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Deskilling in Germany? An Inquiry into the German Industrial Revolution*

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Abstract

It is generally considered that industrialization is accompanied by an increase in the skills of the workforce. However, this complementarity between human and material capital is controversial, particularly in the early phases of the industrial revolution. It is indeed possible that mechanization, by promoting the division of labor, led to a simplification of tasks and thus to a lower demand for skilled labor. This is the so-called de-skilling hypothesis. The aim of this article is to test this hypothesis using Prussian data from the first half of the 19th century. Industrialization is measured at the county level by the number of workers in the metallurgy sector in 1849. An identification strategy based on the county's proximity to coal mines reveals a negative causal impact of industrialization on schooling rates. This effect seemed to persist right up to the eve of German unification.

Keywords: Deskilling, Industrial revolution, Germany

JEL Codes: N33, O15

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1 Introduction

Both the standard view and the Unified Growth Theories consider that technological progress favors the creation of working skills (Galor and Weil, 1999); (Galor, 2011). The mechanization that resulted from the Industrial Revolution fostered the demand for human capital. However, this view stems from observations made in the 20th century. In the 19th century, social movements, particularly Luddism in Great Britain, unveiled the hostility of craftspeople and skilled workers to the mechanization process resulting from the Industrial Revolution. Skilled workers became "mere attendants on machines" in a "grueling process of deskilling [...]" (Lindholdt, 1997, p.867)¹

Brugger and Gehrke present the debates of classical economists about the notion of deskilling (Brugger and Gehrke, 2018). Adam Smith and Karl Marx's conception of technical progress is biased against skilled labor. This bias could be explained by mechanization, the increasing division of labor and the simplification of tasks, or by the ruling classes' wish to weaken workers' bargaining power.² In the early phases of economic development, industrialization would lead to a depreciation of professional qualifications and, more generally, of the value of education. In the case of Great Britain, for example, the use of the steam engine led to a deterioration in the level of primary education, even though it also stimulated the formation of a skilled workforce (e.g.(Nicholas and Nicholas, 1992); (de Pleijt and Weisdorf, 2017); (de Pleijt et al., 2020))³

It would, therefore, seem possible that education benefited from economic growth in the pre-industrial period but that the early stages of the Industrial Revolution were detrimental to education. In England, for example, the sharp increase in the supply of unskilled workers following rural-urban migration may have spurred manufacturers to promote technologies employing mainly unskilled labor (Acemoglu, 2002b). According to de Pleijt, the sharp increase in the average years of education observed in England over a long period was followed by a decline in the onset of the Industrial Revolution (de Pleijt, 2018). Though this result is a simple correlation, one can consider it to corroborate the deskilling hypothesis. There was no evidence of a complementary relationship between technology and workers' skills in the USA until the early 20th century. It was related to the adoption of electric motors and the adoption of new methods of production (Goldin and Katz, 1998). The first industrial revolution is said to have reinforced inequalities between workers by increasing the demand for highly-skilled labor and deskilling the majority of the workforce (Brugger and Gehrke, 2018). In other words, technical change at the end of the eighteenth and nineteenth centuries would replace skills (Acemoglu, 2002b); (Acemoglu, 2002a). It would, therefore, be drastically different from that observed in the twentieth century.

However, there has never been a consensus on the thesis of a disqualifying technical advance.

¹The Luddite movement has been the subject of many studies and interpretations (Sale, 1995) and a vast historiography, which goes beyond the analysis of the effects of mechanization on human capital e.g. (Minard, 2007).

²For an interpretation of the deskilling hypothesis in terms of a Marxist-inspired sociology of labor: (Braverman, 1998) according to which for employers, mechanization is a strategy to weaken the economic weight of skilled workers by replacing them with low-wage unskilled workers.

³According to Nicholas and Nicholas: "The factory deskilled and proletarianized the work force by destroying old skills, substituting unskilled female and child laborers for skilled male workers and relying on power-driven machinery which created jobs that required no formal skills or even rudimentary levels of literacy" (Nicholas and Nicholas, 1992, p.18). For child labor during the Industrial Revolution in Great Britain: (Humphries, 2013).

Brugger and Gehkre point out that Charles Babbage (1791-1871), a classic author, emphasizes the complementarity between skills and capital and that technical progress could destroy some skilled jobs and create other types of jobs. The conclusions of contemporary literature on the hypothesis of technical progress biased against skills are mixed. Theoretically, the relationship between human capital demand and technological progress may be complex, depending on the phase of the industrial revolution. In the early stages of the Industrial Revolution, economic take-off could be biased towards unskilled labor, which was the most abundant factor of production and, consequently, the cheapest. In the advanced stages of the Industrial Revolution, economic growth would foster the demand for fewer, better-educated workforce and would become biased towards skilled labor (O'Rourke et al., 2013).

In this paper, we test the causal impact of industrialization on various human capital proxies using fine-scale (Kreis-county) German historical data. More precisely, we rely on Prussian data covering the first industrial revolution. To our knowledge, this work has not yet been carried out. Choosing 19th German data can be justified as follows.

The German first industrial revolution differs markedly from that of Great Britain. German first industrial revolution came later. Although dates have long been debated, the industrial take-off did not occur until 1840, well after the United Kingdom's (e.g. (Tilly and Kopsidis, 2020)). Until 1873, economic expansion was vigorous: an unparalleled economic boom characterized the period around the 1871 German unification under Prussian leadership. This period was indeed followed by the historical phase known as the "Great Depression" (1873-1895). A stock market crash in Vienna sparked the crisis in 1873, which triggered deflation and the resumption of protectionist measures. It spread to Europe and the United States. However, the crisis in Germany resulted only in a slowdown in growth rates. If one compares real GDP within the 1871 borders and between 1850 and 1875 (1895), one observes an 88% increase (194%) (Torp, 2011). Furthermore, the main features of this first German industrial revolution were the predominance of railways and capital-intensive heavy industries (iron, steel, mining, engineering) oriented towards world markets, cartelization and strong vertical integration.⁴ This situation is quite different from that of the United Kingdom, where the leading sector is textiles.

The impact of industrialization on education could depend on the quality of institutions and economic policies. In this case, Germany would be a better object of study than France or the United Kingdom to highlight these conditional effects. Indeed, Germany lacks political unity before 1871. The extreme political fragmentation goes along with social and institutional spatial heterogeneity. Exogenous shocks that impacted German territories differently are believed to be the cause. The first one was the Protestant Reformation, which could play a decisive role in the spatially unequal spread of education; Protestants encouraged the direct reading of sacred texts in everyday language (Becker and Woessmann, 2009). The second one is a historical event, namely the French occupation of part of German territories and the formation of the Rhine Confederation that gathered France's satellite states in the aftermath of the French Revolution.

This event could also explain inter-regional differences in political and economic modernization

⁴This first industrial revolution came to an end in the 1890s with the rise of the chemical and electrical industries

(Acemoglu et al., 2011). Another source of regional diversity is more "endogenous". It relates to the authoritarian but enlightened bureaucracy of the Prussian state. From the reign of Frederick II, the Great (1740-1786) onward, this bureaucracy initiated liberal economic reforms that entailed an agrarian reform. Prussia implemented them in the wake of the defeat of Jena-Auerstedt (1806) against Napoleon I's troops (Kopsidis and Bromley, 2016); (Kopsidis and Bromley, 2017); (Tilly and Kopsidis, 2020). This regional institutional diversity goes hand in hand with great economic diversity. Indeed, marked regional disparities are a critical feature. Some provinces were more advanced than others: the Rhine province, Saxony, and Westphalia. Others were lagging, especially Bavaria and Prussia on the eastern side of the Elbe River. In the case of Germany, there is a differential gradient concerning the density of industrial activity between the more advanced western regions and the eastern ones. This disparity could be explained by institutional differences, particularly in agrarian structures. A south-west gradient also shapes the German economy (Lee, 1988); (Tilly and Kopsidis, 2020). It is worth noticing that these regional disparities would have been rather persistent and would not have disappeared with the industrialization process of the second half of the 19th century. Neither trade integration, fostered by the 1834 customs union (Zollverein), which places Prussia at the center of the German scene, nor would the improvement of transport networks have eliminated these regional disparities (Lee, 1988).

There is recognition that the 19th-century markets developed before State intervention took place to regulate the labor market. In the early 19th century, the freeing of peasants boosted the labor market. One of the negative consequences was the development of child labor children in coal mines and newly established factories. What also makes the choice of Germany relevant is the existence of legislation designed to protect children's schooling. As early as 1839, we can observe attempts to protect certain groups of workers such as children: the "Verbot der Kinderarbeit in Preussen" banned factory work for children under 9-12 years of age (Schröder, 2000). It was also aimed at increasing school attendance and implementing obligatory school attendance (Stolleis, 2013). The question is whether this legislation has helped neutralize the de-skilling effect of the first industrial revolution. The article is organized as follows. The literature review is provided in section 2. Data and descriptive statistics are presented in section 3. Econometric results are discussed in section 4. Section 5 is devoted to the conclusion.

2 Literature review

Several papers explore econometrically the impact of industrialization on human capital accumulation. We focus here on quantitative historical studies. The first group of papers, the furthest from our work, focuses on a specific sector: shipping, whose expansion is linked to the wave of globalization in the eighteenth and nineteenth centuries. (Chin et al., 2006) studied the impact of the steam engine on the demand for skills in the merchant shipping industry. They found mixed effects: while technological change increased the demand for engineers, skilled seamen were replaced by unskilled engine room operatives. Similarly, (Ojala et al., 2016) argue that the period from the 1750s to the 1910s is characterized by decreased relative demand for skilled labor for seamen working in sailing ships.

Recent works pertain to the United States. Using variation in skill across US counties induced by immigration, (Lafortune et al., 2019) show that capital is more complementary with low-skill labor at the end of the nineteenth century; hence, the mechanization impulse a reduction of the share of high-skill labor.⁵ (Atack et al., 2024) use data from the American manufacturing industry at the end of the nineteenth century. They show that mechanization, defined as the frequent use of an inanimate force (water or steam) on machine work, generates deskilling at the level of production operations. However, the magnitude of the effect is small; the growing labor division directly explains a larger proportion.⁶

The most numerous studies concern Europe, the cradle of the Industrial Revolution. Franck and Galor use French regional data (departments) from the first half of the 19th century (Franck and Galor, 2022). The industrialization variable is the number of steam engines. An instrumental variable estimator is implemented to control for the potential endogeneity bias between industrialization and human capital. The two instruments used are, on the one hand, the distance between the department administrative center and Fresnes-Sur-L'Escaut, where the first steam engine was introduced in France in 1732. The second instrument is the variation in the price of wheat, which captures the variation in agricultural profitability. The authors highlight a positive and significant effect of early industrialization on many primary education indicators (the share of literate men among French army conscripts, the share of children in primary schools, the number of primary school teachers, the share of apprentices public spending on primary schooling) but not on the share of students in middle and high schools. There seems to have been heterogeneity according to level of education, with primary education the main beneficiary. Another work goes in the same direction since it appears that industrialization did not lead to overall deskilling but only to a change in the composition of skills valued by the market (Diebolt et al., 2017).

The deskilling hypothesis, therefore, does not meet the consensus in the literature, even when tested on British data, which have been by far the most exploited by researchers. Feldman and van der Beek focus on the early England industrialization period, which was characterized by an expansion of the machinery sector (Feldman and van der Beek, 2016). They rely on data concerning the number of apprentices (and their share) in the fifteen-year-old cohort and a proxy of industrialization: the number of inventions (patents). They highlight a positive response of the number of new apprentices to the inventions in a context where apprenticeship is the best formal to acquire skills. According to their interpretation, the technological change was skilled biased. Pleijt, Nuvolari, and Weisdorf mobilise England data from the early 19th century at the county level. They measure industrialization with the number of steam engines (de Pleijt et al., 2020). This variable is instrumented by the prevalence of carboniferous rock strata since coal mines are associated with them. It appears that the early English Industrial Revolution was skilled demanding: the number of steam engines decreased the share of unskilled workers.⁷ Moreover, the early industrial revolution

⁵However, this does not mean that the industrial revolution led to a systematic deskilling. Some workers employed in the new production units may have been better qualified than the craftsmen of the pre-industrial phase (Katz and Margo, 2014).

⁶For the early century Gray showed how the adoption of electricity impact the distribution of skill in US manufactory (Gray, 2013).

⁷This result contrasts (de Pleijt and Weisdorf, 2017) who find a rise of the share of unskilled workers during the

does not seem to significantly affect the formation of basic schooling skills (literacy rate, number of primary schools, . . .). Nevertheless, it worsens gender inequalities in literacy.

3 Data and descriptive statistics

We mainly rely on the iPEHD (IFO Prussian Economic History Database). It is collected at the county level, the basic territorial entity in Germany (Becker et al., 2014).⁸ These data were collected by the Royal Prussian Statistical Office over several censuses from 1816 to 1901. We focus in particular on the 1849 census which corresponds to the onset of the Industrial Revolution. The 1864 census is also taken into account to highlight any persistent de-skilling effects. This year, which precedes the beginning of the process leading to German unity around Prussia (creation of the North German Confederation in 1866) can also be seen as the end of the first industrial revolution and the beginnings of the second revolution. This dataset provides various variables pertaining to education, industrialization, population and religion. The dataset offers several proxies of education: the number of pupils that allow computing school enrollments, the number of teachers, and the literacy rate (only in 1871). Several indices allow for measuring industrial development, such as the workforce by sector and the number of factories. The dataset also entails demographic data and information on religious observances.

