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The Consequences of Radical Patent-Regime Change*

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Abstract: This paper analyzes the consequences of radical patent-regime change by exploiting a natural experiment: the forced adoption of the Prussian patent system in territories annexed after the Austro-Prussian War of 1866. Compared to other German states, Prussia granted patents more restrictively by setting higher novelty requirements. Though, patent fees were much lower. By using novel hand-collected data, we show that the forced adoption of the Prussian patent law caused a massive drop in the number of patents per capita in annexed territories. By contrast, we find a significantly positive effect of patent-regime change on world-fair exhibits per capita, which we use as a proxy for non-patented innovation. We interpret this finding as evidence that restricting the granting of patents, which creates more competition, is conducive for the generation of innovation.

Keywords: Innovation, Intellectual Property, Patents, Patent Law, Technological Change

JEL Classification: D2, K11, L51, N0, O14

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1. Introduction

The creation of an innovation-friendly environment is vital for long-run economic growth (Mokyr, 1992). One institutional factor that may affect the conditions for inventors and entrepreneurs is the patent law. While the political supporters consider patent law as necessary to create incentives for innovation, the opponents highlight the growth impeding effects of patents. However, the findings in the theoretical and empirical literature provide ambiguous results (e.g. Boldrin and Levine, 2013, 2010; Hall and Harhoff, 2012).

This paper sheds light on the discussion about the effect of patents on innovation by exploiting a natural experiment. We analyze the consequences of a radical patent-regime change in nineteenth-century Germany: the compulsory and immediate adoption of the Prussian patent system in states that came under Prussian rule after the Austro-Prussian War of 1866. The adoption of the Prussian patent law increased the incentives to apply for a patent, since patent fees dropped massively, while the economic value of a patent increased due to an enlarged domestic market. However, the probability of a successful patent application decreased because the Prussian patent law set stricter novelty requirements and was thus more restrictive. By using a novel hand-collected data set, we show that this patent-regime change caused a significant drop in the number of newly granted patents in annexed territories. Consequently, it became harder for firms to use patents for the creation of market-entry barriers. Put differently, the adoption of the Prussian patent law fostered competition and the free diffusion of knowledge. To test whether this change in the competitive environment affected inventive activity positively, we use new hand-collected data on world-fair exhibits as a proxy for non-patented innovation, as suggested by Moser (2005). The results show a strong and significant increase in the number of world fair exhibits after the adoption of the Prussian patent law. We interpret this as evidence that a patent-regime change that increases competition and knowledge diffusion may foster innovation.

Nineteenth-century Germany provides an ideal setting to analyze the economic effects of patenting because there was distinct regional variation in patent laws before the introduction of a unified German patent law in 1877 (Donges and Selgert, 2019b). Before 1877, each of the German states granted patents based on individual laws, and there was no mutual acceptance of patents. However, a first harmonization occurred already a few years earlier, in the aftermath of the Austro-Prussian War of 1866 and its subsequent territorial changes. Prussia annexed the Kingdom of Hanover and a number of other medium-sized and small German states. An ‘unintended’ consequence of these annexations was the introduction of the Prussian patent law

and the dissolution of all formerly independent patent authorities. However, there was no general legal harmonization so that we can isolate the effect of patent-regime change from other institutional reforms that may have affected innovation. Since all annexations were driven by geo-strategic rather than economic motives, we consider the timing and geographical dimension of this legal transplant as exogenous.

This is the first paper that studies the exogenous adoption of the Prussian patent law in 1866 by using a newly constructed data set. First, we use patent data, which we hand-collected from original archival sources. The data includes information on all domestic patents filed in Prussia between 1855 and 1877.⁴ For the period 1846-66, we add data on domestic patents from four neighboring states that Prussia annexed in 1866 (Kingdom of Hanover, Electorate of Hesse (Hesse-Kassel), Duchy of Nassau, and Free City of Frankfurt am Main). Second, we hand-collected information on the number of products exhibited at the world fairs in London (1862) and Vienna (1873) from original exhibition catalogues in order to create a proxy for innovation that differs from patents.

In our empirical analysis, we apply a two-step procedure. In the first step, we use a yearly panel with district-level data to analyze the effect of patent-law change on the number of patents granted per capita. By applying a linear fixed-effects model, we show that the number of patents dropped significantly after the adoption of the restrictive Prussian patent law. We reject potential alternative explanations for the drop in patenting, including lower incentives because of higher transaction costs, war-related economic distortions, migration, and discrimination. In the second step, we use district-level data on the number of products exhibited at the world fairs in 1862 and 1873 to test the effect of patent law change on (non-patented) innovation. Contrary to the drop in patents, we find a strong and significant increase in the number world-fair exhibits after the adoption of the Prussian patent law. Moreover, we provide empirical evidence to rule out market integration as an alternative explanation for the observed effect.

The paper adds to the empirical literature on the effect of patent laws on innovation and growth (for an overview, see Moser, 2013).⁵ In contrast to the traditional view, recent studies question the role of patents for stimulating inventive activity. Mokyr (2009), for instance, revises the classical interpretation of the English patent system as crucial precondition for the industrial revolution, and Moser (2005) provides empirical evidence that patent law did not stimulate innovation per se, but rather shaped the direction of technical change. This paper complements

⁴ Domestic patents are patents filed by domestic inventors (individuals or firms). We do not include foreign patents (patents filed by foreign inventors) in order to avoid double counting.

⁵ The literature also includes research on other types of intellectual property protection, for example the effect of copyrights on creativity (Moser, 2019).

existing research by taking advantage of an exogenous shock that allows for a better identification of the effects of patent-law change on innovation.

The paper also sheds light on the general debate about the usefulness of patent data for empirical research in economics (for an overview, see Griliches, 1990). Researchers often use patents as an indicator for inventive activity, but patents only reflect a subset. For example, firms can keep production techniques secret instead of filing a patent (Moser, 2012). This strategy is particularly useful when it is difficult to enforce patents in court or in the case of high if not prohibitive patent fees, as in England during the industrial revolution (Mokyr, 2009). Differences in the possibility to keep inventions secret or legal restrictions, excluding for example patents for specific technologies, have to be taken into account when using patents to measure industry-level differences in innovation. Furthermore, differences in patent laws make it difficult to use patents for cross-country comparisons. In this regard, our paper provides a unique historical setting that illustrates problems associated with cross-country comparisons of patenting activity when there are significant differences in patent law.

More generally, the paper relates to the influential literature on the importance of institutions. Following the seminal work of North (1990), empirical studies provide evidence for the link between the quality of institutions and economic development (e.g. De Long and Shleifer, 1993; Acemoglu et al., 2001; Acemoglu et al., 2011). However, the argument that institutions *cause* growth is controversial, since the reverse effect may also be possible (e.g. Glaeser et al., 2004). For a better understanding of the link between institutions on economic growth, it is thus necessary to analyze the channels through which institutions cause growth and, more importantly, to identify the most relevant institutions. The literature considers innovation as an important channel (North and Thomas, 1973; Acemoglu and Robinson, 2012; Donges et al., 2019) so that is important to analyze the design of the patent systems. The findings of this paper suggest that the adoption of a more a restrictive patent system, under which the state grants only a low number of patents, may increase competition, the diffusion of knowledge, and, consequently, innovation. Since the adoption of the Prussian patent law was also associated with a drop in patent fees, making patenting affordable for a larger part of the society, it was akin to the introduction of an *inclusive* institution tearing down economic entry barriers. Thus, there are similarities to the US patent system of the nineteenth century, which the literature considers conducive for the creation of innovation because of its inclusiveness (Khan, 2005; Khan and Sokoloff, 2004).

The paper proceeds as follows. We first provide an overview of the discussion about the opposing effects of patents on innovation. In section three, we describe the historical

background. We then explain our research design and the data set in section four. In section five, we test the effect of patent-regime change on domestic patenting. Next, in section six, we test the effect of patent-law change on non-patented innovation, measured with world-fair exhibits. We then discuss potential channels that explain the observed effects in section seven, and we conclude in section seven.

2. The Patent Controversy

In the literature, there is a vigorous debate about the usefulness of patent protection for technological development and, consequently, economic growth. Economic theory provides arguments for either a positive or a negative effect of patents on innovation (for an overview, see Hall and Harhoff, 2012).

According to the ‘classical’ view, patents are a contract between an inventor and the society: In exchange for a temporary monopoly right, the inventor agrees to reveal an invention to the public allowing for its free use and reproduction after the patent expiration. The temporary monopoly right is considered necessary for stimulating inventive activity, since knowledge is a non-rivaling good. Thus, without patent protection, the private rate of return of an invention would be considerably lower than the social rate of return, and, consequently, the aggregated production of innovation would be below the social optimum. Patents can solve this problem by raising the private rate of return of an invention closer to the social rate of return (Arrow, 1962; North and Thomas, 1976). Patents also allow for the trade of intellectual property, thereby creating a market for inventions (Khan and Sokoloff, 2004; Khan, 2005). Such a market enables private inventors or small firms with limited assets and credit constraints to put their inventions into practice. This may in turn increase the incentives for inventive activity and, thus, the stock of commercially useful knowledge.

In contrast, opponents of the patent system highlight growth-impeding effects. Boldrin and Levine (2010, 2013) stress the anti-competitive and rent-seeking nature of patents. This argument is particularly valid for ‘fundamental’ patents that protect basic innovations. By controlling fundamental patents, firms may effectively block follow-up innovations and achieve a leading edge over competitors or even monopolize markets. In this regard, firms may also misallocate capital in order to gain a patent portfolio that allows blocking competitors through litigation (for a survey, see Hall and Harhoff, 2012).⁶ Moreover, there may be welfare losses

⁶ According to Boldrin and Levine (2010), James Watt provides an example for this strategy. They argue that Watt has successfully delayed technological progress in steam engines by blocking innovation with his 1769 and 1775 patents for the separate condenser.

associated with rent-seeking activity such as lobbying for stricter patent protection in order to restrict market entrance of new competitors. The German chemical industry that pushed the imperial government to reform the patent law in 1891 is an often cited example (Boldrin and Levine, 2013; Hall and Harhoff, 2012; Murmann, 2003).

According to critics of patents, competition may be the best incentive for innovation and productivity growth (Bessen and Maskin, 2009; Boldrin and Levine, 2010, 2013). However, Aghion et al. (2005) provide empirical evidence for an inverse U-shape relation between competition and innovation. Thus, the effect of patents may be conditional to the competitive environment. That is, patent protection may increase social welfare when competition is too strong because, otherwise, first mover advantages from innovation would be eaten up fast. The contrary may be true in markets with low competition.

