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Catching-up and Falling Behind. Knowledge Spillover from American to German Machine Tool Makers[♣]

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Abstract

In our days, German machine tool makers accuse their Chinese competitors of violating patent rights and illegally imitating German technology. A century ago, however, German machine tool makers used exactly the same methods to imitate American technology. To understand the dynamics of this catching-up process we use patent statistics to analyze firms' activities between 1877 and 1932. We show that German machine tool makers successfully deployed imitating and counterfeiting activities in the late 19th century and the 1920s to catch-up to their American competitors. The German administration supported this strategy by stipulating a patent law that discriminated against foreign patent holders and probably also by delaying the granting of patents to foreign applicants. Parallel to the growing international competitiveness of German firms, however, the willingness to guarantee intellectual property rights of foreigners was also increasing because German firms had now to fear retaliatory measures in their own export markets when violating foreign property rights within Germany.

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1 Introduction

In March 2008, the Association of German Machine Builders (*Verband Deutscher Maschinen- und Anlagenbauer*) complained of the notorious Chinese product piracy: "*More than half of the German machine builders discover illegal replicas at exhibitions. Three quarters of these replicas come from China. Unfortunately, China's entry into the WTO in 2001 has not improved the legal protection of intellectual property rights of foreign firms.*[1] *The resulting loss of German mechanical engineering is about seven billions Euros per year* (or about 4 percent of total sales)."[2] The Association of German Machine Builders did not mention that, a century ago, many of its then already existing member firms used the same counterfeiting strategies to catch up to their British and American competitors. Already in 1897, the periodical American Machinist observed: "*In going through the shops of a prominent German machine-tool builder who has been in the United States and got a good many ideas there from, as well bought a good line of the best standard machines from which to copy or vary, in the production of its own line, I notice that every solitary American machine, whether from Providence, New Haven, or Cincinnati, had had the name chipped off and the place painted over.*"[3] Thirty years later, in 1927, the French periodical La Machine Moderne reported: "*Information coming from Germany indicates that a number of American machine-tools are now being copied by German constructors, some of which are made without the slightest alteration. Most of these machines are actually sold as originals, the name of the American constructor of the original machine being mentioned in the advertising notices, and often even appearing stamped on the machine, with the indication 'type' or 'model". We can cite a case where a German firm copied a machine designed and constructed by a well-known American manufacturer, and sold in the United States.*"[4]

We claim in this article that imitating and even counterfeiting advanced foreign technology and products are typical strategies of firms located in an economically backward country. These activities are formally legal when the imitating firms use their new knowledge only in those markets where the intellectual property rights of the original inventor are not protected – like in Germany before 1877. These activities are clearly illegal when the imitating firms sell

[1] „Argumentationshilfe aus dem VDMA zum Stichwort Produktpiraterie", March 2008.
[2] Press release „Produkt- und Markenpiraterie in der Investitionsgüterindustrie 2008" of the VDMA, April 2008.
[3] German Machine Copying, American Machinist, February 1897, p. 116. According to Kiesewetter, the lawyers of McCormick, an American manufacturer of agricultural machinery, accused the German imitators of being the most infamous pirates in 19th century-Europe. See Kiesewetter, H. (1992). Beasts or Beagles? Amerikanische Unternehmen in Deutschland. In Pohl, H. (ed.). *Der Einfluß ausländischer Unternehmen auf die deutsche Wirtschaft vom Spätmittelalter bis zur Gegenwart*. Stuttgart: Franz Steiner, p. 170.
[4] Cited after W.H. Rastall, 2. May 1927, NARA, RG 151, 413 (Box 1806).

their replicas in markets where the intellectual property rights of the original inventor are established – like in the case reported by the French periodical La Machine Moderne. The government of a backward country might tolerate or even foster this illegal behavior of the firms in its jurisdiction because imitating foreign know-how is one of the most promising ways to catch up to the economically and therefore politically leading nations. However, this kind of illegal imitation usually only takes place during a transitional period. On the longer run, both the firms and the government of the economically advancing country face strong incentives to change their behavior from violating to respecting international intellectual property rights.