3.1 Compiling the dataset (over several census years)

We discuss here the building of the dataset relying on the raw data provided by iPEHD. One main advantage is that all data for the same census year are readily available. All counties (Kreis) are in a district (Bezirk) which allows generating district dummies. In Appendix 7.3, we report the list of counties and counties' identifiers, districts and provinces. For the sake of our study, we need to proceed with intertemporal comparisons: we aim at studying deskilling over the German 19th century. We, therefore, must compile an original intertemporal dataset at the county level from the iPEHD data. Over the 19th century due to various administrative reforms and political moves the county names have changed, and the number of counties has increased, which makes the merging of the different census years challenging. We address this issue by aggregating data from later years to the former structure in 1849. A limitation of this method is that it reduces the variation gained from having a larger number of observations. Nonetheless, this approach is essential to maintain intertemporal comparability among the units of observation.⁹

To aggregate the data, we start by standardizing the county identifiers across different census years. All data in iPEHD reflect the administrative conditions at the time of the census publication.

first industrialization but the lack of instrumental variables makes it hard to make a causal interpretation of this result.

⁸The administrative organization in Prussia in the 19th century is the county (Kreis), then the district (Regierungsbezirk) and then the province. The number of counties increased (308 in 1816; 574 in 1901), partly as a result of administrative reorganization following population growth, and partly due to territory gains. By the end of the 19th century, the number of Prussian provinces is 13.

⁹An alternative approach would be to allocate the 1849 data to two or more later divided units. However, this could result in measurement error if the original data were not evenly distributed.

Since the ordering of counties varied across censuses, iPEHD assigns identifiers based on each specific census order. We use these county identifiers to merge the data across the years. To analyze the data using a comparable set of observations, we then collapse the data to the set of counties in 1849, our earliest available data.

However, some variables have missing data in the iPEHD. To address this, we utilize the Galloway Prussia Database 1861-1941,¹⁰ which supplements information about Prussia not covered by iPEHD.¹¹

Additionally, we augment this dataset with coal mines data sourced from the HISTAT database. This involves creating a dummy variable indicating whether each county contains any coal mines. To facilitate analysis, we also construct this variable at the Bezirk (district) level.

3.2 Descriptive statistics (preliminary version)

The description and definitions of all variables used in this study are reported in Appendix 7.1 while descriptive statistics are to be found in Appendix 7.2.

The iPEHD allows retrieving a rich dataset that allow to gauge the development of the Prussian education system that was initiated as early of the 17th century (reference?). At county level, we have information of the number of students enrolled in primary (Elementarschulen) and secondary schools (namely Mittelschulen for boys, Töchterschulen for girls, Höhere Bürgerschulen for boys, Pro-Gymnasien and Gymnasien for boys). In 1849, 16.2% of the total population was enrolled in primary and secondary schools, which amounts to 46% of the total under 14-years population. Male and females exhibit similar schooling rates since male students represent 8.4% of the total population, which means that 7.8% of total population were female students. Most of the students were enrolled in primary schools (15.4%). The available comparable figure for 1864 is 16.4% which denotes a slight increase in the enrollment rates. We eventually consider the literacy rate as measured in 1871 that shows that 63.2% of the over 10-years old population is able to read and write.

It appears that Prussian education systems were more successful in reaching the population and ensuring basic literacy than other European countries in the 19th century. The figures are consistent with work that argues that Prussia benefited from the early introduction of compulsory primary education and had a notable influence on its spread in other countries, such as the Ferry Laws that introduced compulsory primary education in France after 1870 (Sangar, 2020).

In 1849, most of the labor force in Prussia works in the agricultural sector.¹² The number of persons of which main occupation is agriculture represents 43.3% of the total population. The

¹⁰Galloway, Patrick R., 2007, "Galloway Prussia Database 1861 to 1914", www.patrickrgalloway.com.

¹¹To ensure clarity and consistency in our analysis, we prioritize the data from iPEHD as the primary source, considering it to be the 'true' data. We supplement this with information from the Galloway database only where data is missing, despite most of the data aligning between the two sources.

¹²The IPEHD provides the number of people living on farming namely that declare they declare farming as their main occupation. This figure includes Males their Females, Children, and Day Laborers. Name of this variable `ipehd_1849_occ_agri`.

ratio of the workers in factories ¹³ falls to 3.7% while the figure narrows down to 0.3% for the workers enrolled in the metallurgy sector, that will serve as our main industrialization index. The metallurgy workers represented 6.9% of workers hired in the industrial sector. We consider that the full list of activities reported in the metallurgy sector is a relevant and reliable index of the industrialization process and that the 1849 statistic catches the early industrialization process that took place in Prussia in the early 19th century.

As a first assessment of how industrialization interacted with investment in human capital, we compute the aforementioned schooling rates statistics conditional on the median value of the industrialization variable, namely the metallurgy workers. depending on the median value of the latter variable. These simple correlations do not exhibit differences whatever the schooling rates in 1849 or 1864, as well the literacy rate in 1871, which deserves further econometric investigation.

4 Econometric Analysis

Three groups of estimation are carried out. The first uses only data from 1849 which is considered as the first German industrial revolution take-off (Section 4.1). With the same set of variables, we explore potential heterogeneity in the deskilling effect (Section 4.2). The third group of estimates combines industrialization data from 1849 and education data from 1864 and 1871 (Section 4.3). The aim is to test the hypothesis that the de-skilling effect is long-lasting.

4.1 Is there any de-skilling effect in 1849?

4.1.1 OLS Results

The aim of the econometric analysis is to test the deskilling hypothesis according to which the industrialization process during the first industrial revolution has led to a deterioration in education indicators. To this aim, we estimate a model in which the dependent variable is a measure of education and the variable of interest a measure of industrialization. The model is estimated for the year 1849 over the 335 counties. This is the finest possible geographical division: it allows to highlight geographical heterogeneities regarding the intensity of the industrialization (Figure 1).

¹³whose list of activities is available in the Appendix 7.1 table

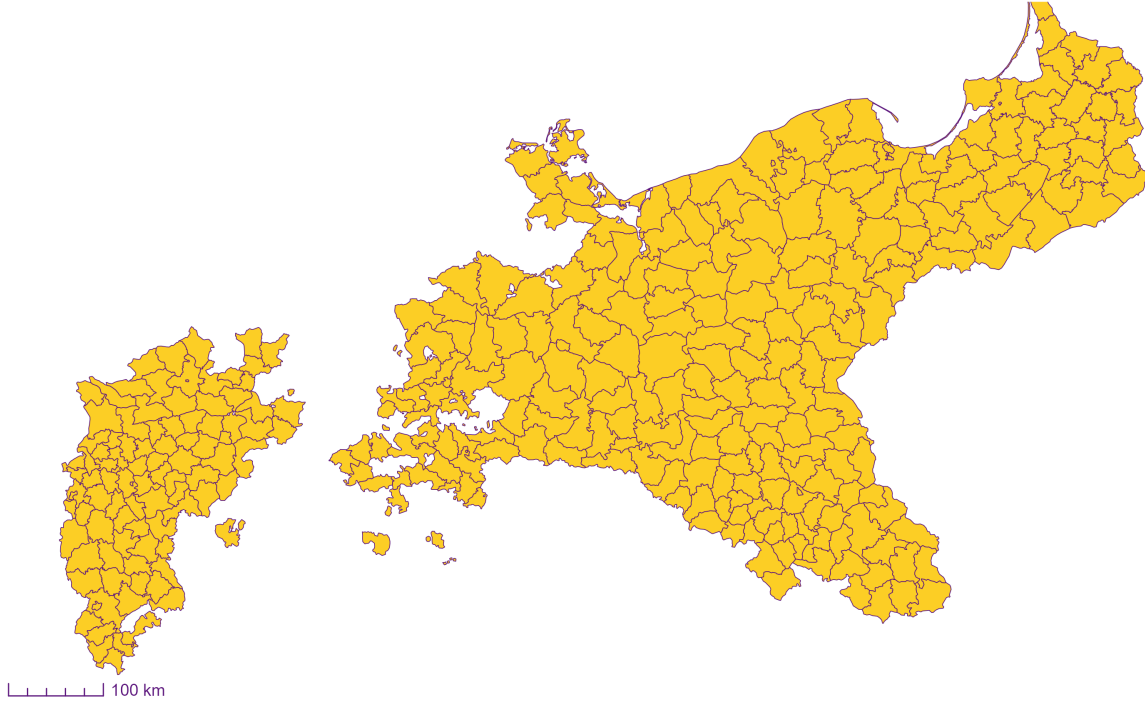


Figure 1: Map of Prussia in 1849 with the 335 counties

We consider the number of students in both primary and secondary education over the total population as an education measurement: $\frac{edu1849_pub_stud}{pop1849_tot}$. For 1849, we do not have other education variables, such as the number of people who can read and write. Moreover, the available data do not allow us to calculate gross enrollment rates for both 1849 and 1864. This is why we have used the total population as the denominator to build this schooling ratio.¹⁴

The number of workers in the metallurgical sector is the main independent variable (*fac1849_metallurgy_workers*), since economic historians have long argued that metallurgy distinctly headed the German industry.

The model to estimate is thus the following:

$$\log\left(\frac{edu1849_pub_stud}{pop1849_tot}\right)_i = \alpha_i + \beta \log(1 + fac1849_metallurgy_workers) + \gamma X_i + \varepsilon_i. \quad (1)$$

With $i=1, \dots, 335$ is the county's (Kreis) index. X_i is a vector of control variables and ε the usual idiosyncratic term. According to the de-skilling hypothesis, we should observe $\beta < 0$. All variables are expressed in logarithms.¹⁵ The models are estimated by OLS adding district (Bezirk) fixed effects to control for unobserved factors (historical, geographical, cultural, ...).¹⁶

¹⁴For robustness, however, we have estimated models where the denominator of the schooling ratio is the population under 14 (below). The results are unchanged.

¹⁵When a variable contains 0's, 1 is then added to the variable to compute the log value.

¹⁶We alternatively used provincial fixed effects. The results are no different from those obtained with fixed Bezirk

The control variables are the following. i) Protestantism may be an important explanatory factor in education, as believers are encouraged to read the Bible directly in their mother tongue. This hypothesis was successfully tested on Prussian data at county level by (Becker and Woessmann, 2009).¹⁷ We consider the share of Protestants in the total population: $\frac{rel1849_pro}{pop1849_tot}$. This variable is expected to increase the level of education.

ii) We assume that there is a positive wealth effect in the education demand. The database for the year 1849 also makes it possible to proxy wealth by two indicators of assets ownership: the number of private buildings: *buil1849_privateline* and the number of rural estates *land1849_far_ext_tot*. We also introduce an indicator of rural estates concentration: the ratio of the number of "large" rural estates (the estates over 5 "Magdeburgen Morgen") over the number of "small" estates (the estates under 5 "Magdeburgen Morgen"): *land1849_unequal_3*. We assume that as the share of large farms increases, the number of workers required increases due to decreasing returns to labour. The impact on the education level could then be negative. Control variables are gradually introduced into the model (Table 1).

The results are not influenced by the control variables included. Whatever the model, it appears that our industrialization proxy significantly and negatively affects the education variable. The last column (OLS6) allows us to check that the results are unchanged if we introduce the under-14 population in the denominator to calculate the schooling ratio. Hence, the deskilling hypothesis cannot be rejected.

4.1.2 TSLS Results

An important question is that of the strategy for identifying a causal impact of industrialization on education. Indeed, the relationship may be inverse. Thus, in the theoretical models of unified growth (Galor, 2011), the role of human capital is considered crucial, even if its importance in the early phases of the Industrial Revolution was downplayed. With the acceleration of technological progress, the demand for human capital is increasing (Galor and Weil, 2000). Mobilizing French data, (Squicciarini and Voigtländer, 2015) show that the upper-tail human capital (the city level subscriptions to the "Encyclopédie" in the mid 18th century) explains the economic growth during the industrial revolution. Using Prussian data collected at county level, (Cinnirella and Streb, 2017) show that literacy rate, a proxy of basic education was positively correlated with technological innovation (measured by patents). This result is somewhat surprising. One might expect that only higher education would be a driver of technological innovation. Perhaps it can be explained by the fact that a high rate of literacy is also accompanied by a high level of higher education, or perhaps a high level of literacy is a necessary condition for the emergence of technological spillovers. Education policies can be used as a tool for economic development and industrialization. Since the Enlightenment, the Prussian state has always attached great importance to education, not only basic and general education, but also to vocational training. Primary school enrollment rates in Prussia in 1849 were far higher than in the rest of Europe (Tilly and Kopsidis, 2020). The effects.

¹⁷For a more contrasting result with the lack of a causal relationship between income and church attendance on Prussian data (Becker and Woessmann, 2013).

Table 1: Basic OLS Results

OLS Dependent variable (OLS1–5): $\log\left(\frac{\text{edu1849_pub_stud}}{\text{pop1849_tot}}\right)$

OLS Dependent variable (OLS6): $\log\left(\frac{\text{edu1849_pub_stud}}{\text{pop1849_f_un14}+\text{pop1849_m_un14}}\right)$

	OLS1	OLS2	OLS3	OLS4	OLS5	OLS6
$\log(1 + \text{fac1849_metallurgy_workers})$	-0.008** (0.004)	-0.009** (0.004)	-0.009** (0.004)	-0.008** (0.003)	-0.007** (0.003)	-0.008*** (0.003)
$\log\left(\frac{\text{rel1849_pro}}{\text{pop1849_tot}}\right)$		0.016*** (0.005)	0.016*** (0.005)	0.020*** (0.005)	0.021*** (0.005)	0.019*** (0.005)
$\log(1 + \text{buil1849_privatehome})$			0.001 (0.022)	-0.063* (0.033)	-0.064* (0.036)	-0.021 (0.024)
$\log(1 + \text{land1849_far_ext_tot})$				0.044** (0.017)	0.045** (0.018)	0.011 (0.011)
$\log(1 + \text{land1849_unequal_3})$					-0.024 (0.108)	-0.284*** (0.082)
Constant	-1.811*** (0.010)	-1.791*** (0.012)	-1.797*** (0.190)	-1.611*** (0.191)	-1.597*** (0.219)	-0.548*** (0.169)
Observations	335	335	335	335	335	335
Adjusted R-squared	0.418	0.426	0.424	0.466	0.465	0.581
District (Bezirk) dummies	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors in parentheses.