Empirical evidence on the effect of patent protection on innovation is also ambiguous and the literature suggests differences between industries. Concerning emerging industries with continuous technical change, Hall and Harhoff (2012) provide a survey on studies arguing that rewards to first mover advantages seem to be key, but not patents. However, there is evidence for a positive correlation between patent protection and innovation in some industries (e.g. in the pharmaceutical industry). Similarly, Galasso and Schankerman (2015) show industry-specific differences concerning the effect of patenting on downstream innovation. Different effects across industries may be a result of different imitation costs relative to the costs of innovation (Mansfield et al., 1981). In industries with a low ratio of imitation to innovation costs, first mover advantages might be eaten up fast creating disincentives for investment in R&D. In industries with high imitation costs, these disincentives might be considerably smaller. Another positive aspect of patents is the public disclosure of inventions. Recent empirical findings suggest that keeping inventions secret may delay follow-up inventions (Gross, 2019). In this regard, the effect of patents on the diffusion of knowledge may also be ambiguous.⁷

The ambiguity of patent protection fuels the economic policy debate since the mid-nineteenth century (Machlup and Penrose, 1950). Throughout the last 150 years, policy advice ranged from abolishing patents to implementing strong international intellectual property rights (Lerner, 2002). In this context, the literature discusses the design of an optimal patent system (Hall and Harhoff, 2012). It should set incentives to encourage innovation for a large fraction of the society, but it should make new useful knowledge also easily accessible. In this regard, there should be low patent fees, a short patent term, a strict examination of novelty, and, at best, the

⁷ Other aspects discussed in the empirical literature include e.g. patent pools, see Lampe and Moser (2010).

state should grant patents only for innovations with high R&D sunk costs, low imitation costs, and inelastic demand (Levine and Boldrin, 2013; Nordhaus, 1969). That is, an optimal patent system should be open to all classes of society, it should ensure the diffusion of patented technologies, and it should only protect the kind of innovation where first-mover advantages are low and not sufficient to produce the socially optimal amount of innovation.

There are also different views concerning to the optimal policy to trigger a catching-up process to technological leaders. The role of patent law for emerging markets is of particular relevance for our empirical setting, since, in the mid-nineteenth century, Prussia and the other German states lagged behind the economic development in England and France. According to Lerner (2002), backward countries should implement weak patent regimes in order to foster the diffusion of useful knowledge from abroad. By contrast, Branstetter et al. (2006) provide empirical evidence that multinational firms transfer more technology to their foreign subsidiaries when patent laws in the receiving countries were strengthened. In a recent study, Auriol et al. (2019) argue that the incentives to protect intellectual property rights differ and depend on stage of the development and the size of an emerging country.

This paper provides an empirical test of the net effect of patent protection on innovation by exploiting the exogenous adoption of Prussian patent law in states that Prussia annexed in 1866. As a corollary, the paper discusses whether one should interpret the Prussian patent system as a blueprint for an optimal patent system for a developing country.

3. Historical Background

Before 1877, every German state used its own patent law (for details, see Donges and Selgert, 2019b). Most states enacted rules regarding the granting of patents in the first half of the nineteenth century, but the patent systems differed widely. There were, for example, differences with regard to the application and examination process, the patent fees, the patent terms, and the discrimination of foreigners. Among the states of the Zollverein (the German customs union that was founded in 1834), there were several attempts to harmonize the patent laws. However, apart from vague guidelines regarding the definition of patentable objects and the trade in patented goods, all further harmonization attempts failed until 1877. There was also no mutual acceptance of patents. This means that an inventor had to apply for a patent separately in each state of the Zollverein. Moreover, a patented invention in one Zollverein state did not imply that the same invention would also get a patent in a second state. There were patent-friendly states granting a relatively high number of patents per capita, while there were also states that pursued a rather restrictive policy granting only a relatively small number of patents per capita

(Donges and Selgert, 2019b). In this regard, the Prussian patent system was the most restrictive one. In the following, we first describe the Prussian patent system and then turn to the patent systems in Hanover and the Hessian states (Hesse-Kassel, Nassau, and Frankfurt am Main), which Prussia annexed after the Austro-Prussian War of 1866 (see Figure 1).

[Insert Figure 1]

3.1 The Prussian Patent System

The Prussian patent system based on a state decree (*Publikandum*) that the Prussian government enacted in 1815.⁸ This decree was the first to set formal rules that the administration had to apply when granting patents. Later, in 1845, the government incorporated this patent *law* into the General Trade Regulation Act of 1845 (*Allgemeine Gewerbeordnung*). It remained effective until the introduction of the nationwide German patent law in 1877, and it applied in all Prussian provinces so that there were no differences in patent law within Prussia.⁹ Moreover, there was only one central patent office in Berlin, which was a subordinate department of the Prussian Ministry of Trade and Commerce.

An important characteristic of the Prussian patent law was that it required the technical examination of each patent application by a commission of experts. This commission had to evaluate whether the invention was novel and relevant enough to get a patent, and whether the public already knew it. Actually, the Prussian officials applied a very strict definition of novelty. When the basic idea of invention was already publicly available, for example published in a scientific journal, the Ministry rejected the patent application because it considered the invention as not novel. Even when an innovation was only known by a small circle, a rejection was very likely. Consequently, this policy set high barriers to get an invention patented. In some cases, the Ministry even rejected inventions that the literature considers as technologically influential. The famous Siemens-Martin process for the production of steel, for example, did not receive a patent in Prussia (Heggen, 1975). Because of its strict novelty definition, the Prussian patent law was by far the most restrictive one among the German states.

In the early years, the patent term was also subject to an individual decision of the Ministry. As in the case of novelty examination, the Ministry used the report of the technical commission to

⁸ For the overview of the Prussian patent system, we use information from Heggen (1975).

⁹ In contrast, there were regional differences in civil law until 1900. In most parts of Prussia, the General State Laws for the Prussian States (*Allgemeines Landrecht*) was applied, while the French civil code was applied in the Province of the Rhine. This difference resulted from the French occupation in the late eighteenth century and the subsequent transplant of French institutions that persisted even after the French occupation (Acemoglu et al., 2011). However, French influence did not affect the design of the Prussian patent law (Donges and Selgert, 2019b).

base its decision. According to the law, the patent term could range between six months and 15 years. However, the Ministry started to standardize the patent term in the 1850s (Donges and Selgert, 2019b). Until 1870, it granted patents for five years and then it reduced the patent term to three years. An extension up to the maximum patent term of 15 years was in general possible, but the patentee had to apply for it separately.

The costs for a patent application were relatively low in Prussia. Inventors only had to pay a small stamp and writing fee for the submission of a patent application, which costed typically between one and 2.5 *Thaler*, while the average yearly income of craftsmen and workers was around 104 *Thaler* in the mid-nineteenth century.¹⁰ In contrast to other countries, there were no additional fees or taxes charged in the case of a successful patent application. The Prussian state even paid the cost for the patent publication and there was no charge for the work of the technical commission, as it was the case in other German states.

Concerning the technical examination and relatively low patent costs, the Prussian system was similar to the patent system of the United States at the time (for the US, see Khan and Sokoloff, 2006). What made the two patent systems different is the strict definition of novelty that set higher requirements to get a patent in Prussia. This restrictive practice reflects the prevalence of economic liberalism within the Prussian administration. In Prussia, many officials supported open markets and opposed the creation of entry barriers after the dissolution of guilds. These ‘free-trade’ liberals lobbied massively against patents, since, from their point of view, patents were a new form of economic restriction hampering the free flow of ideas. Although the liberals were politically influential, they could not push through a general abolition of patents against the patent supporters, who argued that patents created economic incentives for innovation. For this reason, one may characterize the Prussian patent system as a compromise between patent opponents and supporters. As a result, the barriers to *apply* for a patent were very low because of only marginal application costs, but the barriers to *receive* a patent were high, since the Ministry rejected a large fraction of all patent applications because of its narrow definition of novelty.¹¹ In this regard, there was a distinctly different patent policy in Hanover and in the Hessian states.¹²

¹⁰ In the 1850s, one *Thaler* was equal to 0.53 USD (exchange-rate based on the silver value of both currencies). Information on Prussian patent costs is from Röhrich (1863) and Stolle (1855), and information on average incomes is from Gömmel (1979).

¹¹ According to Heggen (1975), only around 10 percent of all applications passed the technical examination in the 1860s and 1870s. The contemporary literature of the nineteenth century reports similar approval rates.

¹² Another characteristic of the Prussian patent system was the discrimination of foreigners. In general, inventors from countries that were not part of the Zollverein were not allowed to file a patent in Prussia (Donges and Selgert, 2019b).

3.2 Patent Laws in Hannover and the Hessian States

In Hanover, the royal government started to regulate the granting of patents in the late 1830s.¹³ Later, in 1847, it incorporated a patent law in the Hanoverian Trade Act. The patent law of 1847 was a reaction on an agreement of the Zollverein member states in 1842. In this agreement, the Zollverein states agreed on (vague) guidelines that the patent authorities should apply when granting a patent. The Zollverein agreement restricted patents to new inventions and set rules that allowed for the trade with patented goods, but it did not induce any further harmonization of patent laws so that distinct differences maintained until 1877.¹⁴ Even though Hanover did not join the Zollverein until 1854, the government incorporated the guidelines of the Zollverein agreement in its patent law. The Hessian states (Hesse-Kassel, Nassau, and Frankfurt am Main) also adopted these rules after 1842. While Hesse-Kassel introduced a (formal) patent law in 1852, the governments of Nassau and Frankfurt am Main continued to grant patents based on administrative ordinances. However, economically, the latter were similar to patent laws.

In all four states, the government instructed a technical commission to examine the novelty of an invention. However, in contrast to Prussia, the examination was less strict and the administration applied a wider definition of novelty. In Hanover, for example, the patent authority allowed for the disclosure of an invention before the patent application as long as the disclosure was restricted to a small circle, while the Prussian patent authority would have considered such an invention as not novel anymore and, consequently, rejected the patent application.¹⁵ In general, the Hanoverian administration was more patent-friendly and considered patents as an important means to foster inventive activity. This view reflects an approach that was less competition-friendly than in Prussia. Prussia liberalized its economy already in 1807 by dissolving guilds and introducing freedom of trade (*Gewerbefreiheit*), while the process of economic liberalization lasted much longer in Hanover and in the Hessian states (Acemoglu et al., 2011). Consequently, in Hanover, there were fewer reservations with regard to the restriction of free trade and the creation of monopolies than in Prussia. The governments of the Hessian states pursued similar policies as Hanover so that the technical examination of patents and the definition of novelty were also less strict than in Prussia.

¹³ In the following overview, we mainly rely on information from Gehm (2004) (for Hanover) and Gehm (2012) (for Hesse-Kassel) as well as on archival sources (in particular for Nassau and Frankfurt am Main).

¹⁴ See Donges/Selgert (2019b) for a discussion of the Zollverein agreement.

¹⁵ There are several archival sources illustrating the differences in patent policy. For example in 1865, the firm “Schäffer and Buddenberg” got a Hanoverian patent for a water meter, although the basic working principle of the water meter was common knowledge. Interestingly, the same firm also tried to patent the water meter in Prussia, but the Prussian technical commission rejected the application because of a lack of novelty; see correspondence in: Niedersächsisches Landesarchiv (NLA), Hann. 95, N. 264.