To elaborate this argument, we sub-divide the catching-up process into the three phases imitation, (adaptive) innovation and diffusion. During the imitation phase, firms of the economically backward country use various imitation channels like reverse engineering, attending international exhibitions and foreign firms, analyzing patent specifications, or hiring foreign craftsmen and engineers to learn from their superior foreign competitors. This new knowledge can be profitably used in their home market because the government of the imitating firms does not enforce the intellectual property rights of the foreign firms in its jurisdiction.[5] In the following phase of innovation, the imitating firms adjust the imitated technologies and products to their own technological capabilities and the demand of their home market. During this process of adaptation imitation is abating because the formerly imitating firms gain step by step the competence to develop their own successful innovations. That is why these firms might now lobby for a functioning domestic patent law which does not discriminate against foreign firms to make sure that, in return, their own intellectual property rights will be guaranteed abroad.

Catching-up, however, is obviously not possible for every country. One of the necessary preconditions for both successful imitations and innovations is the availability of a sufficient stock and structure of human capital. Aghion supposes that during the imitation phase firms rely primarily on workers with secondary education while for innovation workers with tertiary education are needed.[6] As a result, an economically backward country should concentrate first

[5] To avoid misunderstandings, we want to stress that technological transfer is seldom a one-way-street. During the catching-up process firms in the technologically leading country might also learn from the activities of their foreign imitators. For this "reverse flow" see Jeremy, D. J. (ed.). *International Technology Transfer. Europe, Japan and the USA, 1700-1914*, Aldershot: Edward Elgar.

[6] See Aghion, P. (2008). Higher Education and Innovation. *Perspektiven der Wirtschaftspolitik* 9 (Special edition), pp. 28-45.

on the improvement of its education system on the primary and secondary levels. Not until then when the firms of the advancing country approach the technological frontier the improvement of higher education becomes the most important task of education policy. Besides human capital formation, other factors like secure property rights, an incorruptible administration, openness to competition, or financial institutions capable of mobilizing capital for individual firms seem to be also needed for catching-up successfully.[7] Germany went through these institutional reforms in the second half of the 19th century and thereby supplied the domestic firms with the capabilities and resources necessary for imitating and innovating.[8]

During the diffusion phase, the competence to develop innovations spill-over to more and more domestic firms which increases both price and Schumpeterian competition between the growing number of efficient and innovative firms in the backward country considerably. Sometimes, the former backward firms might even take over the global technological leadership and thereby – like the German machine tool makers – change from ruthless imitators to campaigners for the worldwide enforcement of intellectual property rights.

Note that the imitation, innovation and diffusion phases often overlap. Especially during the innovation phase, first, the (illegal) imitation of foreign technology might cease but not totally stop, and, second, the imitation activities between domestic firms might already increase speeding up the diffusion of knowledge. We will see in the following that, in the case of the catching-up process of the German machine tool industry, innovation and diffusion phases in fact took place at the same period of time.

Japanese firms of various sectors went successfully through this whole catching-up process in the second half of the twentieth century; the Chinese case mentioned above is obviously a contemporary example for the beginning of this transition period from backwardness to international competitiveness. We will concentrate on the development of the German machine tool industry between 1877 and 1932 which can be understood as a prime model for

[7] See Abramovitz, M. (1986). Catching-up, Forging Ahead, and Falling Behind. *Journal of Economic History* 46, pp. 385-406; Buchheim, C. (2006). What Causes Late Development? Insights from History. *South African Journal of Economic History* 21, pp. 52-83.

[8] For a survey of the institutional reforms in 19th century-Germany see, for example, Ogilvie, S. and Overy, R. (eds.) (2003). *Germany: A New Social and Economic History Volume 3. Since 1800*. Oxford: University Press. See also Grupp, H., Dominguez-Lacasa, I. and Friedrich-Nishio, M. (2002). *Das deutsche Innovationssystem seit der Reichsgründung*. Heidelberg: Physica Verlag.

explaining later catching-up processes.[9] Methodologically, we rely primarily on the analysis of the patent activities of German and American machine tool makers to answer the following questions:

- How was the chronological sequence of the catching-up process of the German machine tool industry between 1877 and 1932?
- How did the American machine tool makers react against the imitating strategy of the German firms?
- Did the German imitating firms gain an advantage over the non-imitating firms with respect to innovativeness?

In section 2, we will discuss the advantages and shortcomings of the patent data used in this paper. In section 3, we will describe German machine tool makers' catching-up process and the reaction of their American counterparts in detail. Section 4 will conclude.