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

development of a body of engineers and the emphasis placed on technical education were seen as a priority. The aim is to create managers who can initially absorb technological innovations from Great Britain, and who can then participate in technological and industrial progress (Focacci and Perez, 2022). (Becker et al., 2011) highlight that initially better educated counties within Prussia responded more successfully to the opportunities created by the outside technological changes from Britain. This result contrasts with that obtained on British data, which seems to show the low importance of human capital in explaining the industrial revolution.

One solution could be to design a natural experiment using the proximity of different districts to coal and lignite mines as a source of exogenous variability (Fernihough and O’Rourke, 2021). During the first industrial revolution in Germany, the iron and steel industries were heavily dependent on the proximity of mines, which were located mainly in the Ruhr and Silesia regions. In fact, despite progress in transport infrastructure, transport costs are still high enough to make proximity to raw material sources a competitive advantage for companies. Germany could have relied on imported coal, especially from the UK. However, Gutberlet argues that coal imports never resulted in industry development in the German coastal regions. Instead, industrialization (development of metal production and machine tool making) took place in the neighborhood of German coal mining. The same author claims that “domestic coal deposits were an important factor for industrial development” in the country (Gutberlet, 2013, p.56). Moreover, one specific feature of the German industry is that it was vertically integrated: industries secured access to coal mines by acquiring

their own coalfields, especially in the Ruhr basin (Brinkmann, 1933). The prevalence of coal in the energy mix persisted until the 1880s, when electric motors replaced steam engines (Gutberlet, 2014, p.465)

As the location of the mines is correlated with the geological characteristics of the soils and more specifically the presence of strata of carboniferous rocks (de Pleijt et al., 2020), it can be considered as exogenous. The first set of 4 instrumental variables concerns proximity to coal mines. First, we build a dummy variable taking the value of 1 in mining counties and 0 otherwise: *coalmine1849_county*. The drawback of this variable is that it only takes into account mines in the immediate vicinity of industrial activity. To remedy this, another instrument has been defined: a dummy variable taking the value of 1 if there is a mine in the county or in a neighboring county and 0 otherwise: *coalmine1849_county_broad*. In the first-stage equation, we expect these variables to have a positive impact on industrialization.

However, a mine could impact industrial activity over a greater distance than the immediate vicinity. Consequently, a third instrument is defined: the logarithm of the distance between the centroid of the county and the centroid of the nearest mining county, denoted $\log(1 + \text{coalmine1849_county_mindist})$. This is the minimum distance between the county i and a mining county. The expected sign of this variable in the first-stage equation is negative: greater distance increases transportation costs. Finally, we built a fourth instrument, also based on geographical distance, but allowing for the presence of a threshold effect: beyond a given distance, transportation costs become so high that it is no longer profitable to transport coal to the plant. To do this, we calculate the inverse of the distance and transform all observations of this variable below its first quartile into 0: *coalmine1849_county_invdist25*. The result is thus a censored variable at 0 when the distance (inverse of) become very great (low).¹⁸ We expect a positive sign from this instrument on the industrialization variable in the first-stage equation. The mines are mainly located in the Ruhr and the Silesian regions (Figure 2). Figures 3 and 4 map the distance to the nearest coal mine and the proximity index (censored inverse distance) respectively.¹⁹

A second set of instrumental variables is defined. First, it includes the energy of the steam engines measured in horsepower: *steam1849_horsepower*.²⁰ The steam energy is produced by the use of coal in the production process. In the same vein, steam power created a dependence on locally traded coal because of high transportation costs. This is another way of measuring energy availability. Moreover, there's no reason to believe that this variable could affect education other than indirectly through the number of metallurgy workers. Secondly, we consider the number of crew involved in the river navigation: *occ1849_river_crew*.²¹ We assume that this variable is a proxy for the closeness to the major transportation network. On the one hand, it should favor industrial activity and on the other hand, we do not suspect a direct influence of this variable on schooling

¹⁸Using the median or third quartile to build the censored variable does not qualitatively affect the results.

¹⁹This information on the location of mines can be checked by consulting the Chatel and Dollfus Atlas on mining activity in Europe (Varii auctores, 1931).

²⁰The Horsepower is a unit of measurement of power. 1 Horsepower is equivalent to 735/745 Watts.

²¹We also took into account crews involved in maritime shipping. The variable did not prove significant in the first-stage equation. We have no statistics on roads or railroads in 1849. For a study of the relationship between railroads and economic development, see (Braun and Franke, 2022)

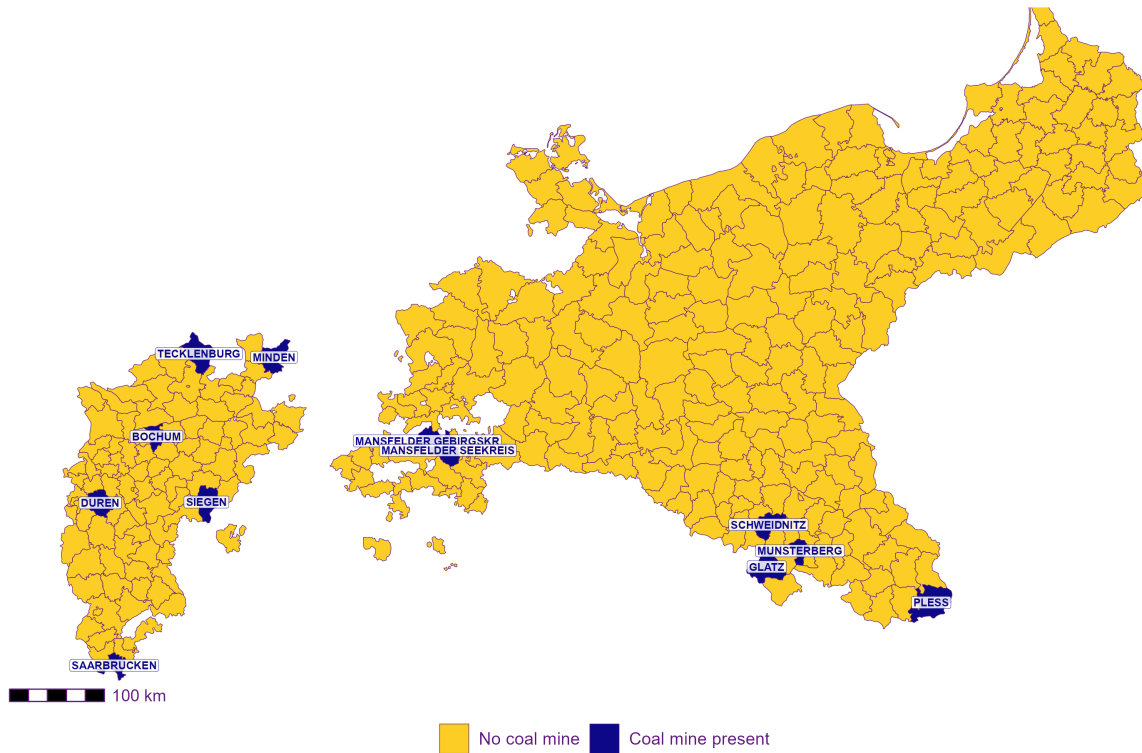


Figure 2: Location of mines in 1849

ratio. The expected sign of these two variables in the first-step equation are positive.

Two groups of models are estimated according to the number of excess instruments. In the first group, the models are exactly identified or the number of excess instruments is one (Table 2). In the second group, the number of excess instruments is two (Table 3). The first-stage equations and the usual diagnostic tests are presented: the over-identification test of Sargan/Hansen (J statistic) and the weak identification test of Cragg- Donald (F-stat).

The most striking result is that, irrespective of the specification chosen, the number of workers in the metallurgy sector negatively affects the measure of education. Moreover, the coefficient is highly unchanging: the de-skilling hypothesis is not rejected. The last column (TSLS7.2) allows us to check that the results are unchanged if we introduce the under-14 population in the denominator to calculate the schooling ratio.

It is now interesting to compare the results with those obtained by OLS. The OLS estimation could underestimate the de-skilling effect of industrialization. There are two possible explanations. On the one hand, industrialization is measured by a proxy variable, and therefore with an error, which generates an attenuation bias. On the other hand, we can reasonably assume that the unobserved determinants of education have a positive impact on industrialization. In other words, there could be an inverse positive correlation between education and industrialization: human

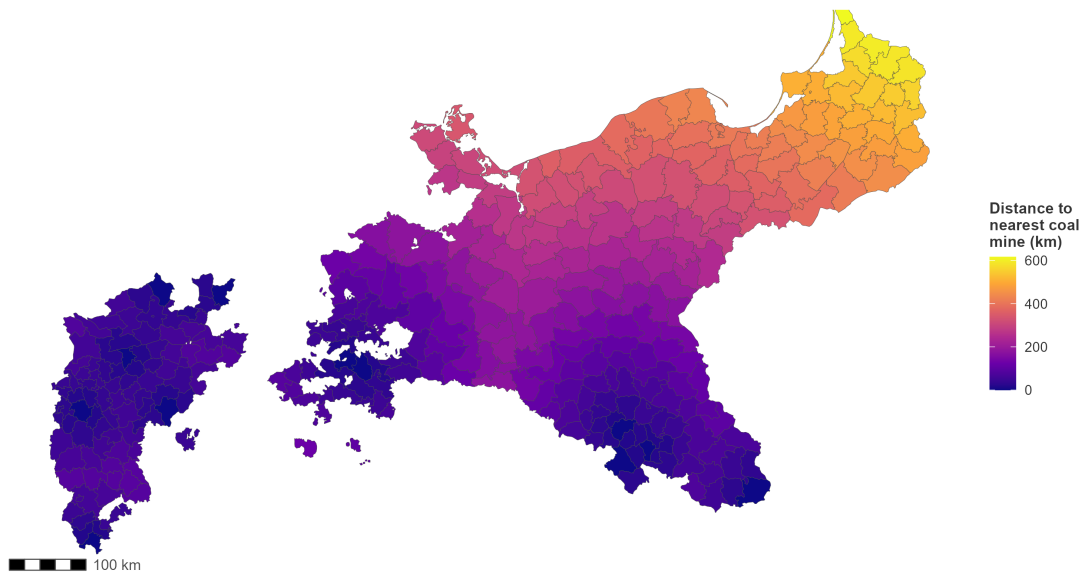


Figure 3: Distance to nearest coal mine (km)

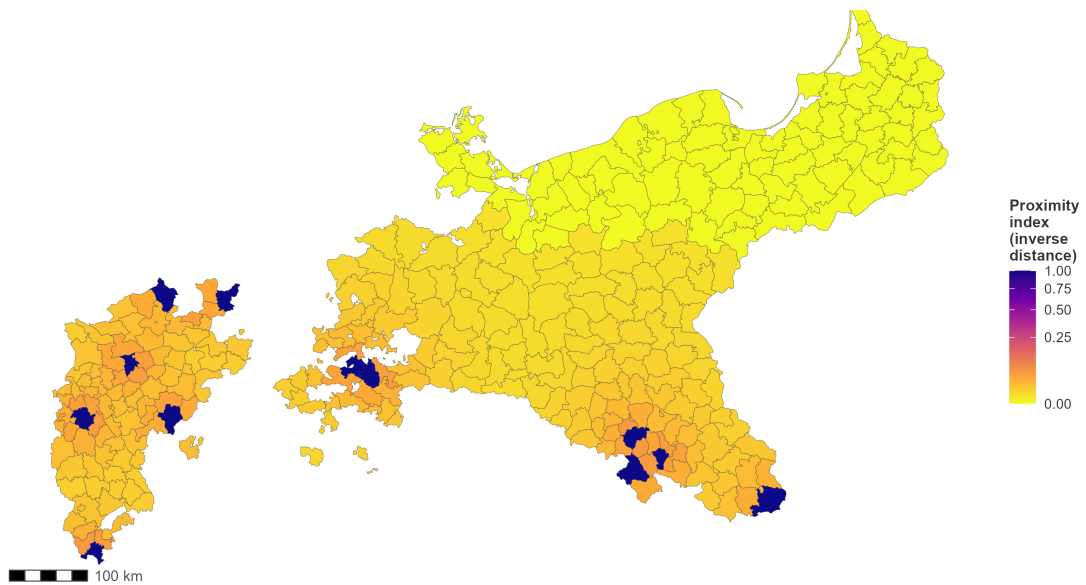


Figure 4: Proximity index (censored inverse distance)

Table 2: Basic results - TSLS

TSLS dependent variable: $\log\left(\frac{\text{edu1849_pub_stud}}{\text{pop1849_tot}}\right)$

First step dependent variable: $\log(1 + \text{fac1849_metallurgy_workers})$

	First stage1	TSLS1	First stage2	TSLS2	First stage3	TSLS3	First stage4	TSLS4
$\log(1 + \text{fac1849_metallurgy_workers})$		-0.047*** (0.011)		-0.045** (0.021)		-0.045*** (0.010)		-0.045*** (0.010)
$\log\left(\frac{\text{rel1849_pro}}{\text{pop1849_tot}}\right)$	0.132 (0.112)	0.031*** (0.008)	0.244** (0.118)	0.031*** (0.009)	0.119 (0.112)	0.031*** (0.007)	0.118 (0.112)	0.031*** (0.007)
$\log(1 + \text{buil1849_privatehome})$	0.795* (0.417)	0.003 (0.036)	1.356*** (0.402)	-0.001 (0.043)	0.779* (0.415)	-0.001 (0.036)	0.780* (0.414)	-0.001 (0.036)
$\log(1 + \text{land1849_far_ext_tot})$	-0.002 (0.124)	0.034** (0.013)	-0.190 (0.140)	0.034** (0.014)	-0.018 (0.126)	0.034** (0.014)	-0.019 (0.126)	0.034** (0.014)
$\log(1 + \text{land1849_unequal3})$	1.824 (1.646)	0.004 (0.098)	0.635 (1.597)	0.002 (0.095)	1.964 (1.658)	0.002 (0.096)	1.973 (1.660)	0.002 (0.096)
<i>Instruments:</i>								
$\log(1 + \text{steam1849_horsepower})$		0.354*** (0.058)			0.341*** (0.060)		0.341*** (0.060)	
$\text{coalmine1849_county}$					0.779* (0.436)			
$\text{coalmine1849_county_invdist25}$							0.812* (0.450)	
$\text{occ1849_river_crew}$			0.002*** (0.001)					
District (Bezirk) dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	335	335	335	335	335	335	335	335
Adjusted R-squared	0.419	0.233	0.366	0.259	0.421	0.259	0.421	0.259
J-statistic (p-value)						1.20 (0.273)		1.23 (0.268)
Cragg-Donald F-stat		45.8		16.4		23.8		23.9

Notes: Robust standard errors in parentheses. The dependent variable in the second stage is the log of public students per capita. The first stage dependent variable is the log of metallurgy workers.