With regard to the comparison of the required technical examination, one also has to take the differences in state capacity into account. Compared to Prussia (19.2 million inhabitants in 1864), Hanover was a state of medium size (1.9 million inhabitants), but Hesse-Kassel (745,063 inhabitants), Nassau (468,311 inhabitants), and Frankfurt am Main (92,244 inhabitants) were relatively small.¹⁶ A thorough technical examination by a permanent and well-funded commission, as it was the case in Prussia, would have overstrained the administrative capabilities of these states. Indeed, the patent authorities in Hanover and in the Hessian states had to rely on changing, non-permanent experts that they recruited temporary either from other departments of the public administrations or business associations.¹⁷ By contrast, in Prussia, the technical commission consisted of full-employed state officials with academic education that were highly paid—a system that was less prone to cronyism and corruption.¹⁸

Compared to Prussia, there were also significant differences in patent costs. In Hannover, the patent fees ranged between six and 31 *Thaler*, Nassau charged on average about 20 *Thaler*, Frankfurt am Main about 8.5 *Thaler*, and in Hesse-Kassel the patent fees ranged between five and 200 *Thaler*, even though such very high fees were not so common (Donges and Selgert, 2019b). These figures show that the Prussian patent fee was by far the lowest. When taking the differences in market size into account, the patent fees charged in Hanover and the Hessian states appear even more expensive. This holds in particular for Frankfurt am Main, where the patent fee was relatively low in absolute terms (only 8.5 *Thaler*), but quite expensive when considering the small size of the market, on which it was valid.

To conclude, the patent systems in Hanover and the Hessian states differed from the Prussian patent system in three respects. First, Hanover and the Hessian states applied a wider definition of novelty so that the chances to get an invention patented was higher than in Prussia. Second, these patent authorities applied a less sophisticated technical examination than in Prussia because free-trade supporters had fewer influence and the size of the states was much smaller so that there were not the same administrative capacities as in Prussia. Third, Hanover and the Hessian states charged significantly higher patent fees than Prussia, in particular when taking differences in market size into account.

¹⁶ All numbers refer to official figures from 1864; data from HGIS-Germany, <http://www.hgis-germany.de/>.

¹⁷ For Hanover: NLA, Hann. 95, N. 264 and Hann. 134, N. 2407; for Hesse-Kassel: report of the Gewerbeverein about the patent application of Henschel and Sohn, Kassel September 18, 1847, collected in: Hessisches Staatsarchiv Marburg (HSM), 27 a II, N. 187.

¹⁸ Details on the staff employed in the technical commission, in: Patentgesetzgebung in den Zollvereinsstaaten, Bd. 6, in: GStA PK, III. HA MdA II, Nr. 1319.

3.3 The Adoption of the Prussian Patent Law

In 1866, after the Austro-Prussian war, Hanover, Hesse-Kassel, Nassau, and Frankfurt am Main came under Prussian rule. While state borders disappeared, institutional differences between Prussia and the newly gained provinces remained for a longer time, since the Prussian administration did not harmonize the legal system until the introduction of a nationwide German civil code in 1900. By contrast, it unified the patent system immediately after the annexations by dissolving all former patent authorities and adopting the Prussian patent law in all new provinces.¹⁹ Consequently, the Prussian Ministry of Trade and Commerce only granted patents for the entire monarchy (including all newly gained territories) after the annexation, which means that it was not possible to get a patent that was valid only in a single province, say Hanover.²⁰ Because of the larger territory and the expected increase in the number of patent applications, the Prussian government increased its staff at the technical commission in 1866.²¹ However, the costs of adopting the Prussian patent system were relatively low because the administration did not rely on subordinate administrative bodies (e.g. regional patent offices) but only on a central patent administration in Berlin. This factor may also explain why the Prussian government was able to harmonize the patent system in such a short period. Apart from that, keeping the old patent authorities in power would have undermined the restrictive policy of the Prussian patent authority so that it was rational to push for an immediate adoption of the Prussian patent law.

Since there were distinct differences before 1866, the adoption of the Prussian system was as a radical patent-regime change in those territories that got under Prussian rule. We can illustrate this by a Hanoverian example: in October 1866, Frank Marquard from New Jersey requested the extension of his existing patent, which he had filed in Hanover, to the entire Prussian Kingdom, but the Prussian patent authority denied his pledge arguing that his invention (cleaning gutta-percha and natural rubber with chloroform) lacked novelty.²² In another case, the Prussian technical commission denied the novelty of a peat press that a Hanoverian citizen

¹⁹ See correspondence between the Prussian Zivilkommissar in Hanover, the Hanoverian Ministry of Interior and the Prussian Ministry of Commerce and Trade. All patent applications from Hanoverian citizens were forwarded to and decided by the Ministry of Commerce and Trade. The correspondence is collected in Niedersächsisches Landesarchiv Hannover (NLA), Preußisches Zivilkommissariat (Hann. 116), Number 153, (henceforth cited as NLA, Hann. 116, N. 153).

²⁰ Prussian Ministry of Trade and Commerce to Prussian Generalgouvernement, Berlin October 23, 1866, in: NLA, Hann. 116, N. 153.

²¹ Details on the staff employed in the technical commission, in: Patentgesetzgebung in den Zollvereinsstaaten, Bd. 6, in: GStA PK, III. HA MdA II, Nr. 1319.

²² Prussian Ministry of Trade and Commerce to Prussian Generalgouvernement, Berlin December 04, 1866, in: NLA, Hann. 116, N. 153.

wanted to patent.²³ These examples suggest that the likelihood to get a patent decreased after the annexation because of stronger novelty requirements under the Prussian patent system.

What makes it an ideal setting to study the economic consequences of patent-law change is that the adoption of the Prussian patent law was not caused or driven by a preceding change in inventive activity or by the emergence of new technologies, but the indirect result of an exogenous event—the Austro-Prussian War.

3.4 The Austro-Prussian War

The Austro-Prussian War was a consequence of the political rivalry between Austria-Hungary and Prussia that characterized the period after the Congress of Vienna (1815). Both great powers claimed the supremacy over the German Confederation,²⁴ but the struggle between Austria-Hungary and Prussia remained non-violent for a long period. In 1864, Prussia and Austria-Hungary even joined their forces to fight against Denmark in the Second Schleswig War of 1864. The Germans prevailed and Denmark had to cede its southern possessions (the Duchies of Schleswig, Holstein, and Lauenburg). After the war, Prussia and Austria-Hungary administered these territories jointly, but disputes about the future territorial organization caused a flare-up of the Austro-Prussian conflict and created the *casus belli* (Wehler, 1995, pp. 283-301). From the Prussian perspective, a military campaign seemed to be promising in summer 1866, since Chancellor Bismarck had succeeded in pushing Italy into a military alliance, while a Russian entry into the war was unlikely. Prussia initiated its campaign against Austria-Hungary with the invasion of Holstein, which was the starting point of the war. Consequently, Austria-Hungary demanded military assistance from the states of the German Confederation. The majority of the German states formally fulfilled the mutual assistance obligation and joined the coalition against Prussia, but most of them without showing strong military commitment. This situation allowed the concentration of Prussian forces, which ultimately defeated the Austro-Hungarian armies in the decisive battle of Königgrätz on 3 July 1866. At the end of July, the war parties ceased all combat operations, and the war ended with a Prussian victory.

Directly after the war, Prussia annexed the territories of Hanover, Hesse-Kassel, and Frankfurt am Main, which all had joined the Austrian coalition against Prussia. Apart from that, Prussia got full control over Schleswig-Holstein, which it had administered jointly with Austria-Hungary since 1864. By controlling these territories, Prussia was able to build a strategically

²³ Prussian technical commission, around January 03, 1867, in: NLA, Hann. 116, N. 153.

²⁴ The German Confederation (*Deutscher Bund*) was an association of independent German-speaking states that was established in 1815.

important land bridge and close the gap between its western provinces—the Rhineland and Westphalia—and the Prussian mainland in the east (see Figure 1). The motives for this territorial expansion were rather geostrategic than economic. Bismarck considered even larger annexations, but William I, King of Prussia, pushed him to pursue a more moderate policy in order to avoid conflicts with other European monarchies and to facilitate the subsequent political rapprochement between Prussia and the southern German states (Schmitt, 1975). The Kingdom of Saxony, for example, remained an independent state, although it was a former Austro-Hungarian ally and a promising target because of its highly developed economy.

The Austro-Prussian War lasted less than two months, and the main combat operations were concentrated in Bohemia. Consequently, there were hardly any war-related destructions—neither in the Prussian mainland nor in the newly gained territories—, and the number of casualties and losses was relatively low, when compared to later conflicts. Most of the German rulers, which formally had followed Austria-Hungary’s call to arms, opposed to send troops and tried to avoid military confrontations with Prussia (Schmitt, 1975). The majority of the German population showed an even stronger aversion against a war among Germans, and the idea of a German nation under Prussian lead was quite popular. As a result, there was hardly any resistance against the Prussian annexations, and the occupation had no long-lasting negative consequences on the local economies. War-related distortions were restricted to summer 1866, and the German economies experienced a decent boom after the war (Wehler, 1995, p. 96). These circumstances allow us to consider the Austro-Prussian War as an exogenous event that caused a patent-regime change in the territories that came under Prussian rule.

4. Research Design and Data

In order to investigate the economic consequence of patent-regime change, we apply a two-step strategy. First, we test how the adoption of the Prussian patent law affected patenting, measured by the number of newly filed domestic patents per capita. Second, we test whether the adoption of the Prussian patent law affected non-patented innovation. By following the seminal idea of Moser (2005), we take world-fair exhibits as a proxy for the latter. In the next subsections, we describe the data sources and provide descriptive statistics for both variables.

4.1 Domestic Patents

Collecting patent data for the period before 1877 is a time intensive undertaking since there are no consistently published and easily accessible patent registers available. Thus, we hand-collected the data from original, hand-written patent lists that are stored in the General State

Archive (*Generallandesarchiv*) in Karlsruhe. The patent authorities compiled these lists and used them for the mutual exchange within the Zollverein between 1845 and 1877. Yearly patent lists are available for each patent-granting state that was part of the Zollverein. These lists contain *all* granted patents (over 17,800 patents) and include the name of the patentee, the occupational background, the place of residence, the date when the patent was granted, and a short technical description of the patent. We digitized all lists and created a data set including all available information for each individual patent. Moreover, we used the technical descriptions in the patent lists to assign a technology class to each individual patent. For a small number of years and states, where the patent lists are missing in the General State Archive, we used additional sources to complete the missing information.

