# The Impact of Institutions on Innovation*

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**Abstract**

This paper studies the impact of institutional reforms on innovation. We use the timing and geography of the French occupation of different regions of Germany after the French Revolution of 1789 as an exogenous shock to the institutions of those regions. Combining novel county-level data on Imperial Germany with data on patents per capita, we show that counties whose institutions are more inclusive as a result of the French occupation become more innovative. The institutional reforms that are associated with comparing a county with no occupation to a county with the longest occupation, result in a 129% increase in the number of patents per capita. This result is robust to alternative explanations, such as reverse causality, human capital and financial development. Our findings point to institutions as a first order determinant of innovation and highlight the role of innovation as a key mechanism through which institutions may lead to economic growth.

***Keywords***: Innovation, Patents, Institutions, Institutional Reform, Economic Growth
***JEL classification***: O31, O43, N43, N13, K40, P16

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This paper studies the impact of institutional reforms on innovation. We use the timing and geography of the French occupation of different regions of Germany after the French Revolution of 1789 as an exogenous shock to the institutions of those regions. Combining novel county-level data on Imperial Germany with data on patents per capita, we show that counties whose institutions are more inclusive as a result of the French occupation become more innovative. The institutional reforms that are associated with comparing a county with no occupation to a county with the longest occupation, result in a 129% increase in the number of patents per capita. This result is robust to alternative explanations, such as reverse causality, human capital and financial development. Our findings point to institutions as a first order determinant of innovation and highlight the role of innovation as a key mechanism through which institutions may lead to economic growth.

# 1 Introduction

Innovation is one of the most critical engines of growth and prosperity (Solow (1957), Mokyr (1992) and Kogan, Papanikolaou, Seru, and Stoffman (2016)). Because of its importance, corporations and national governments spend large amounts of resources in designing and implementing practices and policies with the aim of fostering innovation.[1] However, there are still large gaps in our understanding of what drives innovation.

In this paper, we study the long-run impact of radical institutional reform on innovation. Societies that operate under extractive institutions create an economic environment that aims to sustain the status quo and avoid change. In contrast, inclusive institutions allow equal access to economic opportunities which promotes the development of new ideas and businesses (Acemoglu, Johnson, and Robinson (2001)). Using a novel hand-collected county-level data set on the German Empire we find an economically large impact of the inclusiveness of local institutions on innovation. Regions with more inclusive institutions are significantly more innovative than regions with extractive institutions. This finding not only highlights institutions as a leading determinant of innovation, but also points to innovation as a key channel by which institutions may ultimately lead to economic growth.

We use the timing and geography of French military invasions of different regions in Germany after the French revolution of 1789 as an exogenous shock to the institutions of those regions (Acemoglu, Cantoni, Johnson, and Robinson (2011)). Several aspects of this historical setting make it a good laboratory to study the impact of institutions on innovation. First, the geography of occupations was imposed by the French. Second, the motives behind French occupations were military and geostrategic, not economic. Napoleon wanted to expand the French borders and create a territorial buffer between France and his rivals, Austria-Hungary and Prussia. The choice of German areas to be occupied was thus not driven by the potential for future innovation or future economic growth of these regions, making subsequent increases in innovation unintended consequences of the French occupation.

The French promoted institutional change through the implementation of progressive reforms

[1] For example, in 2015 the White House's Strategy for American Innovation states that "Now is the time for the Federal Government to make the seed investments that will enable the private sector to create the industries and jobs of the future, and to ensure that all Americans are benefiting from the innovation economy" (National Economic Council and Office of Science and Technology Policy (2015)).

that ultimately fostered the modernization of the economy and the society in the occupied territories (Fehrenbach (2008), pp. 82-94). Crucially, the incentives to enact institutional changes in occupied regions were not driven by economic considerations either. The French wanted to spread their new political ideas, which had been formed during the French Revolution. Furthermore, they were motivated by the intention to dissolve the power of local elites, in order to ease the control of the newly gained territories. As a result, regions that were occupied by the French subsequently underwent major institutional reforms, which eroded the privileges enjoyed by the establishment. Moreover, German regions that had longer French occupation experienced deeper institutional change and operated under more inclusive institutions, which were characterized by lower barriers to entry and fewer restrictions on labor and product markets.

These institutional reforms in turn affect innovation in the long-run. The creation of an efficient legal system guaranteeing equal rights through the introduction of the code civil fostered business creation and increased the incentives to innovate. The dissolution of guilds established an innovation-friendly and competitive environment, which replaced an obsolete economic system originating from the medieval times that had prevented the introduction of new production techniques (Ogilvie (2014)). Likewise, the abolition of serfdom and the implementation of agrarian reforms increased the potential for innovation by restricting the power of local elites and promoting social mobility (Blum (1978)). Combing data on patents per capita in 1890, 1900 and 1910 as our measure of innovation with novel county level data, we document that German counties, whose institutions were more inclusive due to the French occupation, became more innovative.[2] The institutional reforms that are associated with moving from a county with no occupation to a county with the longest occupation, result in a 129% increase in patents per capita, when evaluated at the mean.

Second, we investigate the hypothesis that the impact of institutional reforms on innovation might be weaker in regions where impediments for the effective implementation of such reforms exist. This could be the case in regions that were part of former ecclesiastical states, where even after the implementation of the reforms, social norms were still dominated by the Catholic Church, rendering the population and the administration more conservative and backwards (Borutta (2003)). In support of this hypothesis, we find that the institutional reforms which we analyze led to a

[2]There is no nationwide patent data available before 1877, when a harmonized patent law was introduced in the German Empire. A further restriction is the availability of county-level population data from census publications.

significantly smaller increase in innovation in areas that were part of former ecclesiastical states. This result strengthens our identification, since any alternative explanation for our main result also has to explain why the effect of institutional reforms is muted in former ecclesiastical states.

To link the results of the impact of institutions on innovation to the literature on economic development, we study innovation in high- and low-tech industries separately. Our estimates suggest that inclusive institutions might be of particular relevance for high-tech innovations, which were those associated with chemicals and electrical engineering, the booming sectors of the second industrial revolution (Landes (2003)). The change in institutions associated with comparing a region with no French occupation to one with the maximum duration of French occupation implies a 288% increase in high-tech innovation, while the same institutional change leads to a 82% increase in low-tech innovation.

Finally, we perform a battery of tests to demonstrate that our findings are robust to different subsamples and alternative specifications, including different ways of measuring institutional reforms. Moreover, we hand-collect additional data to address concerns that other factors correlated with the French occupation could be driving our results. In particular, we find that our findings are unlikely to be determined by reverse-causality through cross-sectional differences in local economic development, French influence beyond institutions (such as culture, knowledge or technology transfers), by trade and market integration, cross sectional differences in the level of human capital, and by differences in local financial development.

The paper is closely related to three main strands of literature: the literature that studies the causes and consequences of innovation, the literature that analyzes how institutions shape economic activity, and the literature on historical economic development and on the long-run persistence of the effects of historical events.

Previous research has analyzed several determinants of innovation. One key determinant of innovation is the legal environment. In particular, the impact of patent law on innovation has been the object of many studies. For example, Moser (2005) finds that patent law affects the direction of innovation through a shift into industries that are more dependent on patent protection, but does not affect the amount of innovation. In contrast, Boldrin and Levine (2008) claim that legalized monopolies protected by patent law may lead to lower innovation and argue that in industries where patents are less effective, innovation is not lower than in industries where patents are more

frequently used. Previous research has also analyzed the role of the legal environment in terms of bankruptcy codes (Acharya and Subramanian (2009)) and labor laws (Acharya, Baghai, and Subramanian (2013)). The evidence presented in these papers suggests that excessive liquidation in bankruptcy may lead firms to avoid innovation, and that laws that promote stability in firm-employee relationships spur innovation.

Another aspect that has been documented to impact innovation is the availability of finance. For example, Kortum and Lerner (2000), Gompers and Lerner (2001) and Kerr, Lerner, and Schoar (2014) study the impact of venture capitalists and angel investors. Overall, these papers illustrate the positive impact of access to finance on innovation. Additionally, Tian and Wang (2014) show that firms backed by venture capitalists that are more tolerant to failure, innovate more. Hombert and Matray (2015) document a negative impact of US bank branch deregulation on innovation. In addition to banks and early stage investors, the equity market also affects innovation. Bernstein (2015) shows that post IPO firms innovate less internally and are instead more likely to acquire external innovations. Using cross-country evidence Brown, Martinsson, and Petersen (2013) and Hsu, Tian, and Xu (2014) reveal that the development of equity markets and greater shareholder protection positively impact innovation. The relevance of this literature for our setting is supported by the fact that in Berlin a well-functioning market for new technology stocks already existed in the period before World War I (Lehmann-Hasemeyer and Streb (2016)).

Concerning more macroeconomic determinants of innovation, Sokoloff (1988) argues that the location of innovative firms is determined by geographical factors that allow for market access, in particular access to waterways. Shane (1993) asserts that cultural aspects including the degree of risk aversion and of individualism explain differences in innovation across countries. Cinnirella and Streb (2013) suggests that the local provision of human capital has a positive effect on patenting activity. At a microeconomic level, differences in organizational structure (Seru (2014)) and incentive systems (Burhop and Lübbers (2010)) also help to explain the variation in innovation across firms.

Our paper differs from the previous literature by studying the importance of the quality of institutions as a potential determinant of innovation. Our results indicate that the existence of institutions that broaden the access to economic gains leads to a large increase in the innovativeness of a region.

The findings in our paper are also relevant for the literature that studies the role of institutions

as a determinant of economic development. In particular, our paper relates to the work of North (1990), who emphasizes the notion that formal and informal institutions may have a significant impact on economic performance. More recently, Hall and Jones (1999) and Acemoglu, Johnson, and Robinson (2001) analyze global differences in output per worker and income per capita, respectively, and provide evidence that the inclusiveness of institutions is a major determinant of long-run economic growth. This view is supported by Acemoglu, Johnson, and Robinson (2002) and Acemoglu, Johnson, and Robinson (2005). Despite the existence of evidence that links the inclusiveness of institutions to economic growth, there is scant evidence on the mechanisms through which institutions operate to create economic prosperity. We propose innovation as one such channel. In this regard, we differ from prior work which suggests that extractive institutions and the consequent concentration of wealth can limit growth by creating barriers to financial development (Rajan and Ramcharan (2011)) or by preventing the expansion of education (Cinnirella and Hornung (2016)). Other channels linking institutions to growth include foreign direct investment (Alfaro, Kalemli-Ozcan, and Volosovych (2008)) and market integration (Keller and Shiue (2015)).

Last, our paper contributes to the literature that studies historical economic development and the long-run persistence of the effects of historical events. Becker and Woessmann (2009) test the famous hypothesis by Max Weber on the Protestant work ethic, which could explain differences in economic prosperity between Protestant and Catholics regions and countries. Using Prussia as their setting, they find a positive relationship between Protestantism and economic prosperity, which is driven by the higher literacy of Protestants relative to Catholics. Hornung (2014) finds a positive effect of skilled immigration on firm productivity in the receiving economy. The crucial role of human capital as a determinant of economic growth is also highlighted in Cantoni and Yuchtman (2014), who establish that universities have a positive effect on economic activity, and Squicciarini and Voigtländer (2015), who find that upper-tail knowledge raised productivity in innovative industries. Transportation is another possible determinant of growth (Fogel (1964), Donaldson and Hornbeck (2016)). Banerjee and Lakshmi (2005) show evidence for long-run legacy effects of property rights on economic outcomes. Michalopoulos and Papaioannou (2013) document the long run effects of ethnic institutions. Nunn (2008) investigates the negative long run effect of slave trades on African development, and Dell (2010) the long run effect of a forced mining labor system in Peru and Bolivia. Finally, Voigtländer and Voth (2012) finds that Antisemitism persisted in Germany for a 600 year

period.

To the best of our knowledge our paper is the first to present evidence on the relationship between inclusive institutions and innovation. Our result, that inclusive institutions lead to a large increase in innovation, promotes the view that a key channel through which better institutions foster growth might be through the implementation of an economic environment that is more conducive to innovation. The effect we document is present even after institutions are harmonized across Germany, which also underscores the ability for historical events to persist in the long run.

The rest of the paper is organized as follows. In the next section we describe the historical background including the French rule in Germany and discuss the channels by which institutional reforms can impact innovation. In section 3 we describe our data. In section 4 we present our main findings on the impact of institutions on innovation, and in section 5 we implement additional tests that allow us to rule out alternative interpretations for our results. Section 6 concludes. Detailed information on the data can be found in the appendix.

# 2 Historical Background

## 2.1 The French Occupation of Germany and Territorial Changes

In the second half of the eighteenth century, the Holy Roman Empire of German Nations was a loose federation of independent states formally ruled by the Habsburg Emperors.[3] Due to the lack of a central administration, the Empire was a relic of medieval times, consisting of hundreds of different political entities. The French Revolution, starting in 1789, provoked the ultimate fall of the Holy Roman Empire. In 1792, the German monarchies joined a military coalition to counter the revolutionary ideas in France. However, the French revolutionary forces prevailed and turned into the offensive. In order to improve their geo-strategic position, the French occupied all German territories west of the river Rhine by 1795. The result was a buffer zone with the Rhine as its natural border that protected France from potential aggression of its main continental rivals, Prussia and Austria-Hungary. When Napoleon took over power, the pressure on Germany increased further. In 1806, Napoleon expanded the French sphere of influence by means of diplomacy. He forced the

[3] See Fehrenbach (2008) and Whaley (2012) for the history of the French occupation of Germany and the territorial changes.

remaining medium-sized German states to establish the Confederation of the Rhine (Rheinbund) and to form a coalition with France. As a result, the Holy Roman Empire ceased to exist.

Prussia, the most powerful German state, was directly threatened by the Napoleonic expansion and ultimately declared war against France in the autumn of 1806. However, the French prevailed once more. Prussia had to accept the disgraceful peace treaty of Tilsit in 1807 that resulted in significant territorial losses, in particular all provinces west of the river Elbe. Parts of the former Prussian territories were integrated into the Grand Duchy of Berg and the Kingdom of Westphalia, French satellite states that were both ruled by relatives of Napoleon. From a strategic perspective, Berg and Westphalia became French bridgeheads on the Eastern side of the Rhine. Furthermore, Napoleon occupied the free Imperial cities of Bremen, Hamburg and Lübeck and the remaining German territories in the North, giving him control over the coast. This was a strategic necessity, since otherwise the Continental System would have been undermined by contrabandists trading with Britain (Fehrenbach (2008), pp. 95-101). By 1810, the whole Lower Rhine area, Westphalia, the North Sea coast, Hanover, and large parts of Hesse were under French control.

The occupation ended with the swift withdrawal of the French army that had suffered several military setbacks in the course of the German Campaign of 1813. After Napoleon's final defeat in the battle of Waterloo, the European great powers restored the political order of pre-revolutionary Europe. The German states however refrained from the re-establishment of the Holy Roman Empire and the restoration of the old borders.[4] As a result of the French expansion and the subsequent territorial reorganization, all ecclesiastical states, most of the imperial cities, as well as a large number of small independent territories, were integrated into larger states. These changes were not revised and consequently most of the remaining states experienced territorial gains.

In absolute terms, Prussia was the big winner since it could increase its influence as a leading German power by enlarging its possessions. In particular, Prussia gained control over the entire northern Rhineland and Westphalia, but importantly these territories were not its first choice. The Prussian rulers in Berlin pushed for the annexation of the entire Kingdom of Saxony, which had been a long-standing French ally, but this intention was refused by the United Kingdom and Austria-Hungary that wanted to preserve the balance of power in Europe (Flockerzie (1991)). The underlying rationale was that, from the perspective of 1815, Saxony was seen as the most promising region in

[4]See Fehrenbach (2008) for the process of restoration in German states.

terms of economic prospects and was much more developed than the Rhineland or Westphalia.[5] Furthermore, it was located in the East, next to the Prussian heartland which would have made it easier to defend in case of future warfare. By contrast, there was no direct land connection to the Rhineland and Westphalia at this time, making Prussia thereby more vulnerable in a potential war. Interestingly, the unwanted occupied regions of Rhineland and Westphalia, turned out to be the most innovative and economically dynamic part of Germany in the late 19th century. This anecdote provides additional credibility to our identifying assumption that the occupied territories were on average not more developed in economic terms than non-occupied regions.

### 2.2 Institutional Change under French Rule

The French occupation did not only alter the territorial structure of German states, but also had a widespread economic and social impact. During the years of French rule, the occupied territories suffered from the demand for troops and the confiscation of property, food and other goods that were necessary to supply the French forces (Whaley (2012), pp. 558-559). Furthermore, business activity was suppressed in times of war, and the economic blockade of Britain restricted trade. In the short-run, the French occupation might therefore have had a negative impact on innovation.[6] However, in the long-run, it had positive consequences as it fostered economic modernization and social progress.