Columns labeled "First stage" report first-stage regression results; columns labeled "TSLS" report second-stage instrumental variables estimates.

*** p<0.01, ** p<0.05, * p<0.1

capital could be the driving force behind the industrialization process, insofar as engineers and skilled workers are needed to operate factories. In this case, the coefficients estimated by OLS should be biased upwards and thus underestimate the magnitude of the de-skilling effect. When we compare the de-skilling effect estimated by the OLS (Table 1) and the one estimated by the IV method (Table 2 and Table 3), we can see that on the one hand, the marginal effects of the interest variable have the same sign and on the other hand, that the marginal effects is around 6 times greater in absolute value in the second case.

4.2 Is the de-skilling effect heterogeneous?

Two potential sources of heterogeneity are considered. The first one concerns the main independent variable. The second one concerns the dependent variable.

4.2.1 Is the de-skilling effect a characteristic of the metallurgy sector only?

We substitute the number of workers in the metallurgical sector by the total number of workers in the factories: *fac1849_workers*. The aim here is to have a broader measure of the workforce in factories to capture the intensity of the industrialization process. Indeed, the industrialization

Table 3: Basic results - TSLS

TSLS dependent variable (TSLS5–TSLS7.1): $\log\left(\frac{\text{edu1849_pub_stud}}{\text{pop1849_tot}}\right)$

TSLS dependent variable (TSLS7.2): $\log\left(\frac{\text{edu1849_pub_stud}}{\text{pop1849_f.un14}+\text{pop1849_m.un14}}\right)$

First step dependent variable: $\log(1 + \text{fac1849_metallurgy_workers})$

	First stage5	TSLS5	First stage6	TSLS6	First stage7	TSLS7.1	TSLS7.2
$\log(1 + \text{fac1849_metallurgy_workers})$		-0.045*** (0.010)		-0.045*** (0.010)		-0.042*** (0.010)	-0.037*** (0.007)
$\log\left(\frac{\text{rel1849_pro}}{\text{pop1849_tot}}\right)$	0.115 (0.112)	0.031*** (0.007)	0.113 (0.112)	0.031*** (0.007)	0.104 (0.111)	0.030*** (0.007)	0.027*** (0.006)
$\log(1 + \text{buil1849_privatehome})$	0.617 (0.396)	-0.002 (0.034)	0.622 (0.395)	-0.001 (0.034)	0.605 (0.390)	-0.006 (0.034)	0.028 (0.024)
$\log(1 + \text{land1849_far_ext_tot})$	0.017 (0.107)	0.034** (0.013)	0.017 (0.107)	0.034** (0.013)	0.032 (0.103)	0.035** (0.014)	0.003 (0.008)
$\log(1 + \text{land1849_unequal_3})$	1.837 (1.518)	0.002 (0.096)	1.873 (1.527)	0.002 (0.096)	1.832 (1.516)	-0.000 (0.095)	-0.264*** (0.082)
<i>Instruments:</i>							
$\log(1 + \text{steam1849_horsepower})$	0.308*** (0.060)		0.306*** (0.061)		0.306*** (0.060)		
$\text{coalmine1849_county}$	0.867* (0.455)						
$\text{coalmine1849_county_broad}$					0.687** (0.320)		
$\log(1 + \text{coalmine1849_county_mindist})$			-0.078* (0.043)				
$\text{occ1849_river_crew}$	0.002*** (0.001)		0.002*** (0.001)		0.002*** (0.001)		
District (Bezirk) dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	335	335	335	335	335	335	335
Adjusted R-squared	0.436	0.263	0.436	0.261	0.440	0.292	0.469
J-statistic (p-value)		1.23 (0.540)		1.05 (0.592)		5.07 (0.079)	0.49 (0.783)
Cragg-Donald F-stat		19.5		19.4		20.3	19.4

Notes: Robust standard errors in parentheses. The dependent variable in the second stage is the log of public students per capita. The first stage dependent variable is the log of metallurgy workers.

Columns labeled "First step" report first-stage regression results. Columns labeled "TSLS" report second-stage instrumental variables estimates. TSLS7.2 represents an alternative specification.

*** p<0.01, ** p<0.05, * p<0.1

process was not confined to the metallurgy sector, even though this sector played a key role in the first industrial revolution. The model is first estimated by OLS adding Bezirk fixed effects, gradually introducing control variables. An additional control variable is added in a specification (OLS6): the share of metallurgy workers in total factory employment: $\frac{\text{fac1849_metallurgy_workers}}{\text{fac1849_workers}}$. This variable is used to catch any potential heterogeneity effects between the metallurgy sector and the rest of the economy. The OLS results are presented in Table 4. If the results are compared with those obtained for metallurgical workers (Table 1), we observe the same negative sign for the variable of interest. The results are largely unaffected by the inclusion of the different control variables. Furthermore, the education variable is not affected by the share of workers in the metallurgical sector (OLS6).

The model is then estimated with steam energy as an instrumental variable (Table 5).²² Substi-

²²Several over-identified models have been estimated, but the diagnostic tests for the instrumental variables are

tuting total factory employment for employment in the metallurgical sector does not qualitatively affect the results: a deskilling effect is always observed. The de-skilling effect is not specific to the metallurgical sector.

Table 4: Heterogeneity – OLS Results

OLS dependent variable: $\log\left(\frac{\text{edu1849_pub_stud}}{\text{pop1849_tot}}\right)$

	OLS1	OLS2	OLS3	OLS4	OLS5	OLS6
$\log(1 + \text{fac1849_workers})$	-0.034*** (0.010)	-0.037*** (0.010)	-0.043*** (0.011)	-0.033*** (0.009)	-0.034*** (0.009)	-0.033*** (0.009)
$\log\left(\frac{\text{rel1849_pro}}{\text{pop1849_tot}}\right)$		0.018*** (0.004)	0.018*** (0.005)	0.022*** (0.005)	0.023*** (0.005)	0.023*** (0.005)
$\log(1 + \text{buil1849_privatehome})$			0.031 (0.022)	-0.034 (0.033)	-0.036 (0.034)	-0.036 (0.034)
$\log(1 + \text{land1849_far_ext_tot})$				0.039** (0.016)	0.041** (0.017)	0.041** (0.017)
$\log(1 + \text{land1849_unequal_3})$					-0.067 (0.107)	-0.064 (0.107)
$\log\left(1 + \frac{\text{fac1849_metallurgy_workers}}{\text{fac1849_workers}}\right)$						-0.029 (0.046)
District (Bezirk) dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	335	335	335	335	335	335
Adjusted R-squared	0.434	0.444	0.446	0.477	0.477	0.475

Notes: Robust standard errors in parentheses. The dependent variable is the log of public students per capita.

Column 6 includes the ratio of metallurgy workers to total factory workers as an additional control to test for composition effects.

*** p<0.01, ** p<0.05, * p<0.1

4.2.2 Is the de-skilling effect gendered?

We consider an alternative dependent variable: the ratio of the number of male students in both primary and secondary education over the total population: $\frac{\text{edu1849_pub_stud_m}}{\text{pop1849_tot}}$. The model is estimated by the OLS and the TSLS estimators, both with Bezirk fixed effects. Different specifications are estimated. The results are presented in Table 6 (OLS 1; TSLS1.1 and TSLS1.2). The results obtained for male students are not different from those obtained for all students. It is therefore not possible to identify a gendered deskilling effect.

4.2.3 Does the de-skilling effect depend on the educational cycle?

The second variable is the number of students in primary education divided by total population: $\frac{\text{edu1849_pub_ele_stud_mf}}{\text{pop1849_tot}}$. This variable helps to answer the question of whether the effect of deskilling

not satisfactory.

Table 5: Heterogeneity - TSLS results

TSLS dependent variable: $\log\left(\frac{\text{edu1849_pub_stud}}{\text{pop1849_tot}}\right)$

First step dependent variable: $\log(1 + \text{fac1849_workers})$

	First stage	TSLS1	First stage	TSLS2
$\log(1 + \text{fac1849_workers})$		-0.117*** (0.024)		-0.122*** (0.025)
$\log\left(\frac{\text{rel1849_pro}}{\text{pop1849_tot}}\right)$	0.057 (0.038)	0.032*** (0.006)	0.057 (0.038)	0.032*** (0.006)
$\log(1 + \text{buil1849_privatehome})$	0.859*** (0.149)	0.066 (0.040)	0.862*** (0.150)	0.071* (0.041)
$\log(1 + \text{land1849_far_ext_tot})$	-0.061 (0.073)	0.027** (0.012)	-0.062 (0.074)	0.026** (0.012)
$\log(1 + \text{land1849_unequal3})$	-0.650 (0.586)	-0.159* (0.089)	-0.664 (0.588)	-0.170* (0.090)
$\log\left(1 + \frac{\text{fac1849_metallurgy_workers}}{\text{fac1849_workers}}\right)$			0.117 (0.477)	0.061 (0.064)
<i>Instrument:</i>				
$\log(1 + \text{steam1849_horsepower})$	0.144*** (0.021)		0.142*** (0.022)	
District (Bezirk) dummies	Yes	Yes	Yes	Yes
Observations	335	335	335	335
Adjusted R-squared		0.353		0.336
Cragg-Donald F-stat		64.6		58.1

Notes: Robust standard errors in parentheses. The dependent variable in the second stage is the log of public students per capita. The first stage dependent variable is the log of total factory workers rather than metallurgy workers.

TSLS2 includes the ratio of metallurgy to total factory workers to test for composition effects within the industrial workforce.

Steam horsepower serves as the instrument for total factory workers.

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

is greater when only the primary education is considered. The model is estimated by the OLS and the TSLS estimators, both with Bezirk fixed effects. The results are presented in Table 6 (OLS2; TSLS2.1 and TSLS2.2). It appears that the results are similar to those obtained with both primary and secondary education: employment in the metallurgical sector leads to a reduction in the number of pupils in the primary education as a proportion of the total population.

Table 6: Heterogeneity – OLS and TSLS results

OLS1/TSLS1 dependent variable: $\log\left(\frac{\text{edu1849_pub_stud_m}}{\text{pop1849_tot}}\right)$ (male students)

OLS2/TSLS2 dependent variable: $\log\left(\frac{\text{edu1849_pub_ele_stud_mf}}{\text{pop1849_tot}}\right)$ (primary students only)

First step dependent variable: $\log(1 + \text{fac1849_metallurgy_workers})$

	OLS1	First step	TSLS1.1	First step	TSLS1.2	OLS2	First step	TSLS2.1	First step	TSLS2.2
$\log(1 + \text{fac1849_metallurgy_workers})$	-0.005* (0.003)		-0.035*** (0.009)		-0.032*** (0.009)	-0.010** (0.005)		-0.060*** (0.023)		-0.074*** (0.016)
$\log\left(\frac{\text{rel1849_pro}}{\text{pop1849_tot}}\right)$	0.020*** (0.005)	0.115 (0.112)	0.028*** (0.007)	0.104 (0.111)	0.028*** (0.006)	0.020*** (0.007)	0.203* (0.117)	0.034*** (0.011)	0.113 (0.112)	0.037*** (0.011)
$\log(1 + \text{buil1849_privatehome})$	-0.062** (0.029)	0.617 (0.396)	-0.013 (0.027)	0.605 (0.390)	-0.017 (0.027)	-0.055 (0.058)	1.259*** (0.396)	0.029 (0.059)	0.622 (0.395)	0.051 (0.059)
$\log(1 + \text{land1849_far_ext_tot})$	0.029** (0.013)	0.017 (0.107)	0.021** (0.009)	0.032 (0.103)	0.022** (0.009)	0.084** (0.033)	-0.201 (0.137)	0.071*** (0.027)	0.017 (0.107)	0.067*** (0.025)
$\log(1 + \text{land1849_unequal_3})$	-0.145 (0.101)	1.837 (1.518)	-0.124 (0.092)	1.832 (1.516)	-0.126 (0.092)	0.105 (0.171)	1.072 (1.612)	0.139 (0.148)	1.873 (1.527)	0.148 (0.153)
<i>Instruments:</i>										
$\log(1 + \text{steam1849_horsepower})$		0.308*** (0.060)		0.306*** (0.060)					0.306*** (0.061)	
coalmine1849_county		0.867* (0.455)								
coalmine1849_county_broad				0.687** (0.320)						
$\log(1 + \text{coalmine1849_county_mindist})$							-0.142*** (0.044)		-0.078* (0.043)	
occ1849_river_crew		0.002*** (0.001)		0.002*** (0.001)			0.002*** (0.001)		0.002*** (0.001)	
District (Bezirk) dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	335	335	335	335	335	335	335	335	335	335
J-statistic (p-value)			0.43 (0.806)		3.41 (0.181)			1.08 (0.298)		1.53 (0.466)
Cragg-Donald F-stat			19.5		20.3			11.7		19.4

Notes: Robust standard errors in parentheses.

OLS1 and TSLS1 results: Dependent variable is the ratio of male students in primary and secondary education to total population.

OLS2 and TSLS2 results: Dependent variable is the ratio of primary students only to total population.

First step columns report first-stage regressions with $\log(1 + \text{metallurgy workers})$ as the dependent variable.

TSLS columns report second-stage instrumental variables estimates. Each numbered TSLS specification uses different instruments.