We use patents granted in Prussia and four states that Prussia annexed in 1866 (Hanover, Hesse-Kassel, Nassau, and Frankfurt am Main).²⁵ Since the Prussian government dissolved all former patent authorities after the annexations, the patent lists of Hannover, Hesse, Nassau, and Frankfurt am Main are only available until 1866. For the later period, all patents granted to inventors from these territories are included in the Prussian lists. We only include *domestic* patents (patents granted to domestic individuals or firms) and drop all *foreign* patents (patents granted to foreign individuals or firms). By excluding foreign patents, we avoid the double-counting of patents in the pre-1866 period, for example when a Prussian inventor patented the same invention in Prussia and Hanover. After cleaning the data, we assigned the places of residence of the patentees to the corresponding administrative districts. We then aggregated the number of patents by year and district. In total, the data set contains yearly information for 34 administrative districts. Thereof, 26 in old Prussian provinces, six in Hannover, while Hesse-Kassel and Nassau (including Frankfurt am Main) represent one district, respectively.²⁶

To test the effect of patent-regime change, we focus on time windows of eleven years before (1855-65) and after (1867-77) the annexations. During these two periods, we observe in total over 1,900 domestic patents filed by individuals or firms from the sample districts. We start in 1855, one year after Hanover entered the Zollverein, so that we include only member states of the customs union (all other states in the sample had joined the Zollverein earlier). Thus, we avoid problems associated with different trends in the pre-treatment period, since the incentives to file a patent in Hanover increased when the state entered the Zollverein.

²⁵ Due to data availability, we do not include the Prussian province Schleswig-Holstein (under Danish rule before 1866) and the small Prussian exclave Hohenzollern (which was located south of Wuerttemberg).

²⁶ We merge Nassau and Frankfurt am Main because the territories formed one administrative district after the annexations. This is also justified by the fact that both states used similar patent laws before 1866.

4.2 World-Fair Exhibits

To analyze the economic consequences of patent-regime change, we need a proxy for innovation that differs from patents. In this regard, we follow Moser (2005) and use world-fair exhibits as such a proxy. However, while Moser (2005) uses data on the world fairs in London (1851) and Philadelphia (1876), our analysis considers exhibitions closer to the patent-regime change of 1866. Therefore, we use novel hand-collected data on the 1862 world fair in London and on the 1873 world fair in Vienna.²⁷

We digitized the original exhibition catalogues of 1862 and 1873. In total, German exhibitors presented over 2,300 products at the 1862 fair in London and over 6,800 at the 1873 fair in Vienna. For each exhibit, the catalogues list the name of the exhibitor, the place of residence, a description of the exhibited goods, and the corresponding industry. Our data set includes all available information for each individual exhibit. In the empirical analysis, we include all goods of exhibitors from the old Prussian provinces, from territories that came under Prussian rule in 1866 (Hanover, Hesse-Kassel, Nassau, and Frankfurt am Main), and from a group of other medium-sized and small German states (Kingdom of Saxony, Grand Duchy of Hesse (Hesse-Darmstadt), Grand Duchy of Mecklenburg-Schwerin, Duchy of Brunswick, Free Hanseatic City of Bremen, Free Hanseatic City of Hamburg, and Free Hanseatic City of Lübeck). We use the latter as additional ‘control states’. These states bordered Prussia but they were not affected by the annexations of 1866 (see Figure 2). As in the case of patents, we assigned the places of residence listed in the exhibition catalogues to the corresponding districts, and we then aggregated all exhibits by district. In total, the panel-data set contains yearly information for 46 districts. The sample includes data on over 1,900 exhibits from 1862 and over 4,800 exhibits from 1873.

[Insert Figure 2]

4.3 Patents vs. World-Fair Exhibits

Investment goods such as machine tools, machine parts, and production processes represent the vast majority of German patents in the period before 1877, while there are almost no patents on intermediate goods or consumer durables. The nature of the German patent system provides an explanation for this pattern. In 1842, the member states of the Zollverein agreed on some basic guidelines concerning the design of the patent laws.²⁸ The agreement of 1842 prohibited any

²⁷ In 1867, there was a world fair in Paris. However, we do not consider data for this exhibition because it took place less than one year after the treatment so that a significant effect on innovation is very unlikely.

²⁸ See Donges and Selgert (2019b) for a detailed discussion of the Zollverein agreement.

restriction of the trade with patented products in order to avoid the misuse of patents to circumvent the free-trade rules in the common market. However, it explicitly excluded machinery, machine parts, machine tools, and machine-like consumer durables (e.g. musical instruments) from these free-trade rules. Thus, from a commercial perspective, it made little sense to patent goods that differed from the latter categories. To illustrate the effects of the free-trade rules, we take a Hanoverian patent for a new type of high-quality steel sheet as an example. Under the Zollverein rules, it was possible to file a patent for this type of steel sheet, but the free-trade rules did not restrict the sale of the same product imported from another state of the Zollverein. Put differently, a domestic competitor could import the same type of steel sheet from Prussia and sell it without any restrictions in Hanover. Therefore, it was rational to file a patent for the machine tools that were necessary to produce this type of steel sheet.

By contrast, world fair exhibits span a much broader set of innovative products including not only machinery and investment goods, but also a large number of intermediate goods, durable and non-durable consumer goods. Apart from that, the world fairs were also places to present regional-specific commodities such as coal, mineral ores, and agricultural products, which could not get patented.²⁹ The latter type of exhibits do not represent innovations in a narrow sense, even though the availability of modern production techniques (e.g. mining equipment) may have affected their provision.³⁰

This view is consistent with Moser (2005), arguing that world fair exhibits reflect a broader set of innovation than patents, and Moser (2012), showing that only a small fraction of all US exhibits were patented. Moreover, it is consistent with recent findings of Domini (2019), who provides evidence that, in the case of the Turin world fair of 1911, exhibits and patents were rather disjoint sets of innovation with few overlaps.

World fair exhibits were presented by companies, individuals, private business organizations, and public entities. Formally, the participating states enrolled all exhibits. The states' local organization boards corresponded with the local organizers to settle important issues such as display space, transport, and tariffs. National selection committees advertised the exhibitions and invited entrepreneurs to take part. In this regard, private businessmen and the chambers of commerce supported the committees, for example by providing an overview of companies with innovative products that were worth to exhibit. Formally, the national selection committees

²⁹ For example, in 1862, the *Hörder Bergwerks und Hütten Verein* (one of the larger mining companies of the Ruhr district) presented “coal and specimens of intermediate rocks” (1862, exhibit no. 746). An example for the exhibition of agricultural goods is “red wheat, flour, hasty-barley, and oats for sowing” (1873, exhibit no. 630) presented by The Wiesbaden Directors of the Association of the Nassau Farmers and Forest Cultivators.

³⁰ Note that, in the empirical analysis, we show that the results are robust when excluding such commodities.

made the last decision whether to accept an exhibitor or not, but, in practice, selection into the exhibition was made by companies and private organizations and not by the public administration. (Kroker, 1975).

The organizers of the 1862 exhibition in London stipulated that exhibits should have been produced after 1850, which means that the exhibits should be innovative products and produced with the newest production techniques (Hollingshead, 1862, p. 50). Similarly, the organizational statute of the 1873 world fair in Vienna stated that the exhibition should represent the “cultural life of the present” and “promote progress” (Weltausstellung, 1873c). Furthermore, world fairs were a platform used by the participating countries to present their economic power. Therefore, the national selection committees for the world fairs were not only concerned with presenting an encompassing picture of their national industry but also of their technological prowess (Kroker, 1975, pp. 28-30; Pohl, 1989, p. 386). Apart from that, the individual exhibitors had strong economic interest in presenting new inventions and innovative products in order to acquire new customers, raise their profile, or sell licenses for the use of their inventions (Domini, 2019; Kroker, pp. 58-64).

We consider world fair exhibits as innovative products (e.g. machines) or products manufactured with cutting-edge production technologies (e.g. high-quality textiles). Patents, by contrast, were typically filed for cutting-edge production technologies but not for the products manufactured with these technologies. Again, we use an example to illustrate the link between patents and world fair exhibits: a firm presented its new type of high-quality steel sheet at the world fair in 1862, but, given the nature of the German patent laws, there were no patents on this type of steel sheet. By contrast, the firm could have filed a patent for the underlying production technique, in this case the steel-sheet cutting machine, which allowed manufacturing such high-quality products.

Patents may have restricted the diffusion of cutting-edge production technologies and, thus, the ability to produce innovative products. By contrast, the ability to protect such production technologies may have increased the incentives to invent them. In this regard, the question whether the adoption of the Prussian patent system fostered or hampered technological development thus translates into the questions how the patent law change in 1866 affected the protected part of the technological frontier of the annexed territories, and whether the change in patent protection translated in an increase or a decrease of the output produced at the technological frontier.

The following two sections pursue this question in two steps. First, we investigate whether the exogenous transplant of the Prussian patent system to Hannover, Frankfurt, Hesse-Kassel, and

Nassau affected patenting in these territories. Second, we then analyze whether the change in the protection of intellectual property had a positive or negative net effect on cutting-edge products exhibited at world fairs.

5. The Effect of Patent-Regime Change on Domestic Patenting

To analyze the effect of patent-regime change on patenting, we first start with a time series graph that shows the mean number of patents per million inhabitants for districts that Prussia annexed in 1866 and districts that were part of old Prussian provinces, respectively (see Figure 3). The graph spans the period 1846 to 1877. In annexed territories, the mean number of patents fluctuated around the mean of two patents per million inhabitants until 1854. In 1854, it then increased until the early 1860s. We explain this increase with Hanover's entry into the Zollverein, which may have stimulated innovation and growth but also the incentives to file a patent. Before 1866, we then observe, on average, about six patents per million inhabitants. By contrast, there was a downward trend in Prussia's old provinces and from the late 1850s onwards, Prussia granted a much smaller number of patents than the patent authorities of the states that were annexed in 1866. It is important that this difference does not have to reflect differences in innovation because of the differences in the likelihood to get a patent granted. Consequently, in annexed territories, the number of patents drop after the adoption of the Prussian patent law in 1866. Between 1867 and 1877, both time series seem to follow a similar trend, a pattern that we would expect under one patent regime. We also observe a relatively lower number of patent in annexed territories, which we may explain with regional differences in innovativeness.

[Insert Figure 3]

Panel A of Table 1 presents summary statics for the number of patents per million inhabitants, and Panel B of Table 1 presents the corresponding statistics for the (absolute) number of patents. We provide information separately for the old Prussian provinces and annexed territories, and we distinguish between the period before (1855-65) and after the patent law change (1867-77). Note that we drop the year 1866, since the Austro-Prussian War and all subsequent annexations took place in the middle of the year. The war had no negative long-run effect on the German economies, but war-related distortions may have affected inventive activity and the decision to file a patent immediately after the war.

[Insert Table 1]

In the first period, the average yearly number of domestic patents per million inhabitants and district was about 2.9 in the old Prussian provinces, and about 5.3 in Hanover and the Hessian states, which became under Prussian rule in 1866. Put differently, the latter states granted on average about 80 percent more domestic patents per million inhabitants than Prussia. However, this ratio reversed in the period after 1866. The mean number of patents per million inhabitants increased in the old Prussian provinces to about 4.2, while it declined to 2.6 in Hanover and in the Hessian states. We find a similar decline for the (absolute) number of domestic patents (Panel B of Table 1), showing that changes in population do not explain this pattern.