At the end of the 18th century, economic development and the potential for innovation were limited by backward institutions which preserved the power and the privileges of a small elite.[7] However, along with the French troops, the ideas of the French revolution spread over German states and induced a considerable institutional change. In the occupied areas, the French forced substantial reforms which cut down the privileges of the existing elites. These reforms included the

[5] There are no reliable GDP estimates for this period, but several indicators give strong evidence that Saxony was far much developed than other German states, in particular in the leading sectors of the industrial revolution like textile production. In 1815, 284,000 cotton spindles were used in Saxony compared to an estimated number of 360,000 in all German states including Saxony (data from Kiesewetter (2004), p. 175). Saxony could even maintain its leading role until the second half of the 19th century (see also section 6.2, where we discuss these regional differences).

[6] The textile firms in the Rhineland, for example, could not import superior English machinery under the continental blockade. As a consequence, these companies struggled after 1815 due to the antiquated equipment (Kisch (1989), p. 212).

[7] The nobility dominated Germany both economically and politically, and it had been able to retain far-reaching juridical privileges, in particular in rural areas where it owned most of the land (Blum (1978)). In the cities, urban oligarchies limited private entrepreneurship through guilds that formed cartels to prevent market entries. According to Ogilvie (1996) guilds were common in all German states at the end of the 18th century.

establishment of commercial freedom by the dissolution of guilds, the introduction of a general code civil, the the abolition of serfdom and the implementation of agrarian reforms (Acemoglu, Cantoni, Johnson, and Robinson (2011)).[8] Economic motives played only a minor role in the decision to impose the reforms. Apart from ideological reasons, the French wanted to restrict the power of the local elites to facilitate the administration of the occupied areas (Acemoglu, Cantoni, Johnson, and Robinson (2011)), which should serve as buffer territories between France and its continental rivals. After the retreat of the French troops and the restoration of the old order, the German sovereigns recalled some of the Napoleonic reforms in the formerly occupied lands. However, the process of the so called 'Restoration' varied regionally, depending on the duration of the French occupation. In territories where the French occupation lasted only a couple of years the push back was much stronger than in territories with a long period of French rule.[9] As a result of regional variation in the duration of occupation, the inclusiveness of institutions differed enormously between and within German states during the 19th century. In regions where restoration took place as well as in regions that had not been occupied by the French, extractive institutions remained in place for a long period of time. In those locations, the rulers later implemented similar reforms. However, this was done slowly and on average several decades were needed for institutional change to be enacted. Even after the formation of the German Empire in 1871, there were still significant institutional differences that could be traced back to the French invasion. A manifestation of this is the fact that a unique and nationwide civil code did not exist until the introduction of the German Civil Code (Bürgerliches Gesetzbuch) in 1900 (Schubert (1977) and Klippel (1996)).

### 2.3 How Does Institutional Change Foster Innovation?

The institutional improvements that had been promoted under the French rule created an economic environment conducive to innovation. One of the reforms that directly increased the potential for innovation was the establishment of commercial freedom through the abolition of guilds and other

[8] Reform efforts also took place in non-occupied German states, but the local elites often prevented its implementation or effectively lobbied for exemption clauses to maintain their influence. In the Duchy of Nassau and the Grand Duchy of Hesse-Darmstadt, for example, the government discussed the introduction of a code civil, but only letters of intent were drafted and, finally, the consultations ended without results in 1813 (Schubert (1977)). In the non-occupied parts of Prussia some reforms were introduced, but the rural nobility could preserve far-reaching privileges until the end of the century, including the right to administer justice (Wagner (2005)).

[9] In the Rhineland, for example, which was under French control for 19 years, the institutions reforms remained in place. In contrast, old institutions were almost completely restored in the Northern and central German territories that became under French control between 1807 and 1810.

restrictions on trade and production. Originated in the medieval age, guilds were associations of merchants or artisans formed to control their trades and production.[10] In the late 18th century, guilds were still widespread in all German states (Ogilvie (1996)). On the one hand, guilds ensured certain quality standards with regard to both the education of their craftsmen and their finished products, but on the other hand, they acted as entry barriers and an impediment for change and innovation by protecting the interests of the existing members (Ogilvie (2014)). Historical case studies show that guilds directly prohibited the use of modern production techniques in order to maintain the status quo. In the 17th century, for example, the use of engine looms for the production of silk ribbon was effectively inhibited in Cologne, Frankfurt and other major centers of textile production (Pfister (2008)).[11] Before the dissolution of guilds, the incentives to generate economically valuable inventions were very limited since it was not possible to enjoy the resulting economic gains. Furthermore, guilds did not only directly prevent innovation, but also restricted competition. Guilds acted like cartels controlling local monopolies. Members of the guilds had captive markets and thus little incentives to innovate. We therefore argue that another channel by which the dissolution of guilds may have impacted innovation is through its role in creating a more competitive marketplace.[12]

It is important to point out that not all manufacturing businesses were organized in guilds even in regions where guilds still dominated in the early 19th century. Capital-intensive industries such as iron works or porcelain manufactories were typically not part of guilds but required the acquisition of trading licences instead. The licenses were expensive and only scarcely distributed by the rulers. Entrepreneurs had to rely on the goodwill of the administration to get a license, but they had no legal claim. Requests were rejected for various reasons, including when the proposed business plans challenged the economic interests of incumbents.[13] We therefore view the system of trade licenses to impact innovation in a similar manner as the system of guilds. Because the state decrees on the dissolution of guilds usually simultaneously also included the weakening of other restrictions such as

[10] See Ogilvie (2014) for a general overview of the research about the history and the economics of guilds.

[11] In Aachen, where the production and processing of copper had flourished, restrictive guilds impeded technical innovations, causing a large decline of production during the 18th century (Kellenbenz (1977), p. 494). Kisch (1989) illustrates how guilds hampered the introduction of modern production techniques in the Rhineland, and Lindberg (2009) argues that guilds prevented the introduction of modern trade organizations in Danzig and Lübeck.

[12] See Aghion, Bloom, Blundell, Griffith, and Howitt (2005) for an analysis of the effect of competition on innovation.

[13] This can be illustrated by the case of an entrepreneur in the Kingdom of Württemberg who wanted to construct a cotton spinning mill in the Swabian city of Urach in the mid-18th century, but the officials refused his request for a license to protect the local linen weaver guild (Arns (1986)). Other examples for the Kingdom of Württemberg and the Grand Duchy of Baden are reported in Arns (1986) and Fischer (1962).

an easier access to trade licenses and other improvements in economic freedom (Gewerbefreiheit), the timing of this reform proxies for a broad lowering of barriers to entry and more democratic access to economic gains.

Another consequence of the French occupation was the introduction of the code civil. The French established a legal system that separated the judiciary from the public administration, and by which all citizens should be treated as equal before the law (Schubert (1977)). Clear rules were set both in civil and trade law which made it easier to establish a business and therefore increased the potential for innovation. Before the French invasion, patrimonial jurisdiction (Patrimonialgerichtsbarkeit) existed in all German states (Werthmann (1995)). The judiciary was not separated from the local administration under patrimonial jurisdiction. In rural districts, for example, the local lord of the manor was often not only one of the largest landowner but also the mayor, the judge and the person in charge of the local police. While the introduction of the code civil revoked patrimonial jurisdiction in territories under French rule, this practice survived in most of the non-occupied German states for a long period of time.[14] Having a fair judicial system that respects private property is a fundamental aspect of an innovative society. By contrast, under a system of extracting institutions, lack of protection for the gains from innovation leads to a low incentive to innovate in the first place. The implementation of a judicial system that enforces property rights can therefore be a tremendous force in promoting innovation.

A third way in which the French invasions hampered the power of the existing privileged classes and fostered innovation was trough the abolition of serfdom and the subsequent implementation of agrarian reforms. At the end of the 18th century, the manorial system still existed in German states (Blum (1978) and Dipper (1980)). A small group of noblemen, the lords of the manor, owned a high proportion of the land. Their large estates were subdivided in parcels, which were individually cultivated by tributary serfs. This system was ended in two steps as a result of the French invasion. First, serfdom was abolished so that the tributary peasants gained individual freedom, which in turn increased labor market mobility (Dipper (1980)). However, the peasants were still economically dependent on the lords of the manor, who owned the land. Therefore, agricultural reforms aimed at

[14] In 1849, not only the patrimonial courts but also the police powers of the local lords of manor were abolished. However, in some parts of Prussia, alleviated police powers were officially reintroduced in 1853 (Werthmann (1995)). At least in the Eastern provinces of Prussia the local lords of the manor dominated both economically and in the administration up into the 20th century (Wagner (2005)).

transferring the ownership of the land to the peasants were subsequently undertaken.

The specific design of the agricultural reforms varied across German states, but there was a common feature: the tributary peasants were allowed to take the ownership of the land that they had cultivated, but they had to compensate the lord of the manor to some extend, either by installment payments or by the cession of parts of their newly gained land (Achilles (1993)). Similarly to the abolition of guilds, agricultural reforms did not only take place in occupied regions. However, in non-occupied German states the rulers started the process of agricultural reforms on average later and it took much longer to implement. Furthermore, the way in which the reforms were implemented differed greatly across and within German states. In the Eastern provinces of Prussia, which were not occupied by the French, the agricultural reforms were less effective in breaking the economic power of the old elites, since the compensation rules were designed more in favor of the lords. As a result, even after the reforms, a high proportion of land was still owned by a small group of noblemen (Eddie (2008)). Thus, both the abolition of serfdom and the subsequent agrarian reforms reduced the power of the local elites.

As a whole, these institutional changes were a revolution in the way local communities operated and increased the economic incentives and the potential for innovation.

## 3 Data

To test our hypothesis, that institutional change affects innovation, we construct a novel and unique data set by hand-collecting detailed county-level information on Imperial Germany. Due to restrictions on the availability of data, we focus our analysis on three years: 1890, 1900 and 1910. Before 1877 the patent law was not harmonized within Germany and, as such, there is no nationwide patent data available.[15] The selection of our benchmark years is also dictated by the availability of accurate population figures extracted from the official population census records. We end our analysis in 1910 to avoid the contamination of our results with potential effects caused by the economic and social disruptions of the World Wars.

During the period of our analysis, the German Empire was constituted by 25 federal states. Prussia, which accounted for more than half of Germany's population and area, was organized in

[15] The French patent law was neither incorporated in German states after 1815, nor did it shape the German patent systems that emerged during the 19$^{th}$ century. See Kurz (2000) for the history of the German patent law.

provinces (Provinzen), which were subdivided in regions (Regierungsbezirke), and each region was subdivided in numerous counties (Kreise). The medium-sized German states only used regions and counties as organizational units, and the small states were only subdivided in counties. We use data on the county-level, the smallest unit for which population data is available. After adjusting for changes in the administrative structure we obtain a final sample of 975 counties per year covering all 25 federal states of the German Empire.[16]

### 3.1 Patents

As a proxy for innovation, our object of study, we use high-value patents per million inhabitants.[17] We obtain data on high-value patents from Streb, Baten, and Yin (2006), who provide information regarding the geographic distribution of patents, whether they were filed by an individual or a firm, and the technological class of the patent. High-value patents are defined as patents with a lifespan of at least 10 years, with a maximum length of 15 years. Due to the fact that a patentee had to pay an annual charge to renew a patent, one can assume that these patents represent financially valuable products or production technologies (Streb, Baten, and Yin (2006)). We include patents granted to both German individuals and firms. Panel A of Table 1 reports descriptive statistics on patents per million inhabitants separately for counties that were occupied by the French at the beginning of the 19th century and for non-occupied counties. The mean number of patents per capita is distinctly higher in occupied counties for all benchmark years.

### 3.2 Institutional Reforms and French Occupation

We measure the degree of inclusiveness of local institutions with the variable *Reforms*. This variable is an index calculated as the average of the number of years between the implementation of a reform and the year a patent is filed (1890, 1900 or 1910). It takes into account four types of institutional reforms: (i) the introduction of the code civil that guarantees equality before the law, (ii) the abolition of serfdom, (iii) the implementation of agrarian reforms, and (iv) the dissolution of guilds. The Rhineland, for example, has a reform index value of 100.25 for 1900, based on the average of the following reform scores (year of implementation of the reform in brackets): code civil: 98 (1802);

[16] See the appendix for further information on the data presented in this section.

[17] For a discussion of patents as a measure of innovation see, for example, Griliches (1990) and Streb (2016). In section 4.5, we also focus on high-tech patents as those may better capture disruptive innovation.

serfdom: 102 (1798); agrarian reform: 96 (1804); guilds: 105 (1795).

This reforms index was introduced by Acemoglu, Cantoni, Johnson, and Robinson (2011) to study the impact of institutional reforms on urbanization, which they use as proxy for economic growth. There are two main differences between our reforms index and the one they use: *First*, they use highly aggregated data, and as a consequence their index is constructed at the level of German states and at the province-level for Prussia and Bavaria. We, on the other hand, collected additional data in order to include smaller German states and regions that were not covered in their paper. *Second,* we use the data at the county level in order to alleviate measurement error concerns inherent in a province level analysis. As a consequence, our panel consists of 975 counties per year instead of the 19 provinces and states used in Acemoglu, Cantoni, Johnson, and Robinson (2011).[18]

Panel A of Table 1 contains information on the average reforms index in occupied and non-occupied areas in our sample. Consistent with the view that French occupation led to more inclusive institutions, we observe that the reforms index is about 12 years higher in occupied than in non-occupied counties.

In our empirical analysis, we use the variable *Years French Occupation* as an instrument for *Reforms*. *Years French Occupation* is defined in the same way as in Acemoglu, Cantoni, Johnson, and Robinson (2011). A county is classified as occupied if it was under direct French rule or under the rule of a French-controlled satellite state. The latter include the Grand Duchy of Berg, the Kingdom of Westphalia, and the Grand Duchy of Frankfurt, which were ruled by Napoleon's family members. We use historical maps to obtain information about French occupation in all territories that are not considered in Acemoglu, Cantoni, Johnson, and Robinson (2011) and to break the data down to the county-level. The period of French occupation ranges from 0 to 19 years. Summary statistics for *Years French Occupation* are reported in Panel B of Table 1.

### 3.3 Basic Control Variables

In our empirical analysis we include a battery of control variables in order to account for alternative forces that could be associated with regional variation in innovation.

Population density, measured by the number of inhabitants per square kilometer ($Population/Km^2$), is used to control for urbanization. We use population density as a proxy for economic prosperity

[18] In Section 4.6 we show that our results are robust to different ways of measuring institutional reforms.

during our sample period (Ciccone and Hall (1996); Acemoglu, Johnson, and Robinson (2002)). Furthermore, urban areas may obtain better provision of public infrastructure or better allow for spillover of knowledge, which could then lead to more innovation. Summary statistics for *Population/*$Km^2$ are presented in Panel A of Table 1.

Another potential confounding effect is the access to efficient means of transportation. A county that is well connected may have a market reach that is larger than one with large transportation barriers. Indeed, Sokoloff (1988) shows that for the early period of industrialization in the northeast of the United States there is a significantly positive relationship between patenting activity and local access to waterways. In the late nineteenth century, waterways played an important role for the transport of bulk commodities. Inland water transport was much cheaper than railway transport (Wolf (2009)). Therefore, the production of industrial materials, such as iron and steel works, was largely located along rivers. Hence, we control for both the local access to navigable rivers and harbors with the variables *River* and *Harbor*, respectively. Counties that had access to both a river and a harbor might be especially innovative, so we also take the interaction effect of river and harbor into account.

A large endowment of natural resources is an additional factor that we consider. If the French occupation was purposely or by chance correlated with the existence of natural resources, this could bias our results. We control for the existence of coal and ore deposits, two of the most important natural resources at this time, with the variables *Coal Deposits* and *Ore Deposits*. *Coal Deposits* is a dummy that is equal to one if coal deposits are located in the respective county, and zero otherwise. Similarly, *Ore Deposits* is a dummy variable that is equal to one if deposits of iron ore or non-ferrous metals (e.g. copper) are located in the respective county, and zero otherwise.

We also control for the possibility that foreign culture or international trade opportunities may drive our results. We do so by including the variables *Border* and *Border France* in our regressions. *Border* is a dummy that takes the value of 1 if the county is at an external border, and zero otherwise. *Border France* is a dummy variable that takes the value of 1 if the county is at the border to France, and zero otherwise.

In an attempt to account for the degree of innovation prior to the French occupation, we control for the presence of universities in the county in 1789 with the variable *University 1789*. Universities may reflect an interest in the advances of science and technology, and provide training that could

later lead to innovation and economic growth (Cantoni and Yuchtman (2014)). By including this variable in our regressions we aim to control for differences in the local propensity to innovate that pre-date the Napoleonic invasions.