2 The patent data

Our analysis of the patenting activities of the American and German machine tool industries is based on different samples of individual machine tool patents, with each single record including information about the year when the patent was granted (or applied for), as well as the name and location of the firm holding the respective patent. To identify the machine tool patents in the total patent population we use the fact that the German patent office, starting with the introduction of the German patent law in 1877,[10] assigned every patent to a particular technological class. Patents covering the technology of the machine tool industry can be found in the patent classes 47 (machine parts), 49 (mechanical metal working), and 67 (grinding and polishing).

Much is said about the shortcomings of patents as a measure for innovation activities. Griliches has stated: "*Not all inventions are patentable, not all inventions are patents and the inventions that are patented differ greatly in 'quality', in the magnitude of inventive output associated with them.*"[11] The first part of this statement refers to the well-known fact that the propensity to patent varies across industries. Some industries, like the chemical or

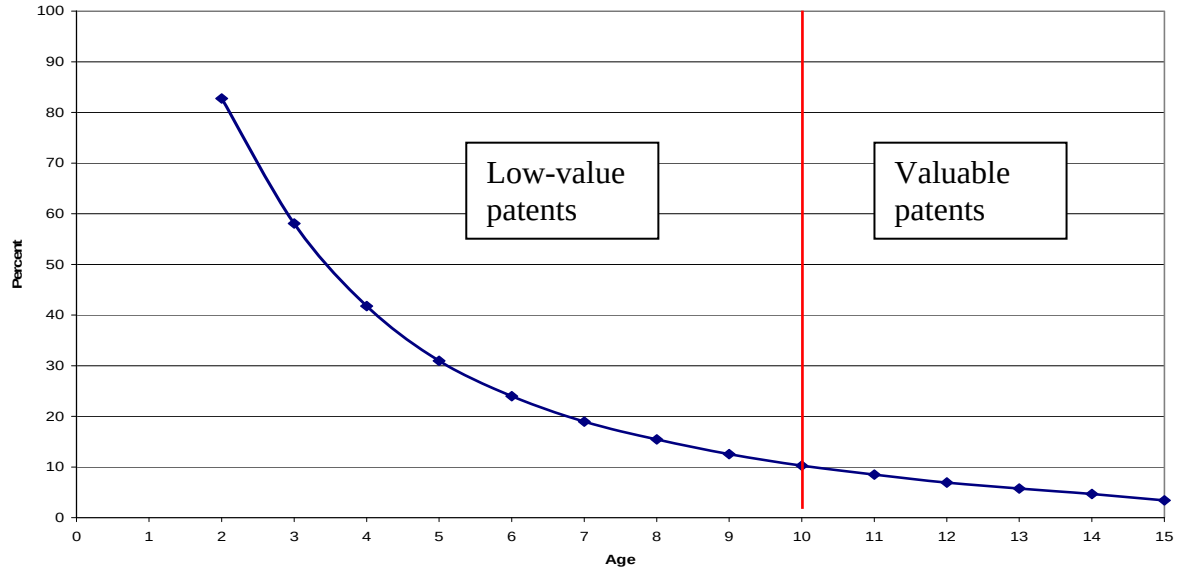
[9] For the similar catching-up process in the German chemical industry see Murmann, J. P. (2003). *Knowledge and Competitive Advantage: The Coevolution of Firms, Technology, and National Institutions.* Cambridge: University Press.
[10] See Seckelmann, M. (2006). *Industrialisierung, Internationalisierung und Patentrecht im Deutschen Reich, 1871-1914*. Frankfurt/Main: Vittorio Klostermann, pp. 86-106.
[11] Griliches, Z. (1990). Patent statistics as economic indicators: A survey. *Journal of Economic Literature* 33, p. 1669.

pharmaceutical industries, try to appropriate the returns of their inventions primarily by patenting, while others prefer keeping their inventions secret instead. It is often claimed that the machine building industry belongs to the later group but we will see in the following that, at least in our period of observation, German and American machine tool makers not only relied on secrecy but also held a considerable amount of patents. The problem that is addressed in the second part of Griliches' statement is probably the more serious one. Pure patent counts allocate the same weight to every patent, no matter whether it has a high or a low economic value for the patentee. Using the number of patents as an indicator for successful innovation activities therefore leads to a potentially large measurement error. We address this problem by analyzing three different types of patent statistics.

