The Impact of Institutions on Innovation*

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Abstract

We study the impact of inclusive institutions on innovation using novel, hand-collected, county-level data for Imperial Germany. Exploiting the timing and geography of the French occupation of different German regions after the French Revolution as an instrument for institutional quality, we find that the number of patents per capita was more than twice as high in counties with the longest occupation as in unoccupied counties. Conservative social norms and low financial development weaken the impact of institutions on innovation. The results suggest that innovation is a quantitatively plausible channel for the previously documented effect of institutions on economic prosperity.

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1 Introduction

Why are some parts of the world rich, while others are poor? It is well established that the quality of institutions is an important determinant of economic well-being (e.g. North (1990), De Long and Shleifer (1993), Hall and Jones (1999), Acemoglu et al. (2001)), but there is still a lack of knowledge about the channels through which inclusive institutions lead to economic prosperity. By documenting that cross-sectional differences in the quality of institutions are a powerful determinant of patents per capita, the contribution of this paper is to highlight a so far overlooked channel: innovation. The economic magnitude of the findings implies that innovation is not only a qualitatively but also a quantitatively plausible channel linking institutions to economic prosperity.

To investigate and quantify the long-run impact of inclusive institutions on innovation, we use a novel, hand-collected, county-level data set on Imperial Germany. Until the late 18^{th} century, extractive institutions were still widespread across the German states (e.g. Blum (1978)). These institutions provided privileges and rents to the few at the expense of the many. A fundamental change occurred after the French Revolution of 1789, when the French occupied large parts of Germany and spread their revolutionary ideas of personal freedom and equal rights. As a consequence, the power of local elites was reduced by the implementation of inclusive institutions such as the French civil code (e.g. Fehrenbach (2008)). These reforms created a more level playing field in terms of economic opportunities, by lowering entry barriers and reducing distortions in labor and product markets. Using the length of the French occupation as an instrument for the quality of local institutions (Acemoglu et al. (2011)), we find an economically large and highly significant effect of institutions on patents per capita in Imperial Germany. Counties with the longest period of occupation, which implemented better institutions earlier, had more than twice as many patents per capita around 1900 as unoccupied counties with more extractive institutions.[1] This result points to institutions as a first order determinant of innovation.

Two aspects of this setting make it a good laboratory to study the impact of institutions on innovation. First, the timing and geography of occupations was imposed by the French, not chosen by the Germans. Second, the motives behind French occupations were military and geostrategic, not economic. Napoleon wanted to expand the French borders to create a territorial buffer between France and its 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 an unintended consequence of the French occupation.

[1] We focus on the period around 1900, since there is no nationwide patent data available before 1877, when a harmonized patent law was introduced in the German Empire.

While we provide historical and quantitative evidence that the French occupation was determined by military and geostrategic considerations, one might still be worried that the occupation was correlated by chance with the growth potential of the occupied areas. A historical event addresses this concern. As compensation for its war efforts against France, Prussia wanted to occupy Saxony, which was considered one of the most prosperous German regions, with high potential for economic growth (Flockerzie (1991)). However, Great Britain and Austria-Hungary were afraid of giving such an economic powerhouse to Prussia. Instead, Prussia was compensated with Rhineland-Westphalia. We thus compare the part of Germany that Prussia wanted against the part that it obtained. Contrary to unoccupied Saxony, Rhineland-Westphalia had undergone the deepest institutional changes, due to undergoing the longest period of French occupation. As a consequence, it became significantly more innovative than Saxony ex-post. This historical event provides evidence against the view that occupied regions were economically more promising ex-ante.

An additional contribution of this paper is to shed light on the microeconomic mechanisms linking the quality of institutions to innovation, by using granular county data and analyzing the circumstances under which institutions have a larger impact on innovation. We show that the effect of institutions is significantly weaker in counties that were part of former ecclesiastical states, where society was more conservative and social norms were dominated by the Catholic Church (Borutta (2003)). This suggests that social norms are important complements of institutions for creating innovation. In addition, we show that the impact of institutions is magnified in counties with more developed financial institutions. The link between financial development and economic growth, with innovation as a central channel, is a well-established empirical finding (King and Levine (1993), Levine and Zervos (1998)). The results of this paper suggest that it is not simply financial development that leads to more innovation, but instead financial development together with a system of inclusive institutions, thereby opening a new perspective on the way in which institutions operate.

To further understand the mechanism behind the impact of institutions on innovation, we study innovations in high- and low-tech industries separately. We find that the impact of institutions on innovation is particularly strong for high-tech industries (chemicals and electrical engineering), which produced innovations such as the light bulb, electricity generators, pharmaceuticals, dyestuffs, and chemical fertilizers (Mokyr (1992)). Counties with the longest period of occupation, which implemented better institutions earlier, had nearly four times as many high-tech patents per capita around 1900 as unoccupied counties with more extractive institutions. These disruptive innovations were at the heart of the Second Industrial Revolution and powered subsequent economic growth and increases in living standards (Landes (2003)). By their nature, high-tech industries were more risky, disruptive and

capital-intensive than low-tech industries. This suggests that institutions are of particular importance for more path-breaking innovations that are most important for economic growth, while more incremental innovations (innovations in low-tech industries) might occur even in an environment with poor institutions. The fact that the economic magnitude is larger in industries more conducive to growth further strengthens innovation as a quantitatively plausible channel through which inclusive institutions affect economic prosperity.

Employing a county-level setting allows us to rule out a series of alternative explanations. First, we account for cross-sectional differences in local economic development with various proxies for GDP per capita, to show that the effect of institutions on innovation is not simply driven by a general increase in economic activity due to better institutions. Even after controlling for sectoral employment shares, reflecting differences in the degree of industrialization and economic development, we find a strong effect. Second, we show that it is unlikely that the transmission of French culture, knowledge, or technology explains the results, by documenting that German counties that border with France, which should be more exposed to such transfers, were not more innovative. Data on steam engines and mechanical spinning mills further allows us to exclude technology transfer as an alternative explanation. Third, we discuss the potential effects of trade and market integration. Based on foreign trade statistics, we find no evidence that France was a dominant trading partner of Germany. Moreover, the impact of institutions on innovation remains strong after controlling for internal market integration. Fourth, we exclude the possibility that differences in human capital drive the findings, by using data on universities and literacy rates. Fifth, we reject inequality as an alternative explanation by controlling for the ownership concentration of agricultural land. Sixth, we show that migration does not explain the findings. Finally, we discuss whether past differences in patent law, which was not harmonized in Germany until 1877, could be driving the findings. We show that the impact of institutions on innovation remains strong if we only focus on Prussia, where a single patent law with a centralized patent authority existed before 1877.

We end the analysis by documenting that the increase in patents per capita due to better institutions leads to higher economic growth, which we proxy with county-level population growth. This finding provides the final piece of evidence in the line of argument that innovation is an important channel through which institutions lead to economic prosperity.

Innovation is a novel channel that has not yet been explored in this field of research. In contrast, past literature has focused on financial development (La Porta et al. (1997, 1998)), inequality (Banerjee and Lakshmi (2005)), provision of public goods (Gennaioli and Rainer (2007), Dell (2010)), capital flows (Alfaro et al. (2008)), education (Cinnirella and Hornung (2016)), market integration (Keller and Shiue (2016)), and local collective action (Dell et al.

(2017)) as potential channels linking inclusive institutions to economic well-being.

The paper also adds to the research on the causes of innovation and suggests institutions as a first order determinant. Other determinants previously documented include patent law (Moser (2005)), labor laws (Acharya et al. (2013)), taxes (Mukherjee et al. (2017)), finance (Gompers and Lerner (2001)), competition (Aghion et al. (2005)), risk aversion and individualism (Shane (1993)), human capital (Cinnirella and Streb (2017)), religion (Bénabou et al. (2015)), and market access (Sokoloff (1988)). To the best of our knowledge, this paper is the first to present evidence on the relationship between inclusive institutions and innovation.

The effect that we document is present even after the harmonization of institutions across Germany, which underscores the persistent effect of inclusive institutions on innovation, providing further evidence on the ability of historical events to have long-lasting consequences (see Nunn (2009) for a survey of this literature).

The rest of the paper is organized as follows. Section 2 explains the historical and institutional background. Section 3 describes the data. Section 4 presents the main findings. Section 5 sheds light on the mechanisms behind the results. Section 6 examines different types of innovation. Section 7 addresses alternative explanations. Section 8 documents the effect of innovation on growth. Section 9 concludes.

2 Historical and Institutional Background

2.1 The French Occupation of Germany and Territorial Changes

In the 18th century, the Holy Roman Empire of the German Nation was a loose federation of states (Whaley (2012)). The French Revolution, starting in 1789, provoked the ultimate fall of the Empire. In 1792, the German monarchies joined a military coalition to counter the revolutionary ideas in France, but the French prevailed. To improve their 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 a natural border to protect France from its continental rivals, Prussia and Austria-Hungary. In 1806, Napoleon forced the remaining medium-sized German states to establish the Confederation of the Rhine 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 autumn 1806. However, the French prevailed once more. Prussia had to accept the peace treaty of Tilsit in 1807, which resulted in significant territorial losses, in particular all provinces west of the River Elbe. Parts of these territories were integrated into the Grand Duchy of Berg and the Kingdom of Westphalia (French satellite states 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, as well as the remaining German territories in the North, giving him control over the coast. This was a strategic necessity, since otherwise the continental blockade would have been undermined by contrabandists trading with Britain (Fehrenbach (2008)). By 1810, the whole Lower Rhine area, Westphalia, the North Sea coast, Hanover, and parts of Hesse were under French control (see Figure 1 for the waves of the French occupation).

The military setbacks of 1813 triggered the end of the French occupation. After Napoleon's final defeat in the Battle of Waterloo, the great powers restored the political order of pre-revolutionary Europe. The German states, however, refrained from the restoration of the Holy Roman Empire (Fehrenbach (2008)). As a result of the French expansion and the subsequent territorial reorganization, a large number of previously independent territories were integrated into larger states. These changes were not revised, so most of the surviving states experienced territorial gains after the Congress of Vienna (1815).

2.2 Institutional Change under French Rule

The French occupation did not only alter the territorial structure of the German states, but the occupied territories also suffered from the demand for troops and the confiscations used to supply the French forces (Whaley (2012)). Furthermore, economic activity was suppressed in times of war, and the blockade against Britain restricted trade. Thus, in the short-run, the French occupation might have reduced innovation.[2] However, we document that the occupation had positive consequences on innovation in the long-run, as it fostered economic modernization and social progress through institutional reforms.

In the 18$^{\text{th}}$ century, economic development and the potential for innovation were limited by backward institutions which preserved the power and privileges of small elites.[3] However, along with the French troops, the ideas of the French Revolution spread across Germany and induced institutional change (Schubert (1977)). In occupied areas, the French forced substantial reforms which cut the privileges of the elites. These reforms included the establishment of commercial freedom through the dissolution of guilds, the introduction of a general civil code, the abolition of serfdom and the implementation of agrarian reforms (Acemoglu et al. (2011)).[4] Economic motives played only a minor role in the decision to impose these reforms. Besides having ideological reasons, the French wanted to restrict the power of the local elites

[2]Rhenish textile firms, for example, could not import superior English machinery during the continental blockade. Thus, these companies struggled after 1815 due to antiquated equipment (Kisch (1989)).

[3]The nobility dominated economically and politically, and it retained juridical privileges, in particular in rural areas (Blum (1978)). City oligarchies limited entrepreneurship through guilds (Ogilvie (1996)).

[4]Reform efforts also took place in non-occupied states, but local elites often prevented the implementation. In Nassau and Hesse-Darmstadt, e.g., the introduction of the French civil code was discussed, but the consultations ended without results in 1813 (Schubert (1977)). Reforms were also introduced in the non-occupied parts of Prussia, but the nobility retained privileges until the end of the century (Wagner (2005)).

to facilitate the administration of the occupied areas. After the retreat of the French troops, the German sovereigns recalled some of the Napoleonic institutions in the formerly occupied lands. However, the process of restoration varied between regions, 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.[5] As a result, the inclusiveness of institutions differed between German regions. 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. One manifestation of this is the absence of a single, unified, nationwide civil code until 1900.

2.3 How Can Institutional Change Affect Innovation?

The institutional improvements brought by the French created an economic environment that was more 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 restrictions on trade and production. Guilds were associations of merchants or artisans formed to control their trades and production. In the 18$^{\text{th}}$ century, guilds were still widespread in all German states (Ogilvie (1996)). Guilds set standards for the education of craftsmen and for product quality, but they also created entry barriers and impeded change by protecting their members' interests and by preventing the introduction of labor-saving production techniques (Mokyr (1992), Ogilvie (2014)).[6] Guilds acted like cartels, controlling local monopolies. Since low competition can reduce incentives for innovation (Aghion et al. (2005)), the dissolution of guilds may have impacted innovation not only directly by breaking up rigid rules, but also indirectly through the creation of more competitive markets.

Factory-based industries such as ironworks were typically not controlled by guilds. However, launching a factory required a trading license, and the rulers seldom distributed such licenses (Fischer (1962)). Entrepreneurs had to rely on the goodwill of the administration, but had no legal claim. Requests were rejected for various reasons, e.g. when the interests of incumbents were challenged.[7] We therefore consider that restrictive trade licenses affected innovation in a similar manner to guilds. The decrees on the dissolution of guilds usually included the weakening of other restrictions, resulting in easier access to trade licenses and a general economic liberalization, so the timing of the dissolution of guilds proxies for a broad

[5] In the Rhineland, which was under French rule for 19 years, inclusive institutions remained in place, while restoration took place in northern and central Germany, where the French occupation was shorter-lived.

[6] In the 17$^{\text{th}}$ century, the use of engine looms for silk ribbon production was inhibited in Cologne, Frankfurt and other German cities (Pfister (2008)), and the guilds in Aachen impeded innovations in the metal industry (Kellenbenz (1977)). See Kisch (1989) and Lindberg (2009) for further examples.

[7] Arns (1986) mentions an entrepreneur who wanted to build a cotton spinning mill in Urach (Württemberg) in the mid-19$^{\text{th}}$ century, but officials did not grant a license, to protect the local weavers' guild.

reduction of entry barriers.

Another consequence of the occupation was the introduction of the French civil code. The French established a legal system that separated the judiciary from the public administration, and under which all citizens should be treated equally before the law (Schubert (1977)). Clear rules were set in both 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 existed in all German states (Werthmann (1995)). Under patrimonial jurisdiction, the judiciary was not separated from the local administration. In rural districts, the local lord of the manor was often not only the largest landowner but also the mayor, the judge, and in charge of the local police. While the introduction of the civil code revoked patrimonial jurisdiction in territories under French rule, this practice survived in most of the non-occupied German regions for a long period of time.[8] A fair judicial system is a fundamental aspect of an innovative society. By contrast, under a system of extracting institutions, the lack of legal protection leads to poor incentives to innovate in the first place. The implementation of a fair judicial system can therefore promote innovation.

Another way in which the French occupation hampered the power of the privileged classes, and thus fostered innovation, was through the abolition of serfdom and through the subsequent agrarian reforms. In the 18$^{\text{th}}$ century, the manorial system still existed in the German states (Blum (1978) and Dipper (1980)). Although its design varied regionally, it had one typical characteristic: a small group of noblemen owned a large proportion of the land, and their estates were subdivided in parcels, which were individually cultivated by tributary peasants. This system was abolished in two steps, as a result of the French invasion. First, the tributary peasants gained individual freedom through the abolition of serfdom, which in turn increased labor market mobility (Dipper (1980)). Second, agricultural reforms were brought in, aiming to transfer land ownership from the aristocratic landowners to the peasants.

The specific design of these agricultural reforms varied, but there was a prevailing feature: the tributary peasants were allowed to take ownership of the land that they had cultivated, but they had to compensate the landowner to some extent, either by installments or through the cession of parts of the newly gained land (Achilles (1993)). Therefore, the abolition of serfdom and the agrarian reforms reduced the power of the local elites. These reforms did not only take place in occupied regions. However, on average, in non-occupied regions the rulers started the process of agricultural reforms later and the implementation took much longer.[9] Furthermore, the implementation of these reforms differed between and within the

[8] In Prussia, patrimonial courts and the police powers of the local lords were abolished in 1849. But in 1853, the alleviated police powers were reestablished in some regions (Werthmann (1995)). Until the 20$^{\text{th}}$ century, the East Elbian lords dominated the local public administration (Wagner (2005)).