The level of local innovativeness could also be driven by cultural factors. Max Weber postulated the famous Protestant work ethic, namely that Protestants are more hard working than Catholics (Weber (1920)). Becker and Woessmann (2009) find for Prussia that Protestant counties are indeed more prosperous than Catholic counties, although they suggest that this effect is not driven by their work ethic but instead by higher incentives to invest in human capital. To measure a potential effect of Protestantism on innovation, which could be either driven by a better work ethic or better human capital, we include *Protestant %*, which measures the share of protestants in each county.

During our sample period, the German Empire included territories where German was not the native language for a large fraction of the population. Although in total, these minorities represented only 7% of the German population, there is large cross-sectional variation with non-native speakers accounting for the majority of population in some counties. In particular, this was the case for the Polish-speaking population in the Eastern Prussian provinces. To rule out the concern that the spatial distribution of minorities drives our results, we include data on non-German-speaking population, which we extracted from the official German population census records. Due to the fact that the non-native German speakers were clustered in only a small number of counties, we include the dummy variable *Minorities* that is equal to one if the fraction of the population whose native language is not German is above 50 percent, and zero otherwise.

In addition, we control for Prussia (in the borders of 1816) in our baseline specifications . This is akin to including a geography fixed effect for Prussia. Note, that Prussia is the only state that is large enough to have enough within state variation in institutions to allow for such a 'geography fixed effect' as the other German states are usually of the size of a Prussian province, if not smaller.[19] Moreover, we include the variable *City State* as a control, which is a dummy variable that takes the value of 1 for Hamburg, Bremen and Lübeck (the city states that existed within the German Empire), and zero otherwise. We control for these states for two reasons. First, Hamburg, Bremen and Lübeck were major harbor cities. Napoleon essentially occupied these cities in 1806 to maintain

[19]The reason we take Prussia in 1816 is that the time period from 1816 to 1864 is the longest one for which there were no major territorial reorganizations in Germany in the 19th century. This suggests that this is the territorial structure that is most appropriate in our setting.

the continental blockade against Great Britain. Second, agricultural reforms were not relevant in city states, as city states incorporated hardly any agricultural land. As such, in the case of city states, our index captures only three of the four institutional reforms.

Panel B of Table 1 presents the summary statistics for all time-invariant control variables, which we use in our basic regressions.

# 4 Results

In our empirical setting we exploit the timing and geography of the French occupation of parts of Germany following the French Revolution as an exogenous shock to the inclusiveness of local institutions. Even though prior to the French occupation German institutions were homogeneous across counties, there were significant changes ex-post.

## 4.1 Determinants of French Occupation

In section 2 we argue that the French occupation was not driven by economic, but instead by military and geo-strategic considerations. We now provide empirical support for this claim. In particular, we test whether pre-1789 controls including geographic aspects such as the existence of rivers, harbors coal and ore deposits predict the length of French occupation. If our argument is valid, we would expect to find the coefficients associated with these variables to be insignificant and the $R^2$ to be close to zero. Our results are presented in Table 2. In addition to the model with equally weighted observations, reported in column 1, we use a model with weighted observations in column 2 to account for differences in the county size. Since for the early nineteenth century population data is not available on the county level, we weight the observations by the area size of each county.[20] To account for possible spatial correlations, we cluster standard errors at the regional level. Overall, the findings in both models support our assumption. *City State* is statistically significant in both specifications. The statistically significant loading on the variable *City State* can be explained by the strategic importance of these cities. All three German city states were occupied in November 1806 to enforce the Continental Blockade due to the fact that these cities had important ports that

[20] An additional argument to weight observations by area is that due to military motives the French occupation might be influenced by the area size of a county. In our subsequent models, where we use data for 1890, 1900 and 1910, we weight our observations by county population.

had to be controlled in order to avoid the contraband trade with Britain. Furthermore, these three cities are geographically clustered in one part of Germany so that it is natural that either all of them or none of them would be occupied. All other variables are insignificant, except for *Harbor* in column 2. The negative coefficient of *Harbor* does not support the view that harbor counties were on average occupied for a longer period of time. We also note that the $R^2$ of the regression is below 3% which suggest that taken as a whole, these factors that were seen as important determinants of economic prospects at the time of the French revolution, did not dictate the geography of the occupations.

### 4.2 First Stage: The Impact of the French Occupation on Institutions

The first step in our empirical analysis is to formally study the impact of the Napoleon occupation of parts of Germany on the inclusiveness of local institutions. In this first stage, we test whether counties that were occupied the longest by the French were also more likely to implement reforms that increased the inclusiveness of the local institutions. We thus use the length of the French occupation as an instrument for *Reforms*. We also include in our specification other important controls that vary across counties and could therefore directly affect local innovation.

The result, presented in column 1 of Table 3, shows an economically and statistically significant relationship between *Years French Occupation* and *Reforms*. An additional year of French occupation is associated with an anticipation of institutional reforms by 1.59 years, on average. Moving from no occupation to the maximum length of French occupation represents a 65% increase in *Reforms*, relative to the average in our sample. The F-statistic for the excluded instrument is 60.52 which attests the strength of the instrument. Having established that the French occupation affects Germany institutions at the county level we proceed to our main task of studying the impact of institutions on innovation.

### 4.3 Main Results: The Impact of Institutions on Innovation

In order to test our main hypothesis, that the inclusiveness of institutions impacts innovation, we study the effect of the instrumented *Reforms* on innovation, which we proxy with patents per capita. We weight our observations by population to avoid the possibility that a group of small counties

(population wise) could bias our estimates.[21] The standard errors are clustered at the regional level to allow for correlation of the error terms within a region across the three years in our sample (1890, 1900 and 1910).[22]

Column 2 of Table 3 contains the main finding of the paper. There is a strong relationship between the inclusiveness of institutions in a county and its innovativeness. The coefficient of 0.405 implies that, evaluated at the mean, going from 0 to 19 years of French occupation, which is equivalent to a change from no treatment to maximum treatment, leads to an increase of about 129% in the number of patents per capita through the implied change in institutions. This result is not only economically large, but is also statistically strong since the p-value of *Reforms* is 0.00%.

This finding holds after including year fixed effects and controlling for other potential determinants of innovation that could, by chance, be correlated with the Napoleonic invasions. In particular, in order to account for the possibility that counties that have a harbor or access to a navigable river may be more active in trade, and in turn, that trade could provide incentives for innovation, we include *Harbor*, *River* and *River*Harbor* as control variables. The variable *River* is not statistically significant (p-value of 10.2%), which shows that access to navigable waterways cannot explain the spatial distribution of German patenting activity at the end of the 19th century. Both *Harbor* and *River*Harbor* are negative and statistically significant. A potential explanation for this finding relates to the possible specialization of counties with harbors and both rivers and harbors in trade, at the expense of other economic activities that could produce more innovations, such as manufacturing. Because agglomeration economies could facilitate the transmission of ideas and as such foster innovation directly, we include population density ($Population/Km^2$) in our model. Our results exhibit a positive relation between agglomeration economies and innovation (Chatterji, Glaeser, and Kerr (2014)). The German border counties were on average significantly less innovative, as the coefficient of our dummy variable *Border* suggests. In addition, we include *Border France,* for which the magnitude of the negative effect is even stronger. We therefore conclude that border effects between France and German states do not drive our results. In order to account for potential pre-existing differences in the propensity of different counties to engage in innovation, we also control for whether a county had a university prior to the French Revolution. We find no statistically significant coef-

[21] However, as we discuss in section 4.6, our results are robust to weighting counties equally in the regression.
[22] The 975 counties used in the analysis are distributed across 80 regions.

ficient associated with the variable *University 1789*. The coefficient of *Protestant %*, which we use to control for the share of Protestants in each county, is positive and statistically significant. This result is consistent with the findings of Becker and Woessmann (2009), who argue that Protestant regions became more developed than Catholic regions as a result of higher incentives to accumulate human capital. *Minorities* has a statistically significant negative effect on innovation. This result reflects the fact that the counties with a high share of non-German inhabitants were all located in the rural and less developed counties of the Eastern Prussian provinces. For *Prussia 1816*, we find a negative coefficient, which could be driven by the fact that agriculture dominated the economy in the Eastern Prussian provinces.[23] The coefficient of *City state* is statistically insignificant, which indicates that Bremen, Hamburg and Lübeck, the old and traditional trade cities, were on average not more innovative than other places. Finally, we find no evidence that natural resources were crucial for innovation since the coefficients of *Coal Deposits* and *Ore Deposits* are both statistically insignificant.

### 4.4 The Differential Impact of Institutions on Innovation in Ecclesiastical States

Institutional change may have a weaker impact on innovation in regions where impediments for the effective implementation of the reforms exist. This could be the case in territories that were dominated by a more conservative population and a more backward administration for a long period of time. To test whether the effect of reforms is weaker in such territories, we focus on counties that were part of independent ecclesiastical states until the German mediatization of 1803 (Reichsdeputationshauptschluß), when the French restructured the German lands and abolished the ecclesiastical states. Because of its prominent role in these states, the Catholic Church was a powerful determinant of social and economic behavior, even compared to other regions with the same fraction of Catholics in the local population. The impact of the French occupation on innovation could therefore have been limited by the fact that even after the *formal* implementation of the reforms, the church remained an important determinant of social and economic behavior, which limited *real* improvement in institutions.

During the Kulturkampf (cultural struggle) in the 19$^{th}$ century, the Catholic Church was opposing

[23] To rule out that our results are driven by differences in the share of agricultural employment, we control for sectoral employment shares in section 5.1.

both the separation of the church from the state and the modernization of the society (Clark and Kaiser (2003)).[24] The Catholic Church was able to influence the daily lives of its believers through the local clergy. One prominent example of how the Catholic Church aligned its clergy was the Antimodernisteneid (Oath against modernism) of 1910, which every Catholic clergyman had to swear. With this oath, the Catholic Church was iterating on the 1864 papal Syllabus errorum, in which Catholicism was positioned as the antithesis of modernity (Borutta (2003)).

To identify counties that were part of an ecclesiastical state we hand collect data from historical maps and registers.[25] We then create the dummy variable *Ecclesiastical 1789* that takes the value of 1 if the county is an ecclesiastical state in 1789, and zero otherwise. Ecclesiastical principalities were dominated by a Catholic population, a fact that could drive our result. As in our main regression, we also include the share of Protestants (*Protestants %*) in our model to rule out this concern.

Ecclesiastical states were all located in the Western part of the German Empire. For this reason, and due to the fact that the Eastern Prussian provinces, East Elbia (Ostelbien), were dominated by agriculture, we exclude East Elbia from our sample. This ensures that our results do not reflect structural differences between the West and the East.[26] We instrument the variables *Reforms* and *Reforms *Ecclesiastical 1789* with both the years of French occupation and the interaction of the years of French occupation with *Ecclesiastical 1789*.[27] The results are presented in Table 4. As before, the coefficient associated with *Reforms* is positive and highly significant, indicating a positive relationship between the inclusiveness of institutions and innovation. Moreover, the interaction of *Reforms* with *Ecclesiastical 1789* is significantly negative. This confirms our hypothesis that former ecclesiastical states may be less prone to increase innovation following an exogenous improvement in local institutions. Compared to the mean treatment effect, the impact that the French occupation ultimately had on innovation is on average 71% lower in Ecclesiastical states, where institutional change was less effective. In addition, we find that former ecclesiastical territories were not more

[24] See, for instance, the "Kölner Wirrungen" ("Cologne Turmoil") in which the Catholic Church was opposing the traditionally Protestant Prussian government on several issues, including mixed marriages between Catholic-Protestant couples and higher education policies (Keinemann (1974)).

[25] See Appendix A6 for a detailed description of the data sources.

[26] See Appendix A1.2 for a more detailed description of this sub-sample.

[27] More precisely, we estimate two first stage regressions, one for *Reforms* and another one for *Reforms*Ecclesiastical 1789*. We use both *Years French Occupation* and *Years French Occupation*Ecclesiastical 1789* as instruments in each of the two first stage regressions. Among the two instruments ,we find that *Years French Occupation* is the predominant factor determining *Reforms*, while *Years French Occupation*Ecclesiastical 1789* is the primary determinant of *Reforms*Ecclesiastical 1789*.

innovative than other territories as the coefficient associated with *Ecclesiastical 1789* is statistically insignificant. Interestingly, the coefficient associated with *Protestants %* becomes statistically insignificant once we control for ecclesiastical state. This suggests that previously documented differences between Protestant and Catholic regions may not be driven by work ethic or human capital (Becker and Woessmann (2009)), but instead by differences in governance, conservatism or other historical legacies associated with former ecclesiastical states.

This result also strengthens our identifying assumption, that the French occupation affected innovation through its effect on the inclusiveness of institutions, and not through any other factors that may also have been influenced by the French occupation. If there is an alternative channel by which French occupation impacted innovation, it not only has to explain our main result - the effect of institutions on innovation in general - but also the weaker impact of institutions in former ecclesiastical states.[28]

### 4.5 Different Types of Innovation

In addition to our main result, we analyze whether our findings differ between high- and low-tech industries. This distinction is important, as it allows us to better understand the potential impact of innovation on growth. High-tech industries differ from low-tech industries in several dimensions: first, innovation in high-tech requires a larger amount of physical and human capital; second, R&D investment tends to be much riskier in high-tech industries than in low-tech industries; and third, when successful, high-tech innovation tends to be more disruptive and more conducive to economic growth. We categorize patents as high-tech based on their technological class. We define high-tech patents as those in chemicals or electrical engineering; all remaining patents are categorized as low-tech.[29] Both the chemical and the electrical industry were the two booming sectors of the second industrial revolution (see Henderson (1975) and Streb, Baten, and Yin (2006)). In columns 1 and 2 of Panel A of Table 5 we divide our sample into high-tech and low-tech patents, and redo our analysis for each of these categories separately. The first aspect to note when analyzing these models is that our findings hold for both types of patents separately. Second, and most importantly,

[28] In section 5, we address potential alternative explanations in detail.

[29] Chemicals include general chemical processes and applications, textile chemistry, fertilizers and dyestuffs; electrical engineering includes electrical trains and railway equipment and electrical equipment in general. See Appendix A2 for further information about the technology classes used by the Imperial Patent Office.

the results are economically more significant for high-tech patents. For ease of interpretation, we present the economic magnitudes implied by these results in Panel B. The change in institutions associated with going from 0 to 19 years of French occupation implies a 288% increase in high-tech innovation, while the same institutional change leads to a 82% increase in low-tech innovation, when evaluated at the mean. These results suggest that formal institutions may be especially relevant for high-tech innovation.

Next, we test whether the effect of institutions differs if we separately analyze patents filed by firms and patents filed by individual inventors. In columns 3 and 4 of Panel A of Table 5 we show that our results hold for both groups independently. We find that going from 0 to 19 years of French occupation causes institutional reforms that lead to a 197% increase in corporate innovation and a 64% increase in patents by individuals. One interpretation of these findings is that inclusive institutions are particularly important for corporate innovations, which require a higher amount of investment in both physical and human capital.

Finally, in column 5 of Panel A we include only high-tech patents filed by firms. We do so, because these patents were the ones most associated with subsequent economic growth (Henderson (1975)). In that regard, focusing on this subsample allows us to further test the view that an important channel by which inclusive institutions may lead to economic growth is through the creation of an environment conducive to innovation. As column 5 of Panel A shows, our effect also holds for this subsample. An increase in *Reforms* associated with going from 0 to 19 years of French occupation is associated with an increase in the inclusiveness of institutions that leads to a 359% increase in the number of corporate high-tech patents per capita.[30] This result therefore suggests that inclusive institutions were important historical preconditions for the rise of the German chemical and electrical industry at the end of the 19th century.

### 4.6 Robustness Tests

In order to underscore the general and robust nature of our results we perform a series of tests that altogether alleviate the concern that the relationship we establish is spurious.

In column 1 of Panel A of Table 6 we repeat our analysis without weighting observations by

[30] We note that the inclusiveness of institutions also has a positive and significant effect on all patents that are not high-tech patents filed by corporations (the complementary set of patents for corporate high-tech patents).

population. Although this could lead our magnitudes to be unrepresentative of the average effect of institutions on innovation, it allows us to exclude the concern that our results are driven by just a few heavily populated counties. Our results remain highly statistically significant and economically large.