Patents applied for are a measure for inventions which were appraised to be new and potentially profitable by the applying firms. *Patents granted,* in contrast, are a measure for inventions which were judged to be new by the patent office. *Long-lived patents* are an indicator for innovations which became in fact profitable. This later group was identified by Streb et al. using a special feature of the German patent law.[12] According to this law, patent protection could last up to fifteen years but was not for free. Rather, the patentee had to pay at the beginning of each year an increasing renewal fee in order to keep his patent in force. This annual renewal fee came to 50 Marks in the first two years, and grew then by 50 Marks each year up to 700 Marks at the beginning of the fifteenth year. Consequently, a patent holder had to decide annually if he was going to renew his patent for another year or not. The outcome of this decision depended on the patentee's expectations about the future returns and costs of holding the patent. The later were determined by the renewal fees and were therefore foreseeable with certainty. In contrast, the future returns, which could result either from selling the innovation as a temporary monopolist or by licensing another producer to do so, were highly uncertain. Streb et al. assumed that the majority of patent holders renewed their patents only if the present value of the expected future returns exceeded the present value of the future costs. Under this assumption, a long life span of a historical patent undoubtedly indicates its comparatively high private economic value.

[12] See Streb, J., Baten, J. and Yin, S. (2006). Technological and geographical knowledge spillover in the German Empire 1877-1918. *Economic History Review* 59, pp. 347-373.

Figure 1 The survival rate of German patents[a]



a This calculation is based on information on the patent cohorts 1891-1907. See *Blatt für Patent-, Muster- und Zeichenwesen* (1914), p. 84.

A basic question of this life span approach is how many years a patent had to be in force to be interpreted as a valuable patent. Figure 1 shows that about seventy percent of all German patents granted between 1891 and 1907 were already cancelled after just five years. After the fifth year the speed of patent cancellation was decelerating. About 10 percent of all patents were still in force after 10 years, 4.7 percent of all patents reached the maximum age of fifteen years.

As figure 1 also illustrates, Streb et al. decided to use the cut-off point of 10 years to distinguish valuable patents from low-value patents.[13] The choice of this cut-off point was not arbitrary. Pakes observes that the low renewal fees at the beginning of a patent's life allow the inventor to use the patent as a comparatively cheap option that protects the new knowledge and gives him or her the time to learn more about the technological and economic prospects of the invention.[14] In the view of this fact it would be conceivable to interpret those patents that survived this learning process and lived therefore at least about 5 years as the valuable

[13] The identification of an individual patent's life span is generally possible because the German patent office published every year the patent numbers of those patents still in force. Since one would have to search for the respective patent number in up to fifteen annual lists, the process of making out the individual life span of one single patent needs at least about 15 minutes. That is why, given the budget constraint of their project, Streb et al. were not able to figure out the exact life span of each of the 800,000 German patents between 1877 and 1932. Choosing instead to use the cut-off point of 10 years, they had to search only for those individual patents that survived at least 10 years.

[14] See Pakes, A. (1986). Patents as options: some estimates of the value of holding European patent stocks. *Econometrica*, 54, pp. 755-784.

patents of the patent population. Sullivan, however, came to the result that most of the value of the patent stock built up in the second half of the nineteenth century in Britain and Ireland was concentrated in the upper ten percent of the long-lived patents. Following this hint Streb et al interpret the upper 10 percent of the long-lived patents as the valuable patents of the German patent population and therefore selected all patents that survived at least ten years.[15] This selection process resulted in a data base containing 39,343 valuable patents of the German Empire (1877-1918) and 27,340 valuable patents of the Weimar Republic (1919-1932)[16] – among those all long-lived machine tool patents which were granted to German and foreign machine tool makers.