[9] See Ashraf et al. (2017) for additional information on the process of agricultural reforms in non-occupied

German states. For example, in unoccupied East Elbia, the agricultural reforms were not effective in breaking the economic power of the old elites, since the compensation rules were designed in favor of the lords (Eddie (2008)).

As a whole, these institutional changes were a revolution in the way local communities operated and significantly increased the economic incentives to innovate.

3 Data

We construct a novel data set by hand collecting detailed county-level information on Imperial Germany. Due to data availability, we focus on 1890, 1900 and 1910. Before 1877, German patent law was not harmonized and there was no nationwide patent register.[10] The selection of years is also dictated by the availability of census data. The analysis ends in 1910 to avoid the results being contaminated by the economic and social disruptions of the World Wars.

The German Empire had 25 federal states. Prussia, accounting for more than half of the population and area, was organized into provinces (Provinzen), which were subdivided into regions (Regierungsbezirke), and each region was subdivided in counties (Kreise). The medium-sized and small German states were organized in a similar way. We use county-level data, the smallest unit for which data is available. After adjusting for changes in the administrative structure, we have 881 counties per year, spread over 80 regions, covering all 25 federal states of the German Empire (see Appendix B for information on the data).

3.1 Institutions and French Occupation

We measure the inclusiveness of local institutions with the variable *Institutions*. This index takes four measures of the inclusiveness of institutions into account: (i) introduction of a civil code, which guaranteed equality before the law, (ii) abolition of serfdom, (iii) implementation of agrarian reforms, and (iv) dissolution of guilds. The index is the mean of the number of years between the implementation of each reform and the year a patent is filed (1890, 1900 or 1910). The Rhineland, for example, has an index value of 100.25 for 1900, based on the average of the following index scores (year of reform implementation in brackets): code civil: 98 (1802); serfdom: 102 (1798); agrarian reform: 96 (1804); guilds: 105 (1795).

This index was introduced by Acemoglu et al. (2011) to study the impact of institutional reforms on urbanization, which they use as a proxy for economic development.[11] There are two main differences between our institutions index and theirs: first, they use highly aggregated data, since their index is constructed at the level of German states and at the

Prussian provinces and in Prussian provinces where restoration took place.

[10] French patent law was not incorporated in German states after 1815, nor did it shape the German patent laws that emerged in the 19$^{\text{th}}$ century. See Kurz (2000) for the history of German patent law.

[11] See Appendix Appendix A.5 and Kopsidis and Bromley (2016) for a discussion of the institutions index.

province level for Prussia. We 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 881 counties per year, instead of the 19 provinces and states used by Acemoglu et al. (2011). Out of these 881 counties, 211 counties are in states or regions not included in their data set. Table 1 contains information on the average institutions index in occupied and non-occupied areas in the sample. Consistent with the view that French occupation led to more inclusive institutions, the institutions index is about 12 years higher in occupied counties than in non-occupied counties.

We use the variable *Years French Occupation* as an instrument for *Institutions*. *Years French Occupation* is defined as the number of years for which a county was occupied. A county is classified as occupied if it was under direct French rule or was part of the Grand Duchy of Berg, the Kingdom of Westphalia, or the Grand Duchy of Frankfurt, which were ruled by members of Napoleon's family. Figure 1 illustrates the regional differences in the length of French occupation, ranging from 0 to 19 years, and Figure 2 shows regional differences in the inclusiveness of institutions.

3.2 Patents

As a proxy for innovation, we use high-value patents per million inhabitants.[12] We obtain patent data from Streb et al. (2006), who provide information about the location of the patentee, whether the patent was filed by an individual or a firm, and the technology 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. Since a patentee had to pay an increasing annual fee to renew a patent, one can assume that these patents represent financially valuable products or production technologies (Streb et al. (2006)). We include all patents granted to German individuals and firms. Table 1 reports statistics for formerly occupied and for non-occupied counties, respectively. The mean number of patents per capita is distinctly higher in occupied counties. Figure 3 illustrates the spatial distribution of patenting activity.[13]

4 Results

4.1 Determinants of French Occupation

In Section 2, we explain why the French occupation was driven by military and geostrategic considerations, not by economic motives. We now provide empirical support for this statement by testing whether we can predict the length of occupation with pre-1789 variables that

[12] For a discussion of patents as a measure of innovation see Griliches (1990) and Streb (2016).

[13] The spatial distribution of patents per capita also reflects differences in population density (Figure A1).

account for large cities and potential geographic determinants of economic prosperity, such as rivers or coal deposits. If the argument that the occupation is not related to the underlying economic characteristics is valid, we would expect to find the coefficients of these variables to be insignificant and the R^2 close to zero. The results are presented in columns 1 and 2 of Table 2. In addition to equally weighted observations in column 1, we use area weighted observations in column 2 to account for differences in county size.[14] We cluster standard errors at the region level. Overall, the findings in columns 1 and 2 support the assumption that the French occupation is not related to the underlying economic determinants of the occupied counties, given that the adjusted R^2 of both models is below 3%.

To illustrate the military and geostrategic motives behind the French occupation, we re-estimate the models in columns 1 and 2 by adding *Distance to Paris* as an explanatory variable. Columns 3 and 4 indicate that *Distance to Paris* is highly significant with a negative point estimate, and the adjusted R^2 of both specifications increases by more than 20 percentage points. The patterns observed strengthen the argument that the occupation was driven by military and geostrategic considerations.[15]

The significant effects of *City State* and *Hanseatic League* in columns 3 and 4 are in line with this argument. *City State* controls for Hamburg, Bremen, and Lübeck, which were occupied in November 1806 due to their large ports, to enforce the continental blockade. *Hanseatic League* indicates former cities of the Hanseatic League, which was a trade federation in the late medieval period. The positive effect of *Hanseatic League* can be explained by these cities being located in the North and mainly near to the coast.

4.2 Main Results: The Impact of Institutions on Innovation

To analyze the impact of institutions on innovation, we use an instrumental variable approach. In the first stage of the model, we test whether we can predict the inclusiveness of institutions (*Institutions*) using the length of French occupation (*Years French Occupation*). In the second stage, we study the effect of *Institutions,* instrumented with *Years French Occupation*, on patents per capita, which we use as a proxy for innovation. By including a battery of county-level controls in both stages, we account for other potential determinants of innovation. Summary statistics for these variables are reported in Table 1. In addition, we include year fixed effects, and cluster the standard errors at the region level to allow for correlation of the error terms within a region across the three sample years.[16] We weight ob-

[14] We cannot weight by the county population, since this data is not available for the early 19$^{\text{th}}$ century.

[15] In the IV-models later on, we cannot control for distance to Paris, since we would control for a determinant of the French occupation, while instrumenting with its length. However, the results remain significant in all models, if we use distance to Paris as an instrument for *Institutions*.

[16] We cannot include geography fixed effects, since the institutions are generally homogenous within a region or province.

servations by population, to avoid the possibility of small counties (population-wise) biasing the estimates.

The results of the first stage regression are presented in column 1 of Table 3. We find a positive and statistically significant relationship between *Years French Occupation* and *Institutions*. The magnitude of the estimated effect is large. An additional year of French occupation is associated with inclusive institutions being in place for an additional 1.61 years. Moving from no occupation to the maximum length of French occupation (19 years) implies a 70% increase in the number of years inclusive institutions have been in place. The F-statistic for the excluded instrument is 64.20, which attests to the strength of the instrument.

The results of the second stage regression–the main finding of the paper–are presented in column 2 of Table 3. We find a strong relationship between the inclusiveness of institutions and innovation. The coefficient of 0.402 implies that going from 0 to 19 years of French occupation, which is equivalent to a change from no treatment to maximum treatment, leads to a 128% increase in the number of patents per capita, evaluated at the mean, through the implied change in institutions.[17] The effect is economically large and highly significant.

This finding holds after including year fixed effects and controlling for other potential determinants of innovation. First, we account for population density ($Population/Km^2$, see Figure A1), computed at the county level, which is a well-established proxy for economic prosperity (Ciccone and Hall (1996), Acemoglu et al. (2002)). The magnitude of the estimated coefficient suggests a strong link between population density and innovation, since a one standard deviation increase in population density leads to a 111% increase in patents per capita, if evaluated at the mean. Market access may also affect innovation (Sokoloff (1988)). We therefore control for counties with important harbors (*Harbor),* access to navigable rivers (*River),* and access to both (*River*Harbor).* The effect of *River* is positive and statistically significant, which suggests that counties with access to rivers were on average more innovative. The coefficient of *Harbor* is not significant, while *River*Harbor* is negative and statistically significant. A potential explanation for this significant result is that counties with major harbors, which were connected with their hinterland by rivers, specialized in trade, at the expense of manufacturing which typically produces more patents. We also account for the effect of foreign culture and cross-border trade by including dummies for counties at an external border (*Border)* and for counties at the border with France (*Border France*), respectively. The coefficient of *Border* is significantly negative, and the negative

[17]This magnitude is computed in the following way. Subtract the average of *Institutions* for counties with no occupation from the average of *Institutions* for counties with the maximum occupation. Multiply this difference with the estimate for *Institutions* in the second stage of the IV. Dividing the resulting number by the mean number of patents per capita over all counties results in an implied increase of 128%. All averages are population weighted. All similar magnitudes reported in the paper are computed in the same way.

effect of *Border France* is even stronger. Since access to natural resources could also affect innovation, we use dummy variables to control for counties with coal deposits (*Coal Deposits*) and metal ore deposits (*Ore Deposits*), but we find no significant effects on patents per capita. To account for potential pre-occupation differences in the propensity to innovate, we use a dummy that is equal to one if a city with more than 5,000 inhabitants was located within the respective county in 1750. The results show that patents per capita were on average significantly higher in these counties. This could be due to proto-industrial manufacturing businesses with a skilled labor force, or to the concentration of 'upper-tail' knowledge elites in these cities (Squicciarini and Voigtländer (2015)). In addition, we use *University 1789* to control for the existence of a university in 1789, since universities provide training that could lead to innovation and economic growth (Cantoni and Yuchtman (2014)), but we find no significant effect. *Hanseatic League* indicates whether a former member city of the Hanseatic League (an important trade federation during the late medieval period) was located in the respective county. We find a significantly negative relation with patents per capita. This result is consistent with the findings in the literature that provide evidence for a relative economic decline of these cities after the medieval period (Lindberg (2009)). The coefficient of *Protestant %*, the share of Protestants in each county, is positive and statistically significant. This result reflects 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. An additional factor that could have influenced innovation is the local presence of minorities with a native language other than German. In total, these minorities represented only 7% of the German population, but they were clustered in a small number of counties. For this reason, we control for minorities non-parametrically with the dummy variable *Minorities*, which is equal to one if the fraction of the population whose native language was not German is above 50%. *Minorities* has no significant point estimate. We control for Prussia in the borders of 1816 with *Prussia 1816*, which is akin to including a geography fixed effect for Prussia.[18] The coefficient of *Prussia 1816* is significantly negative. One explanation for this finding is the relative importance of agriculture in the Eastern part of Prussia. Finally, we include *City State* to control for Hamburg, Bremen, and Lübeck, the city states of the German Empire. We use *City States* for two reasons. First, these major harbor cities were occupied by Napoleon in 1806, to maintain the blockade against Great Britain. Second, the index captures only three of the four institutional reforms in these city states, since agricultural reforms played no role due to scarcity of agricultural land. The significant coefficient of *City state* indicates that these cities were on average more innovative.

[18]Prussia is the only state large enough to have variation in institutions to allow for such a 'geography fixed effect', while the other German states are usually the size of a Prussian province, if not smaller.

4.3 Correlation between Occupation and Economic Potential

While we provide historical (Subsection 2.1) and quantitative evidence (Subsection 4.1) that the French occupation was determined by military and geo-strategic considerations and not by economic ones, one might be worried that the French occupation was correlated by chance with the future growth potential of the occupied areas. We use a historical case study to argue that, if anything, the French occupation was negatively correlated with the underlying growth potential of the occupied areas–at least in the eyes of contemporaries such as the rulers of Prussia, Austria-Hungary, and the United Kingdom.

We start by restricting the sample to the Rhineland, Westphalia, and Saxony (see Appendix B.1.2). This is motivated by the territorial reorganization after the Congress of Vienna. While the French had occupied the Rhineland, Westphalia, and the Northern part of the Prussian province of Saxony, the old territories of the Kingdom of Saxony, one of Napoleon's military allies, had not been under French rule. After the French defeat, Prussia had to be compensated with territorial gains. Prussia was pushing to be compensated with the whole territory of the Kingdom of Saxony, which was at the time considered to be one of the most prosperous German regions with a high potential for economic growth.[19] However, the United Kingdom and Austria-Hungary 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, and not its prosperous heartland (Flockerzie (1991)). In addition, Prussia was compensated with the Rhineland and Westphalia. From a Prussian perspective, these regions were considered economically and strategically less attractive than Saxony. Importantly, the 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. The results in column 1 of Table 4 provide evidence that the Rhineland and Westphalia became significantly more innovative *ex-post* due to the earlier implementation of institutional reforms, even though Saxony seemed to be economically more promising *ex-ante*. If the French occupation was correlated with the underlying growth potential of the occupied regions, then Prussia should have been aiming to gain the Rhineland and Westphalia. Instead, Prussia pushed for Saxony. This test provides evidence against the view that occupied regions were economically more promising and more likely to innovate in the absence of French occupation.

4.4 Robustness Tests

Next, we perform a series of robustness tests that altogether alleviate the concern that the relationship we establish is spurious. In column 2 of Table 4, we exclude East Elbia (Ostel-

[19] See various economic indicators in Kiesewetter (2004) that support this argument.

bien) from the sample (see Appendix B.1.3). East Elbia represents the Prussian provinces east of the River Elbe, which were dominated by agriculture and a rural aristocracy, and could therefore be a worse control group for the occupied areas. However, the effect of *Institutions* remains economically and statistically significant if we exclude East Elbia. Column 3 shows that the result also holds if we perform the analysis only within Prussia in the border of 1816. 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 addition, we vary the instrument as well as the measure of institutional quality in columns 4 to 6 of Table 4. In column 4, we replace the instrument *Years French Occupation* with an occupation dummy, which takes the value of one if the county was occupied by the French. The effect of *Institutions* remains economically and statistically significant. On average, occupied areas implemented institutional reforms 12 years earlier than non-occupied areas. This leads to a 77% increase in patents per capita, compared to the mean in the sample. *ln(Institutions)* is the natural logarithm of *Institutions*, which we use in column 5 to allow for a non-linear effect. Using this alternative specification, we find that the difference in institutional quality associated with going from 0 to 19 years of occupation leads to a 131% increase in innovation. Finally, column 6 shows that the results also hold if we use *Alternative Institutions*. This alternative index of institutional quality differs from the main index by including the abolition of patrimonial courts as an additional institutional reform (see Appendix B.2.2). The end of patrimonial justice was a major step towards a society in which all people are treated equally before the law. In some regions, in particular in the Rhineland where the French occupation lasted longest, patrimonial justice was abolished with the introduction of the French civil code. However, it persisted for longer in non-occupied states and states where the old order was restored after the occupation (Werthmann (1995)). As column 6 shows, the effect of institutions on innovation remains highly significant. Furthermore, the magnitude of the effect is almost the same as that obtained with the main index, which underlines the robustness of the results.

We conduct a series of further robustness tests, for which we report the results in Appendix A.3. First, we show that the effect of *Institutions* remains highly significant and economically large, if we use a specification without weighting the observations by population. This test allows us to exclude the concern that the results might be driven by a few heavily populated counties. Second, we document that the results hold if we run separate regressions for the years 1890, 1900, and 1910. When we contrast institutions in counties with no occupation against those in counties with 19 years of occupation, we find a 223% increase in patents per capita for 1890, 125% for 1900, and 99% for 1910. The reason for the stronger effect in earlier years is that institutions were not harmonized until 1900. The fact that we find

significant effects even in 1910 is testament to the long-run impact of inclusive institutions on innovation. This highlights that the effect of institutions on innovation is a relatively slow-decaying and long-lasting process.

