The market for patents in Imperial Germany*

by

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The market for patents in Imperial Germany

Abstract:
We describe and investigate the market for patents in late 19th and early 20th century Germany using a new and comprehensive database containing information for about 20,000 transactions. It turns out that a lively and growing market for patents existed in the German Empire. Most transaction involved the transfer of patents with an above average quality from individual inventors to firms and to newly-created – ‘entrepreneurial’ – firms. In addition, high-quality patents were traded between established firms. Moreover, patent lawyers acted as market intermediaries adding value to the average value of transferred patents. However, we show, on a macroeconomic level, that there was no causal relationship between the size of the patent market, income per capita, and real wages.

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I. Introduction

During the 1990s and early 2000s, technology related payments and receipts – e.g., licence fees and patent royalties – increased sharply in OECD countries. In 2005, for example, the average value of imports and exports of technology equalled about 0.55 percent of GDP. This is, compared to the value of trade in goods and services of about 25 percent of GDP in 2005 a small, but still significant amount, representing a value of about $190 billion. This exchange of technology should make all participants better-off since standard arguments as in the case of trade in goods and services are at work here: division of labour and specialisation of production foster growth and efficiency. Beyond standard gains from trade arguments, however, trade in technology has a significant additional effect on welfare. The public good character of innovations allows multiple users to combine research and development (R&D) efforts and to employ the same innovation. Consequently, trade in technology enables producer to draw the best innovation from a larger pool of inventions. This, in turn, shifts the production possibility frontier of all participants outwards and increases per capita income (Spulber, 2008).

In the same way, this argument applies to technology trade within countries. More specifically, a thriving market for patents within a country should increase per capita income and productivity. However, empirical studies of national technology markets and patent transfers within countries are nearly non-existent. Exceptional are the papers by Serrano (2006, 2007). He investigated all recorded patent transfers in the U.S. between 1981 and 2002. Serrano showed that (i) individual inventors and small firms are likely to transfer their patents to larger firms; (ii) patents issued in electronics, pharmaceuticals, and computers are most likely to be traded; (iii) more often cited and thus more valuable patents have a higher transfer probability; (iv) previously traded patents are more likely to be traded again than patents not previously traded. Furthermore, his findings suggest that the gains from trade realized on the U.S. market for patents were at least about $6.3 billion over the period 1981 to 2002.

In a similar way, economic historians have long emphasised the importance of the creation and exchange of knowledge in promoting economic development (e.g. Landes, 1969; Rosenberg, 1976; Abramowitz, 1986). However, historical research focused on international technology transfer on a macroeconomic level or on the international transfer of individual technologies (e.g., Fremdling’s, 2000, case study of the pig iron industry). National markets for technology were mostly neglected so far. Outstanding is the work by Lamoreaux and Sokoloff (1999), who investigate the market for patents in the U.S. between 1870 and 1910.
They figure out that 70-80 percent of the patents granted were assigned (i.e. traded) during this period. Yet, this figure includes the transfer of patents from employed inventors to their firms as well as the partial selling of patent rights. In many cases, for example, not the entire patent but only the right to use the patent exclusively in a specified geographic area was sold. In addition, Lamoreaux and Sokoloff (2005) supported the hypothesis that division of labour was a driving force behind the development of the market for technology. During the late 19th century, individual ‘Schumpeterian’ inventors specialised on the production of new technology sold their inventions regularly to established firms. Furthermore, Lamoreaux and Sokoloff (2002) showed that problems of asymmetric information between buyers and sellers of patents were reduced by the emergence of patent lawyers, who acted as market intermediaries.

This paper contributes to this literature by providing the first quantitative investigation of a market for patents using non-U.S. data. More specifically, we employ newly collected German patent transfer data for the period 1877 to 1913 to evaluate if markets for technology evolved outside the U.S. The German case is a particularly promising area of research for several reasons. First of all, professional R&D management by corporations emerged much earlier in Germany than in other countries. This is reflected, for example, in the foundation of corporate R&D laboratories in the German chemical and pharmaceutical industry during the 1870s and 1880s (König, 1996; Murmann, 2006). Second, the German patent law enacted in 1877 most likely fostered the development of a market for technology. German patents represented very secure property rights, since the patent office thoroughly evaluated the technical innovativeness of the patent. Moreover, patent infringements were mostly settled between the publication of a patent application and the issue of the patent. Furthermore, a patent had to be put into use within three years after issue, setting a strong incentive for small inventors to sell or licence their patent to a firm. In addition, comparatively high patent fees were an additional incentive for small inventors to sell their patents. Finally, patents were issued to the person registering the patent at the patent office. Consequently, inventions made by employed inventors were registered by the firms, not by the employees. Thus, the German patent transfer data did not include the transfer of patents within firms and give a much more precise picture of market transactions than U.S. data.

We show that a lively market for patents emerged in Germany soon after enacting the first unified German patent law in 1877. In addition, trading activity on this market grew over time, in absolute number as well as in relation to the number of patents in force. Dominant actors on the market were firms: about two-thirds of all patents transferred on the market were
acquired by firms. Moreover, firms were quite good in screening successful patents on the market and bought – on average – patents with a high quality. Finally, patent lawyers acted successfully as intermediaries on the market for patents. In particular, they assisted firms to acquire valuable patents.

The remaining parts of the paper are organised as follows. In Section II, we describe the historical and institutional background of the late 19th and early 20th century German patent market. Section III presents the data sources and the construction of the data set. Section IV contains the results of two econometric exercises: first, we evaluate the factors influencing the average value of traded patents; second, we investigate the macroeconomic relations between patent trade and per capita income. The final Section V concludes the paper.

