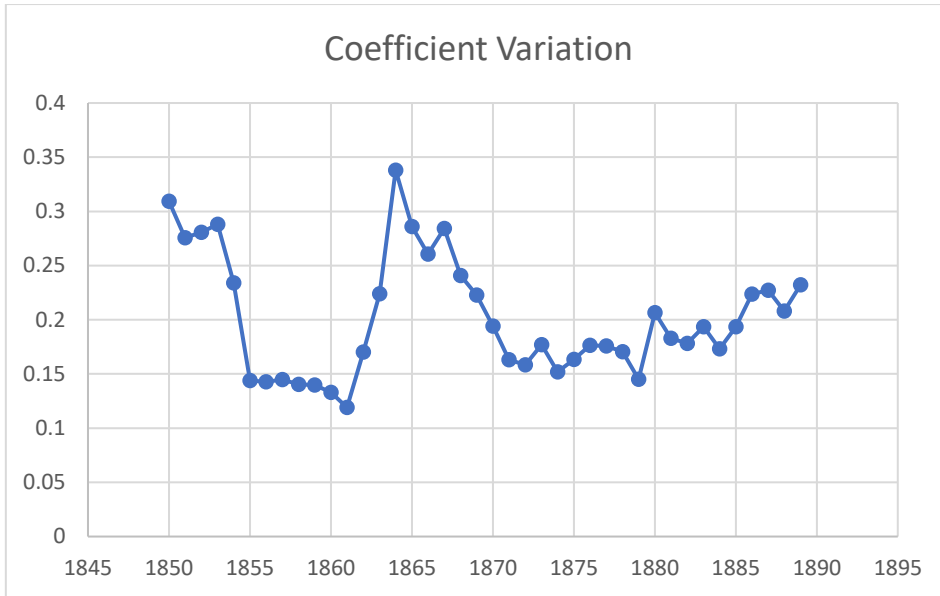
Source: see text



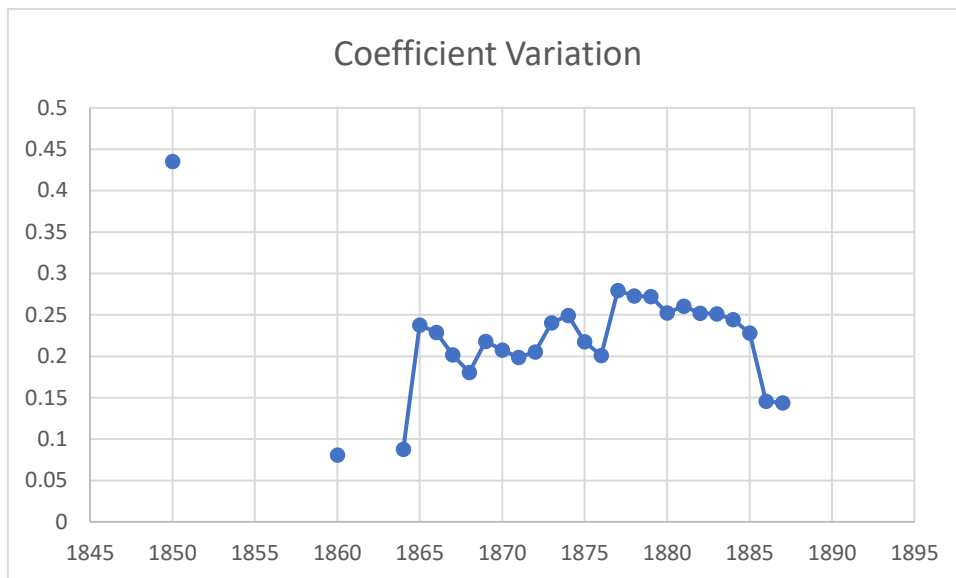
**Figure A.1** Sigma-Convergence Between Cities Excluding Hamburg