The map of the French occupation in Figure 1 shows occupied exclaves surrounded by non-occupied counties and non-occupied enclaves surrounded by occupied counties. While the overall occupation was not driven by economic considerations or correlated with growth potential, one might be worried that this might not hold for the exclaves or enclaves, and that this could affect the results. However, this is disproven by historical evidence, and the results remain virtually unaffected or are even stronger, if we drop exclaves and enclaves from the sample, or if we code non-occupied enclaves as occupied and occupied exclaves as non-occupied. The findings are also unaffected if we "smooth" the occupation border by excluding all "bulges" that protrude into (non-)occupied areas, or code the corresponding counties such that the border between occupied and non-occupied areas is "smooth".

In Figure 3, one can observe a small number of counties with a very high number of patents per capita. Such a clustering of innovative activity in a small number of highly innovative regions is common. Today in the United States, for instance, Silicon Valley stands out as a small but highly innovative cluster. Nevertheless, we account for the concern that these observations constitute outliers that might drive the results. The effect of *Institutions* remains highly significant and economically large when we winsorize patents per capita. We also estimate a Poisson regression in the second stage of the IV to account for the relatively high number of zero observations. The estimates imply that implementing all institutional reforms one year earlier leads to a statistically significant increase of roughly 5.5% in the number of patents in the county, underlining the robustness of the results.

One interesting question that we are unable to answer with our research design relates to the impact of each individual measure of institutional quality included in the index. This is because 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 measures of institutional quality without violating 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).

5 Mechanisms: Do Institutions Operate in Isolation?

5.1 Cultural Norms and Institutional Reforms

In this section we analyze which factors complement institutions in creating an environment conducive to innovation. One factor that may lead to less innovation, even when inclusive

institutions are in place, is a more conservative culture. To study this channel, we focus on counties that were part of independent ecclesiastical states until the German mediatization of 1803, 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 a similar share of Catholic population and even once these former ecclesiastical states were ruled by secular rulers. During the Kulturkampf (cultural struggle) in the 19th century, the Catholic Church opposed both the separation of the church from the state and the modernization of society (Clark and Kaiser (2003)).[20] One prominent example how the Catholic Church diminished the role of institutions in fostering innovation 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)). 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.

To test whether there is a differential effect in former ecclesiastical states, we define the dummy variable *Ecclesiastical 1789* (see Appendix B.5.1), which is one if a county was part of an ecclesiastical state in 1789, and interact this variable with *Institutions*. The variables *Institutions* and *Institutions*Ecclesiastical 1789* are instrumented with both *Years French Occupation* and the interaction of *Years French Occupation* with *Ecclesiastical 1789*.[21] Since ecclesiastical states were dominated by a Catholic population, and the religious composition of the population could affect economic outcomes (Lecce and Ogliari (2017)), we also control for the share of Protestants, as in all regressions.

The results are presented in column 1 of Table 5. As before, the coefficient of *Institutions* is positive and highly significant, but the coefficient of the interaction *Institutions*Ecclesiastical 1789* is significantly negative. Compared to the mean treatment effect, the impact of institutions on patents per capita is 40% lower in ecclesiastical states. The main effect of *Ecclesiastical 1789* is not significant. The findings support the notion that the impact of institutions on innovation is weaker in more conservative areas. Interestingly, the coefficient of *Protestants %* becomes insignificant once we control for ecclesiastical states. 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 conservatism or other historical legacies associated with former ecclesiastical states.

[20] See, e.g., the "Kölner Wirrungen" in which the Catholic Church was opposing the Prussian government on several issues, including Catholic-Protestant marriages and higher education policies (Keinemann (1974)).

[21] See Wooldridge (2010), pp. 262-268 for a discussion of non-linear endogenous variables.

5.2 Access to Finance

Inclusive institutions provide economic agents with the opportunity to reap the gains of their ingenuity, however, without access to finance, certain ideas may not be transformed into commercially viable products. Similarly, a developed financial sector may not lead to a high level of innovation if a system of crony capitalism is in place and market access is restricted, as in the case of guilds. Even though, on their own, institutions and access to finance may not lead to high innovation, when combined they could produce a powerful mix.

To test the hypothesis that inclusive institutions and access to finance are important complementary inputs in the production of innovation, we test whether the impact of institutions on innovation is stronger in regions that were more financially developed. In the German states, a modern and widespread banking system did not emerge until the second half of the 19$^{\text{th}}$ century, when high numbers of savings banks, credit cooperatives, and joint stock banks were founded (Guinnane (2002)). Before that, financial services were mainly provided by private bankers such as the famous Rothschild family in Frankfurt am Main. For this reason, there is no data available that allows us to measure differences in financial development for this period. We therefore rely on data from the employment census of 1895 to account for differences in financial development. We compute the share of people employed in the banking sector and define *Banking* as a dummy that is one if the share of the workforce in banking is larger than 0.1%, indicating counties with good access to financial services at the end of 19$^{\text{th}}$ century.[22] The historical literature suggests that most of these places were already regional financial centers before the French occupation (Klein (1982)).

In column 2 of Table 5, we test whether finance and institutions act as complements, by interacting *Institutions* with *Banking*, and by using *Years of Occupation*Banking* as an additional instrument. We use this interacted variable in addition to the main variable and include *Banking* to account for general differences in financial development. The coefficient of *Banking* is not significant, but those for *Institutions*Banking* and *Institutions* are positive and statistically significant.[23] Comparing the estimates for the main effect and the interaction effect, the impact of institutions on innovation is more than 200% stronger in financially developed counties. The link between financial development and economic growth, with innovation being a central channel, is a well-established empirical finding (King and Levine (1993), Levine and Zervos (1998)). The results suggest that it is not simply financial development that leads to more innovation, but rather financial development together with a system of inclusive institutions. Similarly, institutions may on their own have a positive

[22] The median employment share in banking relative to total county employment was 0.05% in 1895.

[23] The result is not driven by counties with better institutions having a larger fraction of the population in banking. Among the counties with at least 0.1% of the workforce in banking, the distribution of banking employment relative to workforce in relation to institutions is inverse v-shaped.

effect on innovation, but this effect is magnified when finance is also available.

6 Different Types of Innovation

An additional contribution of this paper is that we study the impact of institutions on different types of innovation, by analyzing whether the findings differ between high- and low-tech industries. This distinction allows us to better understand the potential impact of innovation on growth. High-tech industries differ from low-tech industries in three dimensions: first, innovation in high-tech industries requires a larger amount of physical and human capital; second, investment in research and development tends to be much riskier in high-tech industries; third, when successful, high-tech innovations tend to be more disruptive and more conducive to economic growth. We categorize patents based on the technology class reported in the patent statistics. Patents related to chemicals or electrical engineering are defined as high-tech, since these industries were important drivers of the second industrial revolution (Mokyr (1992)). All other patents are categorized as low-tech (see Appendix B.3.2).

In columns 1 and 2 of Table 6, we divide the sample into high- and low-tech patents. The findings hold for both types of patents separately, but the effect is economically larger for high-tech patents.[24] For ease of interpretation, we present the economic magnitudes implied by these results in the row below the point estimates in Table 6. The change in institutions associated with going from 0 to 19 years of French occupation implies a 279% increase in high-tech patents, while the same institutional change leads to an 83% increase in low-tech patents, when evaluated at the mean. 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 Table 6, we show that the results hold for both groups independently. The effect is larger for firm patents. Finally, in column 5, we examine high-tech patents filed by firms. As column 5 shows, the coefficient of *Institutions* remains highly significant, and the magnitude of the effect is the strongest in comparison to the other sub-samples.

These results suggest that formal institutions may be especially relevant for high-tech innovation and point to inclusive institutions as an important precondition for the rise of the German chemical and electrical industries at the end of the 19^{th} century. Since these were the booming industries of the second industrial revolution, the findings in this section further strengthen the argument that innovation is an important channel through which inclusive institutions lead to economic prosperity.

[24]Since the share of innovations protected by patents could differ across industries (Moser (2005)), a concern is that local industry structure could drive the results. We address this concern by focusing on high-tech patents, which are based on industries with a similar patenting intensity.

7 Alternative Explanations

7.1 Economic Development and Industrialization

The findings so far indicate that the institutional change caused by the French occupation fostered innovation. An alternative explanation could be a general increase in economic activity due to more inclusive institutions, which in turn affected innovation. To account for this concern, we control for population density in all regressions, which is a well-established proxy for economic development (Ciccone and Hall (1996), Acemoglu et al. (2002)). We now provide additional evidence that institutions directly affected innovation, and that economic growth is unlikely to be driving the results.

To control for differences in local economic development that might not be captured by population density, we use additional data on the composition of the workforce. Counties with a high share of employment in manufacturing, mining, and services were on average more prosperous and had grown faster than counties where agriculture still dominated (Kuznets (1971)). We use *Manufacturing+Mining Workforce %,* the share of people employed in manufacturing and mining relative to the total number of employees in a county, and *Services Workforce %,* the share of people employed in the private service sector relative to the total county employment. Due to data availability, we match the patent and population data of 1890, 1900, and 1910 with data from the employment censuses of 1882, 1895, and 1907, respectively. We also introduce *Coal Mining 1850* (*Coal Mining 1880*), which measures the coal production in 1850 (1880) divided by the population in the respective year. Both are computed at the region level for data availability reasons. These variables are used to account for the importance of coal mining during the process of industrialization.[25]

In column 1 of Table 7, we add *Manufacturing+Mining Workforce %* and *Services Workforce %* as control variables to the baseline model. The coefficients are positive, but only the effect of *Services Workforce %* is significant. In columns 2 to 5, we show various specifications with *Coal Mining 1850* and *Coal Mining 1880* included, but we find no significant effect of these variables. The impact of *Institutions* remains economically and statistically significant in all columns. The coefficient of 0.303 in column 1 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 97% increase in patents per capita, compared to an increase of 128% for the baseline specification. The effect, although large in economic terms, decreases with the inclusion of these additional variables. This is not surprising, since counties with more innovation should also exhibit stronger growth than counties with less innovation.

[25] We include *Coal Deposits* as a baseline control to measure the existence of coal deposits. By contrast, *Coal Mining 1850* and *Coal Mining 1880* reflect the amount of coal per capita that was actually extracted.

7.2 Culture, Technology and Knowledge Transfer

The French occupation induced institutional change, but the French influence may have extended beyond institutions. Other potential channels include an entrepreneurial culture or knowledge and technology transfers from the French to the Germans.

The transmission of French culture and the potential for technology and knowledge transfers should be higher for counties that border with France, since these counties were not only more likely to be occupied, but German-French interactions should also have been stronger at the border. We would expect a positive coefficient for *Border France* if culture, technology or knowledge transfers had fostered innovation. However, the impact of *Border France* is significantly negative in the second stage regression (column 2 of Table 3). We interpret this as evidence that the results are not driven by culture, technology or knowledge transfers.

The fact that the impact of institutions is stronger for high-tech patents provides further evidence that technology transfer is an unlikely channel, since the chemical industry and electrical engineering (the high-tech sectors) were new industries that 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 chemicals, while France lagged behind in these sectors (Mokyr (1992)). If the French brought superior knowledge, 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. By contrast, France had a competitive edge in the leading sectors of the first industrial revolution, for example in the textile industry. During the Napoleonic Wars, the French textile industry flourished, since British imports had to be replaced by domestic production as a result of the blockade (Juhász (2015)), and there was also a textile boom in the occupied German Rhineland (Fehrenbach (2008)). However, historical case studies provide no evidence that import substitution fostered the transfer of French technology in this sector. Kisch (1989) even argues that the Rhenish textile firms suffered from antiquated machinery after the French occupation, because they could not import modern British technology during the blockade.

Although there is no evidence in the literature, we formally test whether the French supplied occupied territories with superior production technologies, which could have affected the ability to innovate, by using hand-collected data on the local endowment of steam engines and mechanical cotton spinning mills. The steam engine was universally used in almost all industries and represents one of the most important inventions of the first industrial revolution, and mechanical cotton spinning mills were the most advanced textile-production facilities in this period. If technology was imported, we would expect to find a positive correlation between the past endowment of steam engines and mechanical cotton spinning mills, and patents per capita. We therefore include *Steam Engines 1861* and *Spinning Mills*

1861 as additional controls in column 1 of Table 8.[26] *Steam Engines 1861* is the number of steam engines per million inhabitants within each region in 1861, and *Spinning Mills 1861* measures the number of mechanical cotton spinning mills per million inhabitants. The data is based on an 1861 industrial survey, which was conducted in the Zollverein, the customs union that existed before the German unification of 1871. The sample is thus restricted to the Zollverein states. The coefficients for *Steam Engines 1861* and *Spinning Mills 1861* are not significant, while the effect of *Institutions* remains strong and significant. We conclude that there is no evidence that the results were driven by French technology transfer.

7.3 Trade and Market Integration

If previously occupied territories were more engaged in trade with France, this could explain a higher number of patents per capita in these regions. We already address this concern by controlling for border effects in all regressions. If trade was crucial, we would expect to observe a higher number of patents per capita in counties that border with France, since these counties were more exposed to German-French trade. However, we find a significantly negative coefficient of *Border France* in column 2 of Table 3, meaning that there is no evidence for such an effect. The coefficient of *Border* is also significantly negative.

Based on the existing country-level foreign trade statistics, we cannot directly identify counties or regions that traded relatively more with France after the occupation. More precisely, we cannot formally test whether France accounted for a higher share of foreign trade in previously occupied counties. However, aggregated import and export statistics of the Zollverein and the German Empire reveal that trade with France was less important than trade with other European countries such as the United Kingdom, Austria-Hungary, Switzerland, or the Netherlands. The share of imports and exports from and to France was rather low, given the size of the French economy and the proximity to Germany. In 1841, a year for which data is available, France ranked fourth in the trade statistic, accounting for only 8.4% of the imports and 11.4% of the exports of the Zollverein states, and it even lost shares in the subsequent decades.[27] Furthermore, we find no historical evidence that occupied areas profited from preferential trade agreements with France after the occupation. Since it is very unlikely that the French occupation fostered trade with Germany, we refute trade with France as a potential channel that could explain differences in innovation.

A further channel through which the French occupation might have affected innovation is market integration (Keller and Shiue (2016)). As described in Subsection 2.1, the occupations initiated a territorial reorganization by the dissolution of formerly independent small principalities, ecclesiastical states, and imperial cities. It could be that areas that could afford to

[26] We show additional model specifications in the Appendix A.4.1.

[27] We report aggregated import and export statistics for several years in Appendix A.4.2.

be more politically fragmented were those with higher economic potential, so the territorial reorganization could have unleashed economic growth through market integration. Failing to control for this could bias the estimates if the French occupied politically fragmented territories. We address this concern in columns 2 and 3 of Table 8, by measuring the potential gains from internal market integration with *Old territories* and *Old territories/km²*, respectively. *Old territories* is the number of independent territories that existed in 1789 within each region. *Old territories/km*^{2} is *Old territories* divided by the area of the region. In addition, we include in both specifications the dummy variable *Internal Border,* which is one if the county was at a state border in 1816 and if the neighboring state was part of the German Empire in 1871. This variable accounts for market integration effects that appeared after the French occupation, particularly effects caused by the formation of the Zollverein (Keller and Shiue (2014)). We also include the dummy variable *Zollverein 1842* in both regressions, which is one if the county was part of a Zollverein state in 1842.[28] In column 2, we include *Old territories*, *Internal Border*, and *Zollverein 1842* as additional controls, but we find no significant effects, while the coefficient of *Institutions* remains large and significant. The specification reported in column 3, adds *Old territories/km*^{2}, *Internal Border*, and *Zollverein 1842*. We find a significantly positive effect of *Zollverein 1842* and a significantly negative effect of *Old territories/km*^{2}. More importantly, the coefficient of *Institutions* remains highly significant and the economic magnitude even increases in comparison with the baseline model. Thus, we reject market integration as an alternative explanation.[29]

7.4 Human Capital

Human capital is another factor that could drive the results, since regions with a more educated and skilled population were more innovative (e.g. Hornung (2014), Cinnirella and Streb (2017)). It could be that occupied regions were already better endowed with human capital before the occupation. Thus, we control for universities in 1789 in all models, but find no evidence of a significant effect on patents per capita (column 2 of Table 3). We also control for large cities in 1750 (*Large City 1750*), which represent centers of proto-industry and 'upper-tail knowledge' (Squicciarini and Voigtländer (2015)). Unsurprisingly, we observe a significantly positive effect of *Large City 1750* in all models.