II. Historical and institutional background

Germany’s rise to one of the leading industrial economies during the second half of the 19th century is often ascribed to its ability to innovate. In particular, the success of Germany’s chemical and electrical engineering industries was connected to the inventions made. In turn, the inventive activity of the modern sector was fostered by the high-quality of Germany’s system of higher education, the substantial governmental support for science, and the emergence of industrial research laboratories (Landes, 1999: 290-291; Cameron / Neal, 2003: 242-243). The increasing innovative capacity of the German economy is, for example, reflected in the rising number of patents granted as well as in the rising number of economically valuable patents granted, i.e. patents in force for at least ten years (see Figure 1).

The total number of patents granted varied between 4,000 and 5,000 between 1877 and 1890. Thereafter, the number of patents granted per year increased to about 10,000. After 1906, the number of patents granted per year varied at around 13,000. The share of valuable patents varied between six and eight percent until 1886. Thereafter, the fraction of valuable patents was about eight to ten percent until 1904. Subsequently, the share of valuable patents increased to more than ten percent; but this development is most likely due to the exemption of patent fees during the First World War as well as to the substantial decline of real patent fees during the German hyperinflation of the early 1920s, which makes the identification of valuable patents on the basis of a patent’s lifetime much more complicated (Streb / Baten, 2007: 256-258). Nevertheless, the number of patents as well as the average quality of patents increased over time.
Scattered evidence from archival sources shows that the market for patents existed in late 19\textsuperscript{th} and early 20\textsuperscript{th} century Germany. For example, on 1 August 1908, the Darmstadt-based pharmaceutical firm E. Merck and Dr. M.K. Hoffmann, a chemist from Leipzig, sealed a contract regulating the transfer of patent-no. 185,600. This patent referred to a new way of producing mercuric oxyde (\textit{Quecksilberoxydul}). After signing the contract, Merck paid a fixed amount of 500 Mark to Hoffmann. Moreover, after successful clinical trials, the inventor would receive another 500 Mark. In case of a successful market launch, the inventor would receive another 400 Mark as soon as Merck earned a profit with the product, taking development and production costs into account. Finally, the inventor would receive 20 percent of the accounting profits made with the product.\textsuperscript{1} However, comprehensive firm-level data are unavailable. Thus, such case studies can only be employed to illustrate the working of the market for patents.

Central for the emergence of a market for technology are secure property rights and institutions reducing the asymmetry of information between buyer and seller of a patent. The security of intellectual property rights was relatively high in Germany from 1877 onwards. First of all, each patent application was assessed by the patent office regarding novelty and potential conflicts with existing patents. In a next step, the patent application was published

\textsuperscript{1} Merck Record Office, R 1 / 42 and Burhop (2008).
and an appeal against the patent could be made. Only if no convincing appeal was made, the patent was finally granted (Seckelmann, 2006: 257-260). Between 1877 and 1913, the total number of patent applications was 765,653. Most applications felt through the technical examination by the patent office and only 304,057 patent applications were published. 11,701 published patents were not granted due an appeal made. Of the patents granted, only 877 were repealed by the patent office later on. Moreover, between 1902 and 1913, only 359 cases of patent infringements were put to trial. In about half of those cases, the patentee won the case. Comparing the number of patents repealed or the number of patent infringements with the number of patents in force shows that patents were indeed a very secure property right. Furthermore, the German patent law stimulated the transfer of patents, since the law stipulated the application of a patent within three years after issue. If the patent was not put into use by the patentee, the patent office could annul the patent. Moreover, the patentee had to pay an annual fee to keep the patent active. This fee was only 30 Mark for the first year and 50 Mark for the second year of protection, but thereafter it increased substantially by 50 Mark per year up to the maximum annual fee of 700 Mark for the 15th and final year of protection. The cumulated fee for the first three years was 180 Mark – about one-fifth of the annual per capita income in 1913 – but the fees for the fourth year of protection amounted to 150 Mark. The high fees and the compulsory implementation should have increased the incentives to sell patents on the market.

III. Data sources and descriptive statistics

Patent transfer data were published annually for the years 1884-1887 and 1889-1913 by the Imperial patent office. For the period 1877-83, only data referring to the patents transferred between 1877 and 1883 and still in force in March 1884 are available. Moreover, patent transfer data are unavailable for 1888 since the patent transfer register was not published in this year. Finally, the patent office stopped the publication of the transfer register at the outbreak of World War I. Therefore, transfer data are unavailable from 1914 onwards. We collected transfer data by hand using the annual “Verzeichnis der vom Kaiserlichen Patentamt im Jahre [...] erteilten und noch in Wirkung stehenden Patente“. This annual informs about a transfer of a patent and includes information about the patent number, the technology class, the name and place of residence of the new patent holder and the name and place of residence of a patent lawyer engaged into the transfer. We utilized the patent number to figure out the year of issue of the patent and – but only for a random sub-sample of about 30 percent patents – the name and place of residence of the original patent holder. Moreover,
we employed the patent number to figure out the total lifetime of the patent. This task was fulfilled using the annual register of valid patents.

Four potential shortcomings of the data should be kept in mind. First, the annual register of patent transfers did not contain all transferred patents, but only those for which the change in ownership was not contained in the in the register of newly granted patents. This implies that a patent transfer sealed between issue of the patent and the publication of the patent yearbook by the patent office was not separately listed. For example, a patent issued on 1 July 1900 and transferred before the publication of the next patent yearbook – in March 1901 – would not be included into the register of transferred patents. Theoretically, this error could be eliminated by comparing the name of the patent holder written on the patent and the name of the patent holder registered in the patent yearbook. However, faced with a total number of more than 200,000 patents, this strategy is clearly infeasible. This shortcoming is, however, only relevant for our analysis if the ratio of the number of patents transferred during the year of issue compared to the number of patent transferred during later years varies over time or if the characteristics of the patents not included into our transfer data set differs from the characteristics of patents included into our dataset.2

The second drawback of our data set is the fact that not all transfers registered by the patent office were transfers caused by economic motives: patents were regularly transferred if a change in the legal form of the patent holder occurred. For example, the German electrical engineering firm Siemens changed the legal form twice – first from an OHG to a KG and then to an AG – and each time all patents were transferred to the new firm. This patent transfer is, however, not caused by an economic motive related to the patent itself. In addition, block-transfers of patents due to mergers & acquisitions (M&A) were observed. Such transfers, on the other hand, can be counted as firm-to-firm patent transactions since the transfer of production technology codified in patents is an inherent component of M&A activity. Furthermore, transfers from an individual to another individual as an inheritance were registered by the patent office. Such transfers are not related to market transactions of patents and are coded accordingly.