*** p<0.01, ** p<0.05, * p<0.1

4.3 Is the de-skilling effect lasting?

To answer this question, we estimate a model with the dependent variable is the number of students in both primary and secondary education over the total population in 1864: $\frac{edu1864_stud}{pop1864_tot}$. The variables of interest are the number of workers in the metallurgical sector in 1849 (OLS1, TSLS1.1) and the total number of workers in the factories in 1849 (OLS2, TSLS2). We consider as a control variable the share of Protestants in the total population in 1864: $\frac{rel1864_pro}{pop1864_tot}$.

The results are presented in Table 7. In the first instance, OLS estimates are carried out with the number of workers in the metallurgical sector in 1849 (OLS 1) and the total number of workers in the factories in 1849 (OLS2). There is no reason to suspect an inverse correlation between education measured in 1864 and industrialization in 1849. The deskilling effect is only observed if we consider all workers in the factories. However, the OLS estimator may be biased in the presence of measurement errors, or if the unobserved determinants of industrialization in 1849 are still having an impact on the education measured in 1864. Moreover we add the total length of all types of roads in 1862: *trans1862.len_road_tot* is a proxy of the unknown length of roads in 1849.²³ Estimates are therefore made using the instrumental variables available in 1849. It appears that the de-skilling effect remains whether we consider all workers in the factories (TSLS2) or only those working in the metallurgical sector (TSLS1.1).

One might wonder whether these results are not the consequence of the omission of an industrialization variable in 1864. Consequently, we add in two specifications (TSLS1.2 and TSLS1.3) a proxy of the industrialization in 1864: the total number of residents employed in industry: *occ1864_ind*. Given the lack of instrumental variables, we consider this variable to be exogenous. This variable turns out to be insignificant and, above all, its introduction does not eliminate the persistent nature of the de-skilling effect following industrialization in 1849.

²³The length is expressed in Prussian miles. Data constraints prevent the use of additional control variables.

Table 7: Long-lasting deskilling – OLS and TSLS results (1864)

OLS and TSLS dependent variable: $\log\left(\frac{\text{edu1864_stud}}{\text{pop1864_tot}}\right)$

	OLS1	First step	TSLS1.1	First step	TSLS1.2	First step	TSLS1.3	OLS2	First step	TSLS2
$\log(1 + \text{fac1849_metallurgy_workers})$	-0.006 (0.004)		-0.034*** (0.008)		-0.032** (0.014)		-0.031** (0.013)			
$\log(1 + \text{fac1849_workers})$								-0.025*** (0.009)		-0.072*** (0.015)
$\log(\text{rel1864_pro}/\text{pop1864_tot})$	0.009* (0.004)	0.146 (0.114)	0.017*** (0.006)	0.115 (0.116)	0.017*** (0.006)	0.137 (0.118)	0.019*** (0.006)	0.010** (0.004)	0.033 (0.046)	0.015*** (0.004)
$\log(\text{occ1864_ind})$				0.884*** (0.266)	-0.001 (0.026)	0.777*** (0.287)	-0.008 (0.025)			
<i>Instruments:</i>										
$\log(1 + \text{trans1862_len_road_tot})$						0.383 (0.244)			0.033** (0.013)	
$\log(1 + \text{steam1849_horsepower})$		0.350*** (0.057)		0.232*** (0.067)		0.251*** (0.067)			0.183*** (0.020)	
$\text{coalmine1849_county}$		0.841* (0.446)		0.829* (0.438)					-0.083 (0.238)	
$\log(1 + \text{coalmine1849_county_mindist})$						-0.049 (0.042)				
District (Bezirk) dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	335	335	335	335	335	335	335	335	335	335
Adjusted R^2	0.451	0.413	0.259	0.435	0.275	0.439	0.299	0.466	0.588	0.381
J-statistic (p-value)			3.31 (0.069)		3.15 (0.076)		1.70 (0.193)			0.65 (0.420)
Cragg-Donald F-stat			29.698		10.190		10.655			53.319

Notes: Robust standard errors in parentheses.

Dependent variable: $\log(\text{edu1864_stud}/\text{pop1864_tot})$.

First step columns report first-stage regressions. OLS1, TSLS1.1–TSLS1.3 use metallurgy workers; OLS2, TSLS2 use total factory workers.

District (Bezirk) dummies included in all specifications.

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

Table 8: Long-lasting deskilling – OLS and TSLS results (1871)

OLS and TSLS dependent variable: $\log\left(\frac{\text{lit1871_raw_ov10}}{\text{pop1871_tot}}\right)$

Independent predetermined interest variable: $\log(1 + \text{fac1849_metallurgy_workers})$

	OLS3	First step	TSL3.1	First step	TSL3.2	First step	TSL3.3
log(pop1871_tot)	0.027** (0.013)		0.046** (0.023)		0.047** (0.023)		0.045* (0.023)
log(1 + fac1849_metallurgy_workers)	-0.005* (0.003)	0.030** (0.015)	-0.006** (0.003)	0.030** (0.015)	-0.006** (0.003)	0.030** (0.015)	-0.006** (0.003)
log(rel1871_pro/pop1871_tot)	0.016*** (0.005)	0.014 (0.019)	0.015*** (0.005)	0.015 (0.019)	0.015*** (0.005)	0.017 (0.020)	0.015*** (0.005)
<i>Instruments:</i>							
log(1 + steam1849_horsepower)		0.091*** (0.009)		0.092*** (0.009)		0.093*** (0.009)	
coalmine1849_county_broad		0.036 (0.059)					
trans1862_len_road_tot		0.021*** (0.005)		0.021*** (0.005)		0.022*** (0.005)	
trans1862_len_wat_tot		0.009** (0.005)		0.009** (0.005)			
District (Bezirk) dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	335	335	335	335	335	335	335
Adjusted R^2	0.741	0.533	0.740	0.534	0.740	0.530	0.740
J-statistic (p-value)			2.542 (0.468)		1.840 (0.399)		1.476 (0.224)
Cragg-Donald F-stat			39.982		53.275		77.474

Notes: Robust standard errors in parentheses.

Dependent variable: $\log(\text{lit1871_raw_ov10}/\text{pop1871_tot})$.

First step columns report first-stage regressions with $\log(\text{pop1871_tot})$ as the dependent variable.

TSLS columns report second-stage instrumental variables estimates. Each numbered TSLS specification uses different instruments.

District (Bezirk) dummies included in all specifications.

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

An interesting question is whether the lasting de-skilling effect of the first industrial revolution extends beyond 1864. We have education data for 1871. It's no longer a question of the number of pupils in relation to the population, but of the proportion of people who can read and write. More precisely, we consider the number of residents over ten years old able to read and write over the number of residents in 1871: $\frac{lit1871_raw_ov10}{pop1871_tot}$. Our variable of interest is always the number of workers employed in the metallurgical sector in 1849. We control for the share of Protestants in the total population as of 1871. According to (Lee and Marschalck, 2000), the vigorous industrial expansion between 1875 and 1905 was the primary driver of urban growth. It motivates us to add the county population in 1871 (*pop1871*) while considering its drivers. This variable can be seen as a proxy for urbanization, a phenomenon we can't measure directly at the county level. The same authors also noticed that immigration barriers and controls persisted until 1862. We can, therefore, reasonably assume that the demographic structure in the 40s of the 19th century was not different from that before the Industrial Revolution. It is, thus, captured by district fixed effects for the 1849 and 1864 estimations. In this specification, industrialization measured in 1849 is considered predetermined, which is reasonable given the time gap between the two dates. In this specification, we suspect the 1871 population of being endogenous. We, therefore, instrument it by the energy of the steam engines measured in horsepower in 1849, a dummy variable taking the value 1 when a coal mine exist in the county or in a neighboring county, by the total length of all types of roads in 1862 and by the total length of water roads (*trans1862.len.wat_tot*). The expected sign of these three instrumental variables in the first-stage equation is positive.

Results are presented in Table 8. The main finding is that, whatever the specification which differ according to the instrumental variables set, the industrialization variable measured in 1849, i.e. employment in the metallurgical sector, still has a negative impact on the measure of education in 1871. The de-skilling effect generated by the first industrial revolution therefore appears to have been long-lasting, as it continued to be observed in 1864 and 1871.

5 Concluding remarks

This study examines the de-skilling hypothesis, based on the rich Prussian data collected before German unification. According to this hypothesis, the first phase of the industrial revolution was associated with a lower demand for human capital. The data are reported at county level, the smallest administrative unit in Germany, and have been published by iPEHD. The variable of interest, industrialization, and the dependent variable, human capital, are measured respectively by the number of workers in the metallurgical sector and the enrollment rates in both primary and secondary education for the year 1849. Given that a potential endogeneity bias may impact the relationship between education and industrialization, an identification strategy primarily driven by the availability of energy resources in each county was built. The considered instrumental variable is the counties' proximity to coal mines, measured according to various metrics. An alternative identification strategy was used. It is based on both steam engine energy and the number of crews involved in river navigation. Whatever the specification, the deskilling hypothesis is not rejected. This de-skilling effect is always observed when we use a more general measure of industrialization,

namely the number of workers in factories. Consequently, the deskilling effect is not limited to the metallurgical sector alone, even though it played a key role in the early phases of the industrial revolution in Germany. Moreover, it appears that this deskilling effect is not gendered. Moreover, if we consider only primary education as a measurement of human capital, the negative impact remains robust. Finally, it appears that the deskilling effect is long-lasting, since industrialization measured in 1849 has a negative impact on human capital measured in 1864 and 1871.

A further step towards improving this work is to take into account the neighborhood externalities that can potentially link Prussian counties together through, for example, labour displacements. But it is already possible to assert that the relationship between industrialization, on the one hand, and human capital, on the other, is not straightforward. The assumption that technical progress by pushing up the return on human capital, necessarily leads to an increase in the stock of human capital, cannot be taken for granted. While the complementary relationship between material and human capital seems to have been the rule throughout the 20th century, some periods in history may be characterized by a substitutability. Classical economists were therefore right to consider, at least for their time, that technical progress could be biased against skilled labor. This intuition aligns with contemporary research on non-neutral and biased technical progress (e.g. (Acemoglu, 2002a)).

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7 Appendix

7.1 Appendix - variables' definitions and names

7.1.1 1849

	Original definition in German	Definition	Variables Male	Variables Female	Variables Total/ratios
Education					
<i>Source:</i> Statistisches Bureau zu Berlin (1851-55), vol. 2, pp. 409-551					
<i>IPEHD 1849 codebook:</i> Churches and Education 1849					
Elem.	Oeffentliche Unterrichts-Anstalten; Elementarschulen; Zahl der Kinder, welche die Schulen gewöhnlich besuchen; Knaben	1849: Elementary schools: number of male and female students	edu1849_pub_ele_stud_m	edu1849_pub_ele_stud_f	edu1849_pub_ele_stud_mf; edu1849_pub_ele_stud_mf / pop1849_tot
Second.	Oeffentliche Unterrichts-Anstalten; Mittelschulen für Söhne;	(Public) Mittelschulen for boys. Nb of students	edu1849_pub_mim_stud_m		
Second.	Oeffentliche Unterrichts-Anstalten; Schulen für Töchter, welche nicht in Begriff der Elementarschulen fallen; Zahl der Schülerinnen	(Public) Töchterschulen for girls. Nb of students		edu1849_pub_mif_stud_f	
Second.	Oeffentliche Unterrichts-Anstalten; Höhere Bürgerschulen; Zahl der Schüler	(Public) Höhere Bürgerschule for boys. Nb of students	edu1849_pub_high_stud_m		
Second.	Oeffentliche Unterrichts-Anstalten; Pro-Gymnasien; Zahl der Schüler	(Public) Pro Gymnasien for boys. Nb of students	edu1849_pub_pgy_stud_m		
Second.		(Public) Gymnasien for boys. Nb of students	edu1849_pub_gym_stud_m		
Total sec.		Sum of all secondary schools students			edu1849_pub_sec_stud_mf; edu1849_pub_sec_stud_mf / pop1849_tot

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	Original definition in German	Definition	Variables Male	Variables Female	Variables Total/ratios
Prim. & sec.		Elementary and secondary school students, total			edu1849_pub_stud = edu1849_pub_sec_stud_mf + edu1849_pub_ele_stud_mf; edu1849_pub_stud / pop1849_tot
Population					
<i>Source:</i> Statistisches Bureau zu Berlin (1851-55), vol. 1, pp. 1-278					
<i>IPEHD 1849 Codebook:</i> Buildings, Population, Disabilities and Livestock 1849					
Total pop.	Menschen; Zahl aller Einwohner; Summe	Sum of total population in 1849			pop1849_tot
Pop. <14	Menschen; Dem Alter und Geschlechte nach; Unter-Vierzehnjährige; Summe der Kinder bis zum vollendeten 14. Jahre; Knaben; Mädchen	Sum of population under 14 years old, Male and female	pop1849_m_un14	pop1849_f_un14	
Protestant	Menschen; Dem Religionsverhältnisse nach; Evangelische Christen	Nb of Protestants in 1849; Share of protestants			rel1849_pro; rel1849_pro / pop1849_tot

	Original definition (IPEHD)	Definition	Sectors/activities	Variables	Aggregated variables
Industrialization					
<i>Source:</i> Statistisches Bureau zu Berlin (1851-55), vol. 6a, pp. 1-995.					
<i>IPEHD 1849 codebook:</i> Factories 1849					