Apart from potential pre-occupation differences, the French occupation could have affected human capital directly, for example by improving the provision of education. Such an effect would provide an alternative to institutions as the main channel. To address this issue, we include *Illiterates 1876 %, University,* and *Technical University* as additional controls in column 4 of Table 8. *Illiterates 1876 %* is the share of illiterates in the conscript age-group

[28] The results are robust to earlier or later benchmark years (see Appendix B.5.8 for more information).
[29] For additional tests on market integration see Appendix A.4.2.

of 1875/76. This data is only available at the province level for Prussia and at the state level for all other German territories. Since we treat these states as being equivalent to a Prussian province, we cluster observations at the province level. *University* is a dummy that is one if a university was located in a county in the respective year, and we use the dummy variable *Technical University* to control for technical universities or mining academies, since they train engineers who may be more likely to innovate than graduates from non-technical sciences. Column 4 of Table 8 indicates that the share of illiterates is significantly negatively correlated with innovation, but there is neither a significant effect for *University* nor for *Technical University*. The coefficient for *Institutions* is slightly smaller compared to the baseline regression, but it remains economically and statistically significant. Thus, human capital is not a plausible alternative explanation for the impact of institutions on innovation.

7.5 Inequality

Counties with high inequality could be less innovative (Akcigit et al. (2017)), as inequality could affect inventors' ability to finance innovation (Rajan and Ramcharan (2011)), and it could negatively affect the provision of human capital (Cinnirella and Hornung (2016)). The late 19$^{\text{th}}$ century was characterized by considerable geographical variation in the concentration of landownership, which we use as a proxy for wealth inequality. Some parts of Germany, such as Baden or Wuerttemberg, had a much lower degree of landownership concentration than other parts, in particular East Elbia, where a high share of the land was controlled by a small aristocratic elite (Eddie (2008)). If inequality was higher in non-occupied counties, differences in inequality, and not institutions, could drive the results. We already alleviate this concern with column 2 of Table 4, where we document that the results are robust to excluding East Elbia. In addition, we use hand-collected data on landownership, based on the agricultural census of 1895 (see Appendix B.5.11), which allows us to compute county-level Gini coefficients of landownership concentration. Column 5 of Table 8 indicates that the effect of inclusive institutions on innovation is virtually unaffected by the inclusion of the Gini coefficient of landownership concentration as an additional control. The point estimate for *Inequality* is insignificant. We thus refute inequality as an alternative explanation.

7.6 Migration

Regions with strong economic growth might attract migrants, while also being more innovative. In this case, migration could reflect unobserved economic fundamentals that are not captured by the proxies for economic development and industrialization included in the previous tests. We use region-level data from the 1885 census, which provides the number of inhabitants born outside the respective province, to capture both international and intra-German migration. Column 6 of Table 8 documents that *Migration*, the fraction of non-

native inhabitants in each region, does not affect the relationship between the inclusiveness of institutions and innovation, while the point estimate of *Migration* is insignificant.[30]

7.7 Patent Law

Differences in patent law can affect innovation (Moser (2005)). Before 1877, the German patent law was not harmonized and the patent laws differed distinctly between the German states (Kurz (2000)), so we can only use data for the period after 1877.[31] Although we cannot directly control for possible long-lasting legacy effects resulting from past differences in the patent law, we circumvent this issue by restricting the analysis to counties that were part of Prussia in 1816, and were thus governed by a single Prussian patent law and a single Prussian patent office in Berlin. Column 3 of Table 4 documents that the estimate of *Institutions* is virtually unaffected, when the sample is restricted to Prussia in 1816.[32] Thus, differences in patent laws before 1877 cannot explain the effect of institutions on innovation.

8 The Effect of Innovation on Economic Growth

So far, we document a strong positive link between the inclusiveness of institutions and patents per capita, thereby highlighting innovation as a plausible channel through which institutions affect economic growth. To formally test this channel, we use a three-stage least squares (3SLS) model. As a proxy for economic growth, we employ population growth—a well-established measure (De Long and Shleifer (1993), Squicciarini and Voigtländer (2015)).

In the first stage, we instrument the inclusiveness of institutions with the years of French occupation, and we use the estimated *Institutions* in the second stage to study the effect on patents per capita. In the third stage, we test whether differences in patents per capita in 1890 and 1900 affect population growth in 1890-1900 and 1900-1910, respectively. The controls used in the baseline specification in Table 3 are included in all three stages of the model. Furthermore, we control for past population growth (*Past Growth*) in all three stages, to account for a possible trend in population growth. As before, we weight observations by population (for details, see Appendix B.7).

The estimated coefficients of the 3SLS model are reported in Table 9. The results of the first (column 1) and the second stages (column 2) confirm the previous findings and show that the length of French occupation explains differences in the inclusiveness of institutions, and that in turn, these institutions affect patents per capita. In column 3, we extend the findings by documenting a significant effect of patents per capita on future economic growth. The

[30] A qualitative analysis of the patentees' names shows that there is no evidence for French migration.

[31] As noted in Section 3, French patent law was not incorporated in German states after 1815, nor did it shape the German patent laws that emerged in the 19th century.

[32] Prussia is the only state large enough to have variation in institutions that allows for a within-state test.

change in institutional quality associated with moving from no occupation to the maximum length of occupation ultimately causes an increase of 0.33 percentage points in the annual county-level population growth rate in the third stage, through its impact on patents per capita in the second stage. The magnitude of the estimated effect is economically large, when compared with the mean population growth rate of 1.14 percentage points, which supports the idea that innovation is a plausible channel through which institutions affect economic prosperity. With this result, we build a bridge between the literature that links innovation to growth (e.g. Akcigit et al. (2017)), and the research on the effect of institutions on growth (e.g. Acemoglu et al. (2001)).

9 Conclusion

We investigate the impact of inclusive institutions on innovation using novel, hand-collected, county-level data for Imperial Germany. After the French Revolution, the French occupied parts of the German states for geo-strategic reasons. We use this occupation, which was uncorrelated with economic fundamentals, as an instrument for local differences in institutions. Regions occupied for longer were early implementers of better institutions, creating an economy with fewer entry barriers and distortions in labor and product markets.

We provide evidence for a long-run effect of institutional quality on innovation. Counties with the longest occupation, which implemented better institutions earlier, had more than twice as many patents per capita around 1900 as unoccupied counties with more extractive institutions. The findings are particularly pronounced for innovations in the chemical industry and electrical engineering. This suggests that inclusive institutions were instrumental—if not a necessary condition—for the second industrial revolution, which was driven by these industries. The results thus point to institutions as a first order determinant of innovation. Importantly, we also show that the increase in patenting activity due to better institutions leads to greater economic growth.

A key advantage of this study is the use of granular county-level data, which contrasts the often highly aggregated data used in this field of research. Such data allows us to contribute to the institutions literature by distinguishing between different economic forces and alternative explanations to a degree that country-level data does not permit. In particular, we document that institutions do not act in isolation. The impact of institutions on innovation is limited in former ecclesiastical states, where social norms determined by the Catholic Church helped to maintain a more conservative society, while the effect of inclusive institutions is magnified in counties where access to finance was available. By studying the heterogeneity in the effect of inclusive institutions, we shed light on the microeconomic channels through which the quality of institutions affects innovation, and on the shape of the production function for innovation.

Moreover, we are able to show that the results are unlikely to be driven by a general increase in economic development due to better institutions or by other potential confounding effects, such as French influence through culture or technology transfers, human capital, or trade.

The effect of institutions on economic development has been well studied (e.g. North (1990), De Long and Shleifer (1993), Acemoglu et al. (2001)). This literature suggests that differences in institutional quality can explain why some countries are poor and others rich. However, there is still a lack of knowledge about the channels through which institutions operate. We contribute to this fundamental question by investigating a so far overlooked channel: innovation. The economic magnitude of the findings indicates that innovation is a quantitatively plausible channel for the large positive effect of inclusive institutions on economic prosperity.

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Table 1: Summary Statistics

This table presents summary statistics for the main variables. Institutions is an index that measures the inclusiveness of local institutions. The index is the average of the number of years between the implementation of four institutional reforms (introduction of the civil code, abolition of serfdom, implementation of agrarian reforms, dissolution of guilds) and the filing of a patent. Years French Occupation is the number of years of French occupation. Patents is the number of patents per million inhabitants. Population/km^2 is population divided by square kilometers. River (Harbor) is a dummy that takes the value of one if a county had a navigable river (sea harbor). River*harbor is the interaction of the two variables. Border (Border France) is a dummy that takes the value of one if a county was at an external border of the German Empire (with France). Coal Deposits (Ore Deposits) is a dummy that takes the value of one if a county had deposits of coal (iron ore or non-ferrous metals). Large City 1750 is a dummy that takes the value of one if the county had a city with more than 5,000 inhabitants in 1750. University 1789 is a dummy that takes the value of one if a county had a university in 1789. Hanseatic League is a dummy that takes the value of one if a city in the county was a member of the Hanseatic League in the medieval period. Protestants % is the percentage of the population that was Protestant. Minorities is a dummy that takes the value of one if the fraction of the population whose native language was not German was above 50%. Prussia 1816 is a dummy that takes the value of one if a county is part of Prussia in 1816. City State is a dummy that takes the value of one if a county is part of one of the city states: Hamburg, Bremen or Lübeck. All variables are weighted by population, using the population weights of 1900. Dummy variables are multiplied by 100 to facilitate their display. For more details, see Appendix B.

	Occupied			Not Occupied		
	Mean	St. Dev.	N	Mean	St. Dev.	N
Institutions	70.21	21.20	251	58.33	9.73	630
Years French Occupation	9.30	5.81	251	0.00	0.00	630
Patents	12.14	24.81	251	8.95	17.89	630
Population/km^2	1,141.16	1,933.27	251	2,442.35	6,770.19	630
River	53.45	49.98	251	39.91	49.01	630
Harbor	9.25	29.04	251	5.36	22.53	630
River*Harbor	8.18	27.46	251	2.18	14.63	630
Border	10.93	31.27	251	16.43	37.08	630
Border France	3.43	18.25	251	1.07	10.29	630
Coal Deposits	36.70	48.29	251	25.55	43.65	630
Ore Deposits	16.42	37.12	251	13.13	33.80	630
Large City 1750	30.03	45.93	251	23.81	42.63	630
University 1789	11.97	32.52	251	12.57	33.17	630
Hanseatic League	24.73	43.23	251	12.06	32.59	630
Protestants %	59.60	33.96	251	65.90	35.89	630
Minorities	0.00	0.00	251	10.33	30.46	630
Prussia 1816	58.05	49.45	251	49.49	50.04	630
City State	6.13	24.03	251	0.00	0.00	630

Table 2: The Determinants of French Occupation

This table presents estimates of the determinants of French occupation using OLS. The dependent variable is the number of years for which a county was occupied by the French, which varies between 0 and 19 years. Distance to Paris is the great circle distance in km between the main city in each county and Paris. All other variables are defined in Table 1. One cross-section is used in the analysis. In the regression models of columns 1 and 3, observations are equally-weighted. In the regression models of columns 2 and 4, 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.

	Years French Occupation			
	(1)	(2)	(3)	(4)
Distance to Paris			-0.009***	-0.008***
			(0.000)	(0.000)
River	1.173	0.628	1.103	0.630
	(0.125)	(0.260)	(0.107)	(0.209)
Harbor	-1.579**	-1.446**	-0.171	-0.700
	(0.024)	(0.037)	(0.801)	(0.266)
River*Harbor	0.265	3.400***	-0.026	1.069
	(0.821)	(0.002)	(0.974)	(0.386)
Coal Deposits	0.987	0.537	1.061	0.204
	(0.208)	(0.361)	(0.126)	(0.686)
Ore Deposits	1.457	1.513	0.641	-0.056
	(0.228)	(0.159)	(0.529)	(0.955)
Large City 1750	-0.099	-0.421	-0.202	-0.318
	(0.834)	(0.532)	(0.601)	(0.506)
University 1789	0.981	2.162	0.229	0.792
	(0.323)	(0.142)	(0.791)	(0.453)
Hanseatic League	1.311*	1.266	1.695***	1.373**
	(0.068)	(0.123)	(0.007)	(0.037)
City State	3.409***	1.936	2.466***	1.980*
	(0.001)	(0.106)	(0.001)	(0.058)
Adj. R^2	0.029	0.027	0.231	0.255
N	881	881	881	881
Cluster	Region	Region	Region	Region
Weighting	Equal	Area	Equal	Area

Table 3: The Impact of Institutions on Innovation

This table presents estimates of the impact of institutions on innovation using an instrumental variables approach. In the first stage (column 1), we instrument Institutions with the years of French occupation. In column 2, we present the estimates from the second-stage regression of patents per capita on the instrumented Institutions 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) Institutions	(2) Patents
Years French Occupation	1.607***	
	(0.000)	
Institutions		0.402***
		(0.001)
Population/km^2	0.000	0.003***
	(0.625)	(0.000)
River	0.854	4.662*
	(0.314)	(0.099)
Harbor	3.067	-2.706
	(0.265)	(0.265)
River*Harbor	-3.338	-11.616**
	(0.247)	(0.019)
Border	0.884	-4.228**
	(0.373)	(0.015)
Border France	16.299**	-16.804***
	(0.013)	(0.002)
Coal Deposits	-3.221***	1.621
	(0.006)	(0.202)
Ore Deposits	1.509	-0.540
	(0.155)	(0.783)
Large City 1750	-0.198	10.319***
	(0.861)	(0.006)
University 1789	4.577**	-7.529
	(0.035)	(0.148)
Hanseatic League	-6.006***	-6.283**
	(0.000)	(0.047)
Protestants %	-0.050**	0.034*
	(0.011)	(0.080)
Minorities	-1.858	-0.680
	(0.250)	(0.722)
Prussia 1816	14.863***	-11.155***
	(0.000)	(0.002)
City State	-7.461**	18.620***
	(0.029)	(0.000)
Adj. R^2	0.808	0.397
N	2,643	2,643
F-Stat. Ex. Instr.		64.20
Year FE	Yes	Yes
Cluster	Region	Region
Weighting	Population	Population

Table 4: Robustness Tests: Varying Sample, Instrumental Variables and Variables of Interest

This table presents estimates of the impact of institutions on innovation under different specifications. We present second-stage estimates of the impact of institutions on innovation, where Institutions is instrumented by the years of French occupation in all models, except for the model in column 4. The dependent variable is patents per capita. In column 1 (3), only counties in the Rhineland, Westphalia and Saxony (Prussia) are included in the sample. In column 2, East Elbia is excluded from the sample. In column 4, Institutions is instrumented with a dummy that is one if a county was occupied by the French. In column 5, we use the logarithm of Institutions. In column 6, 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. 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 details on the data, see Appendix B.

	Patents					
	(1)	(2)	(3)	(4)	(5)	(6)
Institutions	0.174*	0.294*	0.399***	0.822***		
	(0.079)	(0.078)	(0.000)	(0.002)		
ln(Institutions)					31.928***	
					(0.001)	
Alternative Institutions						0.366***
						(0.001)
Adj. R^2	0.486	0.398	0.533	0.367	0.393	0.401
N	450	2,013	1,110	2,643	2,643	2,640
F-Stat. Ex. Instr.	550.59	48.21	471.19	10.69	39.77	113.80
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	West vs. Saxony	Excl. East Elbia	Prussia 1816	All	All	All
IV French Occ.	Years	Years	Years	Dummy	Years	Years

Table 5: Channel: Do Institutions Operate in Isolation?