To study the effects of the patent law change on patents per capita, we employ a linear panel regression model with district- and year-fixed-effects including yearly observations for 34 administrative districts (see the summary statistics in Table 1). The basic regression equation takes the following form:

$$(1) \quad \ln(PPC_{it}) = C + \beta \text{Annexed}_i \times T_{Post1866} + D_i + T_t + X'_{it} \gamma + \varepsilon_{it}$$

$\ln(PPC_{it})$ denotes the natural logarithm of one plus the number of patents per million inhabitants in district i and year t . We use the interaction term $\text{Annexed}_i \times T_{Post1866}$ to test how the forced adoption of the Prussian patent law affected patenting. Annexed_i is a dummy variable that equals one if the district was part of a state that Prussia annexed in 1866, and zero otherwise, while $T_{Post1866}$ is a dummy variable that equals to one for all years after 1866, and it zero for all years before 1866. β is the coefficient that measures the effect of patent-law change. In addition, we include district-fixed-effects (D_i) to account for general time-invariant factors that may explain persistent regional differences in patenting,³¹ and year-fixed effects (T_t) to account for the secular increase in inventive activity during the nineteenth century. X_{it} indicates a vector including additional control variables that vary both other time and between districts, and γ is the vector of coefficients. C is the regression constant, and ε_{it} is the error term. Moreover, we use robust standard errors clustered at the level of Prussian provinces.

[Insert Table 2]

Table 2 reports regression results for the effect of patent-law change on patenting. In column (1), we report the coefficient for the basic specification of the above-described model, including district-fixed and year-fixed effects but without additional controls. We find a significantly

³¹ Such factors include geographic characteristics affecting market access (Sokoloff, 1988), persistent differences in human capital (Becker and Woessmann, 2009; Cinnirella and Streb, 2017), or the inclusiveness of institutions (Acemoglu et al., 2011; Donges et al., 2019).

negative effect of patent law change on patents per capita. The magnitude of the coefficient of *Annexed State* \times $T_{Post1866}$ implies that, after controlling for district- and year-fixed effects, the yearly number of patents per capita drops about 56 percent after the adoption of the Prussian patent law.³² In column (2), we use the same specification but include three additional control variables: *Population Density*, *Steel Production*, and *Coal Mining*. *Population Density* is a proxy for economic development (district-level data on GDP per capita is not available for that time). Moreover, *Population Density* captures potential differences in human capital resulting from agglomeration effects because, typically, densely populated areas facilitate the exchange of knowledge and attract highly educated people. By controlling for *Steel Production* and *Coal Mining*, we account for different growth trends in districts with mining and heavy industry. After controlling, for these variables, the coefficient of *Annexed State* \times $T_{Post1866}$ changes only slightly and it remains highly significant. We can interpret the estimated coefficient as a decrease in the number of patents per capita by 58 percent. To show that these results are statistically robust, we test in column (3) whether the effect also holds after excluding all eastern Prussian provinces (East Elbia), which lagged behind economically. There is a long literature discussing the causes and consequences of economic backwardness within Prussia, in particular researches pointed to the role of human capital (e.g. Becker and Woessmann, 2009; Cinnirella and Streb, 2017). In this regard, East Elbian districts might be a bad control group when analyzing the determinants of patenting and innovation. However, when excluding these underdeveloped provinces, the estimated coefficient of *Annexed State* \times $T_{Post1866}$ remains significant. The magnitude of the estimated coefficient implies a decrease by over 60 percent after the adoption of the Prussian patent law.

Taking the natural logarithm of the endogenous variable allows for a better interpretation of the coefficients. However, in order to compute the logarithms, we add the value one to the actual number of patents per million inhabitants, since there are many zero observations—a typical characteristic of patent data. This transformation can influence the results. For this reason, we also estimate the model without taking the logarithm. In columns (4) to (6), we use the same specifications as in columns (1) to (3), but with number of patents per million inhabitants (*PPC*) as endogenous variable. In all three columns, the estimated coefficient of *Annexed State* \times $T_{Post1866}$ is significantly negative and the economic magnitude of the effect remains large.

³² Since we use a dummy variable in a log-linear specification, we compute the percentage change in the following way: $\Delta\% = 100(\exp(-0.8323)-1) = -56.5$; for the transformation, see Van Garderen and Sha (2002).

To show that our findings are robust to alternative specifications, we also apply a fixed-effects Poisson regression in columns (7) to (9). We use *Patents*, which is the (absolute) number of patents, as endogenous variable. All three specifications include district-fixed and year-fixed effects and, in addition, the variable *Population*, which is the number of inhabitants (in 1,000), to account for the differences in population. Column (7) shows the results of the basic model, column (8) the model with additional controls, and column (9) the model where we exclude East Elbia. As in the previous cases, the estimated coefficients of *Annexed State* \times $T_{Post1866}$ are significantly negative and the economic magnitudes of the coefficients remain large.

We now focus on the timing of the negative effect on patenting. If the adoption of the Prussian patent law has *caused* the decline in the number of patents per capita, then we would expect an immediate drop, directly after the patent law change. In the following, we test this hypothesis by estimating the following regression model:

$$(2) \quad \ln(PPC)_{it} = C + \sum \beta_t \text{Annexed}_i \times T_t + D_i + T_t + \text{Trend}_i + X'_{it} \gamma + \varepsilon_{it}$$

We define the variables as before. However, in contrast to all previous models, we now interact the dummy variable *Annexed_i* with a series of year dummies T_t . We include interaction terms for each year in the period 1855-64 and 1867-77, and we define 1865 as the reference year. Thus, we estimate 21 interaction coefficients. These coefficients indicate for each year whether there is a significant difference in the number of patents per capita compared to the average in old Prussian provinces, and after controlling for all other effects. We report the estimated coefficients in Figure 4. In Panel A of Figure 4, we report the results for the fixed-effects OLS model with $\ln(PPC)$ as endogenous variable. The left graph (A1) shows the coefficients for the basic specification with district- and year-fixed effects, but no additional controls, and the right graph (A2) the coefficients estimated in the model with *Population Density*, *Steel Production*, and *Coal Mining* as additional controls. In both graphs, we observe a significant drop in patenting, directly after the adoption of the Prussian patent law, and the coefficients remain significantly negative for subsequent years. We find a similar discontinuity in Panel B, where we employ a fixed-effects OLS model with *PPC* as endogenous variable, and in Panel C, where we use a fixed-effects Poisson model with *Patents* as endogenous variable.

[Insert Figure 4]

To conclude, we find evidence that the forced adoption of the Prussian patent law caused an immediate decline in patenting in annexed territories. Though, the incentives to file a patent increased because of lower patent costs and an increase in market size, which made a Prussian

patent more worth than, for instance, a Hanoverian patent. In general, one would expect an increase in patenting when patent costs decrease, as it was the case in the United Kingdom after the patent fee reform of 1884 (Kügler, 2019). However, the adoption of the Prussian patent law decreased the likelihood of a successful patent application because of a more sophisticated technical examination and a stricter definition of novelty. Therefore, the net effect on patenting was negative. In the following chapter, we test the effect on (non-patented) innovation, which we measure with world-fair exhibits.

6. The Effect of Patent-Regime Change on Innovation

A patent-regime change, as it happened in 1866, can affect innovation either negatively or positively. On the one hand, it could be that there were innovation-impeding effects in case that the stronger novelty requirements and the higher rejection rates have discouraged inventive activity in annexed territories after 1866. On the other hand, the adoption of the Prussian patent system may have disrupted technological monopolies that may had hampered the diffusion of new technologies before. In this regard, we would expect innovation-enhancing effects of the patent law change. Concerning the role of economic incentives, we also have to take into account that the adoption of the Prussian patent law made patenting more inclusive because of lower patent costs and patents became more valuable because of larger market size. In this regard, we may also expect a rise in innovation due to higher incentives to apply for patent protection (even though the chances to receive a patent decreased). To test the *net* effects of patent law change on innovation empirically, we now use data on products exhibited at the world fairs of 1862 (London) and 1873 (Vienna).

[Insert Table 3]

In Table 3, we report summary statistics on the number of world fair exhibits per district and million inhabitants for different groups of territories in 1862 and 1873, respectively. We distinguish between three groups: Prussia (old provinces), annexed provinces (Hanover, Hesse-Kassel, and Nassau incl. Frankfurt), and other states (Bremen, Brunswick, Hamburg, Hesse-Darmstadt, Lübeck, Mecklenburg-Schwerin, and Saxony). In Panel A, we report the summary statistics for all exhibits; in Panel B we exclude exhibits in mining and agriculture. Overall, we observe an increase in the mean number of exhibits per million inhabitants when comparing 1862 with 1873. An increase in the size of the exhibition area that was available for German

exhibitors provides one explanation for the rising numbers.³³ However, when comparing the different territories, we find distinct differences in the relative change. In annexed provinces, the number of exhibits per million inhabitants was only 41.9 in 1862 (before the annexation), while it was 68.6 in Prussia's old provinces. This ratio contrasts the relatively lower number of Prussian patents in this period that we show above. However, in 1873, the relation had changed so that the number of exhibits per million inhabitants was higher in the new, annexed Prussian provinces compared to the old provinces. In annexed provinces, we observe on average about 144 exhibits per million inhabitants and district in 1873, compared to 123 in Prussia's old provinces. For the other group of states, we also observe an increase in exhibits per million inhabitants. However, the increase in the mean number of exhibits per million inhabitants between 1862 and 1873 is only 84.6 percent compared to an increase of 234.4 percent in annexed territories. When we exclude exhibits in mining and agriculture, we find similar results. Only for Prussia's old provinces, we find a stronger increase, even though it was still much lower than in annexed territories. To conclude, we have first evidence that the increase in the number of world fair exhibits may have been stronger in annexed territories because of the adoption of the Prussian patent law.

As in the preceding section, we employ again a linear fixed-effects regression model to study the effects of patent-regime change. The regression equation takes the following form:

$$(3) \quad Exhibits_{it} = c + \beta_1 Annexed_i \times T_{1873} + D_i + T_{1873} + X'_{it} \gamma + \varepsilon_{it}$$

$Exhibits_{it}$ denotes the natural logarithm of the number of world fair exhibits per million inhabitants in district i and year t . The interaction $Annexed_i \times T_{1873}$ is our treatment variable defined as the interaction between $Annexed_i$, which is a dummy variable that equals one for districts that Prussia annexed in 1866, and zero for all other districts, and T_{1873} , which is a dummy variable that equals one for 1873, and zero for 1862. As in all previous regressions, we include district-fixed effects (D_i) to take time-invariant differences in the ability to innovate into account, and we include time-fixed effects (T_{1873}) to account for the general increase in world fair exhibits between 1862 and 1873. X'_{it} includes additional control variables. C is a regression constant, and ε_{it} is the error term. β_1 is the coefficients of interest that measures the effect of patent-regime change.