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	Original definition in German	Definition	Variables Male	Variables Female	Variables Total/ratios
Interest var. Workers in industry	Zahl der Arbeiter	All activities listed under "Factories". Includes nb of factories and mills' workers	spin_woolyarn, spin_combyarn, spin_cotton, spin_flax, spin_tow, looms_silk, looms_cotton, looms_linen, looms_wool, looms_hosiery, looms_band, looms_others, fact_thread, fact_silk_ao, wool_cloth, halfwool_cloth, cotton, linen, silk, shawl, band, carpet, passement, hosiery, laces, bleach_unit, bleach_yarn, dye_turkeyred, dye_silk, dye_others, print, water, post_mills, dutchmills, animals	fac1849_spin_woolyarn_workers, fac1849_spin_combyarn_workers, fac1849_spin_cotton_workers, fac1849_spin_flax_workers, fac1849_spin_tow_workers, fac1849_looms_silk_masters, fac1849_looms_silk_assistants, fac1849_looms_cotton_masters, fac1849_looms_cotton_assistants, fac1849_looms_linen_masters, fac1849_looms_linen_assistants, fac1849_looms_wool_masters, fac1849_looms_wool_assistants, fac1849_looms_hosiery_masters, fac1849_looms_hosiery_assistants, fac1849_looms_band_masters, fac1849_looms_band_assistants, fac1849_looms_others_masters, fac1849_looms_others_assistants, fac1849_fact_thread_workers, fac1849_fact_silk_ao_workers, fac1849_wool_cloth_workers, fac1849_halfwool_cloth_workers, fac1849_cotton_workers, fac1849_linen_workers, fac1849_silk_workers, fac1849_shawl_workers, fac1849_band_workers, fac1849_carpet_workers, fac1849_passement_workers, fac1849_hosiery_workers, fac1849_laces_workers, fac1849_bleach_unit_workers, fac1849_bleach_yarn_workers, fac1849_dye_turkeyred_workers, fac1849_dye_silk_workers, fac1849_dye_others_workers, fac1849_print_workers, mill1849_water_masters, mill1849_water_assistants	fac1849_workers_totpop_ratio = fac1849_workers / pop1849_tot

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	Original definition in German	Definition	Variables Male	Variables Female	Variables Total/ratios
			animals, steam, oil, fulling, tan, saw_german, saw_dutch, saw_circular, other, ironworks, wireworks, rake, sewingneedle, fixingpin, ironware, steel, steelware, copperhammer, brass, smeltery, bronzeware, engines, glassworks, grindery, mirrorglass, porcelain, earthenware, chemicals, potboilery, limekiln, brickworks, tarfurnace, cerecloth	mill1849_post.mills_masters, mill1849_post.mills_assistants, mill1849_dutchmills_masters, mill1849_dutchmills_assistants, mill1849_animals_workers, mill1849_steam_workers, mill1849_oil_workers, mill1849_fulling_workers, mill1849_tan_workers, mill1849_saw_german_workers, mill1849_saw_dutch_workers, mill1849_saw_circular_workers, mill1849_other_workers, fac1849_ironworks_workers, fac1849_wireworks_workers, fac1849_rake_workers, fac1849_sewingneedle_workers, fac1849_fixingpin_workers, fac1849_ironware_workers, fac1849_steel_workers, fac1849_steelware_workers, fac1849_copperhammer_workers, fac1849_brass_workers, fac1849_smeltery_workers, fac1849_bronzeware_workers, fac1849_engines_workers, fac1849_glassworks_workers, fac1849_grindery_workers, fac1849_mirrorglass_workers, fac1849_porcelain_workers, fac1849_earthenware_workers, fac1849_chemicals_workers, fac1849_potboilery_workers, fac1849_limekiln_workers, fac1849_brickworks_workers, fac1849_tarfurnace_workers, fac1849_cerecloth_workers	

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	Original definition in German	Definition	Variables Male	Variables Female	Variables Total/ratios
			<p>paper, wallpaper, rubbergoods, leather, glue, cigar, sugarrefinery, mangold_sugar, starch, writing, specialpaper, cardboard, umbrella, paintshop, gold_silver, germansilver, gunpowder, cement, wadding, hairspinnery, glaze, button, railwaycar, waxproduct, chocolate, soap, vinegar, playingcard, beer, brandy, distillery, perfumery, metalletter, threadeye, metalfoundry, copper, gasandcoke, flax, pineseed, fabricflower, rope, pipetube, cheese, others</p>	<p>fac1849_paper_workers, fac1849_wallpaper_workers, fac1849_rubbergoods_workers, fac1849_leather_workers, fac1849_glue_workers, fac1849_cigar_workers, fac1849_sugarrefinery_workers, fac1849_mangold_sugar_workers, fac1849_starch_workers, fac1849_writing_workers, fac1849_specialpaper_workers, fac1849_cardboard_workers, fac1849_umbrella_workers, fac1849_paintshop_workers, fac1849_gold_silver_workers, fac1849_germansilver_workers, fac1849_gunpowder_workers, fac1849_cement_workers, fac1849_wadding_workers, fac1849_hairspinnery_workers, fac1849_glaze_workers, fac1849_button_workers, fac1849_railwaycar_workers, fac1849_waxproduct_workers, fac1849_chocolate_workers, fac1849_soap_workers, fac1849_vinegar_workers, fac1849_playingcard_workers, fac1849_beer_workers, fac1849_brandy_workers, fac1849_distillery_workers, fac1849_perfumery_workers, fac1849_metalletter_workers, fac1849_threadeye_workers, fac1849_metalfoundry_workers, fac1849_copper_workers, fac1849_gasandcoke_workers, fac1849_flax_workers, fac1849_pineseed_workers, fac1849_fabricflower_workers, fac1849_rope_workers, fac1849_pipetube_workers, fac1849_cheese_workers, fac1849_others_workers</p>	

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	Original definition in German	Definition	Variables Male	Variables Female	Variables Total/ratios
Interest var. Metal- lurgy workers	Fabriken in Metall und überhaupt dem Bergbau angehörige oder verwandte Unternehmungen; Eisenwerke - Zahl der Arbeiter	Metallurgy factories and other mining enterprises; 13 activities	ironworks, wireworks, sewing-needle, fixingpin, ironware, steel, steelware, copper-hammer, brass, smeltery, bronze-ware, engines	fac1849_ironworks_workers, fac1849_wireworks_workers, fac1849_rake_workers, fac1849_sewingneedle_workers, fac1849_fixingpin_workers, fac1849_ironware_workers, fac1849_steel_workers, fac1849_steelware_workers, fac1849_copperhammer_workers, fac1849_brass_workers, fac1849_smeltery_workers, fac1849_bronzeware_workers, fac1849_engines_workers	fac1849_metallurgy- workers_totpop_ratio = fac1849_metallurgy- workers / pop1849_tot

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	Original definition in German	Definition	Variables Male	Variables Female	Variables Total/ratios
Interest var. Textile workers	Gespinnste; Maschinen-Spinnerei; Gewebe; Gehende Weberstühle	Spinning; machine spinning; Fabrics; Walking looms. Workers in textile sector		fac1849_spin_woolyarn_workers, fac1849_spin_combyarn_workers, fac1849_spin_cotton_workers, fac1849_spin_flax_workers, fac1849_spin_tow_workers, fac1849_looms_silk_masters, fac1849_looms_silk_assistants, fac1849_looms_cotton_masters, fac1849_looms_cotton_assistants, fac1849_looms_linen_masters, fac1849_looms_linen_assistants, fac1849_looms_wool_masters, fac1849_looms_wool_assistants, fac1849_looms_hosiery_masters, fac1849_looms_hosiery_assistants, fac1849_looms_band_masters, fac1849_looms_band_assistants, fac1849_looms_others_masters, fac1849_looms_others_assistants, fac1849_fact_thread_workers, fac1849_fact_silk_ao_workers, fac1849_wool_cloth_workers, fac1849_halfwool_cloth_workers, fac1849_cotton_workers, fac1849_linen_workers, fac1849_silk_workers, fac1849_shawl_workers, fac1849_band_workers, fac1849_carpet_workers, fac1849_passement_workers, fac1849_hosiery_workers, fac1849_laces_workers, fac1849_bleach_unit_workers, fac1849_bleach_yarn_workers, fac1849_dye_turkeyred_workers, fac1849_dye_silk_workers, fac1849_dye_others_workers, fac1849_print_workers	fac1849_textile_workers

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	Original definition in German	Definition	Variables Male	Variables Female	Variables Total/ratios
Instrum. Steam engines	Dampfmaschinen, worin die Dämpfe mechanisch wirken. Anzahl der Pferdekräfte	Steam engines (excl. steam boilers). Number of horsepower	12 activities: Spinners, weaving, fulling, engine-works, flour-mills, cutting-mills, other-mills, mining, shipping, metal mfg, railways, others	steam1849_spinnery_horsepower, steam1849_weaving_horsepower, steam1849_fulling_horsepower, steam1849_engineworks_horsepower, steam1849_flourmill_horsepower, steam1849_cuttingmill_horsepower, steam1849_othermills_horsepower, steam1849_mining_horsepower, steam1849_shipping_horsepower, steam1849_metal_fab_horsepower, steam1849_railway_horsepower, steam1849_others_horsepower	steam1849_horsepower
Industrialization					
<i>Source:</i> Statistisches Bureau zu Berlin (1851-55), vol. 5, pp. 1-821 <i>IPEHD Codebook 1849: Crafts 1849</i>					
Instrum. Water infra.	Schiffahrt; Flussschiffahrt; Zahl der Schiffsmannschaft	1849: shipping: river: ship crew		occ1849_river_crew	
Industrialization					
<i>Source:</i> Kaufhold & Sachse (1989): Gewerbestatistik Preußens vor 1850					
Instrum. Coalmines	As reported in HiStat. Study number ZA 8481	= 1 if coal mining in county/district			coalmine1849_county, coalmine1849_bezirk
		= 1 if coal mining in county or neighbors			coalmine1849_county_broad
		Min. distance (m) between mining county and county; inverse distance			coalmine1849_mindist; invdist formula
		Censored inverse distance			coalmine1849_invdist25 formula
Control variables					
Real estate	Gebäude: Privat-Gebäude; Privat-Wohnhäuser	Nb of private buildings		buil1849_privatehome	
Land wealth >600	Ländliche Erwerbs-Verhältnisse; Zahl der Besitzungen; von 600 Magdeburger Morgen und darüber	Rural estates: >600 Magdeburger Morgen		land1849_far_ext_ov600	land1849_far_ext_ov600_ratio formula

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	Original definition in German	Definition	Variables Male	Variables Female	Variables Total/ratios
Land 300-600	Ländliche Erwerbs-Verhältnisse; Zahl der Besitzungen; von 300 bis 600 Magdeburger Morgen	Rural estates: 300-600 Magdeburger Morgen		land1849_far_ext_300to600	land1849_far_ext_300to600_ratio formula
Land 30-300	Ländliche Erwerbs-Verhältnisse; Zahl der Besitzungen; von 30 bis 300 Magdeburger Morgen	Rural estates: 30-300 Magdeburger Morgen		land1849_far_ext_30to300	land1849_far_ext_30to300_ratio formula
Land 5-30	Ländliche Erwerbs-Verhältnisse; Zahl der Besitzungen; von 5 bis 30 Magdeburger Morgen	Rural estates: 5-30 Magdeburger Morgen		land1849_far_ext_5to30	land1849_far_ext_5to30_ratio formula
Land <5	Ländliche Erwerbs-Verhältnisse; Zahl der Besitzungen; unter 5 Magdeburger Morgen	Rural estates: <5 Magdeburger Morgen		land1849_far_ext_un5	land1849_far_ext_un5_ratio formula
Total land		Total nb of rural possessions all sizes	Magdeburger Morgen = Prussian area measure (1813)		land1849_far_ext_tot = sum formula
Land inequal.		Ratio of large to small estates			land1849_unequal_3 formula
Other variables					
<i>Source:</i> Statistisches Bureau zu Berlin (1851-55), vol. 5, pp. 1-821					
<i>IPEHD Codebook 1849:</i> Crafts 1849					
Workers in agriculture (ratio)	Ländliche Erwerbs-Verhältnisse; Zahl der Personen, welche vom Landbau sich nähren (einschliesslich Frauen, Kinder, Dienstboten und Tagelöhner); als Hauptgewerbe	Nb of people living on farming: main occupation (including their Females, Children, Day Laborers)		occ1849_farming_main_occu	occ1849_farming_main_occu_totpop_ratio = occ1849_farming_main_occu / pop1849_tot

7.1.2 1862, 1864 and 1871

	Original definition in German	Definition	Variables names Male	Variables names Female	Variables names Total
Education					
<i>Source:</i> Königliches Statistisches Bureau in Berlin (1867), vol. 10, pp. 144-170 and 200-226					
<i>IPEHD 1864 codebook:</i> Education, Population and Religion 1864					
Elementary	Öffentliche Unterrichtsanstalt; Elementarschulen; Schüler (Knaben u. Mädchen)	1864: total number of pupils; public elementary school			edu1864_pub_ele_stud
	Privat.-Unterrichtsanstalten; Elementarschulen; Schüler (Knaben u. Mädchen)	1864: total number of pupils; private elementary school			edu1864_pri_ele_stud
		1864. Total nb of pupils in private and public elementary schools			edu1864_ele_stud = edu1864_pub_ele_stud + edu1864_pri_ele_stud
Secondary					
Public	Öffentliche Unterrichtsanstalt; Mittelschulen für Söhne; Schüler	1864: total number of male pupils; public Mittelschule	edu1864_pub_ mim_stud_m		
	Öffentliche Unterrichtsanstalt; Mittelschulen für Töchter; Schülerinnen	1864: total number of female pupils; public Mittelschule		edu1864_pub_ mif_stud_f	
	Öffentliche Unterrichtsanstalt; Höhere Bürger- u. Realschulen; Schüler	1864: total number of male pupils; public Realschule	edu1864_pub_rea_stud		
	Öffentliche Unterrichtsanstalt; Progymnasien; Schüler	1864: total number of pupils; public Progymnasium	edu1864_pub_pgy_stud		
	Öffentliche Unterrichtsanstalt; Gymnasien; Schüler	1864: total number of pupils; public Gymnasium	edu1864_pub_gym_stud		
Private					
	Privat.-Unterrichtsanstalten; Mittlere und höh. Privatschulen u. Erziehungsanstalt. aller Art: für Söhne; Schüler; Privat.-Unterrichtsanstalten; Mittlere und höh. Privatschulen u. Erziehungsanstalt. aller Art: für Töchter; Schülerinnen	1864: total number of pupils; mittlere and höhere Privatschule for boys and girls	edu1864_pri_ hsm_stud_m	edu1864_pri_ hsf_stud_f	