This table presents estimates of the impact of institutions on innovation, when institutions are interacted with complementary variables that could affect innovation. The dependent variable is patents per capita. We present second-stage estimates of the impact of Institutions and Institutions*Ecclesiastical 1789 on innovation, where Institutions and Institutions*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 that takes the value of one if a county was part of an ecclesiastical state in 1789. Banking is a dummy that takes the value of one if the share of the workforce employed in banking was larger than 0.1% in 1895. We present second-stage estimates of the impact of Institutions and Institutions*Banking on innovation, where Institutions and Institutions*Banking are instrumented by the years of French occupation and the interaction of the years of French occupation with Banking. All columns include the same control variables as in Table 3, but only Protestants % is displayed. The remaining variables are defined in Table 1. The observations are weighted by county population. Standard errors are clustered at the region-level. P-values are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. For more details on the data, see Appendix B.

	Patents	
	(1)	(2)
Institutions	0.453***	0.213***
	(0.000)	(0.002)
Ecclesiastical 1789	8.629	
	(0.258)	
Institutions*Ecclesiastical 1789	-0.180*	
	(0.082)	
Banking		-16.820
		(0.224)
Institutions*Banking		0.448**
		(0.046)
Protestants %	0.027	0.027
	(0.234)	(0.164)
Adj. R^2	0.399	0.438
N	2,643	2,643
F-Stat Ex. Instr.	32.22	79.18
Year FE	Yes	Yes
Cluster	Region	Region
Weighting	Population	Population
Controls	Yes	Yes
Sample	All	All

Table 6: The Impact of Institutions on Different Types of Innovation

This table presents estimates of the impact of institutions on innovation for different types of patents. We present second-stage instrumental variable estimates of the impact of institutions on innovation, measured by patents per capita. Institutions is instrumented by the years of French occupation. 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 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 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 inhabitants. 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 details on the data, see Appendix B.

	(1)	(2)	(3)	(4)	(5)
	High-tech Patents	Low-tech Patents	Firm Patents	Individual Patents	High-tech Firm Patents
Institutions	0.201**	0.201***	0.304***	0.098*	0.188**
	(0.035)	(0.010)	(0.004)	(0.050)	(0.043)
Economic Magnitudes	279%	83%	198%	61%	346%
Adj. R^2	0.176	0.368	0.291	0.304	0.142
N	2,643	2,643	2,643	2,643	2,643
F-Stat. Ex. Instr.	64.20	64.20	64.20	64.20	64.20
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

Table 7: Alternative Explanation: Economic Growth and Industrialization

This table presents estimates of the impact of institutions on innovation, controlling for economic growth and industrialization. We present second-stage instrumental variable estimates of the impact of institutions on innovation, measured by patents per capita. Institutions is instrumented by the years of French occupation. Manufacturing+Mining Workforce % (Services Workforce %) is the employment share of manufacturing and mining (private sector services in %). Coal Mining 1850 (Coal Mining 1880) is the coal production in tons divided by the population in 1850 (1880). 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 details on the data, see Appendix B.

	Patents				
	(1)	(2)	(3)	(4)	(5)
Institutions	0.303**	0.370***	0.391***	0.302**	0.303**
	(0.017)	(0.003)	(0.001)	(0.016)	(0.017)
Manufacturing+Mining	0.119			0.114	0.121
Workforce %	(0.114)			(0.256)	(0.226)
Services Workforce	0.955**			0.958**	0.954**
%	(0.042)			(0.039)	(0.039)
Coal Mining 1850		3.711		0.367	
		(0.132)		(0.904)	
Coal Mining 1880			0.436		-0.020
			(0.132)		(0.959)
Adj. R^2	0.425	0.400	0.399	0.425	0.425
N	2,643	2,643	2,643	2,643	2,643
F-Stat. Ex. Instr.	58.33	68.43	69.51	64.81	61.31
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
Sample	All	All	All	All	All

Table 8: Alternative Explanations

This table presents estimates of the impact of institutions on innovation, controlling for additional variables. We present second-stage instrumental variable estimates of the impact of institutions on innovation, measured by patents per capita. Institutions is instrumented by the years of French occupation. Steam Engines 1861 (Spinning Mills 1861) is the number of steam engines (spinning mills) per million inhabitants in a region in 1861. Old territories (Old territories/km^2) is the number of old territories (per km^2) in a region. Internal border (Zollverein 1842) is one if a county was at a state border in 1816 and if the state was part of the German Empire in 1871 (if a county was in a Zollverein member state in 1842). Illiterates 1876 % is the share of illiterates in a province in 1876. University (Technical University) is one, if a university (technical university) was located in the county in the respective year. Inequality is the Gini coefficient of the ownership concentration of agricultural land. Migration is the share of non-native inhabitants relative to the total population of a region. 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 details on the data, see Appendix B.

	Patents					
	(1)	(2)	(3)	(4)	(5)	(6)
Institutions	0.357**	0.387***	0.601***	0.365**	0.392***	0.412***
	(0.013)	(0.002)	(0.000)	(0.029)	(0.001)	(0.001)
Steam Engines 1861	0.004					
	(0.341)					
Spinning Mills 1861	0.022					
	(0.216)					
Old territories		0.164				
		(0.426)				
Old			-2.219**			
territories/km^2			(0.049)			
Internal Border		0.363	2.043			
		(0.879)	(0.430)			
Zollverein 1842		3.262	5.870**			
		(0.207)	(0.035)			
Illiterates 1876 %				-0.498**		
				(0.015)		
University				2.735		
				(0.666)		
Technical University				-4.836		
				(0.522)		
Inequality					-6.912	
					(0.335)	
Migration						-0.169
						(0.615)
Adj. R^2	0.400	0.399	0.408	0.399	0.398	0.398
N	2,514	2,643	2,643	2,643	2,643	2,643
F-Stat. Ex. Instr.	47.15	83.79	61.09	26.36	62.47	63.09
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Region	Region	Region	Province	Region	Region
Weighting	Populat.	Populat.	Populat.	Populat.	Populat.	Populat.
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Sample	Zollverein	All	All	All	All	All

Table 9: The Effect of Institutions on Growth

This table presents estimates of the impact of institutions on growth, using a three-stage least squares model. In the first stage, we instrument Institutions with the years of French occupation (column 1). In the second stage, we examine the relationship between the estimated Institutions and patents per capita (column 2). We take the estimated patents per capita in the third stage to estimate the effect on future county-level population growth rates (column 3). All control variables from Table 3 are included but not displayed. In addition, we control for past county-level population growth rates. 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 details, see Appendix B and in particular Appendix B.7.

	(1) Institutions	(2) Patents	(3) Growth
Years French	1.596***		
Occupation	(0.000)		
Institutions		0.274***	
		(0.000)	
Patents			0.034***
			(0.009)
Past Growth	-0.067	1.025***	0.317***
	(0.519)	(0.000)	(0.000)
R^2	0.780	0.291	0.295
N	1,762	1,762	1,762
Year FE	Yes	Yes	Yes
Weighting	Populat.	Populat.	Populat.
Controls	Yes	Yes	Yes
Sample	1890+1900	1890+1900	1890+1900

Figure 1: Map of French Occupation

This map shows the length of the French occupation. The borders represent the county structure in the data set. See Appendix B for further information about the data.

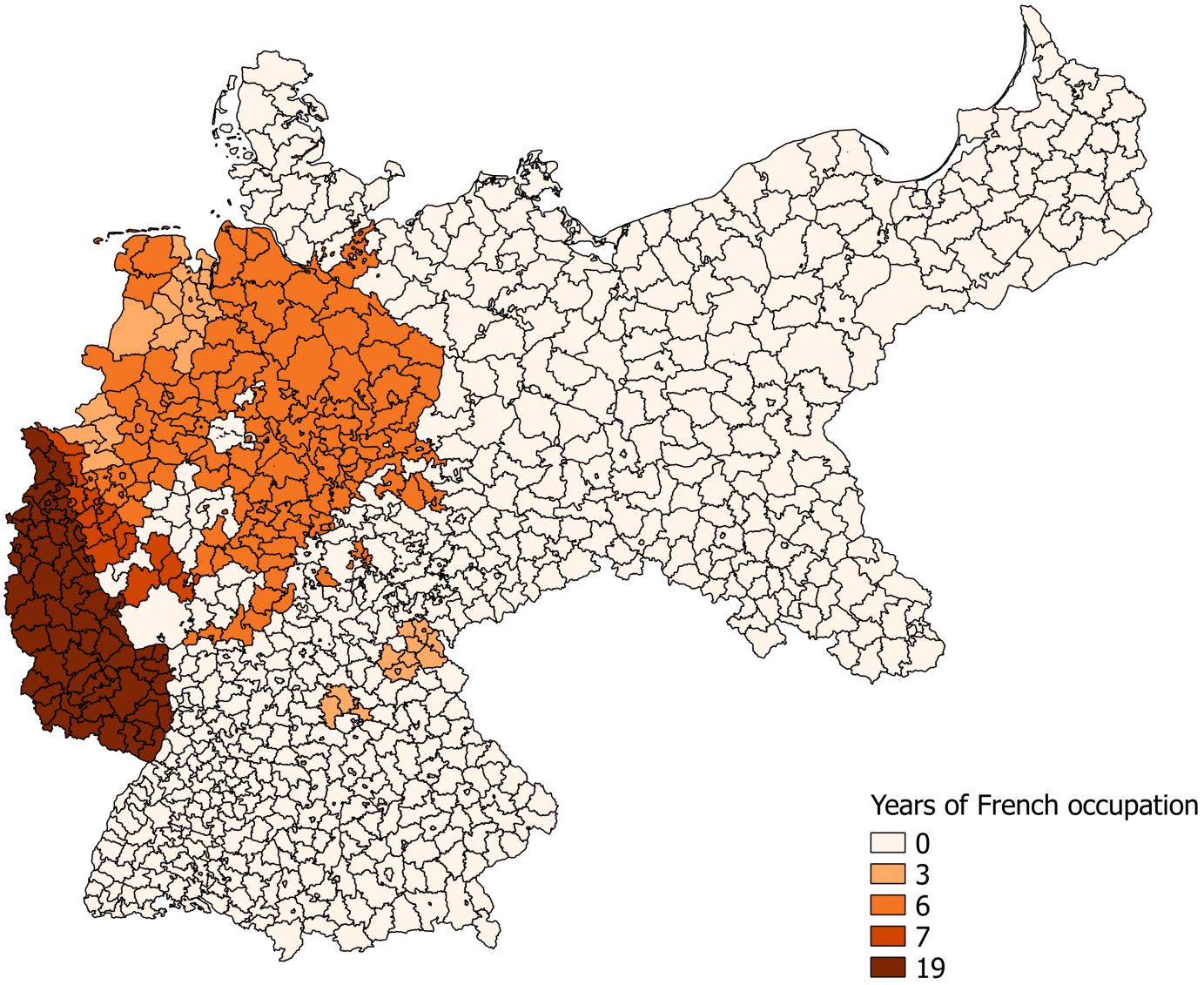


Figure 2: Map of Institutions Index

This map shows regional differences in the Institutions index. The borders represent the county structure in the data set. See Appendix B for further information about the data.

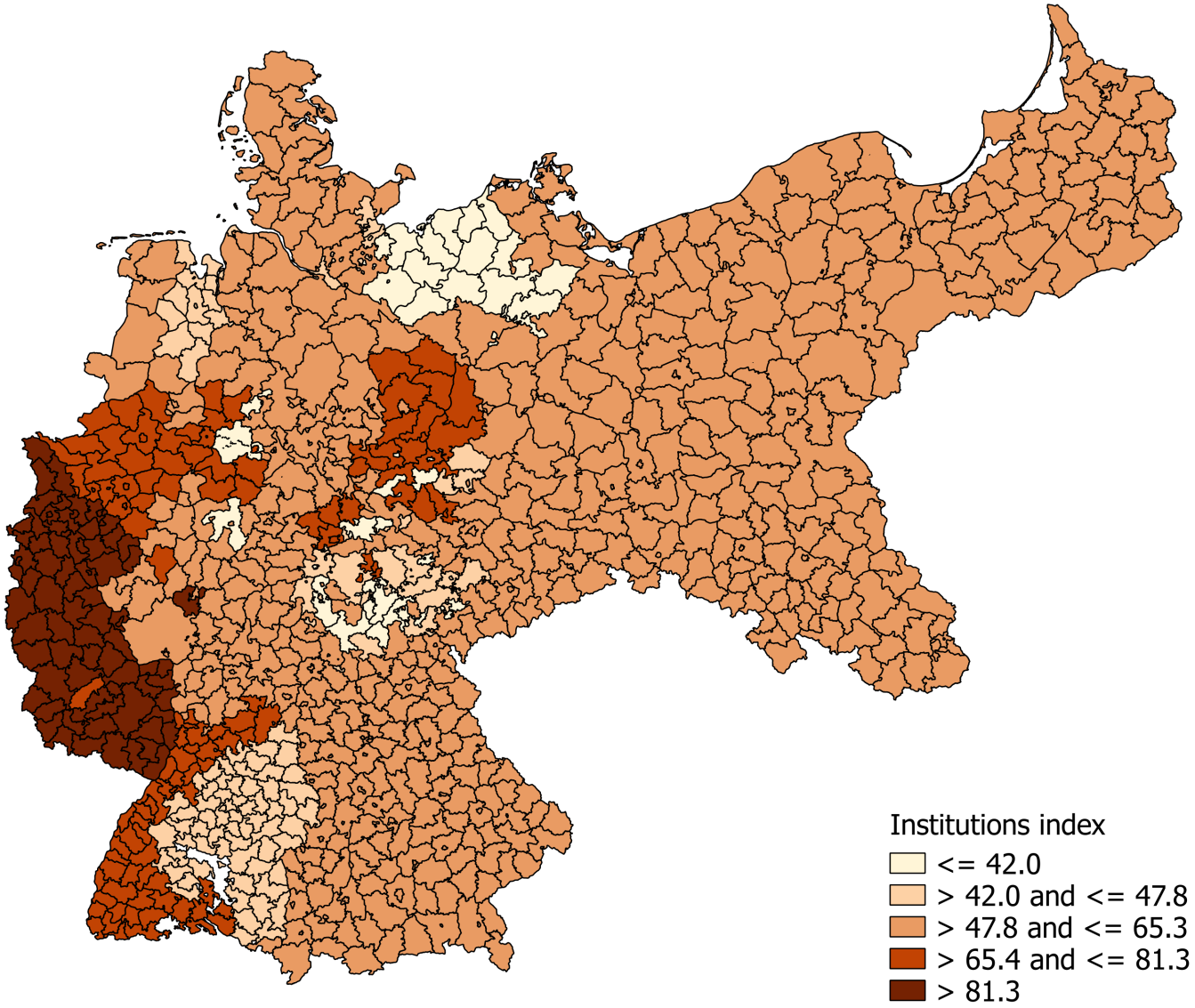
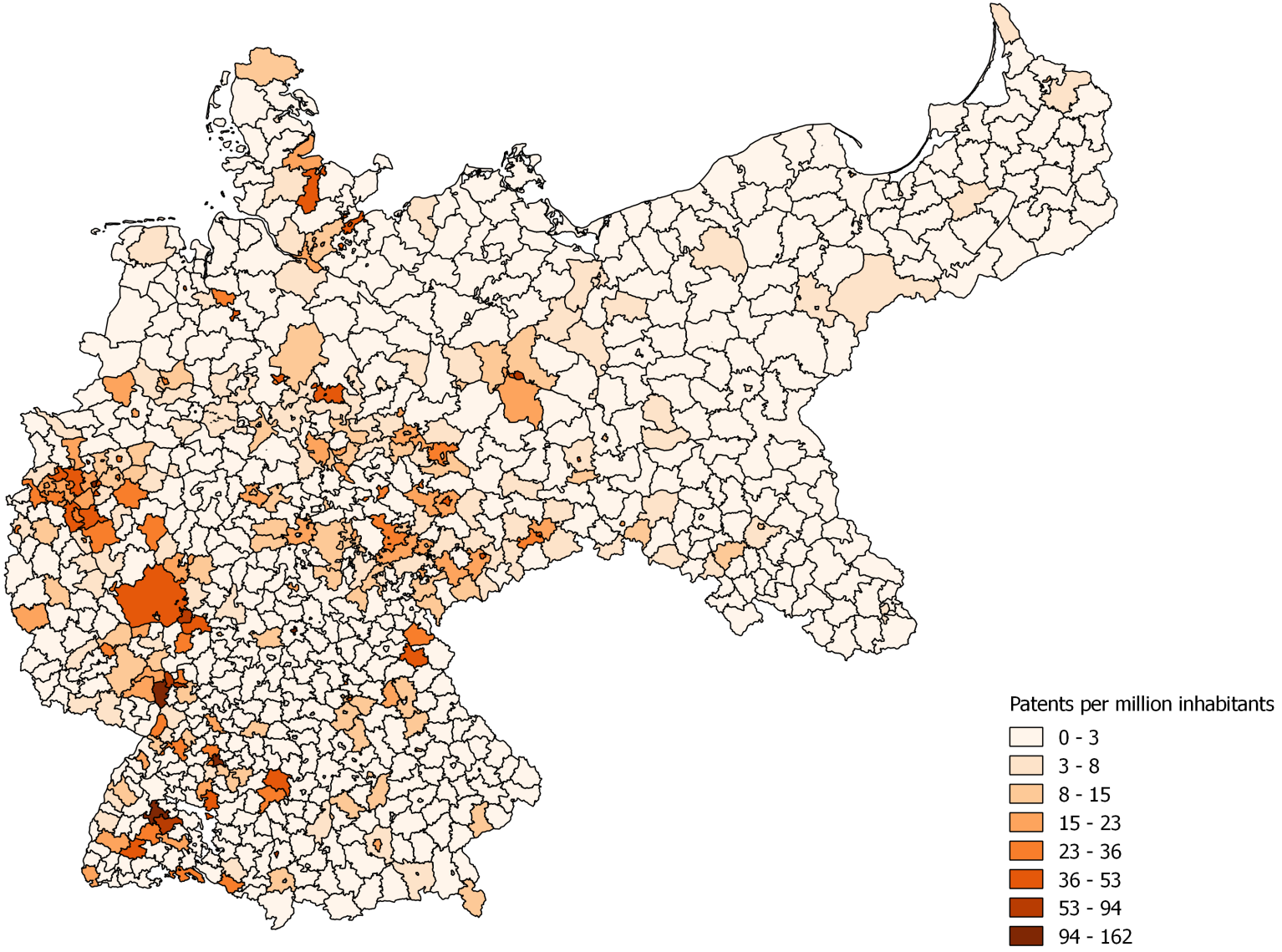


Figure 3: Map of Patents per Capita

This map shows the distribution of the mean number of patents per million inhabitants. The borders represent the county structure in the data set. See Appendix B for further information about the data.