The third drawback of our data relates to the censoring of the data. Patent transfer data were not published for the years after 1913. Consequently, statements regarding the fraction of patents issued during a year and transferred later on are biased for all patents granted from 1899 onwards since these patents could have been transferred in or after 1914. In practice, about 80 percent of all patent transfers were sealed during the first four years after issue.

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2 We will explore this issue by comparing the patents transferred during the first year of their life with the remaining patents in our sample.
Therefore, censoring becomes problematic for patents issued during and after 1910. Moreover, we circumvent this problem in the descriptive analysis by relating the number of patents transferred during a year with the number of patents in force during this year. In the econometric analysis in Section IV, we use period-specific variables to account for systematic variations over time.

Finally, we have to address a standard issue in empirical investigations of patents, namely the question about the economic value of patents. In an ideal world, we would like to know the patent specific social and private returns of a patent. However, this information is generally unavailable. Standard proxies for the value of patents are the lifetime of the patent, the patent fees paid, and the number of citations received (Griliches, 1990; Grupp et al, 2002; Metz / Watteler, 2002). This last measure is unavailable for late 19th and early 20th century German patents and we therefore focus on the first two measures. Yet, patent fees were lifted during the Great War. Moreover, the patent fees were fixed in nominal terms. Therefore, the real patent fees declined substantially during the German hyperinflation of the early 1920s. The impact of these two factors is visible in the average lifetime of patents and in the ‘virtual’ amount of patent fees paid: the average amount of patent fees paid for all patents granted between 1892 and 1906 varied between 600 and 800 Mark, whereas patents granted in 1913 represented a patent value of about 1,200 Mark.

During 1884-87 and 1889-1913, 219,513 patents were granted in Germany. Out of those patents, at least 18,135 patents (8.3 percent) were transferred at least once. Therefore, the rate of patent transfers in late 19th and early 20th century Germany is close to the rate of patent transfer in the U.S. between 1983 and 2002 of 13.5 percent (Serrano, 2007). Moreover, many patents were transferred more than one time: 2,265 patents were transferred twice, 230 patents were transferred three times, and 27 patents were transferred four times. Therefore, the probability that a patent was transferred twice was larger than the probability that a patent was transferred once (12.5 vs. 8.3 percent). This result supports Serrano’s (2007) finding for the modern U.S.

Figure 2 shows the evolution of the number of transactions on the German patent market over time. The total number of transactions carried out during 1884-87 and 1889-1913 was 20,657. Moreover, at least 505 transactions were accomplished between 1877 and 1883. The number of patent transfers fluctuated around 300 per annum until 1893. Thereafter, the number of annual transactions increased substantially, surpassing 1,000 in 1904. The number of transfers peaked in 1911 with 1,607 transfers. The market size of patent transfers did not only increase

\(^3\) We calculate ‘virtual’ patent fees as the amount of fees that would have been paid if the patent fees were not lifted during the wartime.
in absolute number, but also in relation to the number of patents in force. The transfer rate – i.e. the number of transferred patents divided by the number of patents in force during a year – fluctuated between 1.8 and 2.3 percent until 1893. Thereafter, the ratio was always higher than 2.4 percent, with a peak of 3.75 percent in 1904.

**Figure 2**

*Source: Patent transfer data base.*

Most patents were transferred during the early phase of its life: 30.9 percent of all transfers were registered during the first year after issue, 21.6 percent of all transfers were registered during the second year after issue, and 15.9 percent of all transfers were registered during the third year after the issue. Thus, 68.4 percent of all transfers were registered during the first three years after the issue of the patent. At least two arguments can be put forward to explain this finding. First, the patent law dictated that all patents had to be put into use within three years after issue. Consequently, inventors without capacities to use the patents for themselves – for example individual inventors or university professors – had a strong incentive to sell their patents within the first three years after issue. Second, Serrano’s (2007) extension of the classical patent renewal model developed by Schankerman and Pakes (1986) predicts that the trading probability of a patent is declining in its age, since the number of years with patent protection and therefore the expected present value of the monopoly rent is declining in the age of the patent. Therefore, if a patent has an economic value, it should be put into use as
early as possible and if the current owner of the patent lacks the necessary complementary assets, the patent should be transferred to someone with access to complementary assets.

Furthermore, the number of patents traded was clustered in few technology classes: more than 22 percent of all transfers were registered in the four most active technology classes.

The largest number of transfer was registered in electrical engineering (technology class 21) with 2,405 transfers between 1877 and 1913. This is equal to 14.1 percent of all patents granted in this technology class during this period. Other active technology fields were printing machines and typewriters with 848 transfers (13.6 percent of all patents granted; technology class 15), mechanical metal processing (754 transfers; 9.7 percent; technology class 49), and chemical processes and drugs, excluding dyestuffs (752 transfers; 8.4 percent; technology class 12). The dyestuff industry, which was prominent for the early establishment of in-house R&D capacities, was less active on the market for technology. Only 396 patent transfers were registered in technology class 12 (dyestuffs), just 7.3 percent of the number of patents granted.