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	Original definition in German	Definition	Variables names Male	Variables names Female	Variables names Total
	Provinzial-, Kunst- u. Gewerbe, Ackerbau-, Navigations- und Handelsschulen; Schüler	1864: total number of pupils; vocational school			edu1864_pri_voc_stud
Secondary (total)		Total nb of male and female students at secondary level			edu1864_sec_stud = edu1864_pub_mim_stud_m + edu1864_pub_mif_stud_f + edu1864_pub_rea_stud + edu1864_pub_pgy_stud + edu1864_pub_gym_stud + edu1864_pri_hsm_stud_m + edu1864_pri_hsf_stud_f + edu1864_pri_voc_stud
Primary and secondary		Total nb of male and female students at primary and secondary level			edu1864_stud = (edu1864_sec_stud + edu1864_ele_stud)
Population and occupation					
	Gesamtbevölkerung	1864: total number of residents			pop1864_tot
	Glaubensverschiedenheit; Evangelische Christen	1864: total number of protestant residents			rel1864_pro
	Berufsverschiedenheit; Industrie	1864: total number of residents; employed in industry			occ1864_ind

7.1.3 1862 and 1871

	Original definition in German	Definition	Variables names Male	Variables names Female	Variables names Total or ratios
Education					
<i>Sources:</i> Königliches Statistisches Bureau (1873-74), vol. 1-11					
	Ortsanwesende Bevölkerung am 1. Dezember 1871; Alter u. Schulbildung.; Personen über 10 Jahr alt; können lesen u. schreiben	1871: number of residents; over 10y old; able to read and write			lit1871_raw_ov10
	Ortsanwesende Bevölkerung am 1. Dezember 1871; überhaupt Bewohner	1871: total number of residents			pop1871_tot
Infrastructures					
<i>Source:</i> Königlich Preussisches Statistisches Bureau (1863), vol. 3, 206-214					
	Chausseen; Summa	1862: total length of all kinds of country roads in prussian miles			trans1862.len_road_tot
	Schiffbare Wasserstrassen exkl. Küsten und Seen; Summa	1862: total length of navigable waterways in prussian miles			trans1862.len_wat_tot

7.2 Descriptive statistics

Variable names	Definition	N	Mean	SD	Min	Max
Panel A - Dependent variables						
edu1849_pub_stud / pop1849_tot	Nb of elementary and secondary school male and female students over the total population, 1849	335	0.162	0.024	0.065	0.202
edu1849_pub_stud / (pop1849_f_un14 + pop1849_m_un14)	Nb of elementary school male and female students over the total population under 14 y, 1849	335	0.465	0.070	0.188	0.665
edu1849_pub_stud_m / edu1849_pub_stud / pop1849_tot	Nb of male students in both primary and secondary education over the total population, 1849	335	0.084	0.012	0.032	0.103
edu1849_pub_ele_stud_mf / pop1849_tot	Nb of male and female students in primary education over the total population, 1849	335	0.154	0.026	0.059	0.202
edu1864_stud / pop1864_tot	Nb of pupils in private and public elementary schools over the total population, 1864	335	0.164	0.020	0.100	0.263
lit1871_raw_ov10 / pop1871_tot	Nb of residents; over 10y old; able to read and write over the total nb of residents, 1871	335	0.632	0.113	0.256	0.815
Panel B - Independent variables – Industrialisation proxies						
fac1849_metallurgy_workers	Nb of workers in the metallurgy sector (list of activities in Appendix 7.1) in 1849	335	151.681	517.703	0	5764
fac1849_workers	Nb of workers in the industry sector (list of activities in Appendix 7.1) 1849	335	1960.540	3792.142	110	33229
fac1849_metallurgy_workers / fac1849_workers	Ratio of the Nb of workers in the metallurgy sector over all workers in industry, 1849	335	0.069	0.137	0	0.901
Panel A variables interacted with fac1849_metallurgy_workers						
edu1849_pub_stud/pop1849_tot if fac1849_metallurgy_workers \geq Median	Nb of elementary school male and female students over the total population, 1849 if 1849 industrialisation is greater than its median value	168	0.164	0.022	0.096	0.202

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Variable names	Definition	N	Mean	SD	Min	Max
edu1849_pub_stud/pop1849_tot if fac1849_metallurgy_workers < Median	Nb of elementary school male and female students over the total population, 1849 if 1849 industrialisation is lower than its median value	167	0.161	0.025	0.065	0.200
edu1849_pub_stud/ (pop1849_f.un14+pop1849_m.un14) if fac1849_metallurgy_workers ≥ Median	Nb of elementary school male and female students over the total population under 14 y, 1849 if 1849 industrialisation is greater than its median value	168	0.469	0.062	0.289	0.571
edu1849_pub_stud/ (pop1849_f.un14+pop1849_m.un14) if fac1849_metallurgy_workers < Median	Nb of elementary school male and female students over the total population under 14 y, 1849 if 1849 industrialisation is lower than its median value	167	0.461	0.077	0.188	0.665
edu1849_pub_stud_m / edu1849_pub_stud / pop1849_tot if fac1849_metallurgy_workers ≥ Median	Nb of male students in both primary and secondary education over the total population, 1849 if 1849 industrialisation is greater than its median value	168	0.085	0.011	0.051	0.103
edu1849_pub_stud_m / edu1849_pub_stud / pop1849_tot if fac1849_metallurgy_workers < Median	Nb of male students in both primary and secondary education over the total population, 1849 if 1849 industrialisation is lower than its median value	167	0.082	0.012	0.032	0.102
edu1849_pub_ele_stud_mf/pop1849_tot if fac1849_metallurgy_workers ≥ Median	Nb of primary education male and female students over the total population, 1849 if 1849 industrialisation is greater than its median value	168	0.157	0.026	0.059	0.202
edu1849_pub_ele_stud_mf/pop1849_tot if fac1849_metallurgy_workers < Median	Nb of primary education male and female students over the total population, 1849 if 1849 industrialisation is lower than its median value	167	0.151	0.027	0.059	0.199

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Variable names	Definition	N	Mean	SD	Min	Max
edu1864_stud/pop1864_tot if fac1849_metallurgy_workers \geq Median	Nb of pupils in private and public elementary schools over the total population, 1864 if 1849 industrialisation is greater than its median value	168	0.164	0.019	0.108	0.223
edu1864_stud/pop1864_tot if fac1849_metallurgy_workers < Median	Nb of pupils in private and public elementary schools over the total population, 1864 if 1849 industrialisation is lower than its median value	167	0.163	0.021	0.100	0.263
lit1871_raw_ov10/pop1871_tot if fac1849_metallurgy_workers \geq Median	Nb of residents; over 10y old; able to read and write over the total nb of residents, 1871 if 1849 industrialisation is greater than its median value	168	0.646	0.104	0.256	0.790
lit1871_raw_ov10/pop1871_tot if fac1849_metallurgy_workers < Median	Nb of residents; over 10y old; able to read and write over the total nb of residents, 1871 if 1849 industrialisation is lower than its median value	167	0.618	0.120	0.295	0.815
Panel C - Instrumental variables						
steam1849_horsepower	Steam engines in which the vapours act mechanically (i.e. excluding the so-called steam boilers). Number of horsepower	335	200.436	828.949	0	9864
coalmine1849_county	= 1 if coal mining took place in the county in 1849	335	0.036	0.186	0	1
coalmine1849_county_broad	= 1 if coal mining occurs in the county or in the neighbouring counties	335	0.152	0.360	0	1
coalmine1849_county_mindist	Minimum distance in meters between the mining county's centroid and the county'; inverse of the minimum distance	335	163316.9	158098.5	0	616922.6
coalmine1849_invdist25	=1 if Censored inverse distance (first quartile)	335	0.049	0.184	0	1
(sum) occ1849_river_crew	shipping: river: ship crew	335	79.976	195.898	0	1804

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Variable names	Definition	N	Mean	SD	Min	Max
occ1864_ind_cor	1864: total number of residents; employed in industry	335	8906.472	9506.677	1726	150300
trans1862_len_road_tot	1862: total length of all kinds of country roads in Prussian miles	335	11.210	5.926	0	31.200
trans1862_len_wat_tot	1862: total length of navigable waterways in Prussian miles	335	2.461	3.850	0	22.600
Panel D - Control variables						
rel1849_pro / pop1849_tot	Share of protestants in the total population, 1849	335	0.605	0.394	0.002	0.999
rel1864_pro / pop1864_tot	Share of protestants in the total population, 1864	335	0.594	0.387	0.002	0.997
(sum) buil1849_privatehome	Nb of private buildings, 1849	335	5806.513	2093.135	1597	14404
land1849_far_ext_tot	Nb of rural possessions: number of estates:	335	5345.879	4163.432	0	24222
land1849_unequal_3	Ratio of the nb of large estates to the ratio of the nb of small estates	335	0.446	0.186	0	0.862
fac1849_workers_totpop_ratio	Ratio of industry workers to the total population	335	0.037	0.057	0.004	0.490
fac1849_metallurgy_workers_totpop_ratio	Ratio of metallurgy workers to the total population	335	0.003	0.010	0.000	0.145
occ1849_farming_main_occu_totpop_ratio	Ratio of agriculture workers to the total population	335	0.433	0.174	0.000	0.852

7.3 List of counties, bezirks (districts) and provinces

No.	County	Bezirk (district)	Province
1.	Memel	Konigsberg	East Prussia
2.	Fischhausen	Konigsberg	East Prussia
3.	Konigsberg stadtkreis	Konigsberg	East Prussia
4.	Konigsberg landkreis	Konigsberg	East Prussia
5.	Labiau	Konigsberg	East Prussia
6.	Wehlau	Konigsberg	East Prussia
7.	Gerdaun	Konigsberg	East Prussia
8.	Rastenburg	Konigsberg	East Prussia
9.	Friedland	Konigsberg	East Prussia
10.	Preussisch eylau	Konigsberg	East Prussia
11.	Heiligenbeil	Konigsberg	East Prussia
12.	Braunsberg	Konigsberg	East Prussia
13.	Heilsberg	Konigsberg	East Prussia
14.	Rossel	Konigsberg	East Prussia
15.	Allenstein	Konigsberg	East Prussia
16.	Ortelsburg	Konigsberg	East Prussia
17.	Neidenburg	Konigsberg	East Prussia
18.	Osterode	Konigsberg	East Prussia
19.	Mohrungen	Konigsberg	East Prussia
20.	Preussisch holland	Konigsberg	East Prussia
21.	Heydekrug	Gumbinnen	East Prussia
22.	Niederung	Gumbinnen	East Prussia
23.	Tilsit landkreis	Gumbinnen	East Prussia
24.	Ragnit	Gumbinnen	East Prussia
25.	Pillkallen	Gumbinnen	East Prussia
26.	Stalluponen	Gumbinnen	East Prussia
27.	Gumbinnen	Gumbinnen	East Prussia
28.	Insterburg	Gumbinnen	East Prussia
29.	Darkehmen	Gumbinnen	East Prussia
30.	Angerburg	Gumbinnen	East Prussia
31.	Goldap	Gumbinnen	East Prussia
32.	Oletzko	Gumbinnen	East Prussia
33.	Lyck	Gumbinnen	East Prussia
34.	Lotzen	Gumbinnen	East Prussia
35.	Sensburg	Gumbinnen	East Prussia
36.	Johannisburg	Gumbinnen	East Prussia
37.	Elbing landkreis	Danzig	West Prussia
38.	Marienburg in preussen	Danzig	West Prussia
39.	Danzig stadtkreis	Danzig	West Prussia
40.	Danzig landkreis	Danzig	West Prussia
41.	Preussisch stargard	Danzig	West Prussia
42.	Berent	Danzig	West Prussia
43.	Karthaus	Danzig	West Prussia
44.	Neustadt in westpreussen	Danzig	West Prussia
45.	Stuhm	Marienwerder	Posen-West Prussia

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No.	County	Bezirk (district)	Province
46.	Marienwerder	Marienwerder	Posen-West Prussia
47.	Rosenberg in westpreussen	Marienwerder	Posen-West Prussia
48.	Lobau	Marienwerder	Posen-West Prussia
49.	Strasburg	Marienwerder	Posen-West Prussia
50.	Thorn landkreis	Marienwerder	Posen-West Prussia
51.	Kulm	Marienwerder	Posen-West Prussia
52.	Graudenz landkreis	Marienwerder	Posen-West Prussia
53.	Schwetz	Marienwerder	Posen-West Prussia
54.	Konitz	Marienwerder	Posen-West Prussia
55.	Schlochau	Marienwerder	Posen-West Prussia
56.	Flatow	Marienwerder	Posen-West Prussia
57.	Deutsch krone	Marienwerder	Posen-West Prussia
58.	Wreschen	Posen	Posen-West Prussia
59.	Pleschen	Posen	Posen-West Prussia
60.	Schroda	Posen	Posen-West Prussia
61.	Schrimm	Posen	Posen-West Prussia
62.	Kosten	Posen	Posen-West Prussia
63.	Buk	Posen	Posen-West Prussia
64.	Posen landkreis	Posen	Posen-West Prussia
65.	Obornik	Posen	Posen-West Prussia
66.	Samter	Posen	Posen-West Prussia
67.	Birnbaum	Posen	Posen-West Prussia
68.	Meseritz	Posen	Posen-West Prussia
69.	Schildberg	Posen	Posen-West Prussia
70.	Bomst	Posen	Posen-West Prussia
71.	Fraustadt	Posen	Posen-West Prussia
72.	Kroben	Posen	Posen-West Prussia
73.	Krotoschin	Posen	Posen-West Prussia
74.	Adelnau	Posen	Posen-West Prussia
75.	Czarnikau	Bromberg	Posen-West Prussia
76.	Chodziesen	Bromberg	Posen-West Prussia
77.	Wirsitz	Bromberg	Posen-West Prussia
78.	Bromberg landkreis	Bromberg	Posen-West Prussia
79.	Schubin	Bromberg	Posen-West Prussia
80.	Inowrazlaw	Bromberg	Posen-West Prussia
81.	Mogilno	Bromberg	Posen-West Prussia
82.	Gnesen	Bromberg	Posen-West Prussia
83.	Wongrowitz	Bromberg	Posen-West Prussia
84.	Berlin	Potsdam	Brandenburg
85.	Prenzlau	Potsdam	Brandenburg
86.	Templin	Potsdam	Brandenburg
87.	Angermunde	Potsdam	Brandenburg
88.	Oberbarnim	Potsdam	Brandenburg
89.	Niederbarnim	Potsdam	Brandenburg
90.	Beeskow-storkow	Potsdam	Brandenburg
91.	Teltow	Potsdam	Brandenburg
92.	Juterbog-luckenwalde	Potsdam	Brandenburg