For Online Publication

Appendix to "The Impact of Institutions on Innovation"

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A Appendix: Additional Results and Discussions

A.1 Additional Descriptive Statistics

Table A1 documents the summary statistics for the time-varying variables for each year of the sample. The general pattern from Table 1 holds for each individual year, with the level for the variables *Institutions* and *Patents* increasing over time, which is in line with better institutions being in place for longer (*Institutions*) and the growth of innovative activity during the second industrial revolution (*Patents*), while *Protestants* is stable over the years. The decline in the mean of *Population/km²* for the occupied counties from 1900 to 1910 is due to the equal weighting of the *Population/km²* variable. If *Population/km²* is population weighted, then the mean of *Population/km²* increases from 1890 over 1900 to 1910 for both occupied and non-occupied regions.

Table A1: Yearly Summary Statistics for the Time Varying Variables

This table presents yearly summary statistics for the time varying variables. Patents is the number of patents per million county population. Institutions is an index that measures the inclusiveness of local institutions. The index is the average of the number of years between the implementation of four institutions (introduction of the civil code, abolition of serfdom, implementation of agrarian reforms, dissolution of guilds) and the filing of a patent. Population/km^2 is the ratio of population and area. Protestants % is the percentage of the population that was Protestant. Population/km^2 is equally weighted. All other variables are weighted by population. For more details, see Appendix B.

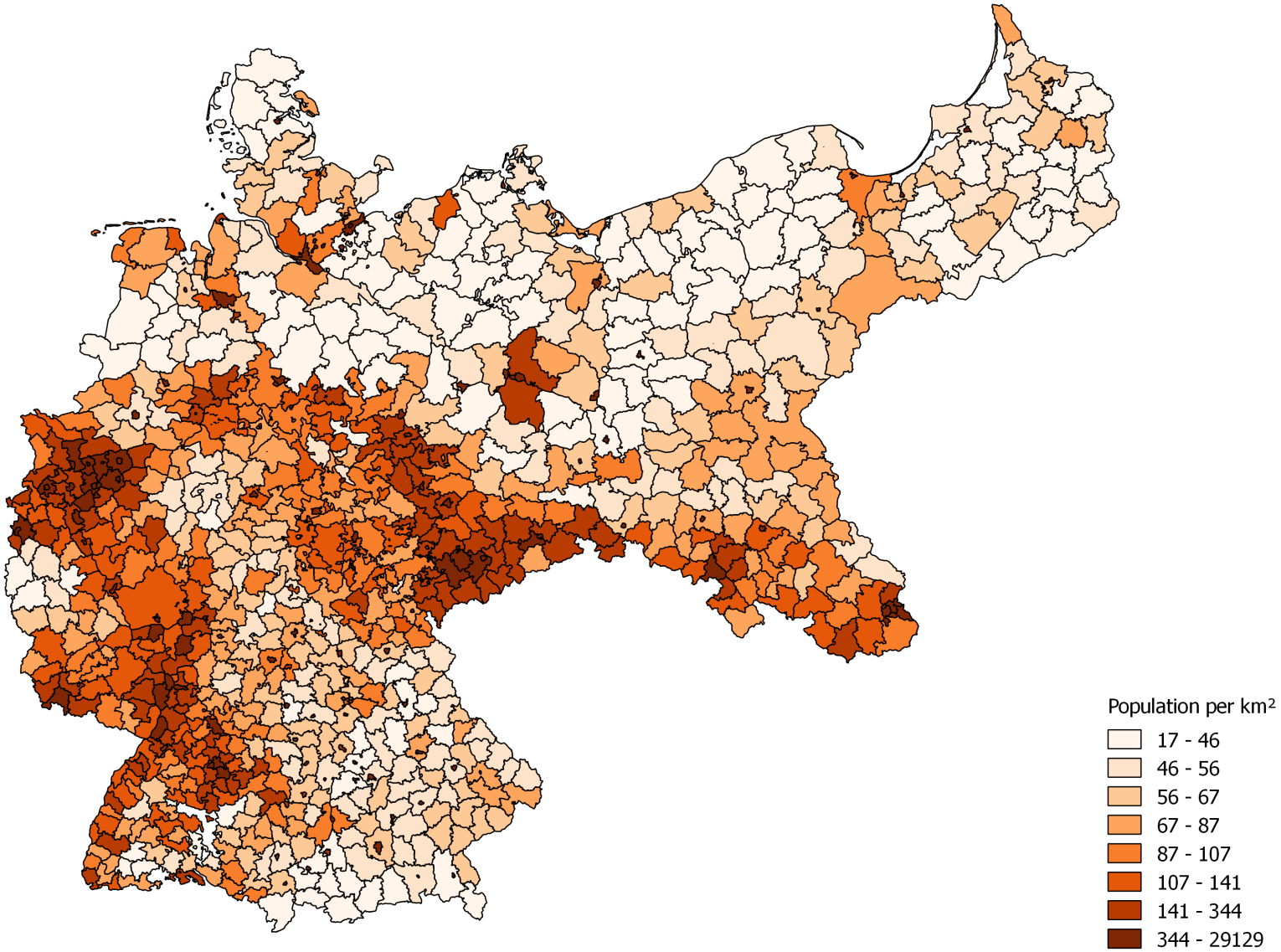
	Occupied			Not Occupied		
	Mean	St. Dev.	N	Mean	St. Dev.	N
1890						
Patents	8.74	17.79	251	3.63	9.15	630
Institutions	62.01	20.42	251	50.33	9.86	630
Population/km^2	537.42	1,261.51	251	405.50	1,627.53	630
Protestants in %	60.07	34.71	251	65.43	36.27	630
1900						
Patents	12.14	24.81	251	8.95	17.89	630
Institutions	70.21	21.20	251	58.33	9.73	630
Population/km^2	663.70	1618.34	251	435.25	1,747.70	630
Protestants in %	59.60	33.96	251	65.90	35.89	630
1910						
Patents	26.90	39.54	251	21.73	39.38	630
Institutions	80.08	20.96	251	68.40	9.69	630
Population/km^2	616.44	1303.62	251	445.67	1802.41	630
Protestants in %	58.52	34.17	251	65.16	35.03	630

A.2 Population Density Map

Figure A1 shows the mean population per square kilometer for Imperial Germany over the years 1890, 1900, and 1910. The borders represent the county structure in the data set, which is explained in Appendix B.1.1. A comparison with the map on the number of patents per capita (Figure 3) indicates that counties with a higher population density on average also produced more patents per capita.

Figure A1: Population Density

This map shows the mean population per square kilometer. The borders represent the county structure in the data set. See Appendix B for further information about the data.



A.3 Additional Robustness Tests

A.3.1 Additional Robustness Tests: Equal Weighting and Individual Years

Throughout the empirical analysis, we weight observations by population, to avoid the possibility that a few small counties could determine the results. We now repeat the analysis of column 2 of Table 3, without weighting observations by population. Although equal-weighting observations could cause the magnitudes to be unrepresentative of the average effect of institutions on innovation, it allows us to exclude the concern that the results are driven by just a few heavily populated counties. We present the results in column 1 of Table A2. The results remain highly statistically significant and economically large.

In columns 2, 3 and 4 of Table A2, we test whether the results hold when we separately analyze the years 1890, 1900 and 1910, respectively. 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 the findings. We find that the results hold for all the years in the sample. When we contrast the impact on innovation of more inclusive institutions in the longest-occupied counties against the data for unoccupied counties, we find a 223% increase in patents per capita in 1890. The magnitudes are 125% in 1900 and 99% in 1910. All effects are evaluated at the respective sample mean. The reason for the results being stronger for earlier years is that institutions were not harmonized across the entire German Empire until 1900. In 1890, there were still regional differences in institutions; 1900 is the first year with harmonized institutions, and by 1910 all counties had 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 inclusive institutions on innovation. This highlights the notion that the effect of institutional change on innovation is a relatively slow-decaying process with long-lasting effects.

Table A2: Robustness Tests: Equal Weighting of Observations and Individual Panel Years

This table presents estimates of the impact of institutions on innovation under different specifications. We present second-stage estimates of the impact of institutions on innovation, where Institutions is instrumented by the years of French occupation. The dependent variable is patents per capita. In column 1, we equally weight observations. In all other columns, counties are weighted by population. In columns 2, 3 and 4, the sample is restricted to the year 1890, 1900 or 1910, respectively. 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 details on the data see Appendix B.

	(1)	(2)	(3)	(4)
	Patents	Patents	Patents	Patents
Institutions	0.270***	0.294***	0.299**	0.556***
	(0.000)	(0.000)	(0.026)	(0.004)
Adj. R^2	0.131	0.195	0.345	0.501
N	2,643	881	881	881
F-Stat. Ex. Instr.	73.50	63.93	63.08	62.86
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

A.3.2 Additional Robustness Tests: Exclaves and Enclaves

The map of the French occupation in Figure 1 shows occupied exclaves surrounded by non-occupied territories, and non-occupied enclaves surrounded by occupied territories. While the overall French occupation was not driven by economic fundamentals or correlated with the underlying growth fundamentals of the occupied areas, one might worry that this might not hold for the exclaves or enclaves and that this could affect the results. We eliminate this concern using both historical evidence and quantitative analysis. All enclaves were part of small principalities located in strategically unimportant regions, in contrast to, for example, the territories along the North Sea which had to be occupied to maintain the blockade against Great Britain. Likewise, the existence of exclaves reflects the political history of these territories. As a result of the Treaty of Tilsit (1807), Prussia lost all territories West of the Elbe—including these exclaves. In Appendix B.1.4, we provide a list of all enclaves and exclaves.

In the following, we provide quantitative evidence that the exclaves and enclaves do not affect the results (for the coding, see Appendix B.1.4). In column 1 of Table A3, occupied exclaves surrounded by unoccupied areas are dropped from the sample. In column 2 of Table A3, occupied exclaves surrounded by unoccupied areas are coded as unoccupied. In both cases, the coefficient for *Institutions* is virtually unaffected. In column 3 of Table A3, unoccupied enclaves surrounded by occupied areas are dropped from the sample. In column 4 of Table A3, unoccupied enclaves surrounded by occupied areas are coded as occupied. In both cases, the coefficient for *Institutions* is slightly larger than in the baseline specification. It also does not affect the findings if we "smooth" the border of French occupation by excluding all "bulges" that protrude into (non-)occupied areas (column 5 of Table A3), or if we code the corresponding counties such that the border between occupied and non-occupied areas is "smooth" (column 6 of Table A3). Finally, column 7 and column 8 combine all prior adjustments by either dropping the affected counties from the sample (column 7), or by coding them in the previously discussed manner (column 8). In both specifications, the point estimate for Institutions increases slightly.

Table A3: Robustness Tests: Exclaves and Enclaves

This table presents estimates of the impact of institutions on innovation under different specifications. We present second-stage estimates of the impact of institutions on innovation, where Institutions is instrumented by the years of French occupation. The dependent variable is patents per capita. In column 1, occupied exclaves surrounded by unoccupied areas are dropped from the sample. In column 2, occupied exclaves surrounded by unoccupied areas are coded as unoccupied. In column 3, unoccupied enclaves surrounded by occupied areas are dropped from the sample. In column 4, unoccupied enclaves surrounded by occupied areas are coded as occupied. In column 5, the border of French occupation is "smoothed" by excluding from the sample all "bulges" that protrude into (non-)occupied areas. In column 6, all "bulge" counties are coded such that the border between occupied and non-occupied areas is "smooth". Column 7 and column 8 combine all the prior adjustments, by either dropping the affected counties from the sample (column 7), or by coding them in the previously discussed manner (column 8). 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 details on the data, see Appendix B and in particular Appendix B.1.4.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Patents	Patents	Patents	Patents	Patents	Patents	Patents	Patents
Institutions	0.405***	0.403***	0.438***	0.437***	0.442***	0.400***	0.445***	0.436***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
Adj. R^2	0.399	0.397	0.399	0.397	0.401	0.397	0.402	0.397
N	2,592	2,643	2,580	2,643	2,556	2,643	2,505	2,643
F-Stat. Ex. Instr.	65.26	65.39	63.35	60.08	63.39	63.37	64.46	59.08
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Region	Region	Region	Region	Region	Region	Region	Region
Weighting	Populat.	Populat.	Populat.	Populat.	Populat.	Populat.	Populat.	Populat.
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	No Exclaves	All	No Enclave	All	Smooth	All	All Adj.	All
IV French Occ.	Years	Exclave Adj.	Years	Enclave Adj.	Years	Smooth	Years	All Adj.

A.3.3 Additional Robustness Tests: Winsorization and Poisson Regression

In Figure 3 one can observe a small number of counties with a very high number of patents per capita, for example the cities of Berlin, Cologne, and Frankfurt am Main. Such a clustering of innovative activity in a small number of highly innovative regions is common. Today in the United States, for instance, Silicon Valley stands out as a small but highly innovative cluster. Nevertheless, we account for the concern that these observations constitute outliers that might drive the results. We winsorize the population-weighted number of patents per capita across all counties at the 1% and 5% levels (columns 1 and 2 of Table A4). The effect of *Institutions* remains highly significant and economically large in these specifications.

In column 3, we present an additional variation on the estimation procedure. Instead of employing a linear regression model, we estimate a Poisson regression in the second stage of the IV to account for the relatively high number of zero observations. Specifically, we estimate the impact of *Institutions* on the absolute number of patents per county (*Number Patents*), instead of patents per capita as in the main specification. Consequently, we add the county population as an additional control in the regression. We confirm the main result in the paper in this alternative specification, as *Institutions* remains highly statistically significant. The estimates imply that implementing all institutional reforms one year earlier leads to an increase of roughly 5.5% in the number of patents in the county.