A stylized fact of historical patent transfer data from Germany as well as from modern U.S. transfer data (Serrano, 2006; Serrano, 2007) is the above average value of traded versus non-traded patents. For the German Empire, aggregate patent survival data are available for all patents issued from 1891 onwards (Kaiserliches Patentamt, 1914: 83; Reichspatentamt, 1930: 77). On average, patents granted between 1891 and 1913 had an average lifetime of 4.6 years, whereas patents granted and transferred during this period had an average lifetime of 7.7 years. Thus, the average lifetime of transferred patents was about two-thirds higher than the lifetime of the average patent. Yet, comparing the mean lifetime over the whole period 1891-1913 did not account for the non-linear design of patent fees in Germany. For example, renewing a patent from the third to the fourth year costs 150 Mark whereas the fees for the 15th year were 700 Mark. Therefore, adding-up nominal patent fees might be a more precise measure of the minimum economic value of a patent. Secondly, we do not observe patent trades after 1913. Consequently, not all trades of patents issued from 1899 onwards are visible in our dataset. Third, the exemption of patent fees during World War I and the sharply declining real patent fees during the hyperinflation of the early 1920s possible distorts the picture. However, the basic finding of a higher value of traded patents compared to the average patent is not affected by these problems. The average amount of fees paid for patents

4 The German patent office allocated a patent technology class to each patent according to the industry of use.
5 This finding is similar to the modern U.S., where Serrano (2006, 2007) found a high trading activity in drugs and pharmaceuticals and a low trading activity in mechanical engineering. Moreover, similar findings are a standard result for empirical investigations of the licensing market (Anand and Khanna, 2000).
issued between 1891 and 1898 was 664 Mark whereas the average patent fee paid for patents issued during this period and transferred later on was 1,688 Mark.

Finally, we turn to the participants on the market for patents, i.e. buyer, sellers, and intermediaries. For a sub-sample of 5,455 patents – this equals 30 percent of the total sample – the name of the original patent owner was collected to figure out, whether the seller of the patent was a firm or individual respectively. Moreover, if two individuals or two firms involved on the two sides of the patent transfer bear the same name, we coded such transactions as changes in legal form and inheritance respectively. It turned out that 30 percent of all patents were transferred from individuals to ‘established’ firms, 23 percent to other individuals with a different name, 6 percent to individuals bearing the same family name, and 8 percent to a firm bearing the name of the individual; this latter type of transfer was classified as ‘entrepreneurial’. The remaining transferred patents originated in firms and were transferred to other firms (14 percent), to individuals (11 percent), and to a firm with the same name, but different legal form (8 percent). Jointly and severally, we observe a substantial transfer of patents from individual inventors to firms: only one-third of all transferred patents originated from firms, but two-thirds of all transferred patents were acquired by firms. This transfer of innovations from ‘Schumpeterian’ inventors to firms is very similar to developments in late 19\textsuperscript{th} and early 20\textsuperscript{th} century United States (Lamoreaux / Sokoloff, 2005).

In addition, we have information about the name of the buyer and seller of a patent for all second-order transfers, i.e. the transfer of a patent which was already transferred before. 2,035 patents fall into this category. The second round of transfers is clearly dominated by firms: 60 percent of these patents were sold by firms (compared to 33 percent in the first round) and 68 percent were bought by firms (compared to 60 percent in the first round). In the second round, 36 percent of transactions are from a firm to another firm, 11 percent are changes related to changes in the legal form of an enterprise, and 13 percent refer to the transfer of a patent from a firm to an individual. Individuals, on the other hand, transferred patents to established firms (19 percent), to entrepreneurial firms (2 percent), to other individuals (14 percent) or as an inheritance (5 percent). Table 1 summarizes the structure of the patent market.
### TABLE 1: ORIGIN AND DESTINATION OF PATENTS

<table>
<thead>
<tr>
<th>Origin of the patent</th>
<th>Destination of patent</th>
<th>Same firm or individual, but different legal form / same family name (inheritance)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PANEL A:</strong> First-round transfers (n=5,455)</td>
<td>Firm</td>
<td>Individual</td>
<td>New firm ('entrepreneurial')</td>
</tr>
<tr>
<td>Firm</td>
<td>14%</td>
<td>11%</td>
<td>8%</td>
</tr>
<tr>
<td>Individual</td>
<td>30%</td>
<td>23%</td>
<td>8%</td>
</tr>
<tr>
<td>Total</td>
<td>44%</td>
<td>34%</td>
<td>8%</td>
</tr>
<tr>
<td><strong>PANEL B:</strong> Second-round transfers (n=2,035)</td>
<td>Firm</td>
<td>Individual</td>
<td>New firm ('entrepreneurial')</td>
</tr>
<tr>
<td>Firm</td>
<td>36%</td>
<td>13%</td>
<td>11%</td>
</tr>
<tr>
<td>Individual</td>
<td>19%</td>
<td>14%</td>
<td>2%</td>
</tr>
<tr>
<td>Total</td>
<td>55%</td>
<td>27%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Source: Patent transfer database; own calculation.

Furthermore, Lamoreaux and Sokoloff (2002) pointed to the relevance of patent lawyers as intermediaries in the market for innovations during late 19th and early 20th century United States. In a similar fashion, patent lawyers were active as intermediaries on the German market for patent transfers. Patent lawyers were active in Germany at least since the mid-19th century, but their functions were substantially clarified after the enactment of the German Patent Lawyer Law (Gesetz über die Patentanwälte) in March 1900 (Kohler, 1902: 692-744; Seckelmann, 2006, 307-323). Until January 1901, 165 patent lawyers were admitted to the bar; until World War I, their number rose to 294. About 57 percent of all patent lawyers practised in Berlin, the official seat of the Imperial Patent Office. As a matter of fact, one task of the patent lawyers was the support of buyers and sellers in patent transfers: in 27 percent of all first-round transfers, the participation of a patent lawyer was revealed in the transfer register. In particular, patent lawyers were involved in 35 percent of all ‘entrepreneurial’ patent transfers, in 28 percent of all firm-to-firm transfers, in 24 percent of all private-to-private transfers, in 20 percent of all firm-to-private transfers, in 19 percent of all inheritance transfers, and in 12 percent of all transfers induced by a change of the legal form of an firm. By and large, patent lawyers were used if firms acquired a patent.
IV. Econometric evaluation