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No.	County	Bezirk (district)	Province
93.	Zauch-belzig	Potsdam	Brandenburg
94.	Potsdam	Potsdam	Brandenburg
95.	Osthavelland	Potsdam	Brandenburg
96.	Westhavelland	Potsdam	Brandenburg
97.	Ruppin	Potsdam	Brandenburg
98.	Ostprignitz	Potsdam	Brandenburg
99.	Westprignitz	Potsdam	Brandenburg
100.	Konigsberg in neumark	Frankfurt	Brandenburg
101.	Soldin	Frankfurt	Brandenburg
102.	Arnswalde	Frankfurt	Brandenburg
103.	Friedeberg	Frankfurt	Brandenburg
104.	Landsberg landkreis	Frankfurt	Brandenburg
105.	Lebus	Frankfurt	Brandenburg
106.	Frankfurt/oder	Frankfurt	Brandenburg
107.	Sternberg	Frankfurt	Brandenburg
108.	Zullichau-schwiebus	Frankfurt	Brandenburg
109.	Guben landkreis	Frankfurt	Brandenburg
110.	Krossen	Frankfurt	Brandenburg
111.	Lubben	Frankfurt	Brandenburg
112.	Luckau	Frankfurt	Brandenburg
113.	Kalau	Frankfurt	Brandenburg
114.	Kottbus landkreis	Frankfurt	Brandenburg
115.	Sorau	Frankfurt	Brandenburg
116.	Spremberg	Frankfurt	Brandenburg
117.	Demmin	Stettin	Pomerania
118.	Anklam	Stettin	Pomerania
119.	Usedom-wollin	Stettin	Pomerania
120.	Uckermunde	Stettin	Pomerania
121.	Randow	Stettin	Pomerania
122.	Greifenhagen	Stettin	Pomerania
123.	Pyritz	Stettin	Pomerania
124.	Saatzig	Stettin	Pomerania
125.	Naugard	Stettin	Pomerania
126.	Kammin	Stettin	Pomerania
127.	Greifenberg	Stettin	Pomerania
128.	Regenwalde	Stettin	Pomerania
129.	Schivelbein	Koslin	Pomerania
130.	Dramburg	Koslin	Pomerania
131.	Neustettin	Koslin	Pomerania
132.	Belgard	Koslin	Pomerania
133.	Furstenthum	Koslin	Pomerania
134.	Schlawe	Koslin	Pomerania
135.	Rummelsburg	Koslin	Pomerania
136.	Stolp landkreis	Koslin	Pomerania
137.	Lauenburg in pommern	Koslin	Pomerania
138.	Butow	Koslin	Pomerania
139.	Rugen	Stralsund	Pomerania

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No.	County	Bezirk (district)	Province
140.	Franzburg	Stralsund	Pomerania
141.	Greifswald	Stralsund	Pomerania
142.	Grimmen	Stralsund	Pomerania
143.	Namslau	Breslau	Silesia
144.	Gross wartenberg	Breslau	Silesia
145.	Ols	Breslau	Silesia
146.	Trebnitz	Breslau	Silesia
147.	Militsch	Breslau	Silesia
148.	Guhrau	Breslau	Silesia
149.	Steinau	Breslau	Silesia
150.	Wohlau	Breslau	Silesia
151.	Neumarkt	Breslau	Silesia
152.	Breslau landkreis	Breslau	Silesia
153.	Ohlau	Breslau	Silesia
154.	Brieg	Breslau	Silesia
155.	Strehlen	Breslau	Silesia
156.	Nimptsch	Breslau	Silesia
157.	Munsterberg	Breslau	Silesia
158.	Frankenstein	Breslau	Silesia
159.	Reichenbach	Breslau	Silesia
160.	Schweidnitz landkreis	Breslau	Silesia
161.	Striegau	Breslau	Silesia
162.	Waldenburg	Breslau	Silesia
163.	Glatz	Breslau	Silesia
164.	Habelschwerdt	Breslau	Silesia
165.	Kreuzburg	Oppeln	Silesia
166.	Rosenberg in oberschlesien	Oppeln	Silesia
167.	Oppeln landkreis	Oppeln	Silesia
168.	Gross strelitz	Oppeln	Silesia
169.	Lublinitz	Oppeln	Silesia
170.	Tost-gleiwitz	Oppeln	Silesia
171.	Beuthen landkreis	Oppeln	Silesia
172.	Pless	Oppeln	Silesia
173.	Rybnik	Oppeln	Silesia
174.	Ratibor	Oppeln	Silesia
175.	Kosel	Oppeln	Silesia
176.	Leobschutz	Oppeln	Silesia
177.	Neustadt in oberschlesien	Oppeln	Silesia
178.	Falkenberg	Oppeln	Silesia
179.	Neisse	Oppeln	Silesia
180.	Grottkau	Oppeln	Silesia
181.	Grunberg	Liegnitz	Silesia
182.	Freistadt	Liegnitz	Silesia
183.	Sagan	Liegnitz	Silesia
184.	Sprottau	Liegnitz	Silesia
185.	Glogau	Liegnitz	Silesia
186.	Luben	Liegnitz	Silesia

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No.	County	Bezirk (district)	Province
187.	Bunzlau	Liegnitz	Silesia
188.	Goldberg-hainau	Liegnitz	Silesia
189.	Liegnitz landkreis	Liegnitz	Silesia
190.	Jauer	Liegnitz	Silesia
191.	Schonau	Liegnitz	Silesia
192.	Bolkenhain	Liegnitz	Silesia
193.	Landeshut	Liegnitz	Silesia
194.	Hirschberg	Liegnitz	Silesia
195.	Lowenberg	Liegnitz	Silesia
196.	Lauban	Liegnitz	Silesia
197.	Gorlitz landkreis	Liegnitz	Silesia
198.	Rothenburg	Liegnitz	Silesia
199.	Hoyerswerda	Liegnitz	Silesia
200.	Osterburg	Magdeburg	Province of Saxony
201.	Salzwedel	Magdeburg	Province of Saxony
202.	Gardelegen	Magdeburg	Province of Saxony
203.	Stendal	Magdeburg	Province of Saxony
204.	Jerichow ii	Magdeburg	Province of Saxony
205.	Jerichow i	Magdeburg	Province of Saxony
206.	Kalbe	Magdeburg	Province of Saxony
207.	Magdeburg	Magdeburg	Province of Saxony
208.	Wanzleben	Magdeburg	Province of Saxony
209.	Wolmirstedt	Magdeburg	Province of Saxony
210.	Neuhaldensleben	Magdeburg	Province of Saxony
211.	Oschersleben	Magdeburg	Province of Saxony
212.	Aschersleben	Magdeburg	Province of Saxony
213.	Halberstadt landkreis	Magdeburg	Province of Saxony
214.	Wernigerode	Magdeburg	Province of Saxony
215.	Liebenwerda	Merseburg	Province of Saxony
216.	Torgau	Merseburg	Province of Saxony
217.	Schweinitz	Merseburg	Province of Saxony
218.	Wittenberg	Merseburg	Province of Saxony
219.	Bitterfeld	Merseburg	Province of Saxony
220.	Delitzsch	Merseburg	Province of Saxony
221.	Saalkreis	Merseburg	Province of Saxony
222.	Halle	Merseburg	Province of Saxony
223.	Mansfelder seekreis	Merseburg	Province of Saxony
224.	Mansfelder gebirgskr	Merseburg	Province of Saxony
225.	Sangerhausen	Merseburg	Province of Saxony
226.	Eckartsberga	Merseburg	Province of Saxony
227.	Querfurt	Merseburg	Province of Saxony
228.	Merseburg	Merseburg	Province of Saxony
229.	Weissenfels landkreis	Merseburg	Province of Saxony
230.	Naumburg	Merseburg	Province of Saxony
231.	Zeitz landkreis	Merseburg	Province of Saxony
232.	Nordhausen landkreis	Erfurt	Province of Saxony
233.	Worbis	Erfurt	Province of Saxony

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No.	County	Bezirk (district)	Province
234.	Heiligenstadt	Erfurt	Province of Saxony
235.	Muhlhausen landkreis	Erfurt	Province of Saxony
236.	Langensalza	Erfurt	Province of Saxony
237.	Weissensee	Erfurt	Province of Saxony
238.	Erfurt landkreis	Erfurt	Province of Saxony
239.	Ziegenruck	Erfurt	Province of Saxony
240.	Schleusingen	Erfurt	Province of Saxony
241.	Tecklenburg	Munster	Westphalia
242.	Warendorf	Munster	Westphalia
243.	Beckum	Munster	Westphalia
244.	Ludinghausen	Munster	Westphalia
245.	Munster landkreis	Munster	Westphalia
246.	Munster stadtkreis	Munster	Westphalia
247.	Steinfurt	Munster	Westphalia
248.	Koesfeld	Munster	Westphalia
249.	Ahaus	Munster	Westphalia
250.	Borken	Munster	Westphalia
251.	Recklinghausen landkreis	Munster	Westphalia
252.	Minden	Minden	Westphalia
253.	Lubbecke	Minden	Westphalia
254.	Herford	Minden	Westphalia
255.	Halle	Minden	Westphalia
256.	Bielefeld landkreis	Minden	Westphalia
257.	Wiedenbruck	Minden	Westphalia
258.	Paderborn	Minden	Westphalia
259.	Buren	Minden	Westphalia
260.	Warburg	Minden	Westphalia
261.	Hoxter	Minden	Westphalia
262.	Arnsberg	Arnsberg	Westphalia
263.	Meschede	Arnsberg	Westphalia
264.	Brilon	Arnsberg	Westphalia
265.	Lippstadt	Arnsberg	Westphalia
266.	Soest	Arnsberg	Westphalia
267.	Hamm landkreis	Arnsberg	Westphalia
268.	Dortmund landkreis	Arnsberg	Westphalia
269.	Bochum landkreis	Arnsberg	Westphalia
270.	Hagen landkreis	Arnsberg	Westphalia
271.	Iserlohn	Arnsberg	Westphalia
272.	Altena	Arnsberg	Westphalia
273.	Olpe	Arnsberg	Westphalia
274.	Siegen	Arnsberg	Westphalia
275.	Wittgenstein	Arnsberg	Westphalia
276.	Wipperfurth	Koln	Rhine
277.	Gummersbach	Koln	Rhine
278.	Waldbröl	Koln	Rhine
279.	Siegbkreis	Koln	Rhine
280.	Mulheim rhein landkreis	Koln	Rhine

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No.	County	Bezirk (district)	Province
281.	Koln stadtkreis	Koln	Rhine
282.	Koln landkreis	Koln	Rhine
283.	Bergheim	Koln	Rhine
284.	Euskirchen	Koln	Rhine
285.	Rheinbach	Koln	Rhine
286.	Bonn landkreis	Koln	Rhine
287.	Kleve	Dusseldorf	Rhine
288.	Rees	Dusseldorf	Rhine
289.	Duisburg	Dusseldorf	Rhine
290.	Geldern	Dusseldorf	Rhine
291.	Kempen	Dusseldorf	Rhine
292.	Krefeld landkreis	Dusseldorf	Rhine
293.	Dusseldorf landkreis	Dusseldorf	Rhine
294.	Elberfeld	Dusseldorf	Rhine
295.	Lennepe	Dusseldorf	Rhine
296.	Solingen landkreis	Dusseldorf	Rhine
297.	Neuss	Dusseldorf	Rhine
298.	Grevenbroich	Dusseldorf	Rhine
299.	Gladbach	Dusseldorf	Rhine
300.	Simmern	Koblenz	Rhine
301.	Koblenz landkreis	Koblenz	Rhine
302.	Sankt goar	Koblenz	Rhine
303.	Kreuznach	Koblenz	Rhine
304.	Zell	Koblenz	Rhine
305.	Kochem	Koblenz	Rhine
306.	Mayen	Koblenz	Rhine
307.	Adenau	Koblenz	Rhine
308.	Ahrweiler	Koblenz	Rhine
309.	Neuwied	Koblenz	Rhine
310.	Altenkirchen	Koblenz	Rhine
311.	Wetzlar	Koblenz	Rhine
312.	Daun	Trier	Rhine
313.	Prum	Trier	Rhine
314.	Bitburg	Trier	Rhine
315.	Wittlich	Trier	Rhine
316.	Trier stadtkreis	Trier	Rhine
317.	Trier landkreis	Trier	Rhine
318.	Bernkastel	Trier	Rhine
319.	Saarburg	Trier	Rhine
320.	Merzig	Trier	Rhine
321.	Saarlouis	Trier	Rhine
322.	Saarbrücken	Trier	Rhine
323.	Ottweiler	Trier	Rhine
324.	Sankt wendel	Trier	Rhine
325.	Erkelenz	Aachen	Rhine
326.	Heinsberg	Aachen	Rhine
327.	Geilenkirchen	Aachen	Rhine

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No.	County	Bezirk (district)	Province
328.	Julich	Aachen	Rhine
329.	Duren	Aachen	Rhine
330.	Aachen stadtkreis	Aachen	Rhine
331.	Aachen landkreis	Aachen	Rhine
332.	Eupen	Aachen	Rhine
333.	Montjoie	Aachen	Rhine
334.	Schleiden	Aachen	Rhine
335.	Malmedy	Aachen	Rhine