Table A4: Robustness Tests: Winsorization and Poisson Regression

This table presents estimates of the impact of institutions on innovation under different specifications. We present second-stage estimates of the impact of institutions on innovation, where Institutions is instrumented by the years of French occupation. In columns 1 and 2, the dependent variable is patents per capita. In column 3, the dependent variable is the number of patents. In columns 1 and 2, a standard instrumental variable approach is used. In column 3, an IV-Poisson approach is used. In column 1 (2), the number of patents per capita is winsorized at the 1% (5%) level. In column 3, county population is added as an additional control variable. 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 details on the data, see Appendix B.

	(1)	(2)	(3)
	Patents Winsorized 1%	Patents Winsorized 5%	Number Patents
Institutions	0.380***	0.303***	0.055***
	(0.001)	(0.001)	(0.001)
Population			0.000
			(0.127)
Adj. R^2	0.438	0.372	
N	2,643	2,643	2,643
F-Stat. Ex. Instr.	64.20	64.20	
Estimation	IV	IV	IV-Poisson
Year FE	Yes	Yes	Yes
Cluster	Region	Region	Region
Weighting	Population	Population	Population
Controls	Yes	Yes	Yes

A.4 Additional Results

A.4.1 Culture, Technology and Knowledge Transfer

We present additional evidence to rule out the notion that technology and knowledge transfers from the French drove the subsequent boom in innovation in the occupied areas. In Subsection 7.2 of the paper, we argue that this concern could be most acute for technologies in which France might have had a competitive advantage relative to the German states: steam engines and mechanical cotton spinning mills. We therefore obtain additional data from the Zollverein census of 1861, to compute the number of mechanical cotton mills per million inhabitants that were in operation in each region in 1861 (*Spinning Mills 1861*), and the number of steam engines per million inhabitants within each region in 1861 (*Steam Engines 1861*). In column 1 of Table 8 of the paper, we jointly include both variables as additional controls. In the following, we provide further specifications to underline the robustness of this result.

In column 1 of Table A5, we first present the results of the baseline estimation for the restricted sample, since data on steam engines and spinning mills is only available for the Zollverein member states, which excludes some territories in the North. The effect of *Institutions* remains almost unchanged compared to the full sample. In column 2 of Table A5, we add only *Steam Engines 1861* as an additional control variable, and in column 3 of Table A5, we add only *Spinning Mills 1861* as an additional control variable. The effects of *Steam Engines 1861* and *Spinning Mills 1861* are not significant, and the effect of *Institutions* remains strong and significant. For comparison, column 4 includes both *Steam Engines 1861* and *Spinning Mills 1861,* which is the specification reported in column 1 of Table 8. Finally, in column 5 of Table A5, we test whether the coefficient of *Institutions* remains significant if we include the employment shares used in Subsection 7.1 of the paper to proxy for economic development (*Manufacturing+Mining Workforce %* and *Services Workforce %*), in addition to *Steam Engines 1861* and *Spinning Mills 1861.* The magnitude of the effect of *Institutions* decreases when adding the employment shares, which reflects the findings of Subsection 7.1, but the effect still remains large in economic terms and highly significant. Overall, these additional results strengthen the argument that the results are not driven by French technology transfer rather than institutions.

Table A5: Alternative Explanation: Technology Import

This table presents estimates of the impact of institutions on innovation, controling for potential technology import. We present second-stage instrumental variable estimates of the impact of institutions on innovation, measured using patents per capita. Institutions is instrumented by the years of French occupation. Steam Engines 1861 measures the number of steam engines per one million inhabitants that were in operation in 1861. Spinning mills 1861 measures the number of mechanical spinning mills per million inhabitants that were in operation in 1861. Manufacturing+Mining Workforce % (Services Workforce %) is the employment share of manufacturing and mining in % (private sector services in %). 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. For more details on the data, see Appendix B.

	Patents				
	(1)	(2)	(3)	(4)	(5)
Institutions	0.410***	0.350**	0.411***	0.357**	0.289**
	(0.001)	(0.015)	(0.001)	(0.013)	(0.047)
Steam Engines 1861		0.005		0.004	0.002
		(0.295)		(0.341)	(0.630)
Spinning Mills 1861			0.029	0.022	-0.001
			(0.170)	(0.216)	(0.964)
Manufacturing+Mining					0.087
Workforce %					(0.313)
Services Workforce					1.077**
%					(0.026)
Adj. R^2	0.398	0.400	0.398	0.400	0.428
N	2,514	2,514	2,514	2,514	2,514
F-Stat. Ex. Instr.	61.92	46.09	61.30	47.15	46.50
Year FE	Yes	Yes	Yes	Yes	Yes
Cluster	Region	Region	Region	Region	Region
Weighting	Populat.	Populat.	Populat.	Populat.	Populat.
Controls	Yes	Yes	Yes	Yes	Yes
Sample	Zollverein	Zollverein	Zollverein	Zollverein	Zollverein

A.4.2 Trade and Market integration

One potential concern which we attempt to rule out relates to the possibility that the French occupied regions could have experienced a larger increase in international or domestic trade. In Subsection 7.3 of the paper, we present several pieces of evidence that rule out this concern. We now present further evidence that an improvement in institutions, and not trade, is the driver of the findings.

In Table A6, we present additional statistics on German foreign trade. We show that between 1841 and 1910, France did not dominate the German import statistics (Panel A), nor the German export statistics (Panel B). 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 the results.

As discussed in Subsection 7.3 of the paper, market integration is another potential channel though which the occupation could have fostered innovation, since the German territories were reorganized in the early 19$^{\text{th}}$ century. In columns 2 and 3 of Table 8, we address this concern in the paper 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 the sample, and *Old territories/km*^{2} is *Old territories* divided by square kilometers. In addition, we use the dummy variable *Internal Border*, which is one if the county was at a state border in 1816 and if the neighboring state was part of the German Empire in 1871, and the dummy variable *Zollverein 1842* to control for Zollverein membership in 1842. In addition to the results presented in column 2 (column 3) of Table 8, where *Old territories* (*Old territories/km*^{2}), *Internal Border* and *Zollverein 1842* are all included in the regression model, we now provide additional specifications in Table A7, in which these additional variables enter separately into the regressions.

In column 1 of Table A7, we find no significant effect of *Old territories,* and the coefficient of *Institutions* remains large and highly significant. In column 2 of Table A7, we find a significantly negative coefficient of *Old territories/km²*. The effect of *Institutions* is highly significant and the magnitude of the effect is even larger than in the baseline model. We include only *Internal Border* in column 3, and only *Zollverein 1842* in column 4 of Table A7. There is neither a significant effect of *Internal Border* nor of *Zollverein 1842,* and the effect of Institutions is almost unchanged compared to the baseline model. To facilitate a comparison across the different specifications, columns 5 and 6 report the specifications discussed earlier, which are already reported in columns 2 and 3 of Table 8.

Table A6: Alternative Explanation: International Trade

This table presents data on Germany's international trade statistics for the 1841 to 1910 period. Panel A reports the share of imports from Germany's main trade partners 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 information on the data source, see Appendix B.6

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 A7: Alternative Explanations: Trade and Market Integration

This table presents estimates of 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 per capita. Institutions 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 (Zollverein 1842) is a dummy equal to one, if a county was at a state border in 1816 and if the state was part of the German Empire in 1871 (if a county was in a Zollverein member state 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 details on the data, see Appendix B.

	Patents					
	(1)	(2)	(3)	(4)	(5)	(6)
Institutions	0.354***	0.540***	0.400***	0.429***	0.387***	0.601***
	(0.004)	(0.000)	(0.001)	(0.000)	(0.002)	(0.000)
Old territories	0.212				0.164	
	(0.300)				(0.426)	
Old		-1.859*				-2.219**
territories/km^2		(0.085)				(0.049)
Internal Border			0.422		0.363	2.043
			(0.859)		(0.879)	(0.430)
Zollverein 1842				3.802	3.262	5.870**
				(0.103)	(0.207)	(0.035)
Adj. R^2	0.399	0.406	0.397	0.398	0.399	0.408
N	2,643	2,643	2,643	2,643	2,643	2,643
F-Stat. Ex. Instr.	58.48	46.34	63.61	90.45	83.79	61.09
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

A.4.3 Human Capital

In Subsection 7.4 of the paper, we address the concern that regional differences in the endowment of human capital could drive the results. We now present additional robustness to the results reported in column 4 of Table 8 of the paper, where we add the variables *Illiterates 1876 %, University* and *Technical University* to the baseline specification jointly. More precisely, we now test in Table A8 whether these variables have an effect on the results when entering separately into the regressions.

In column 1 of Table A8, we find that *Illiterates 1876 %* is significantly negatively correlated with patents per capita. In column 2 of Table A8, we find no significant effect of *University*, which indicates the presence of a university in the respective county. Column 3 of Table A8 shows that there is also no significant effect of *Technical University*, which indicates the presence of a technical university. Across all three regression models, the variable of interest, *Institutions*, remains highly significant. For ease of comparison, we also report column 4 of Table 8 in column 4 of Table A8.

Table A8: Alternative Explanations: Human Capital

This table presents estimates of 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 per capita. Institutions is instrumented by the years of French occupation. Illiterates 1876 % is the share of illiterates in the conscript age-group of 1875/76 at the province level. University is one if a university was located within a county in the respective year. This includes general universities, technical universities, mining academies, medical universities and higher trade colleges. Technical University is 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 Appendix B.

	Patents			
	(1)	(2)	(3)	(4)
Institutions	0.364**	0.400***	0.398***	0.365**
	(0.028)	(0.007)	(0.006)	(0.029)
Illiterates 1876 %	-0.496**			-0.498**
	(0.020)			(0.015)
University		-0.610		2.735
		(0.926)		(0.666)
Technical University			-3.008	-4.836
			(0.684)	(0.522)
Adj. R^2	0.399	0.397	0.397	0.399
N	2,643	2,643	2,643	2,643
F-Stat. Ex. Instr.	25.42	32.63	31.64	26.36
Year FE	Yes	Yes	Yes	Yes
Cluster	Province	Province	Province	Province
Weighting	Population	Population	Population	Population
Controls	Yes	Yes	Yes	Yes

A.5 Discussion of Further Measures for Institutional Quality

As a measure for institutional quality, we use an index that is proposed in Acemoglu et al. (2011a). Acemoglu et al. use this index to analyze the effect of institutional reforms on urbanization. This approach is generally criticized by Kopsidis and Bromley (2016a). Kopsidis and Bromley argue that the index used by Acemoglu et al. (2011a) underestimates the institutional quality of non-occupied territories compared to occupied territories, and they thus provide a list of alternative years of reform implementation. However, we use the original coding, since the coding of Kopsidis and Bromley artificially overestimates institutional quality in non-occupied territories, which we illustrate in the following. Apart from this, Kopsidis and Bromley do not use strict and consistent criteria to identify the years of reform implementation, nor do they provide references that allow the verification of their coding (see their brief online appendix, Kopsidis and Bromley (2016b)). In contrast, Acemoglu et al. (2011a) describe in detail both the criteria used to define the year of reform implementation and the sources for each individual reform (see the online appendix of their paper, Acemoglu et al. (2011b)) The following examples illustrate shortcomings in the approach of Kopsidis and Bromley, who artificially overestimate institutional quality in non-occupied territories:

(1) Introduction of the civil code: Kopsidis and Bromley (2016a) argue that the Prussian October Decree (Oktoberedikt) of 1807 marked the introduction of a civil code in the Eastern provinces of Prussia, while Acemoglu et al. (2011b) use 1900, the year when the nationwide German Civil Law (Bürgerliches 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 the courts. Thus, taking 1807 as the reform year overestimates the institutional quality of these provinces, since highly discriminatory 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 the manor also lost their police powers in 1849, but this privilege was officially reintroduced in 1853, at least in some parts of Prussia (see in particular Werthmann (1995) for the dissolution of patrimonial courts in German states). Moreover, there are detailed historical case studies on society and the daily lives of people in these provinces that point out the persistence of non-inclusive institutions during the 19$^{\text{th}}$ 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 using the variable *Alternative Institutions* (see Subsection 4.4), which includes the abolition of patrimonial courts as an additional measure of institutional quality.

(2) Dissolution of guilds: For the Kingdom of Württemberg, Kopsidis and Bromley (2016a) suggest 1828 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 had a negative impact on economic development. Furthermore, as we have argued in Subsection 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 restrictive and, in the case of Württemberg, this system was also used to protect the interests of powerful guilds (see for example Arns (1986) or Fischer (1962) for the restrictiveness of the trade license system). Since a strict definition is more appropriate, we follow the approach of Acemoglu et al. (2011a) and use the year when commercial freedom (Gewerbefreiheit) was established (in the case of Württemberg, 1862).

(3) Serfdom and agricultural reforms: Kopsidis and Bromley (2016a) argue that the abolition of serfdom is a more a less meaningless measure, which should not be included as a measure for institutional quality in the 19^{th} century, since serfdom was no longer practiced in the Western parts. In the late 18^{th} century, serfdom was indeed less strict than in earlier periods in the Western regions. However, under the manorial system, the lives of the serfs were still restricted to the extent that they were dutiable to their lord of the manor. Depending on how 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 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 relieved of these duties. In territories where serfdom was abolished earlier, other agricultural reforms could also be implemented earlier. The year when a law was finally implemented to regulate the redemption of feudal lands, which reflects the reform measure 'agricultural reforms' in Acemoglu et al. (2011b), marks the end of this reform process. However, it is worth pointing out that excluding this variable does not affect the results. In unreported robustness checks, we computed an institutions index that only includes the introduction of the civil code and the dissolution of guilds, and we also computed an index that only includes the abolition of guilds. In both cases, the results suggest an economically and statistically strong effect of institutions on innovation. However, as we argue above, we believe that the measures used in the paper (*Institutions* and *Alternative Institutions*) are those that most accurately reflect the quality of institutions.

B Appendix: Description of Data and Variables

B.1 Structure of the Data Set

B.1.1 General Structure

The structure of the data set reflects the administrative structure of the German Empire, which consisted of 25 federal states. Prussia was by far the most important federal state, accounting for a population share of 61.2% in 1900 (see Deutsches Reich (1903a) for population figures). It was subdivided into provinces (Provinzen), regions (Regierungsbezirke), and counties (Kreise). The medium-sized states (e.g. the Kingdom of Bavaria) were organized into regions and counties, while the smaller principalities were only subdivided into counties. We use county data, the lowest level for which the census publications of the Imperial Statistical Office provide information. To account for potential correlation within regions, standard errors are clustered at the regional level in all regressions. Every small state that was not subdivided into regions is treated as an independent region. The data set includes all 25 German federal states (excluding the Prussian exclave Hohenzollern, with only 66,780 inhabitants in 1900). Alsace-Lorraine, which was annexed in 1871 after the French defeat in the Franco-German War, is excluded since it was not a federal state, but a territory with a minor status (Reichsland), directly subordinated to the German Emperor, where the inhabitants had less rights than the citizens of the federal states, and it was ruled by an Imperial governor coming from outside Alsace-Lorraine, who was often a high-ranking Prussian officer (see Wehler (1995), p. 325 and pp. 1012-1014).

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. The data set represents the administrative structure in the year 1882, since this is the earliest year for which we use county data from the official census publications (we use data from the employment census of 1882 to control for employment by sector in Table 7). In order to use the same balanced panel in all regressions, we match the counties in all subsequent years to the administrative structure in the year 1882 (for example: Witten (city) was separated from Bochum in 1899. Thus, we merged Witten (city) and Bochum in order to maintain the structure of 1882). Furthermore, for some smaller German federal states (e.g. the Principality of Lippe), some data was only available on a higher aggregated level, meaning that we had to merge counties. After all adjustments, the data set includes 881 county-level observations per year.

B.1.2 Definition of West vs. Saxony

In column 1 of Table 4, 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 Prussian Province of Westphalia, the Prussian Province of Saxony, and the Kingdom of Saxony (in its pre-1815 borders) in this sub-sample.

B.1.3 Definition of East Elbia

In column 2 of Table 4, 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 non-inclusive institutions (see, for example, Eddie (2008) and Wagner (2005)). We define the following Prussian provinces as part of East Elbia: Brandenburg, Silesia, Pomerania, Posen, West Prussia, and East Prussia. Note that we do not treat the German capital Berlin, which was administered as a separate province, as part of East Elbia, since it lacks the relevant socioeconomic features characterizing East Elbia.