In columns 2, 3 and 4 of Panel A of Table 6 we test whether our results hold when we separately analyze the years 1890, 1900 and 1910. We want to exclude the possibility that the pattern we document is driven by a single year of data, which could raise doubts about the validity and general nature of our findings. We find that our results hold for all the years in our sample. When we contrast the impact of more inclusive institutions in the counties with the longest occupation with those in unoccupied counties on innovation, we find a 231% increase in patents per capita in 1890. The magnitudes are 129% in 1900 and 100% in 1910. All effects are evaluated at the respective sample mean. The reason that the results are stronger for earlier years can be explained by the fact that institutions were harmonized across all Germany in 1900. Thus, in 1890 there are still differences in institutions across different parts of Germany; 1900 is the first year with harmonized institutions and by 1910 all counties already experienced at least 10 years of inclusive institutions. The fact that we find significant effects even in 1910 is testament to the long term impact of institutional history on innovation. This highlights the notion that the effect of institutional change on innovation is a relatively slowly decaying process with long lasting effects.

The results of further robustness checks are reported in Panel B of table 6. First, we focus on sub-regions within Germany.[31] In column 1 we exclude East Elbia (Ostelbien) from our sample. East Elbia represents the Prussian provinces East of the river Elbe that were dominated by agriculture. Therefore, this part of Germany could be a worse control group for the occupied areas. The effect of *Reforms* remains economically and statistically significant. Likewise, column 2 shows that our result holds if we perform our analysis only within Prussia, which accounts for more than half of the German population. The motivation for this test is that a within state analysis may provide a more homogeneous sample than the German Empire as a whole. In column 3 we restrict our sample to the Rhineland, Westphalia and Saxony. While the Rhineland, Westphalia, and the Northern part of the Prussian province of Saxony had been occupied by the French, the old territories of the Kingdom of Saxony had not been under French rule. This sample selection is motivated by

[31] See Appendix A1.2 and A1.3 for a description of our sub-samples.

the territorial reorganization of German states resulting from the Congress of Vienna. After the French defeat, Prussia was attempting to be compensated by gaining the whole territory of the Kingdom of Saxony, which was at the time considered as one of the - if not the most - prosperous regions of Germany with a high potential for economic growth.[32] The United Kingdom and Austria-Hungary however did not want to give such an economic powerhouse to Prussia. As a consequence, Prussia could only annex the economically less important Northern part of Saxony, but not its prosperous heartland (Flockerzie (1991)). In addition, Prussia was compensated with the major part of the Rhineland and Westphalia. From a Prussian perspective, these regions were considered both strategically and economically less attractive than Saxony. Interestingly, the regions of Rhineland and Westphalia, which Prussia gained against its initial intentions, had been occupied by the French and thus underwent substantial institutional reforms during the occupation. Our results in column 3 provide evidence that the Rhineland and Westphalia became more innovative *ex-post* due to the earlier implementation of institutional reforms, although Saxony seemed to be economically more promising *ex-ante*. The longest occupied counties implemented institutions that, on average, cause a 56% increase in innovation relative to the non-occupied counties in this sub-sample.

Moreover, in column 4 of Panel B of Table 6, we replace our instrument *Years French Occupation* with an *Occupation dummy*. This variable takes the value of one if the county was occupied by the French, and zero otherwise. The effect of *Reforms* on innovation remains economically and statistically significant. On average, occupied areas implemented institutional reforms 12 years earlier than non-occupied areas (first-stage). In turn, this led to a 73% increase in patents per capita, compared to the mean in our sample.

Finally, we vary our measure of institutional reforms in columns 5 and 6 of Panel B of Table 6. First, we use *ln(Reforms),* defined as the natural logarithm of *Reforms*, in column 5 in order to allow for a non-linear impact of *Reforms* on innovation, which decreases the impact of each additional year of institutional reforms. Using this alternative specification we find that the institutional reforms associated with going from no occupation to longest occupation leads to a 137% increase in innovation. Second, column 6 shows that our results also hold when we construct an alternative reforms index: *Alternative Reforms*. This alternative index differs from our main index in that it includes an additional reform, the year when patrimonial courts were effectively abolished in the

[32] See Kiesewetter (2004) for several economic indicators that underline this argument.

respective county. The end of patrimonial justice was a major step towards a society in which all people are treated equally before the law. While, in some regions, in particular in the Rhineland where the French occupation lasted longer, patrimonial justice was abolished with the introduction of the French code civil, it persisted for a longer period of time in states where the old order had been restored or states that had not been occupied (Werthmann (1995)). As column 6 shows, the effect of institutions on innovation remains highly significant if we use *Alternative Reforms* as our main variable of interest. Furthermore, the magnitude of the effect is almost the same as the one we obtain with our main index, which reflects the fact that our alternative measure is highly correlated with the basic index and alleviates concerns that measurement error in our index could be affecting our results.[33]

One interesting question that we are unable to answer with our research design is related to the individual impact of each institutional reform on innovation. The reason is that the reforms are highly correlated with each other. Counties that abolished serfdom early also tended to adopt agrarian reforms early, for example. Thus, we cannot conduct an instrumental variables analysis using individual reforms as that would violate the exclusion restriction that the instrument (*Years French Occupation*) is correlated with the variable of interest (one individual reform) but uncorrelated with any other determinants of the dependent variable (the other three reforms). To identify which institutional reform is the most important driver of innovation is thus beyond the scope of our paper. This question remains a fruitful area for future research.

## 5 Alternative Explanations

The French occupation could have brought about several changes in the German economy that may not be confined to institutions. In addition, although the French were not aiming to select regions to invade based on local economic prospects, it could be that by chance, the regions that were desirable for strategic reasons were also those that would fare better even in the absence of the French occupation. In this section we deal with this possibility and address several alternative explanations for our results. One challenge for all these alternative explanations however is that they also have to explain why the effect of institutional reforms on innovation is weaker in counties

[33] See Appendix A3.2 for information on *Alternative Reforms* and A3.3 for a discussion of further reform measures.

that were part of an ecclesiastical state prior to the French Revolution (see section 4.4).[34]

### 5.1 Reverse Causality: Economic Growth

One potential concern that we attempt to exclude is the possibility that growth leads to innovation instead of innovation being an engine of growth. If institutional reforms affected growth and in turn, growth fosters innovation, our findings could be a result of growth but not of more inclusive institutions. In this subsection we provide additional evidence that invalidates this interpretation.

In section 4.6 we perform the first test to addresses this concern. We stack the cards against us by comparing innovation in the non-occupied region of Saxony with that in the occupied Rhineland and Westphalia (column 3 of Panel B of Table 6). The idea behind this test is that Prussia attempted to obtain Saxony, but was instead compensated with the Rhineland and Westphalia, against its will. We find that, although in 1815 Saxony was seen as economically more promising, ex-post the Rhineland and Westphalia regions became more innovative due to the inclusiveness of their institutions. While we believe this test provides strong evidence to rule out reverse causality in our setting, we control for local economic development to further address this issue and show that our results remain economically and statistically significant.

The composition of the workforce is our proxy for economic prosperity. We rely on the notion that counties with a high share of people employed in manufacturing, mining and services were on average more prosperous and had grown faster than counties that were still dominated by agriculture at the end of the 19th century (see, for instance, Kuznets (1971)). In order to capture this, we use the following additional variables. *Manufacturing+Mining Workforce %* is computed as the share of people employed in manufacturing and mining relative to the total number of people employed in each county. Similarly, we compute *Services Workforce %* as the share of people employed in the private service sector relative to the total number of people employed in each county. In addition, we use *Mining County,* a dummy variable that is equal to one if the share of employees in mining and primary metal production relative to total employment in manufacturing and mining is larger than five percent in the respective county. Compared to the baseline control variables that merely measure the existence of coal and ore deposits, the variable *Mining County* reflects actual mining

[34]See the appendix for information on the data used to address the alternative explanations.

and metal production.[35] It identifies counties that were specialized in the extraction and processing of natural resources. By using this dummy, we take into account that mining was one of the leading sectors of industrialization in Germany due to the availability of natural resources, in particular coal (Holtfrerich (1973)). Our data considers only the main individual occupation. We compute the shares for 1900 and 1910 based on the German employment census of 1895 and 1907, respectively.

In column 1 of Table 7 we add to our baseline set of control variables the variables *Manufacturing+Mining Workforce %* and *Services Workforce %*. We find that the coefficients associated with these variables are positive and highly significant, reflecting the fact that more prosperous counties produce on average more innovations. A 10 percentage point increase in *Manufacturing+Mining Workforce %* is associated with an increase in innovation that corresponds to 18% of the mean of patents per capita, and a 10 percentage point increase in *Services Workforce %* is associated with an increase in innovation that corresponds to 51% of the mean of patents per capita. On the other hand, the coefficient for *Mining County,* which we add to the specification in column 2 is negative, albeit with a p-value of 12%.

Importantly, the impact of institutions on innovation remains economically and statistically significant in all columns after including these additional controls. The coefficient of 0.27 we find in column 2, when we saturate the regressions with all our controls for economic well-being, indicates that going from 0 to 19 years of French occupation is associated with an increase in the inclusiveness of local institutions that in turn leads to a 68% increase in innovation, comparing to an increase of 110% when estimating our baseline specification for the years 1900 and 1910. We also note that although our results remain economically important, the economic significance drops with the inclusion of these additional variables. This is not surprising, as economic prosperity is itself a function of innovation and as such we may be controlling away part of the effect we want to capture.

### 5.2 French Influence beyond Institutions: Culture, Technology and Knowledge Transfers

As we show in our first stage regression, the French occupations led to the implementation of important institutional reforms. However, the influence of the French may have extended beyond institutions. In particular an entrepreneurial culture or knowledge and technology transfers from

[35] The results are robust to choosing different thresholds for the dummy variable.

the French to the Germans are alternative channels by which the occupation may have impacted the propensity to innovate. We now show that these channels are unlikely to explain our findings.

Both the transmission of French culture and the potential for technology and knowledge transfers should be higher for German counties that border with France. This is not only because border counties were more likely to be occupied by the French, but also because German-French interactions should be stronger at the border to France, leading those German border regions to be those most susceptible to be influenced by access to French culture and in the most favorable position to benefit from knowledge spillovers. We would thus expect that if our findings were driven by culture, technology or knowledge transfers, we should find a positive coefficient (or at the very least an insignificant one) for the variable *Border France*. However, we find that the impact of *Border France* is significantly negative after including *Reforms* in the second stage regression (column 2 of Table 3). We interpret this as evidence that the increase in innovation, which we document in occupied areas, is not driven by the import of culture, technology or knowledge.

In addition, our results are robust to separating the sample into high- and low-tech patents. Both the modern chemical industry and the electrical industry, the high-tech sectors of this period, expanded at the end of the 19$^{\text{th}}$ century, long after the French occupation. By that time, Germany was the leading producer of dyestuffs, pharmaceuticals and other chemical products, while France lagged behind in these sectors (Henderson (1975), pp. 186-198). This timing and the fact that our results are stronger for high-tech patents make it unlikely that the French brought technological knowledge that fostered innovation. If they did, it had to be technology that would become valuable for innovation several decades later and in areas where the French did not seem to have a comparative advantage themselves.

To strengthen our arguments further, we contrast the level of industrial development in 1846 and 1861 for German regions that were occupied by the French relative to unoccupied territories. We find no evidence that occupied regions operated with a technological advantage in the early and mid 19th century, which again suggests that direct technology transfer or knowledge import is not a likely driver of our results. Instead, the French created the institutional setting that allowed occupied areas to be at the forefront of the next wave of innovation, which occurred later in the 19th century. In Table 8, we report the number of wool weaving looms by German states and Prussian provinces. We find no evidence that according to this metric, occupied territories profited more

from textile production technology import from France than non-occupied regions.[36] The same table also reports the number of machine-building factories in absolute and per capita terms. The most developed regions, according to these figures, were Saxony, Brandenburg and Wuerttemberg, which had not been occupied by the French. By contrast, the number of factories was low both in absolute and relative terms in the regions that had been under French rule. We therefore conclude that there is no evidence that occupied territories profited more from the transfer of knowledge and technology than non-occupied regions.

While there is no evidence for technology transfer in high-tech industries, French knowledge could have been important in sectors related to the early industrial revolution, for example, in the textile industry. During the Napoleonic Wars, the French textile industry flourished since British textile imports were substituted by domestic production as a result of the blockade (Juhász (2015)). In the Rhineland, which was under French rule, German textile firms also flourished in this period (Fehrenbach (2008), pp. 103-104). Import substitution policy could thus have fostered French technological transfer in occupied regions. However, there is no evidence that the boom in textile industry during the occupation had a long-run effect on the innovativeness of the regions. By contrast, Kisch (1989) argues that the textile firms in the Rhineland suffered from antiquated machinery after the French withdrew, since it had been difficult to keep up with modern British technology during the years of blockade.

### 5.3 Trade and Market Integration

Another potential concern relates to the possibility that the French occupied regions could have experienced a larger increase in international or domestic trade. Because border regions are likely to be more exposed to international trade, trade but not institutions could be driving the cross-sectional differences in innovation. It is important to note that our baseline specification includes controls for counties that are at an external border and for counties that have a border with France. If international trade, and in particular trade with France, was driving our results, we would expect both of these variables to have a positive coefficient. However, in column 2 of Table 3 the coefficients associated with these variables are negative and statistically significant. Furthermore, import and export statistics of both the Zollverein (the German customs union pre-dating the Germany unifi-

[36] We observe the similar pattern, if we take the number of cotton spindles into account.

cation in 1871) and the German Empire reveal that France did not dominate German foreign trade. In 1841, France was only the fourth most important country of origin for German imports, with a market share of 8.4 percent. This share declined in the following years (Panel A of Table 9). Among Germany's export destinations, France also ranked fourth with a market share of 11.4 percent in 1841. In addition, the share of German exports destined for France subsequently declined to values that ranged from 5.4% to 7.3% (Panel B of Table 9). Trade with France was less important than trade with other European countries like the United Kingdom, Austria-Hungary, Switzerland or the Netherlands. We therefore argue that there is no empirical evidence that the French occupation fostered foreign trade with Germany in the long-run nor that such French-German trade could drive our results.

In addition, as we have shown in section 2.1, the invasions induced a substantial territorial reorganization that included the dissolution and amalgamation of formerly independent small states. Against this backdrop, one could be worried that areas that could afford to be more politically fragmented before the French occupation were those with higher economic potential. The territorial reorganization could then have unleashed economic growth through a positive shock to market integration (Keller and Shiue (2015)). Failing to control for this factor could bias our estimates if the geography of territorial reorganizations was correlated with the geography of French occupation.

In Table 10 we address this concern by measuring the degree of potential gains from internal market integration using two proxies: *Old territories* and *Old territories/km²*. *Old territories* represents the number of independent territories that existed in 1789 within each region (Regierungsbezirk) of our sample. We also divide *Old territories* by squared kilometers to construct the variable *Old territories/km²*. We find a positive coefficient associated with the variable *Old territories* in column 1, and a negative coefficient associated with the variable *Old territories/km²* in column 2. Both coefficients are however statistically insignificant. Our variable of interest, *Reforms,* remains highly statistically significant and is of similar economic magnitude as in our baseline specification (Table 3). Moreover, in column 3 we include the variable *Internal Border,* a dummy variable that is equal to one if the county was located at an internal border (neighboring state became part of the German Empire), based on the borders of 1816. In column 4 we control for the membership of a customs union with the variable *Zollverein 1842* (Keller and Shiue (2014)). This variable is a dummy that equals one if a county was located within a state that belonged to the Zollverein in 1842, and zero

otherwise.[37] Our results show that belonging to the customs union is associated with a 50% increase in innovation, when evaluated at the mean of patents per capita. Finally, in columns 5 and 6 we simultaneously include controls for the number of old territories, borders and customs union. The variable Reforms which measures the effect of institutions on innovation remains highly statistically significant and the economic magnitudes are similar to those of our baseline specification.

### 5.4 Human Capital

An additional potential confounding effect in our analysis relates to human capital.[38] Regions that were occupied by the French could be better endowed with human capital which would then manifest itself in more innovation. In our baseline specification we control for the presence of universities prior to the French occupation. To further address this issue, we include additional controls in our specification to exclude the possibility that human capital, not institutions, is the driver of more innovation. In particular, we control for human capital by including three additional variables: *Illiterates 1876 %, University* and *Technical University.*

The variable *Illiterates 1876 %* is defined as the share of illiterates in the conscript age-group of 1875/76, based on the official records of the Imperial Statistical Office. The data is only available at the province level for Prussia and at the state level for all other German territories. Therefore, we cluster observations at the province-level for all human-capital related specifications. *University* is a dummy variable that is equal to one if a university was located contemporaneously within a county in the respective year, and zero otherwise. We include general universities, technical universities, mining academies, medical universities and higher trade colleges. We also explicitly control for the presence of technical universities or mining academies as these are the types of universities that could have a more direct impact on innovation, since they train engineers who may be more likely to innovate than graduates from non-technical sciences like law or humanities. We therefore include *Technical University* as an additional dummy variable that is equal to one if a technical university or a mining academy existed in a county in the respective year.