The theoretical work by Serrano (2007) and Spulber (2008) provides a set of testable predictions regarding the micro- and macroeconomic functioning and effects of patent markets. Spulber (2008) created a macroeconomic model of international technology transfer. His model already assumes the existence of an auction market for patents. Integration of the innovative capacities of two economies increased the income in both economies, since the producer can now use the best technology available in any of the two economies. Under the assumption that innovations are stochastic, drawing the best innovations from a larger pool of innovations shifts the quality of the best available technology outwards. Spulber (2008: 11-12) shows that the equilibrium number of innovations in the integrated economy is increasing in the total population. Moreover, the number of innovations in the integrated economy is larger than the maximum number of innovations in any single country before the emergence of technology trade. Altogether, technology trade creates gains from trade by increasing the pool of R&D, allowing the best technology to be used in multiple countries. Consequently, we should find a positive relationship between the size of the technology market and the level of per capita income.6

Serrano (2007), on the other hand, focused on the microeconomic aspects of technology trade. He extended the seminal patent-renewal theory developed by Schankerman and Pakes (1986) by a third dimension. In the classical model, the owner of a patent is faced with the choice between renewing and not renewing his patent for another period. Extending the patent protection for another year comes at the costs of the renewal fee, whereas not extending the patent implies forgoing of potential future monopoly profits. A patent owner will extend the patent protection for another year if the expected return of extended patent protection is higher than the renewal fees to be paid. Serrano’s extension of this model gives the owner of a patent a third possibility: selling the patent to another person. Obviously, the buyer of the patent must differ in some respect from the seller of the patent, i.e. by having different expectations regarding the future profits or by having different complementary assets. For example, an established firm has access to a customer base, whereas an individual inventor lacks this complementary asset. One central prediction of this model is a negative relationship between the age of patent and its trading probability. Intuitively, a young patent offers a long period of monopoly protection to its owner and it should thus be more valuable on average. Thus, buyers with better complementary assets – e.g., firms – are more likely to buy the

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6 Enacting the first unified German patent law in 1877 integrated the technology pools of Germany’s federal states. Consequently, Spulber’s model of international technology transfer applies to Germany’s historical patent market.
patent. In addition, classical lemons problems could occur on the market for technology. Therefore, reliable signalling devices could be important to signal the quality of a patent. Serrano (2007) highlighted one particular signalling mechanism: a patent that was traded before was already screened by the market and should consequently have a higher quality than the average patent.

Altogether, we put the following hypotheses to an empirical test: Our first regression tests Serrano’s (2007) hypothesis of a positive relationship between the fact that a patent was already traded before and the value of a patent. Moreover, other signalling devices – e.g., the service of a patent lawyer as market intermediary – could increase the average quality of patents on the market. In addition, we test a key assumption of Serrano’s (2007) model, namely that differences in complementary assets of buyers and sellers of technology are the driving force behind the existence of a market for technology. Results referring to these hypotheses are shown in Tables 2 to 4. Moreover, we test the central prediction of Spulber’s (2008) macroeconomic model of technology transfer. More specifically, we evaluate the causal relationship between the extent of the patent market and the level of per capita income in late 19\textsuperscript{th} and early 20\textsuperscript{th} century Germany.

Regression equations (1) to (3) formalize our testing strategy. The dependent variable in these regressions is a measure of patent value. We experimented with two definitions: First, the log of the number of years a patent was in force; second, the log of patent fees paid over the lifetime of patent. We take the log of the lifetime and the log of fee payments since both variables are censored at zero and since both variables are highly skewed.

A set of dummy variables is used on the right hand side of the regression. First of all, dummy variables indicating if the transfer was firm-to-firm, firm-to-private, private-to-private or entrepreneurial are used. Moreover, we account for the fact that some transfers are, from an economic point of view, not directly related to the patent transfer (inheritance, change in legal form of a firm). In addition, we investigate whether transfers facilitated by patent lawyers have a higher value than other transfers. Moreover, we look at the geographic, cultural, and legal distance between the two parties by including a dummy variable taking the value of one if the patent was transferred to a foreign entity. Furthermore, we test a central prediction of Serrano’s (2007) model: patents which were transferred before should have a higher average value than patents transferred for the first time, since the first patent transfer is a strong signal regarding the quality of the patent. Furthermore, we account for the legal security of patents by including the number of patent infringements per 1,000 valid patents as an explanatory variable. In addition, in the one-way fixed- and random-effects regressions (1) and (2), the
average value of patents granted during a certain year enters the regression to control for variations of the average value of patents over time. This variable is available from 1891 onwards. Therefore, we restrict the regression on patents granted and transferred between 1891 and 1913. Moreover, we use the full sample of available observations for the period 1884-1913 in the two-way fixed effects model (3). This specification includes year-of-grant fixed effect instead of the average value of patents granted during a certain year as explanatory variable. Equations (1) to (3) show the regression equations:

\[
\begin{align*}
V_{i,t} &= \beta x_{i,t} + \alpha_i + \varepsilon_{i,t} \\
V_{i,t} &= \alpha_0 + \beta x_{i,t} + u_i + \varepsilon_{i,t} \\
V_{i,t} &= \alpha_0 + \beta x_{i,t} + \alpha_i + \alpha_t + \varepsilon_{i,t}
\end{align*}
\]

In equations (1) to (3), \(V_{i,t}\) is the value of a transferred patent from technology class \(i\) granted in period \(t\). The vector of coefficients to be estimated using OLS is denoted by \(\beta\). The normally distributed error term \(\varepsilon_{i,t}\) should be uncorrelated with the other right-hand-side variables; otherwise, an instrumental variables estimator would be appropriate. Equation (1) is a standard fixed effects model with a technology-group specific fixed effect \(\alpha_i\). Equation (2) is a standard random effects estimator with an overall constant term \(\alpha_0\) and a technology-group specific disturbance term \(u_i\). Finally, equation (3) describes a two-factor fixed effects model with an overall constant \(\alpha_0\), a technology group specific fixed effect \(\alpha_i\) and a year-of-grant specific fixed effect \(\alpha_t\).