B.1.4 Exclaves and Enclaves

In Subsection 4.4 and Appendix B.1.4, we discuss the extent to which the estimated results are affected by non-occupied enclaves surrounded by occupied territories, or occupied exclaves surrounded by non-occupied territories.

The following territories are coded as *enclaves*, since they were not under French rule: Grand Duchy of Hesse-Darmstadt (Oberhessen and Arnsberg with surrounding counties), Duchy of Nassau, Principality of Lippe, Principality of Schaumburg-Lippe, Principality of Waldeck and Pyrmont.

The following territories are coded as *exclaves*, since they were (temporarily) under French rule: Prussian province of Bayreuth (occupied by the French as a result of the 1807 Treaty of Tilsit; France ceded this territory to the Kingdom of Bavaria in 1810 in the course of a territorial exchange), Erfurt (Prussian territory since the German Mediatization of 1803; occupied by the French as a result of the 1807 Treaty of Tilsit), Schmalkladen (exclave of the Electorate of Hesse; occupied by the French in 1807, when the whole Electorate of Hesse came under French rule).

When we "smooth" the borders, we drop the following territories (code the following counties as not occupied): Free City of Lübeck, Duchy of Lauenburg, Prussian territories in Saxony (including the following counties: Calbe, Halle an der Saale (city), Mansfelder Seekreis, Mansfelder Gebirgskreis, Saalkreis).

B.2 Institutions and French Occupation

B.2.1 Institutions Index

The index of institutional quality (*Institutions*) is based on four measures of institutional quality: the introduction of the 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 et al. (2011a). For the following German states, the reform index is based on information published in their online appendix (Acemoglu et al. (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**, and **Grand Duchy of Mecklenburg-Schwerin**. Since we use county-level data, we adjust and extend the data for some territorial entities. The 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). Furthermore, we collected additional information about the year of reform implementation for all small federal states that are not considered by Acemoglu et al. (2011a). In the following, we document all changes compared to the original coding of Acemoglu et al. (2011a), as well as the sources for information on all newly added territories:

Kingdom of Prussia:

(a) Provinces of Posen and West Prussia: Acemoglu et al. (2011a) do not include the Prussian provinces of Posen and West Prussia in their data set. Since institutional refroms were implemented in the same period as in the Prussian mainland, we use the same institutions index value as for the Prussian provinces of Brandenburg, East Prussia, Pommerania, and Silesia, which are reported in Acemoglu et al. (2011a).

(b) Provinces of Brandenburg, Saxony, and Silesia: We adjust 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.

(c) 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 et al. (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.

(d) 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 et al. (2011a) use province-level data based on the institutions 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 the comments in (b)).

(e) Province of Schleswig-Holstein: Information about institutional reforms in Schleswig-Holstein is reported in Acemoglu et al. (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 et al. (2011a).

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

Kingdom of Bavaria:

Acemoglu et al. (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 institutional quality (according to the definition described above), we use 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 et al. (2011a) do not treat this region separately. Rheinhessen was under French rule and thus implemented reforms earlier. Furthermore, institutions remained in place after the French withdrew. 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 in economic and political terms, so 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 et al. (2011a)).

Grand Duchy of Oldenburg:

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; civil code: Klippel (1996). 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). 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 index 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; civil code: Klippel (1996).

Duchy of Anhalt:

The Duchy was created in 1863 by the 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); civil code: 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; civil code: 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; civil code: 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; civil code: Klippel (1996).

Principality of Lippe:

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

Free and Hanseatic City of Bremen:

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

Free and Hanseatic City of Hamburg:

Abolition of serfdom: Schubert (1977), pp. 381-382; dissolution of guilds: Schulz (1995), p. 145; civil code: Klippel (1996) and Schubert (1977), pp. 153-161. We have no information about agrarian reforms, since Hamburg was a city state. Thus, the index of institutional quality is constructed over three institutions.

Free and Hanseatic City of Luebeck:

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

B.2.2 Alternative Institutions Index

In column 6 of Table 4, we use an alternative index (*Alternative Institutions*) to test whether the results are robust to different measures of institutional quality. *Alternative Institutions* includes the reforms used in the original index (see B.2.1), as well as an additional reform: the year when patrimonial courts were abolished in the respective territory. Consequently, we compute the average index value over five reform measures. Information about the abolition of patrimonial courts is 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 use additional sources for Oldenburg (Eckhardt and Schmidt (1987), pp. 352-353), Anhalt (Kraaz (1898), pp. 192-218), Schaumburg-Lippe (Havliza (1975), pp. 31-36), and Waldeck and Pyrmont (Seidel (1964), p. 182). Since comparable patrimonial courts were not in operation in the city states (Bremen, Hamburg and Lübeck), we do not include this reform. Consequently, *Alternative Institutions* only contains three reforms (abolition of serfdom, dissolution of guilds, and introduction of the civil code) for these cases.

B.2.3 French Occupation

We follow the approach of Acemoglu et al. (2011a) to determine the years of French occupation. A territory is defined as occupied if it was under direct French rule or under the rule of a French-controlled satellite state, which includes the Grand Duchy of Berg, the Kingdom of Westphalia, and the Grand Duchy of Frankfurt. These satellite states were all ruled by family members of Napoleon. The period of French occupation ranges between zero and 19 years. Since Acemoglu et al. (2011a) only provide data on the state level (on the province level for Prussia), we use various historical maps to identify the years of French occupation on the county level. The maps are available on IEG-MAPS (link: http://www.ieg-maps.uni-mainz.de).

Note that we treat counties that were part of the Duchy of Warsaw as not occupied. The Duchy of Warsaw was created as a French satellite state in 1807, but the French lost control over this satellite in early 1813 as a result of Napoleon's failed campaign against Russia. In contrast to other French satellite states, the Duchy of Warsaw, which was partly located in the Eastern part of the provinces of Posen and West Prussia, was not ruled by a French administration, but by King Frederick Augustus I of Saxony, who was one of Napoleon's German allies. However, this rule was only formal, since the Polish nobility remained in power and in control of the public administration. In contrast to German territories that were under French rule, the ideas of the French civil code were not put into practice by the

Polish elites so that extractive institutions persisted. The peasants, for example, remained under the control of the nobility, and Jews were still discriminated, which was a fundamental violation of the ideas of the French civil code (for the history of the Duchy of Warsaw, see Grab (2003)). Due to the lack of effective French influence and the lack of effective institutional change, the Duchy of Warsaw is not comparable with the German territories in the West and North that were under direct French control or the French satellite states ruled by Napleon's family members (e.g. the Grand Duchy of Berg), which we treat as occupied.

B.2.4 Distance to Paris

In columns 2 and 3 of Table 2, we use the variable *Distance to Paris* to identify factors correlated with the years of French occupation. *Distance to Paris* is the great circle distance (in kilometers) between the main city in the county and Paris.

B.3 Patent Data

B.3.1 Patents per Capita

We extracted the patent data from the Baten/Streb patent database (see Streb et al. (2006) for a description of the data set). It contains all patents granted in the German Empire between 1877 and 1913 that were renewed for at least 10 years, out of a maximum length of 15 years permitted by patent law. The data set includes information about the location of the patentee, the technological class of the patent, and 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 that 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)). To ease the display of coefficients, *Patents* represents patents per million inhabitants.

B.3.2 High-tech and Low-tech Patents

In Table 6, we use information about the technology class of the patents to create sub-samples. Technology classes were used by the Imperial Patent Office to classify inventions. In total, there are 89 different major classes. Due to the emergence of new technologies and the rising number of 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 (see for example Henderson (1975) and Streb et al. (2006)). 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 electric trains and electric 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 that originated from the respective county in the respective year, divided by the county population. To ease the display of coefficients, all variables represent patents per million inhabitants.

B.3.3 Firm Patents and Individual Patents

In Table 6, we distinguish between patents filed by firms and patents filed by individuals. The variable *Firm Patents* (*Individual Patents*) is defined as the total number of firm (individual) patents that 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 in A.2.2) filed by firms from the respective county in the respective year, divided by the county population. To ease the display of coefficients, all variables represent patents per million inhabitants.

B.4 Basic Control Variables

B.4.1 Population Density

The variable *Population/Km²* represents the population density measured by the inhabitants of each county, divided by its area in square kilometers. 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)).

B.4.2 Rivers and Harbors

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

and zero otherwise. *River*Harbor* is equal to one if a county has access to both a navigable river and a seaport, and zero otherwise.

B.4.3 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. Since 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. The coding is based on the map *Der Deutsche Bund nach dem Frankfurter Territorialrezess um 1820*, which is available on IEG-MAPS (link: http://www.ieg-maps.uni-mainz.de/gif/d820_a4.htm)). 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.

B.4.4 Coal and Mineral Ore Deposits

Coal Deposits is a dummy variable that is equal to one if coal deposits were located in the respective county, and zero otherwise. In the same way, *Ore Deposits* is defined as dummy variable that is equal to one if deposits of iron ore or other important metals (e.g. copper) are located in the respective county. The data is based on map BI (coal mining) and map BII (metal ore mining) in Pfohl and Friedrich (1928).

B.4.5 Large Cities in 1750

Large City 1750 is a dummy variable that is equal to one if at least one city with more than 5,000 inhabitants was located in the respective county in 1750, and zero otherwise. City population data is from Voigtländer and Voth (2013) (which is based on the data set of Bairoch et al. (1988)).

B.4.6 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. The 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.

B.4.7 Hanseatic League

Hanseatic League is a dummy variable that is equal to one if a former member city of the Hanseatic League, a trade federation of the late-medieval period, was located in the respective county. The data is based on Dollinger (2012), pp. 592-593.

B.4.8 Protestants

Protestants % is the share of the Protestant population as a percentage of the total population in each county. We extracted the data from the official census publications of the Imperial Statistical Office for each year of observation (1900: Deutsches Reich (1903a); 1910: Deutsches Reich (1915)). The census publications provide county-level information about the Protestant and Catholic populations living in each county. Together, Protestants and Catholics account for over 98% of the German population. Note that the census publications only report data on the regional level for 1890 (Deutsches Reich (1894)). Since there is no evidence of a significant change in the spatial distribution of Protestants on the regional level, we use the county data on the share of Protestants in 1900 for 1900 and 1890.

B.4.9 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% in the respective county in 1900, and zero otherwise. The county 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)).

B.4.10 Prussia in 1816

Prussia 1816 is a dummy variable that is equal to one if the county was part of 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. This map is available online on IEG-MAPS (link: http://www.ieg-maps.uni-mainz.de/gif/d820_a4.htm).

B.4.11 City States

City State is a dummy variable 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.

B.5 Additional Control Variables

B.5.1 Ecclesiastical States

In column 1 of Table 5, we use *Ecclesiastical 1789*, which 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 use various historical maps, as well as registers, to identify whether the respective county belonged to an ecclesiastical state. 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. The 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).

B.5.2 Financial Development

In column 2 of Table 5, we measure financial development with *Banking,* a dummy variable that is equal to one if the share of people employed in banking and financial services is larger than 0.1% of the total number of people employed in the respective county in 1895. We use the official German employment census publication of the Imperial Statistical Office to get information about employment (Deutsches Reich (1898b) and Deutsches Reich (1898c)). In order to avoid double-counting, we only consider the main occupation. Note that earlier census publications (in particular the census of 1882) do not report employment in banking and financial services on the county level. For this reason, we refer to the census of 1895 to construct the dummy variable *Banking*.

B.5.3 Employment by Sector

In Table 7, we introduce *Manufacturing+Mining Workforce %*, which 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. We use the official German employment census publications of the Imperial Statistical Office to 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 1882, 1895 and 1907 (1882: Deutsches Reich (1884); 1895: Deutsches Reich (1898b) and Deutsches Reich (1898c); 1907: Deutsches Reich (1910)). We match the employment data for 1882 with patents per capita in 1890, employment data of 1895 with patents per capita in 1900, and employment data for 1907 with patents per capita in 1910.

B.5.4 Coal Mining

In Table 7, we define *Coal Mining 1850* (*Coal Mining 1880*) as the total coal production in tons in a region in 1850 (1880), divided by the population of this region in 1850 (1880). Data on coal production is only available on the regional level. We use the HGIS Germany database (link: http://www.hgis-germany.de/) to get information about coal production and population for 1850 and 1880. For earlier years (e.g. 1840) coal mining data is not available for all regions.

B.5.5 Technology Transfer

In Table 8 and Table A5, we define *Steam Engines 1861* (*Spinning Mills 1861*) as the number of steam engines (mechanical cotton spinning mills) in operation in the respective region in 1861 divided by the number of inhabitants (in millions) in this region in 1861. Note that data on steam engines and mechanical cotton spinning mills is only available on the regional level. The data is based on the 1861 industrial survey of the Zollverein (Zollverein (1861)). Therefore, the data includes only information about the member states of the Zollverein (which excludes the city states (Bremen, Hamburg, and Luebeck) as well as Mecklenburg-Schwerin, Mecklenburg-Strelitz, and Schleswig-Holstein). Region-level population figures are available on the HGIS Germany database (link: http://www.hgis-germany.de/).

B.5.6 Old Territories

In Table 8 and Table A7, we use *Old territories*, which is defined as the number of independent principalities that existed in 1789 within each region (Regierungsbezirk). *Old territories/km*^{2} equals *Old territories* divided by the area in square kilometers of the respective region. *Old*

territories is also used in Acemoglu et al. (2011a), 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 ruled under a dynastic union are only counted once. To get accurate information on the regional 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).

B.5.7 Internal Border

In Table 8 and Table A7, we define *Internal Border* as 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. The 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 classify a county as being at an internal border if it was at the 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 before 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).

B.5.8 Zollverein in 1842

In Table 8 and Table A7, we define *Zollverein in 1842* as 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 in which a significant number of states were still not part of the union. The latter argument no longer holds for 1854, the year of the subsequent major enlargement, when the Kingdom of Hanover and the Grand Duchy Oldenburg joined.

B.5.9 Illiterates

In Table 8 and Table A8, we use *Illiterates 1876 %* 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 in the statistical yearbook.

B.5.10 Universities

In Table 8 and Table A8, we define *University* 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. The 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 which universities were in operation for each year in the 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.

B.5.11 Inequality

In Table 8, we use the variable *Inequality* as a proxy for wealth inequality. The variable is defined as the Gini coefficient of landownership concentration based on data from the agricultural census of 1895 (Deutsches Reich (1898a)). The census records provide information on how much land in a county is owned by how many farms. The data is reported for 18 size categories (farms up to 0.1 are (100 square meter), 0.1-2 ares, 2-5 ares, 5-20 ares, 20-50 ares, 50-100 ares, 1-2 hectares (100 are), 2-3 hectares, 3-4 hectares, 4-5 hectares, 5-10 hectares, 10-20 hectares, 20-50 hectares, 50-100 hectares, 100-200 hectares, 200-500 hectares, 500-1,000 hectares, more than 1,000 hectares). We use data from the 1895 agricultural census for all years in the panel data set.

B.5.12 Migration

In Table 8, we use the variable *Migration* to control for both international and intra-German migration. The variable is defined as the fraction of all non-native inhabitants living in the respective region. Non-native inhabitants are those who were not born in the same state or in the same Prussian province. The data is based on the German population census of 1885 (Deutsches Reich (1888)), which only provides information on the regional level. We use data from the 1885 census for all years in the panel data set.

B.6 Foreign Trade Statistics

In Table A6, 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 are 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).

B.7 Population Growth

In Table 9, we use a three-stage least squares model to test whether differences in patents per capita across counties affect future county-level economic growth, which we proxy with the future average annual compound growth rate of the county population (*Growth*). We compute *Growth* over the period 1890-1900 for the year 1890 and over the period 1900-1910 for the year 1900. Likewise, *Past Growth* is the average annual compound growth rate of the county's population during the preceding period. *Past Growth* is computed over the

period 1890-1900 for the year 1900 and over the period 1885-1890 for 1890. To compute the average annual growth rate for the period 1885-1890, we use additional data from the German population census of 1885 (Deutsches Reich (1888)). The county's population in 1885 is also used to compute the weights for the population-weighted regression in Table 9. If we had not used population data from a date before the date of the outcome variables, then we would have the problem that innovation would simultaneously affect the outcome variable, population growth, and the population weights. This problem is avoided by fixing population data before the sample years 1890, 1900, and 1910.

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