³³ In 1862 (London), the German exhibitors could only use an area of 8,200 square meters, but they could use 36,000 square meters in 1873 (Vienna).

[Insert Table 4]

We use a sample that only consists of Prussian districts (old Prussian provinces and annexed territories). In column (1) of Table 4, we present the basic specification that includes only the interaction term (*Annexed* \times T_{1873}) indicating the effect of patent law change on the number of world fair exhibits per million inhabitants as well as district- and year-fixed effects. The effect of *Annexed* \times T_{1873} is positive and highly significant, which contrasts the drop in patenting that we find in section 5. Moreover, the magnitude of the coefficient is very large implying an increase by 156 percent. In column (2), we include additional time- and district-variant variables to account for differences in regional economic development (*Population Density*, *Steel Production*, and *Coal Mining*) as well as *Distance*, which is the natural logarithm of the great-circle distance between a district capital and the place of the world fair (London in 1862 and Vienna in 1873). We use the latter to account for potentially lower transaction costs for districts that were closer at the place of the exhibition, which might have affected the decision to exhibit a product. After controlling for these additional variables, the effect of *Annexed* \times T_{1873} remains highly significant and the magnitude of the coefficient even increases. Moreover, the effect remains significant and of similar size when excluding the under-developed districts in the Eastern part of Prussia (East Elbia) from the sample in column (3). Finally, we do the same regressions in columns (4) to (6), but the endogenous variable is now *Non-Commodity Exhibits*, which excludes all exhibits in mining and agriculture since patent law might be of less relevance for the extraction of natural resources than for the production of manufactures. Compared to columns (1) to (3), the effect *Annexed* \times T_{1873} decreases in all specifications but the coefficients remain highly significant and the economic magnitudes of large. In column (6), the size of the coefficient of *Annexed* \times T_{1873} still implies an increase by 67 percent.

The results in Table 4 provide evidence for a strong and significant effect of patent-regime change on innovation, but we also have to consider positive effects on innovation that may have resulted from increased market integration. While Hanover was a medium-sized state, Hesse-Kassel, Nassau, and Frankfurt am Main were relatively small. Thus, it could be that these states profited also from entering into the larger Prussian market in 1866. However, it is unlikely that this fact explains the above shown effects because the major step to create a common market in Germany was the formation of the Zollverein in 1834, which Prussia had pushed forward. Like most of the medium-sized and small states, Hesse-Kassel joined the Zollverein already in 1834, Nassau joined in 1835, and Frankfurt am Main in 1836. At the beginning of the 1850s, most of the German states were part of the customs union, and Hanover joined in 1854. Within the

Zollverein, there were no trade barriers, except of the barriers caused by differences in patent laws. Although it may be that the annexations fostered market integration to some extent, the effect should not be high because all states had joined the common market long before. Concerning the effect of market integration, one could also argue that the annexations caused an improvement in the railway network, for example by better connecting the Prussian railway with the railways in annexed territories, and fostered market integration and, consequently, economic growth.³⁴ However, it is very unlikely that this explains the estimated results since the railway systems were already well connected with the Prussian railways long before the annexations.³⁵ If the construction of railways affected innovation through more integrated markets, this effect should have been at work already before 1862.

To rule out market integration as an alternative channel, we extend the sample with territories that were not affected by the annexations but may have profited from market integration after the formation of the German Empire in 1871. If market integration was crucial for innovation, we then expect a similar increase in these territories after 1871. To test whether the number of world fair exhibits changed in these territories significantly, we use the following model:

$$(4) \quad Exhibits_{it} = c + \beta_1 Annexed_i \times T_{1873} + \beta_2 Control-State_i \times T_{1873} + D_i + T_{1873} + X'_{it} \gamma + \varepsilon_{it}$$

We define the variables as in equation (3), and we include the interaction $Control-State_i \times T_{1873}$ as an additional variable. $Control-State_i$ is a dummy that equals one if a district belongs to a German state that was not affected by the annexations and no part of Prussia, and zero for all other districts, and T_{1873} indicates the year 1873. We use this interaction to conduct the Placebo-test: we test whether the number of world fair exhibits increases also in districts where the patent law did not change. Table 5 reports the estimated coefficients for different specifications. In column (1) of Table 5, we show the estimated coefficient for the baseline specification in the sample with Prussia (old provinces and annexed territories) and other states. The effect of $Annexed_i \times T_{1873}$ is strong and significant. The coefficient implies a 140-percent increase in the number of world fair exhibits per million inhabitants. After including additional controls in column (2), this effect even increases. In column (3), we add the Placebo-control effect that we measure with the interaction $Control-State_i \times T_{1873}$. The coefficient of $Control-State_i \times T_{1873}$ is significant at the 10 percent level and the size of the coefficient implies an increase of 43 percent. By comparison, the coefficient of $Annexed_i \times T_{1873}$, which is still highly significant,

³⁴ See Hornung (2015) for the effect of railroads on growth in Prussia.

³⁵ See the maps of the German railway network on IEG-Maps (<https://www.ieg-maps.uni-mainz.de/map5.htm>).

implies an increase of 191 percent. This means that in Prussia's neighboring states, we also find an increase in world fair exhibits, but the effect is much smaller compared to the estimated increase in annexed territories. In column (4) to (6), we exclude again all exhibits related to mining and agriculture and perform the same regressions as in columns (1) to (3). The size of the effect of $Annexed_i \times T_{1873}$ decreases but remains significant. By contrast, we find no significant effect of $Control-State_i \times T_{1873}$ anymore.

[Insert Table 5]

The fact that we observe no similar increase Prussia's neighboring states provides additional evidence that the observed effect in annexed territories was indeed a consequence of the change in patent law, but not caused by an increase in market integration. If market integration would have fostered innovation after the formation of the German Empire, we would expect a strong increase in world fair exhibits in Prussia's neighboring states. Most of these states were relatively small so that the potential returns of market integration should have been high. However, we do not find evidence for such an effect. Put differently, there might be gains from market integration, but it is unlikely that these effects explain the massive increase in the number of world fair exhibits in annexed territories. By contrast, the change in patent law provides a plausible explanation for the observed effects.

7. Discussion of the Results

The exogenous adoption of the Prussian patent law had a significantly negative effect on the number of patents per capita in annexed territories. This finding supports the view in the historical literature that the Prussian patent system was very restrictive, and that the administration granted only a relatively small number of patents. However, we find a significantly positive effect on innovation measured with world-fair exhibits. This finding contrast the view of Heggen (1973) and others, arguing that the Prussian patent system was inefficient because it granted too few patents. We explain the observed increase in world fair exhibits, the cutting-edge products at the time, with two mechanisms.

First, the adoption of the Prussian patent law increased the incentives for inventive activity since it became cheaper to apply for patenting and the value of a patent increased because of a larger market size. However, the actual chance to get a patent was relatively low, given the restrictive character of the Prussian patent system. It may be possible that inventors overestimated their chance of "winning" a patent like people overestimating their chance of winning in the lottery (Mokyr, 2009), but the mere possibility of getting a patent filed would

then have to be enough to incentivize inventive activity. This increase in inventive activity may have shifted the technological frontier, and, consequently, firms were able to produce more cutting-edge products that were eligible for exhibition at the world fairs.

Second, the restrictive novelty requirements and the policy of the Prussian patent authority assured that only a small number of patent applications were successful. Therefore, the adoption of the Prussian patent law made it harder to create entry barriers through patents, and, consequently, allowed for more competition and facilitated the diffusion of knowledge, in particular with regard to production techniques. This allowed more firms to produce at the technological frontier, and, thus, to produce more cutting-edge products. Moreover, the increase in competition may have created additional incentives to invent new production techniques, which in turn may have further shifted the technological frontier.

The findings of this paper suggest that the adoption of the Prussian patent system was beneficial for innovation. In this regard, one can ask to what extent the Prussian patent system resembles an optimal patent system. Nordhaus (1969, pp. 76-86) argues that social welfare first increases with the patent term, but flattens after the patent term reaches a duration between six and ten years. After this point, gains from inducing innovation through patents are offset by the social costs of monopoly. In this regard, the Prussian patent term of five years (since the early 1870s only three years) seems to have been close to the optimal patent term.

8. Conclusion

This paper investigates the effect of patenting on innovation. Exploiting the Prussian annexations after the Austro-Prussian War as a natural experiment, we first find that the adoption of the Prussian patent law caused a drop in the patenting because of a more restrictive patent policy, in particular a stricter definition of novelty requirements. Second, we find that the provision of innovative, cutting-edge products, which we measure with world fair exhibits, increased after the annexations. We interpret this as evidence that a restriction of patenting may foster innovation, when it creates a more competitive environment that allows for a better diffusion of technology. Moreover, since German patents were mainly filed for investment goods or, put differently, *process innovations*, we can argue that restricting the granting of patents allow for a better diffusion of production technologies. This, in turn, allows more firms to manufacture cutting-edge product innovations. Given the technology of the mid-nineteenth-century, betting on competition and free trade paid off for Prussia. A restrictive patent law seems to have facilitated the free flow of knowledge within Prussia. In this regard, it may also explain why Prussia was able to start its catching-up process in this period.