Tables 2 and 3 show the results of equations (1) and (2) using the log of the number of years that a patent was in force (Table 2) and the amount of fees paid for a patent (Table 3) as dependent variable, respectively. In both specifications, the Hausman-test indicates that a random effects model fits the data better than a fixed-effects model. Yet, the results are very similar for both methods. Moreover, it turned out that the residuals of the regression were not significantly correlated with the right-hand side variables. Therefore, it is not necessary to employ an instrumental variable estimator.

First of all, the choice of the dependent variable reflecting the patent value – years in force vs. fees paid – did not influence the results: the sign of the coefficients and the levels of significance are identical. It turned out that firms efficiently screened the market potential of new innovations. Patents transferred from one firm to another firm or from an individual to a firm had a significantly higher value than the average patent. On the other hand, patents
transferred from firms to individuals had a significantly lower value than the average patent. Consequently, firms increased their stock of patents – this was shown in Section III – as well as the average quality of their patents using the market for innovations.

**TABLE 2: THE VALUE OF TRANSFERRED PATENTS I**

**DEPENDENT VARIABLE: LOG (YEARS IN FORCE)**

<table>
<thead>
<tr>
<th>Data for 1891-1913 included</th>
<th>Fixed effects model</th>
<th>Random effects model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>p-value</td>
</tr>
<tr>
<td>Firm-to-firm transfer</td>
<td>0.160</td>
<td>0.000</td>
</tr>
<tr>
<td>Private-to-firm transfer</td>
<td>0.174</td>
<td>0.000</td>
</tr>
<tr>
<td>Firm-to-private transfer</td>
<td>-0.150</td>
<td>0.000</td>
</tr>
<tr>
<td>Inheritance</td>
<td>-0.043</td>
<td>0.230</td>
</tr>
<tr>
<td>Firm changing legal form</td>
<td>0.282</td>
<td>0.000</td>
</tr>
<tr>
<td>Entrepreneurial</td>
<td>0.198</td>
<td>0.000</td>
</tr>
<tr>
<td>Patent lawyer involved</td>
<td>0.100</td>
<td>0.000</td>
</tr>
<tr>
<td>Transfer to foreign owner</td>
<td>-0.025</td>
<td>0.244</td>
</tr>
<tr>
<td>Patent was transferred before</td>
<td>0.339</td>
<td>0.000</td>
</tr>
<tr>
<td>Value of average patent</td>
<td>-6.712</td>
<td>0.000</td>
</tr>
<tr>
<td>Court decisions</td>
<td>-0.300</td>
<td>0.000</td>
</tr>
<tr>
<td>Constant</td>
<td>11.813</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Moreover, entrepreneurial firms – the transfer of a patent from an individual to a firm bearing the same name – received more valuable patents. In addition, firms changing their legal form – mostly an upgrading from a partnership to a limited liability company or to an joint-stock company – transferred valuable patents on average. This could indicate that successful, growing firms earned their success from technological innovativeness. Furthermore, patent lawyers added value, since patents transferred using the expertise of patent lawyers had – on average – a higher value than patents transferred without the service of market intermediaries. Finally, patents that were transferred before had a higher average quality than patents which were transferred once. This supports Serrano’s (2007) hypothesis of a positive quality signal of trading activity. On the other hand, patents transferred from one individual to another individual bearing the same family name – this is most likely an inheritance – and the transfer
to a foreign entity were not relevant for the average value of transferred patents. Moreover, a high number of patent infringements regarding patents issued during a year decrease the average value of transferred patents from this year substantially.

**TABLE 3: THE VALUE OF TRANSFERRED PATENTS II**

**DEPENDENT VARIABLE: LOG (FEES PAID IN MARK)**

<table>
<thead>
<tr>
<th>Data for 1891-1913 included</th>
<th>Fixed effects model</th>
<th>Random effects model</th>
<th>Fixed effects model</th>
<th>Random effects model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>p-value</td>
<td>Coefficient</td>
<td>p-value</td>
</tr>
<tr>
<td>Firm-to-firm transfer</td>
<td>0.334</td>
<td>0.000</td>
<td>0.338</td>
<td>0.000</td>
</tr>
<tr>
<td>Private-to-firm transfer</td>
<td>0.297</td>
<td>0.000</td>
<td>0.310</td>
<td>0.000</td>
</tr>
<tr>
<td>Firm-to-private transfer</td>
<td>-0.206</td>
<td>0.000</td>
<td>-0.194</td>
<td>0.001</td>
</tr>
<tr>
<td>Inheritance</td>
<td>-0.071</td>
<td>0.314</td>
<td>-0.060</td>
<td>0.393</td>
</tr>
<tr>
<td>Firm changing legal form</td>
<td>0.625</td>
<td>0.000</td>
<td>0.622</td>
<td>0.000</td>
</tr>
<tr>
<td>Entrepreneurial</td>
<td>0.339</td>
<td>0.000</td>
<td>0.346</td>
<td>0.000</td>
</tr>
<tr>
<td>Patent lawyer involved</td>
<td>0.184</td>
<td>0.000</td>
<td>0.189</td>
<td>0.000</td>
</tr>
<tr>
<td>Transfer to foreign owner</td>
<td>-0.045</td>
<td>0.295</td>
<td>-0.055</td>
<td>0.197</td>
</tr>
<tr>
<td>Patent was transferred before</td>
<td>0.638</td>
<td>0.000</td>
<td>0.646</td>
<td>0.000</td>
</tr>
<tr>
<td>Value of average patent</td>
<td>-8.330</td>
<td>0.000</td>
<td>-8.331</td>
<td>0.000</td>
</tr>
<tr>
<td>Court decisions</td>
<td>-0.549</td>
<td>0.000</td>
<td>-0.555</td>
<td>0.000</td>
</tr>
<tr>
<td>Constant</td>
<td>61.885</td>
<td>0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hausmann-Test (p-value)</td>
<td>0.326</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>adjusted R²</td>
<td>0.453</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-Test (p-value)</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-6,910</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of observations</td>
<td>4,880</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results from regression equation (3) – the two-factor fixed effects model – are slightly different from the results derived from the canonical fixed- and random-effects estimator. Nevertheless, the key results from Tables 2 and 3 are still valid: firms were quite efficient in screening successful innovations. This is reflected in the significantly positive coefficients for the dummy variables indicating firm-to-firm and private-to-firm transactions. Moreover, the transfer of patents due to a change of the legal form of an enterprise still has a positive connection to the average value of the patents transferred. Alike, the entrepreneurial transfer of patents from individuals to firms bearing the same name has a significantly positive correlation with the patent value. Moreover, Serrano’s (2007) key hypothesis regarding the signalling effect of formerly transferred patents is also still valid. In addition, a high number of patent litigations during a year reduced the average quality of the patents transferred.
Finally, the transfer to a foreign entity or the transfer in course of an inheritance is still not relevant for the value of transferred patents. However, the results from the two-way fixed effects model differ in one dimension from the standard one-way fixed or random effects model: the involvement of a patent lawyer did not add value to the patents transferred. One explanation for this findings – which is, however, not formally tested in the model – is the fact that patent lawyers were largely unregulated and of unknown quality before enactment of the patent lawyer law in 1900. Thereafter, patent lawyers had to pass a legal and a technical examination at the patent office, guaranteeing a minimum standard for their service.