The results show a positive correlation between educational attainment and innovation. In

[37] See the Appendix A7.3 for a detailed explanation of why we choose 1842 as the benchmark year for the Zollverein. Our results are robust to both earlier and later benchmark years.

[38] Cinnirella and Streb (2013) suggest a positive effect of human capital on patenting activity for Prussia. See D'Acunto (2014) for another view on the empirical relationship between human capital and innovation.

column 1 of Table 11 we find that the share of illiterates in a county is negatively correlated with innovation. A one standard deviation increase in the share of illiterates is associated with a decrease of 6% of a standard deviation change in patents. In column 2 we find that counties with a University presence were more likely to innovate and in column 3 we find a small positive coefficient associated with the variable *Technical University*, although the coefficients associated with *University* and *Technical University* are not statistically significant. In column 4 we include all three variables in the same specification and find that only *Illiterates 1876 %* is statistically significant, with a negative point estimate. Across all four regression models, our variable of interest, *Reforms*, remains highly statistically significant and the economic magnitudes are virtually unaffected by the inclusion of the additional controls for the level of human capital of the local population. The institutional reforms associated with going from 0 to 19 years of French occupation lead to a 120% increase in innovation for model 4.

### 5.5 Financial Development

Finally, we test whether our results are driven by financial development. King and Levine (1993) and Levine and Zervos (1998) provide evidence of a link between finance and growth with innovation being a central channel. For the case of Germany, Gerschenkron (1962) highlights the strong relationships between universal banks and large industrial enterprises.[39]

If the French occupation was correlated with financial development, this could be the driver of the increase in innovation that we document. In Table 12 we add to our baseline specification the variable *Banking Workforce* computed as the share of the working population in permille employed in banking in each county. Like our previously constructed occupational measures, this variable only takes into account the main occupation. *No Banking* is a dummy variable that is equal to one for counties where no one was employed in banking according to this definition. As a further robustness check, we use *Banking+Insurance Workforce*, which is defined as the share of people in permille employed in banking and insurance. Consequently, *No Banking+Insurance Workforce* is a dummy variable that is equal to one for counties where no one was employed in banking or insurance. Our data is based on the German employment census of 1895 and 1907.

Table 12 shows that both *Banking Workforce* and *Banking+Insurance Workforce* have a signifi-

[39] See Guinnane (2002) for the debate on the role of universal banks in Germany.

cantly positive effect on innovation. Both *No Banking* and *No Banking+Insurance* have a negative coefficient, although only *No Banking+Insurance* is statistically significant. These results confirm the importance of financial development for innovation. However, the estimate of the impact of institutions on innovation is barely affected by the inclusion of these additional control variables, which increases our confidence in our hypothesis that institutions and not financial development are driving innovation in our setting.

# 6 Conclusion

In this paper, we empirically investigate the impact of institutions on innovation. We use the French occupation of parts of Germany in the early 19th century as a source of exogenous variation in the inclusiveness of local institutions. Regions that were occupied longer were early adopters of reforms that led to more inclusive institutions, creating an economy with fewer barriers to entry and fewer distortions in local labor and product markets.

These improvements in the quality of institutions in turn affected innovation in the long-run. Our results show that counties that were occupied the longest (19 years), and as a consequence put in place better institutions earlier on, had 129% more patents per capita than counties with worse institutions due to zero years of French occupation. We provide evidence that our results are unlikely to be driven by other potential confounding effects that could have been affected by the French occupation. These alternative explanations include reverse causality through economic growth, French influence beyond institutions such as culture or knowledge transfers, trade and market integration, differences in the level of human capital across regions, and financial development.

Our results thus point to institutions as a first order determinant of innovation. The findings in our paper are also relevant to understand the channel by which institutions may affect growth. Our results support the view that a way through which better institutions may lead to economic growth is by promoting a free market system and creating an economic environment more conducive to innovation.

An open question for future research is the identification of 'mediators' between more inclusive institutions and innovation, or, to put it differently, to identify micro-economic channels through which institutions affect innovation. For example, shorter and fairer trials that reduce transactions

costs could lead to higher levels of investment in R&D; better institutions could be related to stricter scrutiny and higher accountability of public officials leading to a more efficient provision of public goods; and lower frictions in labor markets could lead to a more efficient allocation of talent in the economy. Exploring the precise mechanisms that link the inclusiveness of institutions to innovation remains a fruitful avenue for future research.

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Table 1: Summary Statistics

This table presents the summary statistics for the main variables used in the paper. Panel A contains the time varying variables for each year. Panel B contains the time-invariant variables, using the population weights of the year 1900. In both panels we report the mean, standard deviation and number of observations separately for occupied and non-occupied counties. Patents is the number of patents per million county population. Reforms is the index of institutional reforms. The index is calculated as the average of the number of years between the implementation of a reform and the year in which a patent was filed. It considers four institutional reforms: (i) the introduction of the code civil, (ii) the abolition of serfdom, (iii) the implementation of agrarian reforms, and (iv) the dissolution of guilds. Population is the county population. Population/km$^2$ is the ratio of population and area. Protestants % is the percentage of the population that is Protestant. Minorities equals one if the fraction of the population whose native language is not German is above 50 percent. Years French Occupation is the number of years a county was occupied by the French. Area in km$^2$ is the county area in square kilometers. River equals one if a county has access to a navigable river. Harbor equals one if a county has a sea harbor. River*harbor equals one if a county both lies at a river and has a sea harbor. Border equals one if a county is at an external border of the German Empire. Border France equals one if a county is at the border to France. University 1789 equals one if a county has a university in 1789. Prussia 1816 equals one if a county is part of Prussia in 1816. City State equals one if a county is part of the Hanseatic city states Hamburg, Bremen or Lübeck. Coal Deposits equals one if the county has coal deposits. Ore Deposits equals one if the county has deposits of iron ore or non-ferrous metals. Population, area in km$^2$ and population/km$^2$ are equally weighted. All other variables are weighted by county population. Dummy variables are multiplied by 100 to facilitate the display of values. For more detail on the data see the appendix.

Panel A: Time Varying Variables

| | Occupied | | | Not Occupied | | |
|---|---|---|---|---|---|---|
| | Mean | St. Dev. | N | Mean | St. Dev. | N |
| 1890 | | | | | | |
| Patents | 8.66 | 19.77 | 306 | 3.67 | 10.83 | 669 |
| Reforms | 61.95 | 20.43 | 306 | 50.34 | 9.86 | 669 |
| Population | 48,702 | 45,476 | 306 | 48,921 | 69,002 | 669 |
| Population/km$^2$ | 567.26 | 1,417.13 | 306 | 387.48 | 1,581.07 | 669 |
| Protestants in % | 60.28 | 35.01 | 306 | 65.37 | 36.45 | 669 |
| Minorities in % | 0.00 | 0.00 | 306 | 10.81 | 31.07 | 669 |
| 1900 | | | | | | |
| Patents | 12.06 | 26.68 | 306 | 8.98 | 22.24 | 669 |
| Reforms | 70.16 | 21.21 | 306 | 58.34 | 9.73 | 669 |
| Population | 58,247 | 60,921 | 306 | 54,921 | 86,559 | 669 |
| Population/km$^2$ | 700.66 | 1,784.74 | 306 | 416.24 | 1,697.80 | 669 |
| Protestants in % | 59.78 | 34.24 | 306 | 65.82 | 36.06 | 669 |
| Minorities in % | 0.00 | 0.00 | 306 | 10.82 | 31.08 | 669 |
| 1910 | | | | | | |
| Patents | 26.90 | 41.20 | 306 | 21.73 | 45.78 | 669 |
| Reforms | 80.04 | 20.96 | 306 | 68.42 | 9.68 | 669 |
| Population | 70,099 | 82,624 | 306 | 62,056 | 104,600 | 669 |
| Population/km$^2$ | 646.12 | 1,444.50 | 306 | 426.99 | 1,750.88 | 669 |
| Protestants in % | 58.45 | 33.15 | 306 | 65.09 | 35.20 | 669 |
| Minorities in % | 0.00 | 0.00 | 306 | 10.98 | 31.29 | 669 |

Table 1: Summary Statistics (continued)

Panel B: Time Invariant Variables

| | Occupied | | | Not Occupied | | |
|---|---|---|---|---|---|---|
| | Mean | St. Dev. | N | Mean | St. Dev. | N |
| Years French Occupation | 9.28 | 5.81 | 306 | 0.00 | 0.00 | 669 |
| Area in $km^2$ | 419.19 | 272.03 | 306 | 592.53 | 412.34 | 669 |
| River in % | 49.87 | 50.08 | 306 | 38.29 | 48.65 | 669 |
| Harbor in % | 7.62 | 26.57 | 306 | 5.36 | 22.54 | 669 |
| River*harbor in % | 6.59 | 24.85 | 306 | 2.19 | 14.63 | 669 |
| Border in % | 10.34 | 30.50 | 306 | 14.99 | 35.72 | 669 |
| Border France in % | 3.43 | 18.22 | 306 | 1.07 | 10.29 | 669 |
| University 1789 in % | 11.06 | 31.42 | 306 | 12.58 | 33.18 | 669 |
| Prussia 1816 in % | 57.94 | 49.45 | 306 | 49.54 | 50.04 | 669 |
| City State in % | 6.12 | 24.00 | 306 | 0.00 | 0.00 | 669 |
| Coal Deposits in % | 34.73 | 47.69 | 306 | 24.06 | 42.78 | 669 |
| Ore Deposits in % | 15.32 | 36.08 | 306 | 12.58 | 33.19 | 669 |

Table 2: The Determinants of French Occupation

This table estimates the determinants of French occupation using OLS. The dependent variable is the number of years a county was occupied by the French, which varies between 0 and 19 years. All variables are defined in Table 1. One cross-section is used in the analysis. In the regression model of column 1 observations are equally-weighted. In the regression model of column 2 observations are weighted by county area. Standard errors are clustered at the regional level. P-values are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

| | (1) | (2) |
|---|---|---|
| | Years French Occupation | Years French Occupation |
| River | 1.145 | 0.703 |
| | (0.102) | (0.213) |
| Harbor | -1.040 | -1.156* |
| | (0.252) | (0.054) |
| River*Harbor | -0.234 | 1.486 |
| | (0.798) | (0.188) |
| University 1789 | 1.211 | 0.598 |
| | (0.181) | (0.523) |
| City State | 3.726*** | 3.494*** |
| | (0.000) | (0.000) |
| Coal Deposits | 1.044 | 0.451 |
| | (0.165) | (0.444) |
| Ore Deposits | 1.129 | 1.359 |
| | (0.321) | (0.192) |
| Adj. $R^2$ | 0.025 | 0.014 |
| N | 975 | 975 |
| Cluster | Region | Region |
| Weighting | Equal | Area |

Table 3: The Impact of Institutions on Innovation

This table estimates the impact of institutions on innovation using an instrumental variables approach. In the first-stage (column 1) we instrument Reforms with the years of French occupation. In column 2 we present the estimates from the second-stage regression of Patents on the instrumented Reforms and control variables. All variables are defined in Table 1. The observations are weighted by county population. Standard errors are clustered at the regional level. P-values are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

| | (1) | (2) |
|---|---|---|
| | Reforms | Patents |
| Years French Occupation | 1.593*** | |
| | (0.000) | |
| Reforms | | 0.405*** |
| | | (0.001) |
| Population/km$^2$ | -0.000 | 0.003*** |
| | (0.371) | (0.000) |
| River | 1.102 | 4.885 |
| | (0.243) | (0.102) |
| Harbor | 1.346 | -5.782*** |
| | (0.650) | (0.001) |
| River*Harbor | -1.436 | -7.581* |
| | (0.481) | (0.070) |
| Border | 1.434 | -3.500** |
| | (0.154) | (0.028) |
| Border France | 16.062** | -18.648*** |
| | (0.013) | (0.002) |
| University 1789 | 3.120 | -1.669 |
| | (0.167) | (0.731) |
| Protestants % | -0.053*** | 0.041** |
| | (0.008) | (0.033) |
| Minorities | -1.147 | -0.775 |
| | (0.491) | (0.669) |
| Prussia 1816 | 14.119*** | -12.312*** |
| | (0.000) | (0.001) |
| City State | -12.887*** | 6.570 |
| | (0.000) | (0.441) |
| Coal Deposits | -3.076** | 0.954 |
| | (0.012) | (0.491) |
| Ore Deposits | 1.274 | -1.665 |
| | (0.181) | (0.332) |
| Adj. $R^2$ | 0.800 | 0.294 |
| N | 2,925 | 2,925 |
| F-Stat. Ex. Instr. | | 60.55 |
| Year FE | Yes | Yes |
| Cluster | Region | Region |
| Weighting | Population | Population |

Table 4: The Differential Impact of Institutions on Innovation in Ecclesiastical States

This table estimates the differential impact of institutions on innovation for Ecclesiastical states. We present second-stage estimates of the impact of Reforms and Reforms*Ecclesiastical 1789 on innovation, where Reforms and Reforms*Ecclesiastical 1789 are instrumented by the years of French occupation and the interaction of the years of French occupation with Ecclesiastical 1789. Ecclesiastical 1789 is a dummy variable which equals one if a county was part of an ecclesiastical state in 1789. The dependent variable is patents per capita. All columns include the same control variables as in Table 3 but only Protestants % is displayed. The remaining variables are defined in Table 1. East Elbia is excluded from the sample. The observations are weighted by county population. Standard errors are clustered at the regional level. P-values are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. For more detail on the data see the appendix.

| | Patents |
|---|---|
| Reforms | 0.423** |
| | (0.020) |
| Ecclesiastical 1789 | 13.494 |
| | (0.219) |
| Reforms*Ecclesiastical 1789 | -0.287* |
| | (0.059) |
| Protestants % | 0.026 |
| | (0.408) |
| Adj. $R^2$ | 0.296 |
| N | 2,220 |
| F-Stat Ex. Instr. | 15.63 |
| Year FE | Yes |
| Cluster | Region |
| Weighting | Population |
| Controls | Yes |
| Sample | Excl. East Elbia |

Table 5: Different Types of Innovation

This table estimates the impact of institutions on innovation for different types of patents. In Panel A, we present second-stage instrumental variable estimates of the impact of institutions on innovation, measured by patents. Our measure of institutional reforms, Reforms, is instrumented by the years of French occupation. In Panel B, we present the economic magnitudes of the estimates. The dependent variables are High-tech Patents in column 1, Low-tech Patents in column 2, Firm Patents in column 3, Individual Patents in column 4 and High-tech Firm patents in column 5. Patents are categorized as high-tech if they are associated with chemicals and electrical electrical engineering. Low-tech patents are all non high-tech patents. Firm patents are those filed by corporations, and individual patents are those filed by individuals. High-tech Firm Patents are defined as high-tech patents filed by corporations. The economic magnitudes in Panel B are the increase in patents per capita associated with comparing the institutions in a county with no occupation to a county with the longest French occupation. All outcome variables are patents per million population. All control variables from Table 3 are included but not displayed. All remaining variables are defined in Table 1. The observations are weighted by county population. Standard errors are clustered at the regional level. P-values are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. For more detail on the data see the appendix.

Panel A: Regression Estimates

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | High-tech Patents | Low-tech Patents | Firm Patents | Individual Patents | High-tech Firm Patents |
| Reforms | 0.208** | 0.197** | 0.302*** | 0.103* | 0.195** |
| | (0.026) | (0.021) | (0.004) | (0.073) | (0.029) |
| Adj. $R^2$ | 0.118 | 0.278 | 0.219 | 0.221 | 0.091 |
| N | 2,925 | 2,925 | 2,925 | 2,925 | 2,925 |
| F-Stat. Ex. Instr. | 60.55 | 60.55 | 60.55 | 60.55 | 60.55 |
| Year FE | Yes | Yes | Yes | Yes | Yes |
| Cluster | Region | Region | Region | Region | Region |
| Weighting | Population | Population | Population | Population | Population |
| Controls | Yes | Yes | Yes | Yes | Yes |

Panel B: Economic Magnitudes

| (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|
| High-tech Patents | Low-tech Patents | Firm Patents | Individual Patents | High-tech Firm Patents |
| 288% | 82% | 197% | 64% | 359% |

Table 6: Robustness Tests

This table estimates the impact of institutions on innovation under different specifications. We present second-stage estimates of the impact of Reforms on innovation, where Reforms is instrumented by the years of French occupation in all models, except Model 4 of Panel B. The dependent variable is patents per capita. In Model 1 of Panel A we equally weight observations. In all other models counties are weighted by population. In Models 2 to 4 of Panel A the sample is restricted to the year 1890, 1900 or 1910, respectively. In Model 1 of Panel B East Elbia is excluded from the sample. In Model 2 (3) of Panel B only counties in Prussia (the Rhineland, Westfalia and Saxony) are included in the sample. In Model 4 of Panel B, Reforms is instrumented with a dummy that is 1 if a county was occupied by the French. In Model 5 of Panel B we use the logarithm of Reforms. In Model 6 of Panel B we use an alternative index of institutional reforms. All control variables from Table 3 are included but not displayed. All remaining variables are defined in Table 1. Standard errors are clustered at the regional level. P-values are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. For more detail on the data see the appendix.