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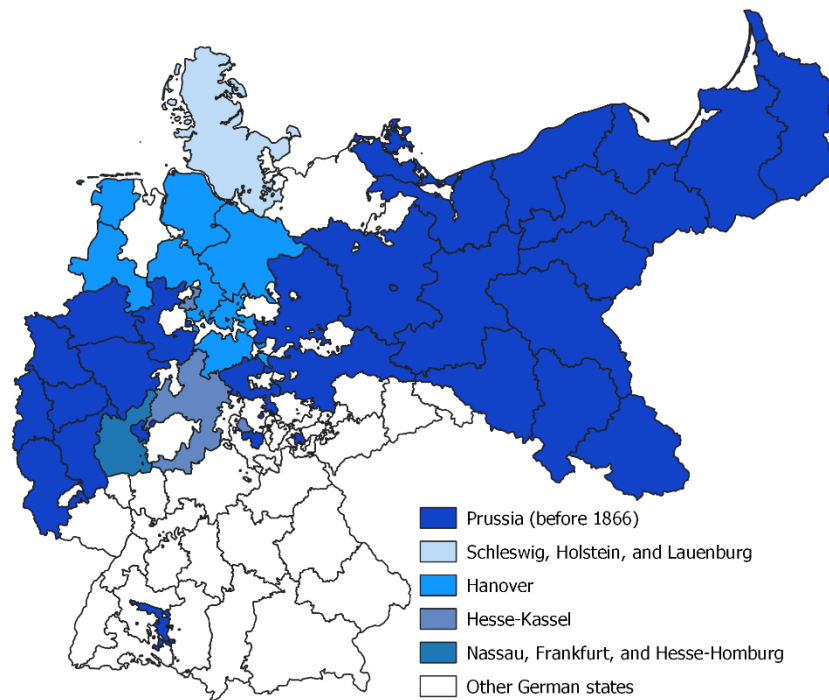
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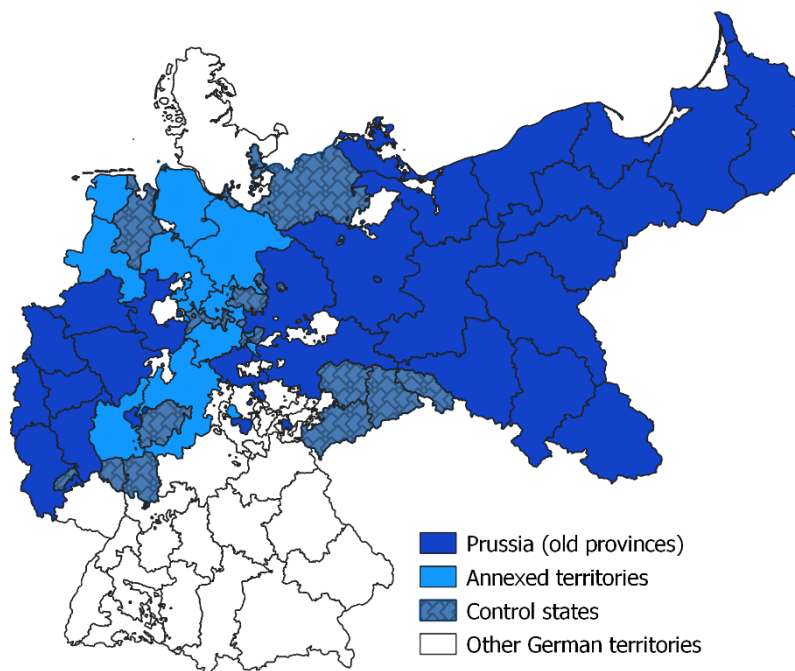
Figures

Figure 1: Prussian annexations after the Austro-Prussian War of 1866



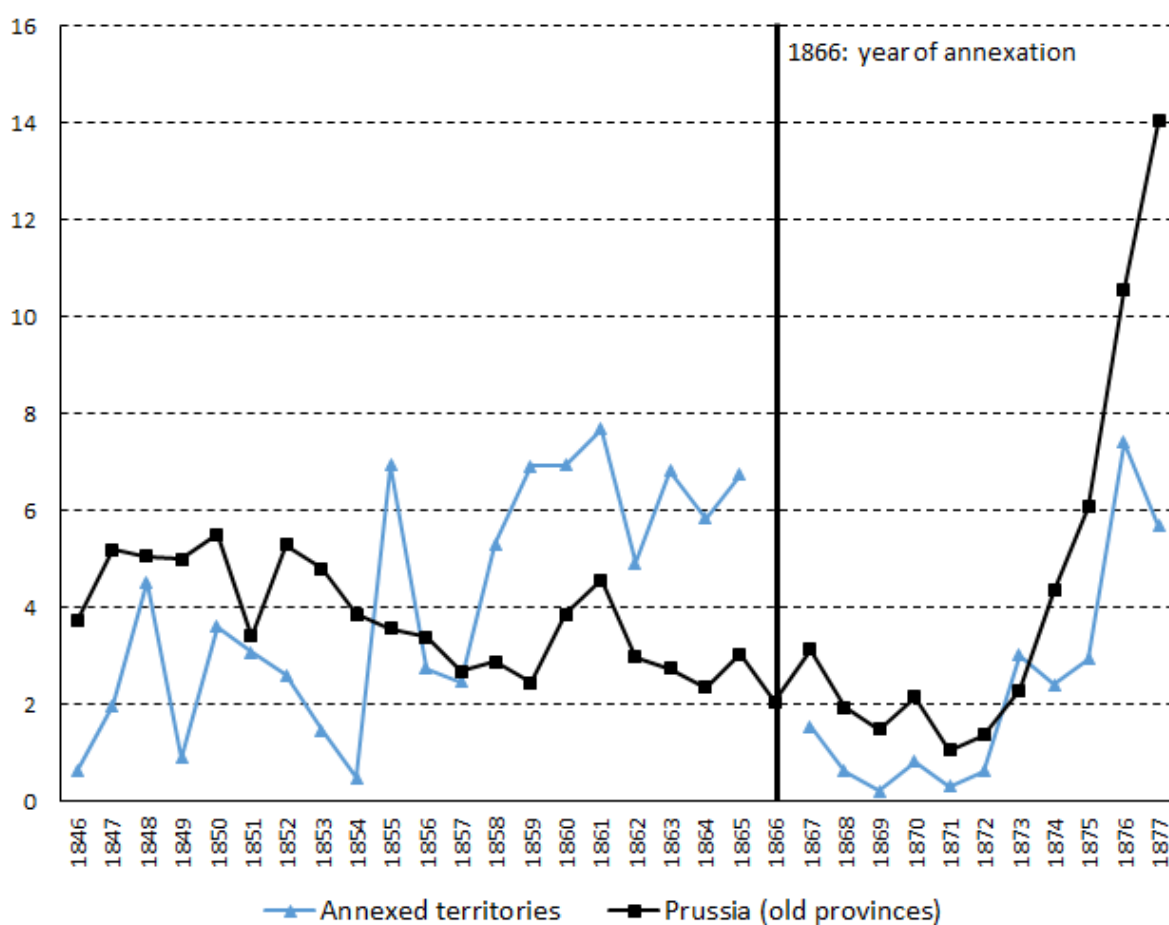
Note: This map illustrates the Prussian annexations after the Austro-Prussian War of 1866. Black lines indicate borders of states and administrative districts.

Figure 2: Territories included in the empirical analysis



Note: This map illustrates the territories included in our empirical analysis. Black lines indicate borders of states and administrative districts.

Figure 3: Mean Number of Domestic Patents per Million Inhabitants, 1846-1877

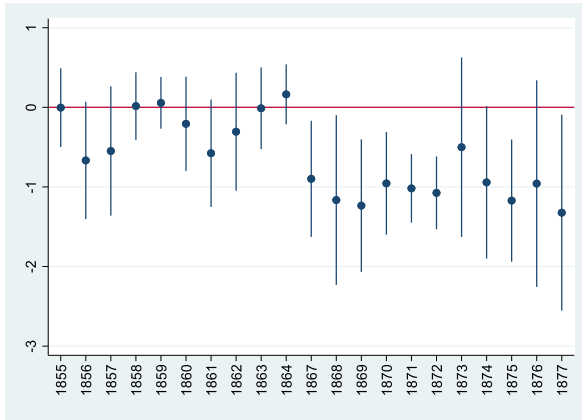


Note: This figure shows the development of the mean number of domestic patents per million inhabitants in districts that were part of annexed territories and districts that were part of old Prussian provinces for the period 1846-77. For annexed territories, we drop 1866 since the annexation took place in summer 1866.

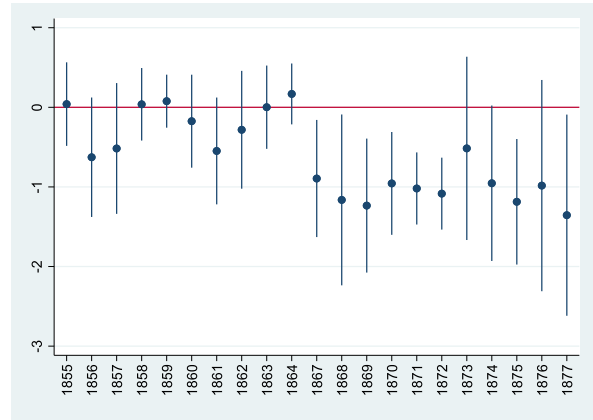
Figure 4: Event Study on the Effect of Patent Law Change on Patenting

Panel A: Fixed-effects OLS with $\ln(\text{PPC})$ as Endogenous Variable

A1: Basic Specification

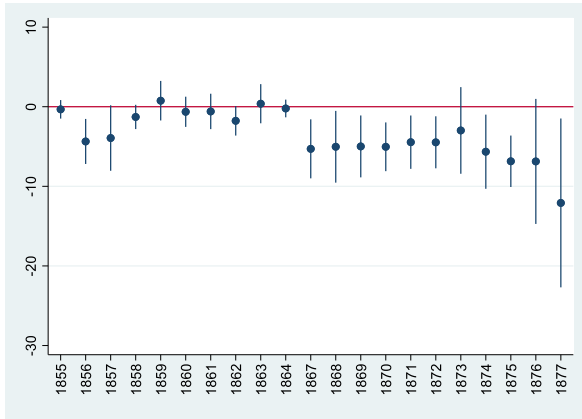


A2: Additional Controls

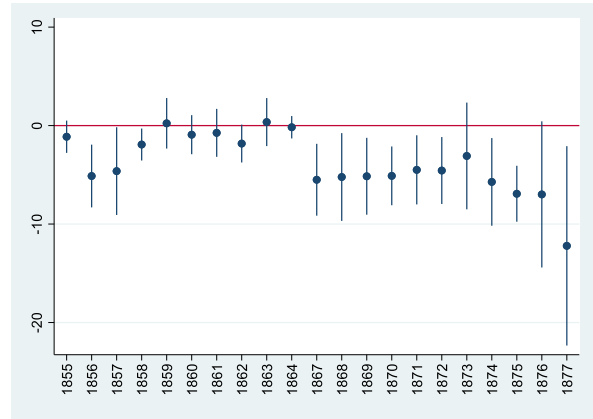


Panel B: Fixed-effects OLS with PPC as Endogenous Variable

B1: Basic Specification

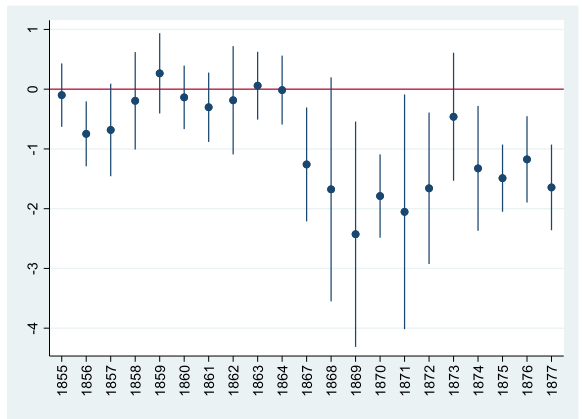


B2: Additional Controls

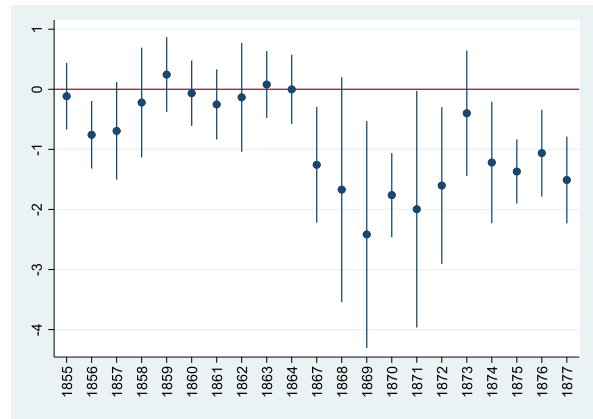


Panel C: Fixed-effects Poisson with Patents as Endogenous Variable

C1: Basic Specification



C2: Additional Controls



Note: The dots show the point estimates for the coefficient of Annexed interacted with the respective time dummies, and the bars show the respective standard errors. We use the fixed-effects OLS model with $\ln(\text{PPC})$ as endogenous variable in Panel A, the fixed-effects OLS model with PPC as endogenous variable in Panel B, and the fixed-effects Poisson model with Patents as endogenous variable in Panel C. In each specification, we control for district-fixed and year-fixed effects. In the specification with additional controls, we also add Population Density, Steel Production and Coal Mining as control variables. In Panel C, we include Population as additional control in both specifications. The reference year is 1865, and we drop observations for 1866 as in all other regressions.