Figure 2 Three types of patents

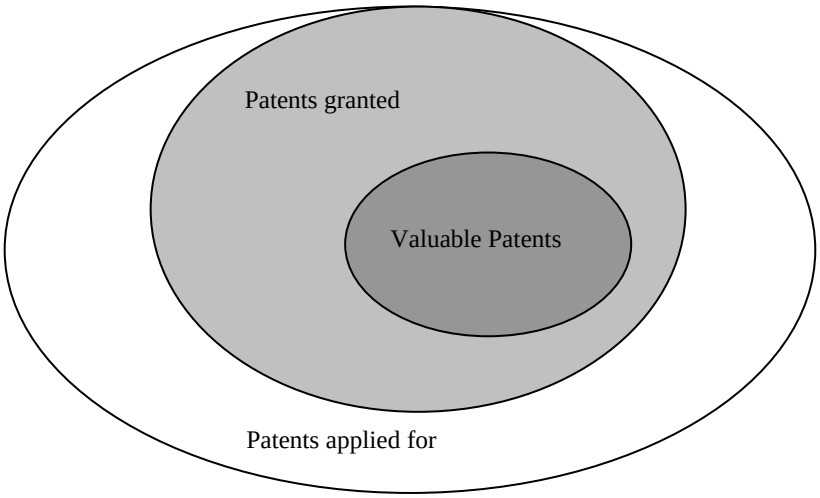


Figure 2 makes clear that, in general, the patents granted are a sub set of the patents applied for, and the valuable patents are a much smaller sub set of the patents granted. The relative usefulness of these three patent data sets depends on the particular scientific objective. If a scholar is primarily interested in the firms' invention activities he or she should concentrate

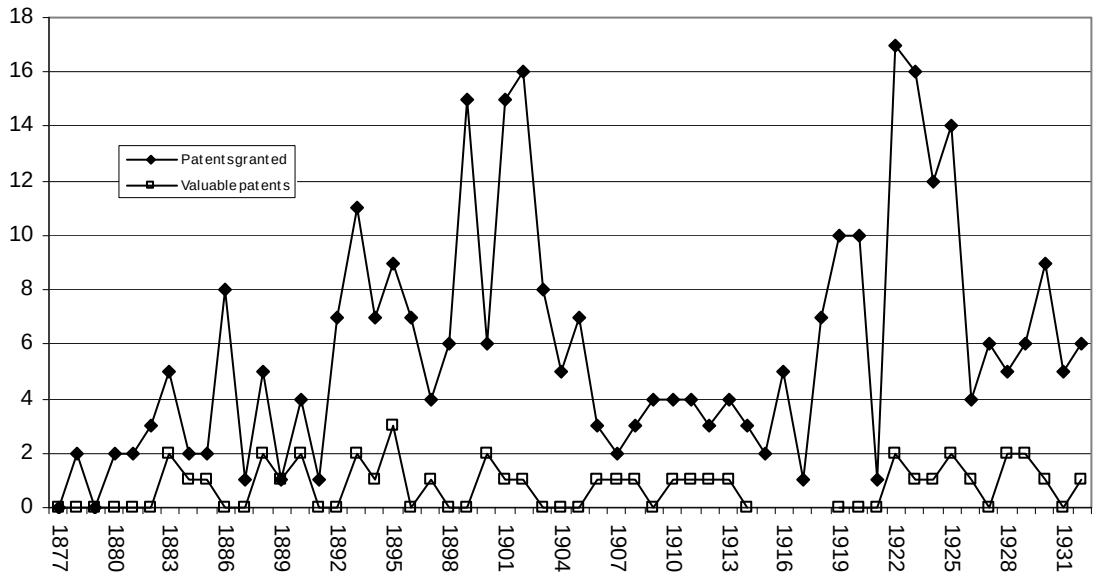
[15] See Sullivan, R. J. (1994). Estimates of the value of patent rights in Great Britain and Ireland, 1852-1976. *Economica*, 61, pp. 37-58. See also Schankerman, M. and Pakes A. (1986). Estimates of the value of patent rights in European countries during the post-1950 period. *The Economic Journal*, 96, pp. 1052-1076.

[16] For other empirical studies using this patent data set see Baten, J., Spadavecchia, A., Streb, J. and Yin, S. (2007). What made southwest German firms innovative around 1900? Assessing the importance of intra- and inter-industry externalities. *Oxford Economic Papers* 59, pp. i105-i126; Degner, H. (2009). Schumpeterian German firms before and after World War I. The innovative few and the non-innovative many. *Zeitschrift für Unternehmensgeschichte* 54, pp. 50-72; Labuske, K. and Streb, J. (2008). Technological creativity and cheap labour? Explaining the growing international competitiveness of German mechanical engineering before World War I. *German Economic Review*, 9, pp. 65-86; Streb, J., Wallusch, J. & Yin, S. (2007). Knowledge spill-over from new to old industries: The case of German synthetic dyes and textiles 1878-1913. *Explorations in Economic History*, 44, pp. 203-223.

on the patents applied for. In cases in which the efficiency of the patent office's screening process is under consideration, a comparison of the patents applied for and the patents granted seems to be advisable. If the main objective is to identify those inventions which became successful innovations it is useful to look first and foremost at the valuable patents.