Panel A: Equal Weighting of Observations and Individual Panel Years

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Patents | Patents | Patents | Patents |
| Reforms | 0.249*** | 0.304*** | 0.308** | 0.563*** |
| | (0.006) | (0.000) | (0.023) | (0.008) |
| Adj. $R^2$ | 0.061 | 0.115 | 0.231 | 0.367 |
| N | 2,925 | 975 | 975 | 975 |
| F-Stat. Ex. Instr. | 50.34 | 61.15 | 59.45 | 58.78 |
| Year FE | Yes | No | No | No |
| Cluster | Region | Region | Region | Region |
| Weighting | Equal | Populat. | Populat. | Populat. |
| Controls | Yes | Yes | Yes | Yes |
| Sample | All | 1890 | 1900 | 1910 |
| IV French Occ. | Years | Years | Years | Years |

Panel B: Varying Sample, Instrumental Variables and Variables of Interest

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Patents | Patents | Patents | Patents | Patents | Patents |
| Reforms | 0.286* | 0.321** | 0.207* | 0.779** | | |
| | (0.091) | (0.017) | (0.054) | (0.015) | | |
| ln(Reforms) | | | | | 32.202*** | |
| | | | | | (0.001) | |
| Alternative Reforms | | | | | | 0.368*** |
| | | | | | | (0.001) |
| Adj. $R^2$ | 0.287 | 0.421 | 0.463 | 0.276 | 0.291 | 0.297 |
| N | 2,220 | 1,635 | 462 | 2,925 | 2,925 | 2,922 |
| F-Stat. Ex. Instr. | 42.69 | 117.87 | 581.08 | 9.37 | 38.08 | 106.12 |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Cluster | Region | Region | Region | Region | Region | Region |
| Weighting | Populat. | Populat. | Populat. | Populat. | Populat. | Populat. |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Sample | Excl. East Elbia | Prussia | West vs. Saxony | All | All | All |
| IV French Occ. | Years | Years | Years | Dummy | Years | Years |

Table 7: Alternative Explanation: Reverse Causality through Economic Growth

This table estimates the impact of institutions on innovation controling for economic prosperity. We present second-stage instrumental variable estimates of the impact of institutions on innovation, measured by patents. Our measure of innovation, Reforms, is instrumented by the years of French occupation. Manufacturing+Mining Workforce % and Services Workforce % are the employment shares of manufacturing and mining, and services in %. Mining County equals one if the share of employees in mining and metal production relative to total employment in manufacturing and mining is larger than 5%. All control variables from Table 3 are included but not displayed. All remaining variables are defined in Table 1. The observations are weighted by county population. P-values are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. For more detail on the data see the appendix.

| | (1) | (2) |
|---|---|---|
| | Patents | Patents |
| Reforms | 0.264* | 0.272* |
| | (0.072) | (0.061) |
| Manufacturing+Mining Workforce % | 0.273*** | 0.300*** |
| | (0.000) | (0.000) |
| Services Workforce % | 0.896** | 0.849* |
| | (0.044) | (0.056) |
| Mining County | | -2.909 |
| | | (0.120) |
| Adj. $R^2$ | 0.357 | 0.357 |
| N | 1,950 | 1,950 |
| F-Stat. Ex. Instr. | 54.46 | 59.59 |
| Year FE | Yes | Yes |
| Cluster | Region | Region |
| Weighting | Population | Population |
| Controls | Yes | Yes |
| Sample | 1900 + 1910 | 1900 + 1910 |

Table 8: Alternative Explanation: Technology Import

This table presents the number of machine-building factories and number of wool weaving looms by German states or Prussian provinces. The number of machine-building factories includes shipyards. # stands for the number of factories/looms. PC stands for the number of factories/looms per thousand inhabitants of the respective state/province. For more detail on the data see the appendix.

| Year | 1846 | | | | 1861 | | | |
|---|---|---|---|---|---|---|---|---|
| State/Province | Factories | | Looms | | Factories | | Looms | |
| | # | PC | # | PC | # | PC | # | PC |
| Occupied | | | | | | | | |
| Brunswick | . | . | . | . | 9 | 32.0 | 119 | 0.42 |
| Electorate of Hesse | 4 | 5.3 | 610 | 0.81 | 7 | 9.5 | 852 | 1.15 |
| Oldenburg and Hannover | . | . | 1,150 | 0.58 | 30 | 14.1 | 1,670 | 0.79 |
| Province of Saxony (Prussia) | 12 | 6.9 | 2,750 | 1.59 | 45 | 22.9 | 2,867 | 1.46 |
| Rhineland (Prussia) | 31 | 11.2 | 9,717 | 3.52 | 72 | 22.4 | 12,456 | 3.88 |
| Westphalia (Prussia) | 16 | 11.1 | . | . | 25 | 15.5 | . | . |
| Total | 63 | | 14,227 | | 188 | | 17,964 | |
| Non-occupied | | | | | | | | |
| Anhalt | 2 | 13.2 | 749 | 4.96 | 9 | 49.7 | 172 | 0.95 |
| Baden | . | . | 346 | 0.25 | . | . | 599 | 0.44 |
| Bavaria | 14 | 3.6 | 3,189 | 0.82 | 23 | 5.6 | 2,656 | 0.65 |
| Brandenburg (Prussia) | 42 | 25.3 | 5,338 | 3.22 | 96 | 50.3 | 12,718 | 6.66 |
| East Prussia (Prussia) | 11 | 7.5 | . | . | 19 | 11.4 | . | . |
| Hesse-Darmstadt | 14 | 16.5 | 299 | 0.35 | 30 | 35.1 | 351 | 0.41 |
| Lippe | . | . | . | . | 1 | 9.2 | 20 | 0.18 |
| Nassau | 1 | 2.0 | 77 | 0.15 | 7 | 12.5 | 46 | 0.08 |
| Pomerania (Prussia) | 4 | 3.5 | . | . | 10 | 7.2 | . | . |
| Posen (Prussia) | 2 | 1.5 | . | . | 10 | 6.8 | . | . |
| Saxony | 232 | 126.9 | 13,741 | 7.52 | 164 | 74.1 | 17,379 | 7.85 |
| Silesia (Prussia) | 13 | 4.3 | 3,034 | 0.99 | 36 | 10.7 | 4,476 | 1.32 |
| Thuringian states | 2 | 2.1 | 4,101 | 4.41 | 18 | 18.0 | 10,282 | 10.26 |
| Waldeck and Pyrmont | . | . | . | . | . | . | 35 | 0.60 |
| Wuerttemberg | 17 | 9.9 | 2,570 | 1.49 | 48 | 27.9 | 1,841 | 1.07 |
| Total | 354 | | 33,444 | | 471 | | 50,575 | |
| Not classified & Others | 0 | | 991 | | 6 | | 5,203 | |

Table 9: Alternative Explanation: International Trade

This table presents information on the Germany's main trade partners for the period of 1841 to 1910. Panel A reports the share of imports from the main trade partners of Germany relative to total imports in percentage. Panel B presents the share of exports relative to total exports in percentage. Exports and imports for 1841 and 1851 include both Zollverein member and non-member states that became part of the German Empire in 1871. The category Others includes all countries for which no separate figures are available. For more detail on the data see the appendix.

Panel A: German Import Statistics

| Year | 1841 | 1851 | 1890 | 1900 | 1910 |
|---|---|---|---|---|---|
| Austria-Hungary | 13.3 | 9.4 | 14.0 | 12.0 | 8.5 |
| Belgium | 4.4 | 11.4 | 7.4 | 3.6 | 3.6 |
| Denmark | 1.3 | 1.2 | 1.4 | 1.2 | 1.8 |
| France | 8.4 | 6.1 | 6.3 | 5.1 | 5.7 |
| Netherlands | 19.6 | 20.0 | 7.2 | 3.6 | 2.9 |
| Russia | 2.8 | 3.6 | 12.7 | 11.9 | 15.5 |
| Sweden | 1.0 | 0.7 | 1.1 | 1.7 | 1.8 |
| Switzerland | 8.3 | 9.3 | 4.1 | 2.8 | 1.9 |
| United Kingdom | 23.1 | 25.4 | 15.0 | 13.9 | 8.6 |
| USA | 3.0 | 2.8 | 9.5 | 16.9 | 13.3 |
| Others | 14.9 | 10.1 | 21.3 | 27.3 | 36.3 |
| Total | 100 | 100 | 100 | 100 | 100 |

Panel B: German Export Statistics

| Year | 1841 | 1851 | 1890 | 1900 | 1910 |
|---|---|---|---|---|---|
| Austria-Hungary | 17.2 | 22.5 | 10.3 | 10.7 | 11.0 |
| Belgium | 3.0 | 9.1 | 4.4 | 5.3 | 5.2 |
| Denmark | 3.3 | 3.0 | 2.2 | 2.6 | 3.0 |
| France | 11.4 | 5.4 | 6.8 | 5.8 | 7.3 |
| Netherlands | 11.7 | 12.4 | 7.6 | 8.3 | 6.7 |
| Russia | 6.4 | 7.3 | 6.1 | 6.8 | 7.3 |
| Sweden | 1.4 | 1.4 | 2.7 | 2.9 | 2.5 |
| Switzerland | 11.2 | 9.2 | 5.3 | 6.1 | 6.1 |
| United Kingdom | 20.9 | 15.9 | 20.7 | 19.2 | 14.7 |
| USA | 1.3 | 4.9 | 12.2 | 9.2 | 8.5 |
| Others | 12.2 | 9.0 | 21.8 | 22.8 | 27.7 |
| Total | 100 | 100 | 100 | 100 | 100 |

Table 10: Alternative Explanations: Trade and Market Integration

This table estimates the impact of institutions on innovation after controling for different measures of trade and market integration. We present second-stage instrumental variable estimates of the impact of institutions on innovation, measured by patents. Our measure of innovation, Reforms, is instrumented by the years of French occupation. Old territories represents the number of independent territories that existed in 1789 within each region (Regierungsbezirk). Old territories/km$^2$ is Old territories divided by square kilometers. Internal Border is a dummy variable which equals one if a county is located at an internal state border. Zollverein 1842 is a dummy which equals one if a county was part of a German state that was a member of the German customs union Zollverein in 1842. All control variables from Table 3 are included but not displayed. All remaining variables are defined in Table 1. The observations are weighted by county population. Standard errors are clustered at the regional level. P-values are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. For more detail on the data see the appendix.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Patents | Patents | Patents | Patents | Patents | Patents |
| Reforms | 0.342*** | 0.515*** | 0.403*** | 0.454*** | 0.406*** | 0.596*** |
| | (0.007) | (0.000) | (0.001) | (0.000) | (0.001) | (0.000) |
| Old territories | 0.278 | | | | 0.185 | |
| | (0.231) | | | | (0.393) | |
| Old territories/km$^2$ | | -1.608 | | | | -2.024* |
| | | (0.124) | | | | (0.063) |
| Internal Border | | | 0.414 | | 0.303 | 1.782 |
| | | | (0.878) | | (0.909) | (0.525) |
| Zollverein 1842 | | | | 6.510** | 5.866** | 8.177*** |
| | | | | (0.010) | (0.023) | (0.005) |
| Adj. $R^2$ | 0.296 | 0.300 | 0.294 | 0.296 | 0.297 | 0.304 |
| N | 2,925 | 2,925 | 2,925 | 2,925 | 2,925 | 2,925 |
| F-Stat. Ex. Instr. | 54.24 | 48.04 | 59.90 | 89.66 | 81.39 | 66.17 |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Cluster | Region | Region | Region | Region | Region | Region |
| Weighting | Population | Population | Population | Population | Population | Population |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |

Table 11: Alternative Explanations: Human Capital

This table estimates the impact of institutions on innovation after controling for human capital. We present second-stage instrumental variable estimates of the impact of institutions on innovation, as measured by patents. Our measure of innovation, Reforms, is instrumented by the years of French occupation. Illiterates 1876 % is defined as the share of illiterates in the conscript age-group of 1875/76 at the province level. University equals one if a university was located within a county in the respective year. It includes general universities, technical universities, mining academies, medical universities and higher trade colleges. Technical University equals one if a technical university or mining academy was located in the county in the respective year. All control variables from Table 3 are included but not displayed. All remaining variables are defined in Table 1. The observations are weighted by county population. Standard errors are clustered at the province level. P-values are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. For more detail on the data see the appendix.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Patents | Patents | Patents | Patents |
| Reforms | 0.365** | 0.415*** | 0.406*** | 0.377** |
| | (0.017) | (0.002) | (0.003) | (0.014) |
| Illiterates 1876 % | -0.561** | | | -0.580** |
| | (0.022) | | | (0.016) |
| University | | 4.061 | | 7.034 |
| | | (0.485) | | (0.165) |
| Technical University | | | 0.971 | -3.922 |
| | | | (0.888) | (0.593) |
| Adj. $R^2$ | 0.295 | 0.294 | 0.294 | 0.296 |
| N | 2,925 | 2,925 | 2,925 | 2,925 |
| F-Stat. Ex. Instr. | 23.28 | 28.98 | 27.97 | 24.40 |
| Year FE | Yes | Yes | Yes | Yes |
| Cluster | Province | Province | Province | Province |
| Weighting | Population | Population | Population | Population |
| Controls | Yes | Yes | Yes | Yes |

Table 12: Alternative Explanations: Financial Development

This table estimates the impact of institutions on innovation after controling for financial development. We present second-stage instrumental variable estimates of the impact of institutions on innovation, as measured by patents. Our measure of innovation, Reforms, is instrumented by the years of French occupation. Banking Workforce is computed as the share of the working population employed in banking in each county and is expressed in permille. No Banking equals one if nobody is employed in banking in a given county. Banking+Insurance Workforce is computed as the share of the working population employed in banking and insurance in each county and is expressed in permille. No Banking+Insurance equals one if nobody is employed in banking or insurance in a given county. Data for these variables are available for the years 1900 and 1910. All control variables from Table 3 are included but not displayed. All remaining variables are defined in Table 1. The observations are weighted by county population. Standard errors are clustered at the regional level. P-values are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. For more detail on the data see the appendix.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Patents | Patents | Patents | Patents |
| Reforms | 0.401*** | 0.435*** | 0.392*** | 0.438*** |
| | (0.005) | (0.006) | (0.006) | (0.006) |
| Banking Workforce | 3.705*** | | | |
| | (0.000) | | | |
| No Banking | | -2.716 | | |
| | | (0.149) | | |
| Banking+Insurance Workforce | | | 2.152*** | |
| | | | (0.000) | |
| No Banking+Insurance | | | | -3.542* |
| | | | | (0.069) |
| Adj. $R^2$ | 0.364 | 0.321 | 0.367 | 0.321 |
| N | 1,946 | 1,946 | 1,946 | 1,946 |
| F-Stat. Ex. Instr. | 59.83 | 59.35 | 59.50 | 59.71 |
| Year FE | Yes | Yes | Yes | Yes |
| Cluster | Region | Region | Region | Region |
| Weighting | Population | Population | Population | Population |
| Controls | Yes | Yes | Yes | Yes |
| Sample | 1900 + 1910 | 1900 + 1910 | 1900 + 1910 | 1900 + 1910 |

# Appendix

## A1 Structure of the Data Set

### A1.1 General Structure

The structure of our data set reflects the administrative structure of the German Empire, which consisted of 25 federal states. Prussia was by far the most important one, accounting for a population share of 61.2 percent in 1900 (see Deutsches Reich (1903a) for population figures). It was subdivided in provinces (Provinzen), regions (Regierungsbezirke), and counties (Kreise). The medium-sized states like Bavaria or Saxony were organized in regions and counties, while the smaller principalities were only subdivided in counties. We use county data, the lowest level for which the official census publications of the Imperial Statistical Office provide information. To account for potential correlation within regions, standard errors are clustered at the region level in all regressions. Every small German state, which was not subdivided into regions, is treated as an independent region. In total, we consider all 25 German federal states. Alsace-Lorraine, which was annexed in 1871 as a result of the French defeat in the Franco-German War, is excluded since it was not a federal state: Alsace-Lorraine was a territory with a minor status (Reichsland) directly subordinated to the German Emperor, where the inhabitants had less rights than the citizens of the German federal states, and it was ruled by an Imperial governor coming from outside Alsace-Lorraine, who frequently was a high-ranking Prussian officer.