<table>
<thead>
<tr>
<th>TABLE 4: THE VALUE OF TRANSFERRED PATENTS III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data for 1884-1913 included</td>
</tr>
<tr>
<td>Dependent variable: Log(Years in force)</td>
</tr>
<tr>
<td>Dependent variable: Log(Fees paid in Mark)</td>
</tr>
<tr>
<td>Coefficient</td>
</tr>
<tr>
<td>Firm-to-firm transfer</td>
</tr>
<tr>
<td>Private-to-firm transfer</td>
</tr>
<tr>
<td>Firm-to-private transfer</td>
</tr>
<tr>
<td>Inheritance</td>
</tr>
<tr>
<td>Firm changing legal form</td>
</tr>
<tr>
<td>Entrepreneurial</td>
</tr>
<tr>
<td>Patent lawyer involved</td>
</tr>
<tr>
<td>Transfer to foreign owner</td>
</tr>
<tr>
<td>Patent was transferred before</td>
</tr>
<tr>
<td>Court decisions</td>
</tr>
<tr>
<td>Constant</td>
</tr>
</tbody>
</table>

Hausmann-Test (p-value) | 0.000 | 0.000 |
adjusted R² | 0.629 | 0.597 |
F-Test (p-value) | 0.000 | 0.000 |
Log-likelihood | -2.959 | -6.978 |
Number of observations | 5,500 | 5,500 |

*Two-factor fixed-effects vs.*

Finally, we turn to the macroeconomic implications of patent trade. Most recently, Spulber (2008: 12) theoretically showed that the opening-up of an economy to international technology trade increases the per-capita income for every consumer in the integrated economy. Combining this theoretical results with the time structure of events assumed by Spulber (2008: 2) – invention, auction of the invention on the market for technology, and use of the new technology for the production of final goods – yields a causal relationship running from invention to technology trade and finally to per capita income.
Figure 3 displays the central variables of this model, the number of patents transferred per year and the real per-capita income in Germany during the period 1883-1913. Both variables drifted upwards: the number of patent transfers increased from 258 in 1883 to 1,277 in 1913; the per-capita income increased from 514 Mark in 1883 to 802 Mark in 1913. Thus, the average growth rate of the patent market was much higher than the average growth rate of the per-capita income. Both variables obviously have an upward trend and it is likely that the time series have a unit-root. Consequently, it is not appropriate to use the classical Granger-causality test, since this test can only be used for stationary and non-cointegrated time series. A more general test for causality in VARs (vector auto-regressions) is the method proposed by Toda and Yamamoto (1995). This test is independent of unit-roots and cointegration. This is of special relevance, since tests for unit-roots and cointegration generally have low power in small samples. Thus, causality tests, depending on unit-root and cointegration properties can well have serious pre-test biases.

We employed the augmented Dickey-Fuller (ADF) unit-root tests to estimate the number of unit roots. It turned out that both, the times series of patent transfers and the time series of per

---

7 The missing patent transfer data for 1888 were ‘estimated’ using the mean ratio of transferred patents over valid patents in 1887 and 1889 multiplied with the number of valid patents in 1888.
capita income, have one unit-root. Moreover, we test for co-integration using Johanson’s test. Both, the lambda-maximum and the trace-test, support the hypothesis of no co-integration between the two variables. This indicates that no long-term equilibrium relationship existed between the patent transfers and per capita income. From a more technical point of view, absence of co-integration implies that we can calculate a VAR model using the first differences of both time series and that we can calculate the classical Granger non-causality tests of the VAR coefficients. All standard lag-length criteria support the choice of an optimal lag-length of one in the level- as well as in the first-difference VAR.

Moreover, we address the issue of pre-test biases by estimating a unit-root augmented level-VAR to conduct the Toda-Yamamoto non-causality test. More specifically, we need to know the maximum order of integration involved in the model, \(d_{\text{max}}\), and the optimal lag-length \(m\) for a VAR. We can then estimate a VAR in levels with a lag length of optimal lag length \(m\) plus \(d_{\text{max}}\). Causality is inferred only from the optimal lag-length VAR coefficients using standard Wald- or t-tests.