It is important to note that these three types of patents not necessarily display a parallel development over time. Figure 3 shows, for example, that the machine tool makers of the industrial district Chemnitz had a rather constant annual number of valuable patents while their number of patents granted was especially high in the 1890s and the 1920s. It would therefore be wrong to infer from the rising number of patents granted a similar boom of valuable patents and therefore of innovativeness.

Figure 3 Patents granted and valuable patents of the machine tool makers in Chemnitz[a]



a Source: Baten/Streb patent data base and Richter's patent data.

In this paper, we match the Baten/Streb patent data base (about 66.700 valuable patents for the period 1877-1932) with Richter's patent data about the patenting activities of American and German machine tool makers for four different groups of patent holders which vary in the depth of patent information available:

- 479 German firms which were member of the association of German machine tool makers or were identified as machine tool makers in trade journals. Available are their valuable patents in the German jurisdiction.

- The subgroup of all German machine tool makers of the industrial district of Chemnitz, the birthplace of the German machine tool industry. In addition to their valuable patents, their patents granted including the application date in the German jurisdiction are known.
- 408 American firms which were member of the Association for Manufacturing Technology or its predecessor the National Machine Tool Builders Association or were identified as machine tool makers in trade journals. Available are their patents granted including the application date and their valuable patents in the German jurisdiction.
- The subgroup of all American machine tool makers of the industrial district of Cincinnati which was along with New England and Philadelphia one of the most important focal points of the American machine tool industry. In addition to their patents granted including the application date and their valuable patents in the German jurisdiction, their patents granted including their application date in the American jurisdiction are known.

We will use these four patent data sets to analyze the details of German machine tool makers' catching-up process in the following section.

3 The catching-up of the German machine tool makers

By the Paris world exhibition in 1867, German machine tool makers began with imitating American machine tools.[17] The most important imitation channel was reverse engineering. German firms imported one specimen of a particular machine tool type and used this as a model to copy the whole machine tool or at least some of its main components. Trade fairs and world exhibitions were the second most important information source.[18] German engineers examined innovative foreign machinery on the ground and then prepared written reports about their findings which could also be used by German machine tool makers who had not the funds to travel to the trade fairs and world exhibitions by themselves. International trade journals were also used to learn more about foreign innovations. Already in 1897, the machine tool maker Schubert & Salzer, for example, employed a translator to scrutinize the

[17] For more details about the imitation channels used by the German machine tool makers see Richter, R. (forthcoming). *Der amerikanische und deutsche Werkzeugmaschinenbau zwischen Konvergenz und Divergenz, 1870-1933.* Bielefeld.
[18] See Moser, P. (2005). How do Patent Laws influence Innovation? Evidence from Nineteenth-Century World's Fairs. *American Economic Review* 95, p. I214-I236.

sixty international trade journals the firm had subscribed to.[19] As an additional written information source, American patent specifications were circulated among the German machine tool makers.