The county borders changed over time as a result of administrative reforms. In most cases, the size of the counties was reduced so that the number of counties increased. Our data set represents the administrative structure in the year 1890, our first sample year. In order to generate a balanced panel, we match the counties in all subsequent years to the administrative structure in the year 1890 (for example: Witten (city) was separated from Bochum in 1899. Thus, we merged Witten (city) and Bochum in order to maintain the structure of 1890). Furthermore, for a couple of smaller German federal states (e.g. the Principality of Lippe), some data was only available on a higher aggregated level so that we had to merge counties. After all adjustments, our data set includes 975 county-level observations per year.

### A1.2 Definition of East Elbia

In Table 4 and column 1 of Panel B in Table 6, we use a sub-sample which excludes East Elbia (Ostelbien), the Eastern Prussian provinces that were dominated by agriculture. In the historical literature, this geographical area is typically associated with economic backwardness, a high landownership concentration and bad institutions (see, for example, Wagner (2005) for a detailed description of the society in East Elbia). We define the following Prussian provinces as part of East Elbia: Brandenburg, Silesia, Pomerania, Posen, West Prussia, and East Prussia. Note that we treat the capital city Berlin, which was administered as a separate district, not as part of East Elbia since it lacks the relevant socioeconomic features that characterize East Elbia.

### A1.3 Definition of West vs. Saxony

In column 3 of Panel B in Table 6, we use the sub-sample West vs. Saxony to compare economically leading regions in the Western and Eastern parts of Germany. We include the Prussian Rhine Province, the Province of Westphalia, the Prussian Province of Saxony, and the Kingdom of Saxony (in its pre-1815 borders) in this sub-sample.

## A2 Patent Data

We extracted our patent data from the Baten/Streb patent database (see Streb, Baten, and Yin (2006) for a detailed description of the data set). It contains all patents granted in the German Empire between 1877 and 1913 that were renewed for at last 10 years, out of a maximum length permitted by patent law of 15 years. The original data set includes information about the location of the patentee, the technological class of the patent, and information regarding whether the patentee was a firm or a private individual. We assigned every patent to the historic German county, where the patentee was located. The variable *Patents* is defined as the total number of patents, which originated from the respective county in the respective year, divided by the county population. Population figures for 1890, 1900 and 1910 are extracted from the official census records of the Imperial Statistical Office (1890: Deutsches Reich (1894); 1900: Deutsches Reich (1903b); 1910: Deutsches Reich (1915)).

In addition, we used information about the technology class of the patents to create sub-samples.

Technology classes were used by the Imperial Patent Office in order to classify inventions. In total, there were 89 different major classes. Due to the emergence of new technologies and the rising number patents, the Imperial Patent Office extended its classification scheme by introducing sub-classes in 1900 (for example, class 21 (electrical engineering) was subdivided into 8 sub-classes ranging from 21a (communications engineering) to 21h (processes and installations for electrical heating and smelting including metalworking based on electrically generated heat)). We use this classification to distinguish between high-tech and low-tech patents. High-tech patents are defined as all patents related to the chemical industry and electrical engineering, the two leading sectors of the second industrial revolution. For the chemical industry, we include general chemical processes and applications (class 12), fertilizers (class 16), dyestuffs (class 22), and textile chemistry (class 8i to 8o); for electrical engineering, we include general electrical engineering (class 21) as well as electrical trains and electrical railway equipment (20k and 20l). All other classes are defined as low-tech. The variable *High-tech Patents* (*Low-tech Patents*) represents the total number of high-tech (low-tech) patents, which originated from the respective county in the respective year, divided by the county population.

Furthermore, we distinguish between patents filed by firms and individuals. The variable *Firm Patents* (*Individual Patents*) is defined as the total number of firm (individual) patents, which originated from the respective county in the respective year, divided by the county population. Accordingly, we use the variable *High-tech Firm Patents* for all high-tech patents (see definition above), which were filed by firms from the respective county in the respective year, divided by the county population.

To ease the display of coefficients all patent variables represent patents per million inhabitants.

## A3 Institutional Reforms

### A3.1 Reform Index

Our index (*Reforms*) is based on four institutional reforms: the introduction of a civil code, the abolition of serfdom, the implementation of agrarian reforms and the dissolution of guilds. We determine the year of reform implementation according to Acemoglu, Cantoni, Johnson, and Robinson (2011a). For the following German states, our reform index is based on information published in their online

appendix (Acemoglu, Cantoni, Johnson, and Robinson (2011b)): Kingdom of Prussia, Kingdom of Bavaria, Palatinate (Bavarian exclave west of the Rhine), Kingdom of Saxony, Kingdom of Wuerttemberg, Grand Duchy of Baden, Grand Duchy of Brunswick, Grand Duchy of Hesse-Darmstadt, Grand Duchy of Mecklenburg-Schwerin. Since we deal with data on the county level, we adjusted and extended the data for some territorial entities. Our information about the political affiliation of counties or border changes is based on various maps that are published online on the server for digital historical maps at the Leibniz Institute of European History in Mainz (IEG-MAPS) (link: http://www.ieg-maps.uni-mainz.de). In addition to the territories above, we collected information for all small German states for which accurate information about the year of reform implementation is available in the historic literature. Our sources are described below. In the following, we document all changes compared to the original coding of Acemoglu, Cantoni, Johnson, and Robinson (2011a), as well as the sources for all newly added territories:

**Kingdom of Prussia:**

(a) Provinces of Brandenburg, Saxony and Silesia: We take account for those counties that formed the Northern part of the Kingdom of Saxony before 1815. These counties were annexed by Prussia and became part of the Prussian provinces of Brandenburg, Saxony and Silesia. Institutional change did not take place before 1815 in these counties. We therefore adjust the reform index accordingly.

(b) Province of Hesse-Nassau: As a result of its victory in the Austro-German War, Prussia annexed several territories (Electorate of Hesse, Duchy of Nassau, Landgraviate of Hesse-Homburg, and Free City of Frankfurt am Main), which constituted the Prussian province of Hesse-Nassau in the subsequent years. Acemoglu, Cantoni, Johnson, and Robinson (2011a) report reform data for the Northern part (former Electorate of Hesse), but not for the region in the South-West (former Duchy of Nassau). Information about the years of reform implementation for the missing part is from Schüler (2006). Furthermore, we adjust the values for the county of Biedenkopf, which belonged to Hesse-Darmstadt until 1866, and thus differed with regard to the years of reform implementation.

(c) Rhine Province: The main part of the province is located west of the Rhine, but there were also several counties on the East side (core territory of the Grand Duchy of Berg until 1815). Acemoglu, Cantoni, Johnson, and Robinson (2011a) use province level data based on the reforms in the western part. Since the years of reform implementation differ slightly for the counties on the East side, we use additional information from Klippel (1996) and Schubert (1977) to adjust the

data. Furthermore, the counties of Altenkirchen and Neuwied belonged to Nassau until 1866, and thus differed in institutional quality. We use information from Schüler (2006) to get data for the years of reform implementation in Nassau (see also our comments in (b)).

(d) Province of Schleswig-Holstein: Information about institutional reforms in Schleswig-Holstein is reported in Acemoglu, Cantoni, Johnson, and Robinson (2011a). Lauenburg was part of the Kingdom of Hanover until 1866, and therefore the years of reform implementation differed. After the Prussian annexation of Hanover, Lauenburg became part of Schleswig-Holstein. We take this change into account and adjust the reform values. Information about reforms in Hanover, which we use for Lauenburg,is reported in Acemoglu, Cantoni, Johnson, and Robinson (2011a).

(e) Province of Westphalia: The Southern part of the province belonged to Hesse-Darmstadt until 1815, where reforms were implemented in different years. We therefore adjust our reform data for the respective counties based on information about reform implementation in Hesse-Darmstadt.

**Kingdom of Bavaria:**

Acemoglu, Cantoni, Johnson, and Robinson (2011a) only consider the Eastern part of Bavaria (the mainland around Munich), but not the Frankonian and Swabian regions. Since we identify no differences with regard to the year of reform implementation, we take the same variables as for the Eastern part of Bavaria.

**Grand Duchy of Hesse-Darmstadt:**

The western part on the left side of the Rhine (Rheinhessen) became part of Hesse-Darmstadt as a result of the Congress of Vienna. Acemoglu, Cantoni, Johnson, and Robinson (2011a) do not treat this region separately. Rheinhessen was under French rule and thus implemented reforms earlier. Furthermore, institutions remained after the French withdraw. We therefore assign the same reform values for Rheinhessen as for the Palatinate.

**Grand Duchy of Mecklenburg-Strelitz:**

Mecklenburg-Schwerin and Mecklenburg-Strelitz were strongly linked with regard to economic and political terms so that reforms were implemented in the same years and the same way (see Mast (1994), pp. 113-153). We therefore use the same years of implementation as for Mecklenburg-Schwerin (see Acemoglu, Cantoni, Johnson, and Robinson (2011a)).

**Grand Duchy of Oldenburg:**

Besides its main territory in the north-west of Germany, Oldenburg possessed two small exclaves:

Birkenfeld (in the Rhineland) and the Principality of Luebeck (north of the independent city of Luebeck). For the main territory: abolition of serfdom: Eckhardt and Schmidt (1987), p. 717-719; agricultural reforms: Eckhardt and Schmidt (1987), p. 717-719; dissolution of guilds: Eckhardt and Schmidt (1987), p. 354; code civil: Klippel (1996). The introduction of some reforms differed for both exclaves, in particular for the territory of Birkenfeld which was under French occupation for 19 years. We thus adjusted the corresponding reform values based on information in Eckhardt and Schmidt (1987) and Schubert (1977).

**Grand Duchy of Saxe-Weimar-Eisenach:**

Abolition of serfdom: Patze and Schlesinger (1978), p. 41; agricultural reforms: Patze and Schlesinger (1978), p. 142; dissolution of guilds: Patze and Schlesinger (1978), p. 144; code civil: Klippel (1996).

**Duchy of Anhalt:**

The Duchy was created in 1863 by unification of Anhalt-Dessau and Anhalt-Bernburg. We treat the preceding territories separately since the years of reform implementation differed. We used the following sources: abolition of serfdom: Kraaz (1898) pp. 190-206 and p. 214; agricultural reforms: Kraaz (1898), pp. 218-223; dissolution of guilds: Norddeutscher Bund (1869); code civil: Klippel (1996); Schubert (1977).

**Duchy of Saxe-Altenburg:**

Abolition of serfdom: Patze and Schlesinger (1978), p. 41; agricultural reforms: Patze and Schlesinger (1978), p. 142; dissolution of guilds: Patze and Schlesinger (1978), p. 144; code civil : Klippel (1996).

**Duchy of Saxe-Coburg-Gotha:**

Abolition of serfdom: Patze and Schlesinger (1978), p. 141-142; agricultural reforms: Patze and Schlesinger (1978), p. 142; dissolution of guilds: Patze and Schlesinger (1978), p. 144; code civil: Klippel (1996).

**Duchy of Saxe-Meiningen:**

Abolition of serfdom: Patze and Schlesinger (1978), p. 141; agricultural reforms: Patze and Schlesinger (1978), p. 142; dissolution of guilds: Patze and Schlesinger (1978), p. 144; code civil: Klippel (1996).

**Principality of Lippe:**

Abolition of serfdom and agricultural reforms: Arndt (1992), pp. 266-272; dissolution of guilds: Arndt (1992), p. 295; introduction of code civil: Klippel (1996).

**Principality of Reuss, older line:**

Abolition of serfdom and agricultural reforms: Patze and Schlesinger (1978), p. 142; dissolution of guilds: Patze and Schlesinger (1978), p. 144; code civil: Klippel (1996).

**Principality of Reuss, younger line:**

Abolition of serfdom: Patze and Schlesinger (1978), p. 41; agricultural reforms: Patze and Schlesinger (1978), p. 142; dissolution of guilds: Patze and Schlesinger (1978), p. 144; code civil: Klippel (1996).

**Principality of Schaumburg-Lippe:**

Abolition of serfdom: Havliza (1975), p. 13-34; agricultural reforms: Schneider (1983); dissolution of guilds from Norddeutscher Bund (1871), p. 714; code civil: Klippel (1996).

**Principality of Schwarzburg-Rudolstadt:**

Abolition of serfdom: Patze and Schlesinger (1978), p. 141-142; agricultural reforms: Patze and Schlesinger (1978), p. 142; dissolution of guilds: Patze and Schlesinger (1978), p. 144; code civil: Klippel (1996).

**Principality of Schwarzburg-Sondershausen:**

Abolition of serfdom: Patze and Schlesinger (1978), p. 141-142; agricultural reforms: Patze and Schlesinger (1978), p. 142; dissolution of guilds: Patze and Schlesinger (1978), p. 144; code civil: Klippel (1996).

**Principality of Waldeck and Pyrmont:**

Abolition of serfdom and agricultural reforms: Seidel (1964), pp. 181-182; dissolution of guilds: Brand (2006), p. 97; code civil: Klippel (1996).

**Free and Hanseatic City of Bremen:**

Abolition of serfdom: Schubert (1977), pp. 381-382; dissolution of guilds: Schulz (1995), p. 157; code civil: Klippel (1996) and Schubert (1977), pp. 153-161. We have no information about agrarian reforms since Bremen was a city state. Thus, the reform index is constructed over three reforms.

**Free and Hanseatic City of Hamburg:**

Abolition of serfdom: Schubert (1977), pp. 381-382; dissolution of guilds: Schulz (1995), p. 145; code civil: Klippel (1996) and Schubert (1977), pp. 153-161. We have no information about agrarian

reforms since Hamburg was a city state. Thus, the reform index is constructed over three reforms.

**Free and Hanseatic City of Luebeck:**

Abolition of serfdom: Schubert (1977), pp. 381-382; dissolution of guilds: Endres (1926), p. 145; code civil: Klippel (1996) and Schubert (1977), pp. 153-161. We have no information about agrarian reforms since Luebeck was a city state. Thus, the reform index is constructed over three reforms.

### A3.2 Alternative Reform Index

We use an alternative reform index (*Alternative Reforms*) to test whether our results are robust to different measures for institutional quality. *Alternative Reforms* include the reforms mentioned above and is computed in the same way, but it also includes an additional reform measure: the year when patrimonial courts were effectively abolished in the respective territory. Consequently, we compute the average index value over five reform measures. Information about the abolition of patrimonial courts are from Werthmann (1995), and for all Thuringian states (Saxe-Weimar-Eisenach, Saxe-Altenburg, Saxe-Coburg-Gotha, Saxe-Meiningen, Reuss, younger line, Reuss, older line, Schwarzburg-Rudolstadt, and Schwarzburg-Sondershausen) from Heß (1993), p. 64. We used additional sources for Oldenburg (Eckhardt and Schmidt (1987), pp. 352-353), Anhalt (Kraaz (1898), pp. 192-218), Schaumburg-Lippe (Havliza (1975), p. 31-36), and Waldeck and Pyrmont (Seidel (1964), pp. 182). Since comparable patrimonial courts were not in operation in the city states (Bremen, Hamburg and Lübeck), we do not include this reform. Thus, *Alternative Reforms* only contains three reforms (abolition of serfdom, dissolution of guilds and code civil) for these cases.

### A3.3 Discussion of Further Reform Measures

Kopsidis and Bromley (2016a) suggest a different coding of the reform index. In particular, they argue that the coding in Acemoglu, Cantoni, Johnson, and Robinson (2011a) underestimates the institutional quality of non-occupied territories and thus provide a list of alternative years of reform implementation. There are several reasons why we refer to the original coding. First, Acemoglu, Cantoni, Johnson, and Robinson (2011a) describe in detail both the criteria that were used to define the year of reform implementation as well as the sources for each individual coding (see in particular the online appendix of their paper (Acemoglu, Cantoni, Johnson, and Robinson (2011b))) while

Kopsidis and Bromley (2016a) use not only less strict criteria, but also provide no references for the individual years of reform implementation at all (see the online appendix of their paper (Kopsidis and Bromley (2016b))). Second, since Kopsidis and Bromley (2016a) provide no sources, we checked their coding based on the historical literature. We are confident that the coding of Acemoglu, Cantoni, Johnson, and Robinson (2011a) reflects the institutional quality better. The following two examples underline this argument:

For the Kingdom of Wuerttemberg, Kopsidis and Bromley (2016a) suggest that 1828 should be used as the year when guilds were abolished. In their appendix, they motivate this by the fact that the Common trade regulation act (Allgemeine Gewerbeordnung) was introduced in 1828. This trade act caused the dissolution of some guilds, but there is strong evidence from historical studies that the remaining guilds still affected the economic development in a negative way. Furthermore, as we have argued in section 2.3, even sectors that were not regulated by guilds were heavily restricted since trade licenses were necessary to establish a business. The allocation of trade licenses was very restricted and, in the case of Wuerttemberg, this system was also used to protect the interest of powerful guilds (see section 2.3, and, for example, Arns (1986) or Fischer (1962) for the restrictiveness of the trade license system). In the same way as Acemoglu, Cantoni, Johnson, and Robinson (2011b), we therefore define the year of reform implementation as the year when commercial freedom (Gewerbefreiheit) was established (in the case of Wuerttemberg: 1862).