Source: author's own elaboration from Pfister (2018) data

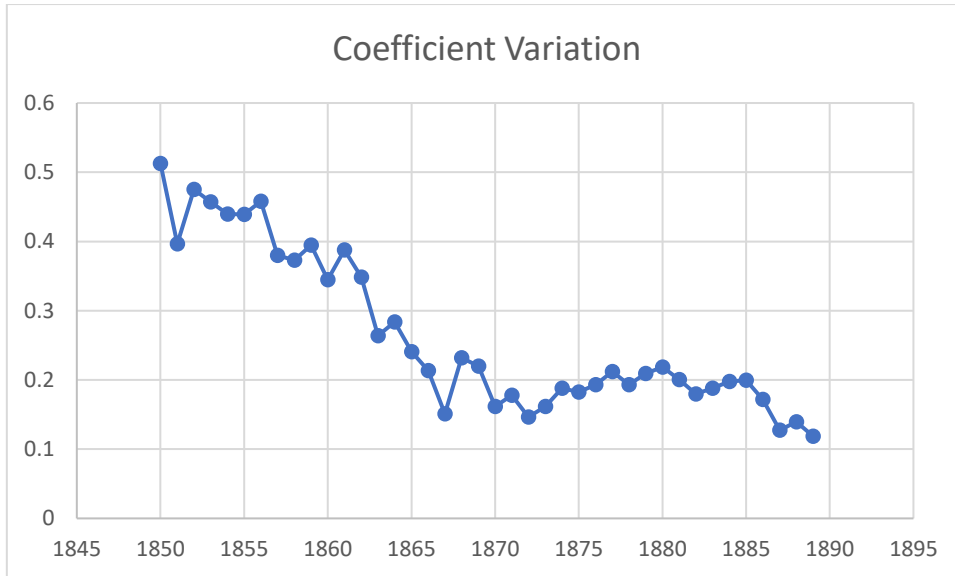




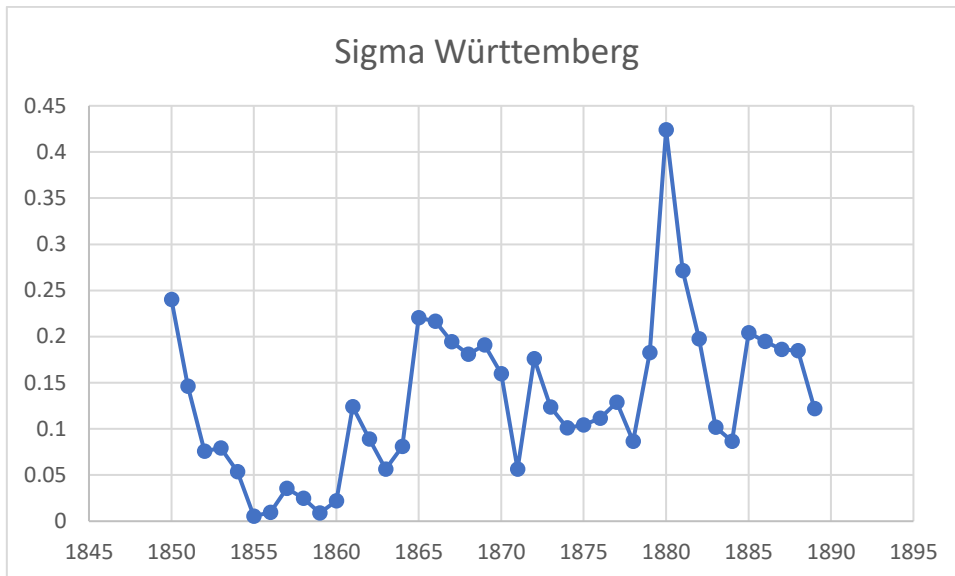
**Figure A.2** *Sigma-Convergence Between Prussian Cities*  
 Source: author's own elaboration from Pfister (2018) data



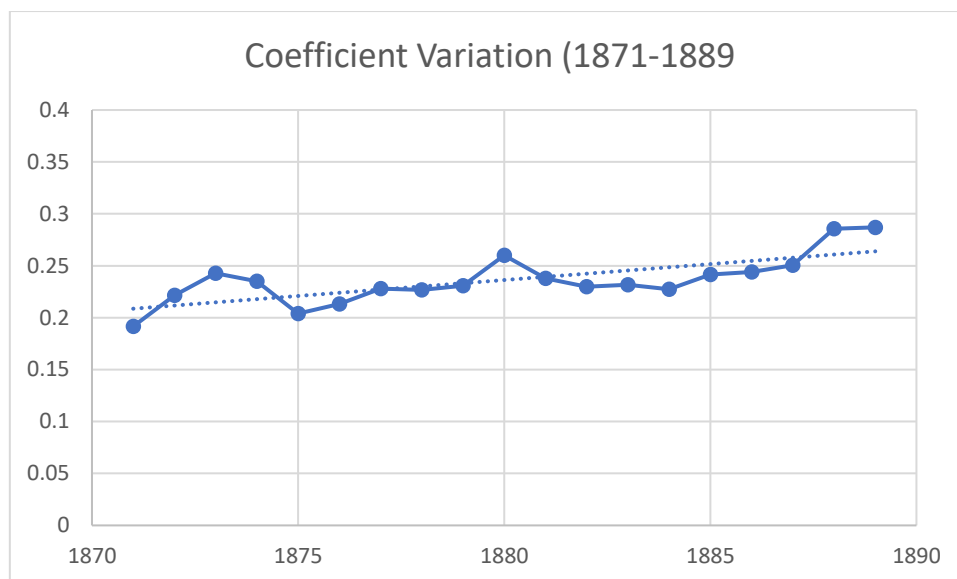
**Figure A.3** *Sigma-Convergence Between Saxon Cities*  
 Source: author's own elaboration from Pfister (2018) data



**Figure A.4** *Sigma-Convergence Between Bavarian Cities*  
 Source: author's own elaboration from Pfister (2018) data



**Figure A.5** *Sigma-Convergence Between Württembergian Cities*  
 Source: author's own elaboration from Pfister (2018) data



**Figure A.6** Sigma-Convergence Between Cities, Second Period with Trendline

Source: author's own elaboration from Pfister (2018) data

**Table A.14** Convergence of North German Cities, Second Period

| Dependent variable: Growth in $\ln(\text{Realwage})_{1871-1889}$ |                           |                           |                      |
|--|---------------------------|---------------------------|----------------------|
|  | (1)                       | (2)                       | (3)                  |
| $\ln(\text{Realwage})_{1871}$                                    | -0.0122<br>(0.0265)       | -0.0158<br>(0.0301)       | -0.00271<br>(0.0280) |
| $\text{Popdens}_{1871}$  | 0.0000602*<br>(0.0000287) | 0.0000654*<br>(0.0000345) |                      |
| $\text{Railway}_{1871}$  | -0.561*<br>(0.297)        | -0.708<br>(0.583)         |                      |
| $\text{HC}_{1871}$   |                           | -3.456<br>(11.62)         |                      |
| <i>Constant</i>  | 0.117<br>(0.184)          | 0.161<br>(0.240)          | 0.000103<br>(0.191)  |
| N  | 17                        | 17                        | 17                   |
| R <sup>2</sup>   | 0.289                     | 0.294                     | 0.001                |

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$