Tables

Table 1: Summary Statistics: Domestic Patents

Panel A: Number of Domestic Patents per Million Inhabitants						
	1855-65			1867-77		
	Mean	Std. Dev.	N	Mean	Std. Dev.	N
Prussia (old provinces)	2.93	6.76	286	4.22	10.11	286
Annexed territories	5.33	7.01	88	2.64	3.98	88
Panel B: Number of Domestic Patents						
	1855-65			1867-77		
	Mean	Std. Dev.	N	Mean	Std. Dev.	N
Prussia (old provinces)	1.93	3.83	286	3.76	10.47	286
Annexed territories	2.10	2.64	88	1.18	2.11	88

Note: This table presents summary statistics for the number of domestic patents per million inhabitants in Panel A and the number of domestic patents in Panel B. We report summary statistics by territories for the periods 1855-65 and 1867-77, respectively. The observations are yearly and on the district-level. We weight the number of domestic patents per million inhabitants by the average population share of each district.

Table 2: The Effect of Patent Law Change on Patenting

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	OLS	OLS	OLS	OLS	OLS	OLS	Poisson	Poisson	Poisson
	Ln(PPC)	Ln(PPC)	Ln(PPC)	PPC	PPC	PPC	Patents	Patents	Patents
Annexed x $T_{Post1866}$	-0.8323 *** (0.2540)	-0.8680*** (0.2672)	-0.9365** (0.2903)	-4.7019** (1.6132)	-4.4663** (1.5736)	-4.9975** (1.7516)	-1.2348*** (0.3691)	-1.1572*** (0.3457)	-1.1456*** (0.3650)
Population							0.0429 (0.4832)	3.2260*** (1.0568)	3.1996*** (1.1498)
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional Controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Cluster	Province	Province	Province	Province	Province	Province	No	No	No
N	748	748	484	748	748	484	726	726	484
Sample	Full	Full	Excluding East Elbia	Full	Full	Excluding East Elbia	Full	Full	Excluding East Elbia
Within R ²	0.33	0.34	0.38	0.23	0.24	0.29	.	.	.
Log Pseudolikelihood	-899.93	-892.47	-675.04

Note: In columns (1) to (3) we use a fixed-effects OLS regression with Ln(PPC) (= natural logarithm of 1 + patents per million inhabitants) as dependent variable. In columns (4) to (6) we use a fixed-effects OLS regression with PPC (= patents per million inhabitants) as dependent variable. In columns (7) to (9), we use a fixed-effects Poisson regression with Patents (number of patents) as dependent variable. The interaction Annexed x $T_{Post1866}$ estimates the effect of patent-law change. Annexed is a dummy variable indicating whether Prussia annexed the district in 1866, and $T_{Post1866}$ is a dummy variable indicating the post-1866 period. In all columns, we include a constant, district-fixed effects, and year-fixed effects, and we use robust standard errors clustered at the province level in columns (1) to (6). In columns (2) and (3), (5) and (6), and (8) and (9), we include the following additional control variables: Population Density (= natural logarithm of inhabitants (in 1,000) per km²), Steel Production (= natural logarithm of 1 + steel production per capita), and Coal Mining (= natural logarithm of 1 + coal mining per capita). In the Poisson regressions (columns (7) to (9)), we add Population (= inhabitants in 1,000) as additional control. In columns (3), (6), and (9), we exclude the eastern Prussian provinces. Standard errors are in parentheses. ***, **, and * denotes significance at the 1%, 5%, and 10% levels, respectively.

Table 3: Summary Statistics for World Fair Exhibits

Panel A: Exhibits per Million Inhabitants							
	1862			1873			Δ in %
	Mean	Std. Dev.	N	Mean	Std. Dev.	N	
Prussia (old provinces)	68.59	93.29	26	122.51	129.52	26	78.6
Annexed territories	41.92	35.31	8	143.97	80.66	8	243.4
Other states	178.67	154.98	12	329.75	205.33	12	84.6

Panel B: Non-commodity Exhibits per Million Inhabitants							
	1862			1873			Δ in %
	Mean	Std. Dev.	N	Mean	Std. Dev.	N	
Prussia (old provinces)	45.47	81.40	26	98.68	119.52	26	117.0
Annexed territories	32.80	29.63	8	113.39	52.18	8	245.7
Other states	143.76	134.35	12	267.92	175.15	12	86.4

Note: This table presents summary statistics for the number of world fair exhibits per million inhabitants. We distinguish between three different groups of states: Prussia (old provinces), annexed provinces (Hanover, Hesse-Kassel, and Nassau incl. Frankfurt), and a group of other medium-sized and small German states (Other states) that we use as additional control group (Brunswick, Bremen, Hamburg, Hesse-Darmstadt, Lübeck, Mecklenburg-Schwerin, and Saxony). Data is on the level of administrative districts and on the state level for the smaller states. In Panel A, we report summary statistics for all exhibits; in Panel B, we only include non-commodity exhibits, which excludes all exhibits related to mining and agriculture. Δ in % indicates the increase in the mean between 1862 and 1873.

Table 4: Effect of Patent Law Change on World Fair Exhibits (Basic Sample)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	OLS
	Exhibits	Exhibits	Exhibits	Non-Com. Exhibits	Non-Com. Exhibits	Non-Com. Exhibits
Annexed x T_{1873}	0.9397*** (0.1452)	1.0551*** (0.1654)	0.9970*** (0.1841)	0.6645*** (0.1217)	0.6819*** (0.1033)	0.5112** (0.1778)
Constant	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Additional Controls	No	Yes	Yes	No	Yes	Yes
Cluster	Province	Province	Province	Province	Province	Province
N	68	68	44	68	68	44
Sample	Prussia	Prussia	Prussia	Prussia	Prussia	Prussia
Excluded Provinces	No	No	East Elbia	No	No	East Elbia
Within R ²	0.65	0.72	0.80	0.73	0.79	0.84

Note: This table presents estimates for the effect of patent law change on the number of world fair exhibits per million inhabitants. We use a linear fixed-effects regression model. The natural logarithm of the number of world fair exhibits per million inhabitants (Exhibits) is the dependent variable in columns (1) to (3). The interaction Annexed x T_{1873} estimates the effect of patent law change. Annexed is a dummy variable indicating whether Prussia annexed the district in 1866, and T_{1873} is a dummy variable indicating the period after 1866. We include a regression constant, district-fixed effects, and year-fixed effects, and we use robust standard errors clustered at the level of Prussian provinces in all regressions. The sample is restricted to Prussia (old provinces and annexed territories) in all specifications. In column (2), we add four additional control variables: Population Density (= natural logarithm of the number of inhabitants (in 1,000) per km²), Steel Production (= natural logarithm of 1 + steel production per capita), Coal Mining (= natural logarithm of 1 + coal production per capita), and Distance (= natural logarithm of the great circle distance between the district capital and the place of exhibition). In column (3), we use the specification of column (2), but we exclude the eastern provinces of Prussia (East Prussia, West Prussia, Pomerania, Posen, and Silesia). In columns (4) to (6), we perform the same regression as in columns (1) to (3), but we use the natural logarithm of non-commodity exhibits per million inhabitants (Non-Com. Exhibits) as dependent variable. The latter exclude all exhibits in the sectors mining and agriculture. We report the standard errors in parentheses. ***, **, and * denotes significance at the 1%, 5%, and 10% levels, respectively.

Table 5: Effect of Patent Law Change on World Fair Exhibits (Extended Sample)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	OLS
	Exhibits	Exhibits	Exhibits	Non-Com. Exhibits	Non-Com. Exhibits	Non-Com. Exhibits
Annexed x T_{1873}	0.8755*** (0.1180)	0.9303*** (0.1621)	1.0679*** (0.1581)	0.6961*** (0.0962)	0.6766*** (0.0978)	0.7121*** (0.1071)
Other State x T_{1873}			0.3578* (0.2011)			0.0925 (0.1605)
Constant	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Additional Controls	No	Yes	Yes	No	Yes	Yes
Cluster	Province	Province	Province	Province	Province	Province
N	92	92	92	92	92	92
Sample	Prussia + Others	Prussia + Others	Prussia + Others	Prussia + Others	Prussia + Others	Prussia + Others
Within R ²	0.63	0.69	0.70	0.71	0.78	0.78

Note: This table presents estimates for the effect of patent law change on the number of world fair exhibits per million inhabitants. We use a linear fixed-effects regression model. The natural logarithm of the number of world fair exhibits per million inhabitants (Exhibits) is the dependent variable in columns (1) to (3). The interaction Annexed x T_{1873} estimates the effect of patent law change. Annexed is a dummy variable indicating whether Prussia annexed the district in 1866, and T_{1873} is a dummy variable indicating the period after 1866. We include a regression constant, district-fixed effects, and year-fixed effects, and we use robust standard errors clustered at the level of Prussian provinces in all regressions. The sample includes Prussia and other German states (Brunswick, Bremen, Hamburg, Hesse-Darmstadt, Lübeck, Mecklenburg-Schwerin, and Saxony). In column (2), we add four additional control variables: Population Density (= natural logarithm of the number of inhabitants (in 1,000) per km²), Steel Production (= natural logarithm of 1 + steel production per capita), Coal Mining (= natural logarithm of 1 + coal production per capita), and Distance (= natural logarithm of the great circle distance between the district capital and the place of exhibition). In column (3), we use the specification of column (2), but we include an additional interaction term Other State x T_{1873} to perform a Placebo-control test. Other State is a dummy variable indicating a district that was not part of Prussia and not annexed. In columns (4) to (6), we perform the same regression as in columns (1) to (3), but we use the natural logarithm of non-commodity exhibits per million inhabitants (Non-Com. Exhibits) as dependent variable. The latter exclude all exhibits in the sectors mining and agriculture. We report the standard errors in parentheses. ***, **, and * denotes significance at the 1%, 5%, and 10% levels, respectively.