The results for the classical VAR estimated in first-differences are:

\[
\begin{align*}
\Delta Y_t &= 10.7082 - 0.0064\Delta Y_{t-1} - 0.0006\Delta T_{t-1} \\
(4) &\quad (3.67) \quad (-0.33) \quad (-0.33) \\
\Delta T_t &= 52.6676 - 0.0504\Delta Y_{t-1} - 0.0257\Delta T_{t-1} \\
(5) &\quad (1.72) \quad (-0.24) \quad (-1.35)
\end{align*}
\]

It turned out that the Granger-causality running from \(\Delta T_{t-1}\) to \(\Delta Y_t\) is insignificant (t-value = -0.33) and has the wrong sign. Thus, the standard VAR analysis did not support Spulber’s (2008) hypothesis of a positive impact of technology transfer on per-capita income.

However, Spulbers’s (2008) model is formulated in levels, not in first differences. Consequently, we employ the Toda / Yamamoto (1995) causality test, which based on a level VAR. The results are as follows:

\[
\begin{align*}
Y_t &= 69.8873 + 0.0848Y_{t-1} + 0.0034Y_{t-2} + 0.0006T_{t-1} + 0.0019T_{t-2} \\
(6) &\quad (1.67) \quad (4.41) \quad (0.18) \quad (0.30) \quad (1.01) \\
T_t &= -77.0564 + 0.0468Y_{t-1} + 0.1102Y_{t-2} + 0.0587T_{t-1} + 0.0142T_{t-2} \\
(7) &\quad (-1.77) \quad (0.23) \quad (0.56) \quad (2.98) \quad (0.74)
\end{align*}
\]

\(8\) We employ an ADF test with constant, but without drift rate and simulated the p-values based on 5,000 draws. The null hypothesis of a unit root was not rejected for the per-capita income (patent transfers) on a level of \(p=0.924\) (\(p=0.718\)). The null hypothesis of a unit root of the first differences was rejected on a level of \(p=0.010\) (\(p=0.046\)).
Again, the influence of $T_{t-1}$ on $Y_t$ is insignificant. However, using the theoretically correct specification in levels generated the correct sign of the coefficient. Nevertheless, the coefficient is insignificant and we cannot support Spulber’s (2008) macroeconomic model.

Yet, Spulber’s (2008) model implicitly assumes that all individuals are either inventors or producers. Therefore, per capita income equals labour productivity in his model. Under the additional assumption that workers are paid according to (marginal) productivity, we can replace the time series of per capita income, $Y_t$, by the time series of real wages, $W_t$. The results for the standard VAR in differences are shown in equations (8) and (9); the results for the lag-augmented level VAR are shown in equations (10) and (11).

\[
\begin{align*}
\Delta W_t &= 15.8216 - 0.01110 \Delta W_{t-1} - 0.0044 \Delta T_{t-1} \\
&= -0.67 & (4.29) & (-1.75) \\
\Delta T_t &= 51.9066 - 0.0353 \Delta W_{t-1} - 0.0247 \Delta T_{t-1} \\
&= -0.26 & (1.86) & (-1.32) \\
W_t &= 94.8066 + 0.0818 W_{t-1} + 0.0069 W_{t-2} - 0.0027 T_{t-1} + 0.0057 T_{t-2} \\
&= 0.0111 & (4.60) & (-0.74) & (2.85) & (0.75) \\
T_t &= -91.1885 + 0.0371 W_{t-1} + 0.0956 W_{t-2} + 0.0560 T_{t-1} + 0.0138 T_{t-2} \\
&= 0.0269 & (1.51) & (0.39) & (1.00) & (2.27)
\end{align*}
\]

The results presented in equations (8) to (11) confirm the results derived in the regressions using the income per capita: trading activity on the patent market was unrelated to the macroeconomic performance of late 19th and early 20th century Germany. The main reason for this finding is most likely the comparatively small size of the patent market. Between 1877 and 1913, about 600 patents were transferred annually. On average, the fees paid over the lifetime of a transferred patent were about 1,700 Mark. Thus, a fee-based measure of the patent market would value the market size at about one million Mark per annum, less than 0.004 percent of the average annual net national product over the period 1877-1913. Therefore, the trading volume on the market for patents seems to be too small to have a measurable macroeconomic effect. Furthermore, the time-lag between the auction of the patent on the market for technology and its impact on the evolution of per-capita income might be longer than one year. Such long-run effects are, however, not detected by our causality test. Nevertheless, the absence of co-integration between the variables indicates that

---

9 The real wage series is taken from Hoffmann (1965). We cannot reject the unit root hypothesis for the level of this series (p-value = 0.8854) and also for the first difference of the real wage series (p-value = 0.1046). Moreover, we cannot reject the hypothesis of a unit root in the twice differenced series (p-value = 0.6692). Yet, it is unlikely to have an I(3) process for wages. However, the low power of unit root test in small samples is well-known and we therefore assume that the real wage series is integrated of order one. Moreover, Johanson’s co-integration test unambiguously supports the hypothesis of no co-integration relationship.
no long-run relationship between the size of the patent market and the income per capita existed in late 19\textsuperscript{th} and early 20\textsuperscript{th} century Germany.

V. Conclusion
Immediately after the enactment of the first unified German patent law in 1877, a market for patents emerged in Imperial Germany. During the late 19\textsuperscript{th} and early 20\textsuperscript{th} century, a steadily growing number of patents were transferred, mainly from individual inventors to firms. Moreover, patents were transferred in the course of upgrading of legal forms of enterprises or from Schumpeterian inventors to their upstart firms. It turned out that firms efficiently screened patents and acquired – on average – more valuable patents on the market. On the other hand, firms sold less valuable patents off to individuals. Furthermore, secure property rights and patent lawyers acting as market intermediaries facilitated the transfer of patents. Jointly and severally, the market for patents in Imperial Germany was very similar to the U.S. patent market during the same period. Finally, we show that the size of the patent market was too small to have an effect visible on the macroeconomic level.

Future research will focus on the determinants of the probability that a patent was transferred at all. Moreover, a series of econometric stability test will be conducted.
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