For the Eastern provinces of Prussia, Kopsidis and Bromley (2016a) argue that the Prussian October Decree (Oktoberedikt) of 1807 marked the introduction of the code civil in Prussia, while Acemoglu, Cantoni, Johnson, and Robinson (2011b) use 1900, the year when the nationwide German Civil Law (Bürgerlisches Gesetzbuch) was introduced. The latter is motivated by the fact that under the General State Laws for the Prussian States (Allgemeines Landrecht für die Preußischen Staaten), which existed until 1900, people were not treated equally before court. From our point of view, taking 1807 as the year of introduction completely overestimates the institutional quality of these provinces since very discriminating legal institutions had not yet been abolished in comparison with the territories that had been under French rule. In particular, patrimonial justice persisted in the Eastern Prussian provinces until 1849. The local lords of manor lost their police powers in the same years, at least in some parts this privilege was officially reintroduced in 1853 (see in particular Werthmann (1995) for the dissolution of patrimonial courts in German states). Apart from that,

there are detailed historical case studies about the society and daily live of people living in this provinces that point out to the persistence of non-inclusive institutions during the 19th century (see, for example, Wagner (2005)). Given the previously mentioned arguments, we use 1900 as the year when the code civil was introduced. Nevertheless, we account for this concern, with the variable *Alternative Reforms* (see section 4.6 and A3.2), which includes the abolition of patrimonial courts as an additional measure.

Apart from their critique regarding the coding of the specif reforms, Kopsidis and Bromley (2016a) argue that the abolition of serfdom is a more a less meaningless measure, which should be excluded from the construction of the *Reforms* variable. In the late 18th century, serfdom was indeed less strict than in earlier periods. However, it should be used as a measure for institutional quality even it was not comparable with a kind of slavery in our period of interest. Under the manorial system, the live of the serfs was restricted to the extend that they were dutiable to their lord of manor. Depending on the way serfdom was organized locally, the people had to pay monetary contributions, they had to deliver payments in kind, or they had to fulfill work obligations (see, for example, Achilles (1993)). These measures in turn restricted both social mobility and labor market mobility. The formal abolition of serfdom was the first step in a series of agricultural reforms in which the former serfs were relived from these duties. In territories where serfdom was abolished earlier, other agricultural reforms could also be implemented earlier. The year when a law was implemented that finally regulated the redemption of feudal lands, which reflects the reform measure 'agricultural reforms' in Acemoglu, Cantoni, Johnson, and Robinson (2011b), is in most cases the end of this reform process. However, it is worth to point out that excluding this variable does not affect our results. In additional unreported robustness checks, we included a reform index that only includes the introduction of the code civil as well as the dissolution of guilds, and we also ran our regressions for guilds only. In both cases our results suggest a economically and statistically strong effect of institutions on innovation. However, from our point of view the measures used in our paper (*Reforms* and *Alternative Reforms*) reflect the actual institutional quality far better.

### A4 French Occupation

We follow the approach of Acemoglu, Cantoni, Johnson, and Robinson (2011a) to identify the years of French occupation. We define a territory as occupied if it was under direct French rule or under

the rule of a French-controlled satellite state, which include the Grand Duchy of Berg, the Kingdom of Westphalia, and the Grand Duchy of Frankfurt, which were ruled by family members of Napoleon. Accordingly, the period of French occupation ranges between 19 and zero years. Since Acemoglu, Cantoni, Johnson, and Robinson (2011a) only provide data on the state level (on the province for Prussia), we used various historical maps to identify the years of French occupation on the county-level. The maps are published online on IEG-MAPS (link: http://www.ieg-maps.uni-mainz.de).

## A5 Basic Control Variables

### A5.1 Population Density

The variable *Population/Km²* represents the population density measured by the inhabitants of each county divided by its area size in square kilometers. Both county population and area size are extracted from the official German census publications (for 1890: Deutsches Reich (1894); for 1900: Deutsches Reich (1903b); for 1910: Deutsches Reich (1915)).

### A5.2 Rivers and Harbors

*River* is a dummy variable that is equal to one if the respective county is located at a navigable waterway, and zero else. We include all rivers and canals that were navigable in 1850, based on the map *Schiffahrtsstrassen im Deutschen Zolllverin 1850*, which is available online on IEG-MAPS (link: http://www.ieg-maps.uni-mainz.de/gif/w850d_a4.htm). We use the same map to identify counties with major seaports. The dummy variable *Harbor* is equal to one if a seaport is located in the respective county, and zero otherwise. In addition, *River*Harbor* is a dummy variable that is equal to one if a county has both access to a navigable river and a seaport, and zero otherwise.

### A5.3 Border Counties

*Border* is a dummy variable that is equal to one if a county was located at an external border of the German Empire, and zero otherwise. Due to the fact that Alsace-Lorraine was part of France until 1871, we treat the border between Alsace-Lorraine and the adjoining German federal states (Prussia, Bavaria (Palatinate), and Baden) as an external border. Thus, this border definition reflects the situation after the Congress of Vienna (1815), which shaped economic activity in these counties in

the long-run. In the same way, we define the dummy variable *Border France,* which is equal to one if the county was located at the border to France after the Congress of Vienna, and zero otherwise.

### A5.4 Universities in 1789

*University 1789* is a dummy variable that is equal to one if a university was located in the respective county in 1789, and zero otherwise. We use De Ridder-Symoens (1992), De Ridder-Symoens (1996), and Rüegg (2004) to obtain information about the formation of universities in German states. Our data includes information about the year when a university was opened, whether and when a university was closed, and whether and when it was reopened. This data allows us to determine the universities that were in operation in 1789. We include general universities, technical universities, mining academies, medical and veterinary universities, and higher schools of commerce. Theological universities, academies of arts and academies of music are not taken into account.

### A5.5 Protestants

*Protestants in %* represents the share of the Protestant population as a percentage of the total population of each county. We extracted the data from the official census publications of the Imperial Statistical Office for each year of observation (1890: Deutsches Reich (1894); 1900: Deutsches Reich (1903a); 1910: Deutsches Reich (1915)). The census publications provide county-level information about the Protestant and Catholic population living in each county, respectively. Together, Protestants and Catholics account for over 98 percent of the German population.

### A5.6 Minorities

*Minorities* is a dummy variable that is equal to one if the share of the population with a mother-language other than German is higher than 50 percent in the respective county in 1900, and zero otherwise. Our county-level data is based on the official census publication of the Imperial Statistical Office, which provides information about non-German-speaking minorities on the county-level (Deutsches Reich (1903b)).

### A5.7 Prussia in 1816

*Prussia 1816* is a dummy variable that is equal to one if the county was located in Prussia after the Congress of Vienna (1815), and zero otherwise. See the map *Der Deutsche Bund nach dem Frankfurter Territorialrezess um 1820* for the Prussian territory after the Congress of Vienna, which is available online on IEG-MAPS (link: http://www.ieg-maps.uni-mainz.de/gif/d820_a4.htm).

### A5.8 City States

*City State* is a dummy variable that is equal to one if the county was part of one of the city states that existed in the German Empire (Bremen, Hamburg, and Luebeck), and zero otherwise.

### A5.9 Natural Resources

*Coal Deposits* is a dummy variable that is equal to one if coal deposits were located in the respective county, zero otherwise. In the same way, *Ore Deposits* is defined as dummy variable that is equal to one if deposits of iron ore or or other important metals (e.g. copper) are located in the respective county. We include all counties in which coal or ore mining facilities were in operation in the 1920s. These counties represent the counties where the extraction of coal and metal ore was economically feasible form the perspective of the nineteenth century. The data is based on map BI (coal mining) and map BII (metal ore mining) in Pfohl and Friedrich (1928). In addition, we used further sources to ensure that we do not miss mining counties where the resources were already exhausted in the course of the nineteenth century (in particular: Bartels and Slotta (2012) and Weber (2015).

## A6 Ecclesiastical States

*Ecclesiastical 1789* is a dummy variable that is equal to one if the county was part of an ecclesiastical principality in 1789, and zero otherwise. Ecclesiastical principalities include all ecclesiastical Electorates (Cologne, Mainz, Trier), Prince-Bishoprics (e.g. Münster), Prince-Abbeys (e.g. Kempten), and territories of religious orders of knights (Order of St. John's, Teutonic Knights). We used various historical maps as well as registers to identify, whether the respective county belonged to an ecclesiastical states. Due to the strong political fragmentation, some counties belonged to various political entities in 1789. We only set the dummy variable equal to one if a significant part of the respective

county was part of an ecclesiastical state. Our coding is based on various sources: for a general register for all former German territories: Köbler (1992); for the territories of the Rhineland: map 5.1 in Irsigler (1982); for the territories in the Palatinate: map 001 in Alter (1964); for the territories in Hesse: map 22 in Hessisches Landesamt für Geschichtliche Landeskunde (1984); for the territories in the South-West (subsequent states of Baden and Wuerttemberg): map *Herrschaftsgebiete und Ämtergliederung in Südwestdeutschland 1790* in: Schröder and Miller (1988); for the territories in the South-East (subsequent federal state of Bavaria): information in Bayrische Staatsbibliothek München (2009).

## A7 Further Control Variables

### A7.1 Employment by Sector

*Manufacturing+Mining Workforce %* represents the share of people employed in manufacturing and mining relative to the total number of people employed in the respective county, and *Services Workforce %* the share of employees in the private service sector, respectively. We use the official German employment census publications of the Imperial Statistical Office get information about the employment by sectors. In order to avoid double-counting, we only consider the main occupation. Employment census data is available for the years 1895 and 1907 (1895: Deutsches Reich (1898a) and Deutsches Reich (1898b); 1907: Deutsches Reich (1910)). We match the employment data for 1895 with patents per capita in 1900, and the employment data for 1907 with patents per capita in 1910.

*Mining County* is a dummy variable that is equal to one if the share of employees in mining and primary metal production (e.g. steelworks, copper mills) relative to total employment in manufacturing and mining is larger than five percent in the respective county. The employment census publications mentioned above do not provide aggregate figures for employment in mining and metal production separately, but only for manufacturing and mining in total. Due to these data constraints, we use additional publications that are based on the official employment census (1885: Deutsches Reich (1899); 1907: Deutsches Reich (1909a) and Deutsches Reich (1909b)).

### A7.2 Technology Transfer

In Table 8, we report the number of machine-building factories (including shipyards) and the number of wool weaving looms that were in operation in German states in 1846 and 1861. The data is based on official surveys in the German Customs Union (Zollverein) states. Note that for some states data is missing for 1846 since these states joined the Zollverein in subsequent years. Factory data is from Becker (1962 (2010)) and data about wool weaving looms is from Blumberg (1965 (2014)), table 26. In addition to the absolute number, we report the number of machine-building factories and wool weaving looms per thousand inhabitants. Population data is from Franzmann (2013).

### A7.3 Trade and Market Integration

In Table 9, we report German import and export statistics by country of origin and destination for several years. Exports and imports for 1841 and 1851 include both Zollverein member and non-member states that became part of the German Empire in 1871. The data for 1841 and 1851 is from von Borries (1970), table 42. Exports and imports for 1890, 1900 and 1910 are based on the official trade statistics published in the yearbooks of the Imperial Statistical Office (Deutsches Reich (1892), p. 65; Deutsches Reich (1905), pp. 169-171; Deutsches Reich (1913), pp. 241-242). Others includes all countries for which no separate figures are available in von Borries (1970).

*Old territories* represents the number of independent principalities that existed in 1789 within each region (Regierungsbezirk), and *Old territories/km²* equals *Old territories* divided by the area size in square kilometers of the respective region. *Old territories* is used in Deutsches Reich (1892), too, but at a higher level of aggregation. *Old territories* includes secular principalities that were immediate to the Emperor (reichsunmittelbar), independent ecclesiastical territories (Electorates, Prince-Bishoprics, Prince-Abbeys, and territories of religious orders of knights), free imperial cities and territories of the Imperial Knights. The latter represent a large number of micro states that were organized in different leagues and cantons (e.g. the canton Odenwald of the Franconian Circle). Since even very detailed maps only report the Imperial Knights as a whole or by canton, but not separately, we treat these micro states as one old territory. Territories that were reigned under a dynastic union are only counted once. To get accurate information on the region-level, we use the following sources: for a general register for all former German territories: Köbler (1992); for a

general overview (and the Eastern territories in particular): map *Deutschland 1792*, which is available on IEG-MAPS (link: http://www.ieg-maps.uni-mainz.de/gif/w850d_a4.htm); for the territories of the Rhineland: map 5.1 in Irsigler (1982); for the territories in the Palatinate: map 001 in Alter (1964); for the territories in Hesse: map 22 in Hessisches Landesamt für Geschichtliche Landeskunde (1984); for the territories in the South-West (subsequent federal states of Baden and Wuerttemberg): map *Herrschaftsgebiete und Ämtergliederung in Südwestdeutschland 1790*, in: Schröder and Miller (1988); for the territories in the South-East (subsequent state of Bavaria): information in Bayrische Staatsbibliothek München (2009).

*Internal Border* is a dummy variable which equals one if a county is located at an internal state border, and zero otherwise. We define internal state border as a border between states that were located on the territory of the subsequent German Empire. Our coding is based on the borders that were established after the Congress of Vienna (see the map *Der Deutsche Bund nach dem Frankfurter Territorialrezess um 1820* , which is available online on IEG-MAPS (link: http://www.ieg-maps.uni-mainz.de/gif/d820_a4.htm)). We therefore treat a county as internal border county if it was at the common border of two states that became part of the German Empire in 1871 (e.g. the border between the kingdoms of Bavaria and Wuerttemberg), or if it was at the border to a state that was dissolved until 1871 (e.g. the border between the Kingdom of Hanover and Prussia; the Kingdom of Hanover was annexed by Prussia after the Austro-Prussian War in 1866).

*Zollverein in 1842* is a dummy variable that is equal to one if the county was located within a state that belonged to the German Customs Union (Zollverein) in 1842, and zero otherwise. See the map *Deutscher Zollverein 1842*, which is available on IEG-MAPS (link: http://www.ieg-maps.uni-mainz.de/map4.htm). The Zollverein was founded in 1834 under the leadership of Prussia. By 1842, most German states had joined the customs union except for the states in the North that had access to the coast. We choose 1842 as a benchmark year for the following reasons: First, the effect of market integration should be stronger for the states that had no access to the coast, second we want to select a year for which still a significant number of states were not part of the union. The latter argument does not hold anymore for 1854, the year of the subsequent major enlargement, when the Kingdom of Hanover and the Grand Duchy Oldenburg joined.

### A7.4 Human Capital

*Illiterates 1876 %* is used as a proxy for human capital. It is defined as the share of illiterates in the conscript age-group of 1875/76. The data is extracted from the yearbook of the Imperial Statistical Office (Deutsches Reich (1880), p. 151). It is only available on the province level for Prussia, and on the state level for all other German territories. We use 1875/76 since the Imperial Statistical Office did not publish figures for earlier years.

*University* is defined as a dummy variable that is equal to one if a university was located in the respective county in the respective year, and zero otherwise. We use De Ridder-Symoens (1992), De Ridder-Symoens (1996), and Rüegg (2004) to get information about the formation of universities in German states. Our data includes information about the year when a university was opened, whether and when a university was closed, and whether and when it was reopened. This data allows us to determine the universities that were in operation for each year in our sample. *University* includes general universities, technical universities, mining academies, medical and veterinary universities, and higher schools of commerce. Theological universities, academies of arts and academies of music are not taken into account. *Technical University* is a dummy variable that is defined in the same way, except that it includes only technical universities and mining academies.

### A7.5 Financial Development

*Banking Workforce %* is defined as the share of people employed in banking relative to the total number of people employed in the respective county, and *Banking+Insurance Workforce %* represents the share of people employed in banking and insurance, respectively. We used the official German employment census publications of the Imperial Statistical Office get information about employment. In order to avoid double-counting, we only consider the main occupation. Employment data is available for the years 1895 and 1907 (1895: Deutsches Reich (1898a) and Deutsches Reich (1898b); 1907: Deutsches Reich (1910)). We match the employment data for 1895 with patents per capita in 1900, and the employment data for 1907 with patents per capita in 1910. Based on the same data, we define *No Banking* as a dummy variable that is equal to one if there is no employment in banking in the respective county and year, and zero otherwise, and *No Banking+Insurance* is equal to one if we observe neither employment in banking nor in insurance, and zero otherwise.

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