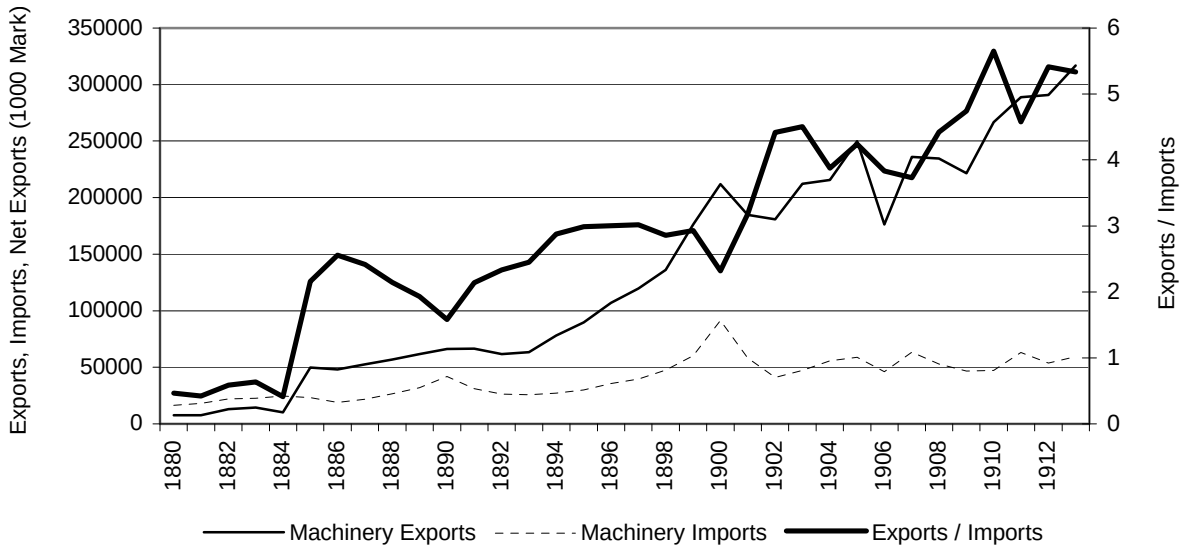
During the intensification of this imitation process the acquirement of personal, often tacit knowledge became more and more important. German entrepreneurs traveled to the United States to inspect American plants or even to assume a temporary employment there. In a publication commemorating the 50th anniversary of the firm J.E. Reinecker, for example, it is stressed that this firm owed much of its technological progress to the wide experience the entrepreneur's son gained during his one-year stay in the United States.[20] The same firm hired in 1897 an American expert for machine tool technology who had once presented the innovations of an American firm from Philadelphia at the Chicago world exhibition in 1893.[21] An imitation channel with growing importance were the information about innovative machine tools international resellers distributed among the different firms they represented.[22] In December 1903, for example, the French reseller of the Wanderer Works advised this German firm to imitate the new features of the Brown & Sharpe and Cincinnati milling machines.[23] In the late 19th century, no other machine tool dealer network was as dense and highly developed as the one built up by the German firms which had establishments in all industrial countries with the exception of the UK.

The most successful German imitators used these various imitation channels in combination and permanent. Data for the German machine building industry as a whole, presented in figure 4, reveal that this catching-up process, which was not limited to the sub group of machine tool makers, helped to boost the international competitiveness of the German firms in the longer run. In 1885, German machinery exports surpassed imports for the first time. After a two-year-lasting collapse of both quantities during the global economic crisis of

[19] See Miller, F. J. (1897). *American and Other Machinery Abroad. Being a Study of the European Field for the Introduction of American Machinery*. New York: Press of the American Machinist, p.72.
[20] See *J. E. Reinecker Chemnitz 1859-1909*, Leipzig: Meisenbach Riffarth, 1909, p. 15.
[21] See Miller, F. J. (1897). *American and Other Machinery Abroad. Being a Study of the European Field for the Introduction of American Machinery*. New York: Press of the American Machinist, p.76.
[22] In contrast to other industries in which sales agencies acted as "information brokers", machine tool dealers did not charge their clients for new information about the innovations of their competitors. Instead, they used this kind of knowledge transfer as a mean to improve the competitiveness of their clients' products. For the role of international resellers as „information brokers" see Streb, J. (2001). Möglichkeiten und Grenzen der Schumpeterschen Diversifizierung. Die Entwicklung der Firma Freudenberg & Co. Weinheim vom spezialisierten Ledererzeuger zum Kunststoffverarbeiter mit breiter Angebotspalette. *Zeitschrift für Unternehmensgeschichte* 46, pp. 131-159, especially pp. 139-143.
[23] See Staatsarchiv Chemnitz 31030, Rot 201: Letter by Wanderer-Directorate to Winklhofer, 23. December 1903.

1901/1902, machinery exports returned to their upward trend while machinery imports stagnated on a low level. Consequently, the export-import ratio more than doubled between 1900 and 1913. According to Reitschuler (1963, p. 253), in 1913, Germany was the world's largest exporter in the field of mechanical engineering selling abroad machinery being worth 175.7 million US $ while at the same time the value of machinery export was 162.1 million US $ for the United States and 171.7 million US $ for Great Britain.[24]

Figure 4 Export-Import ratio of German machine builders[a]



a Labuske, K. and Streb, J. (2008). Technological Creativity and Cheap Labour? Explaining the Growing International Competitiveness of German Mechanical Engineering before World War I. *German Economic Review* 9, p. 67.

In the following, we analyze the German machine tool makers' catching-up process on basis of the patent statistics explained in section 2. Figure 5 shows that, measured by the average annual number of valuable patents of the 479 German machine tool makers, we can distinguish five different phases which match our qualitative and anecdotic evidence of the timing of this repeated catching-up process:

- the first imitation period ((Paris world exhibition 1867)/Introduction of the German patent law 1877 to 1899)[25] with 2.4 valuable patents per year,

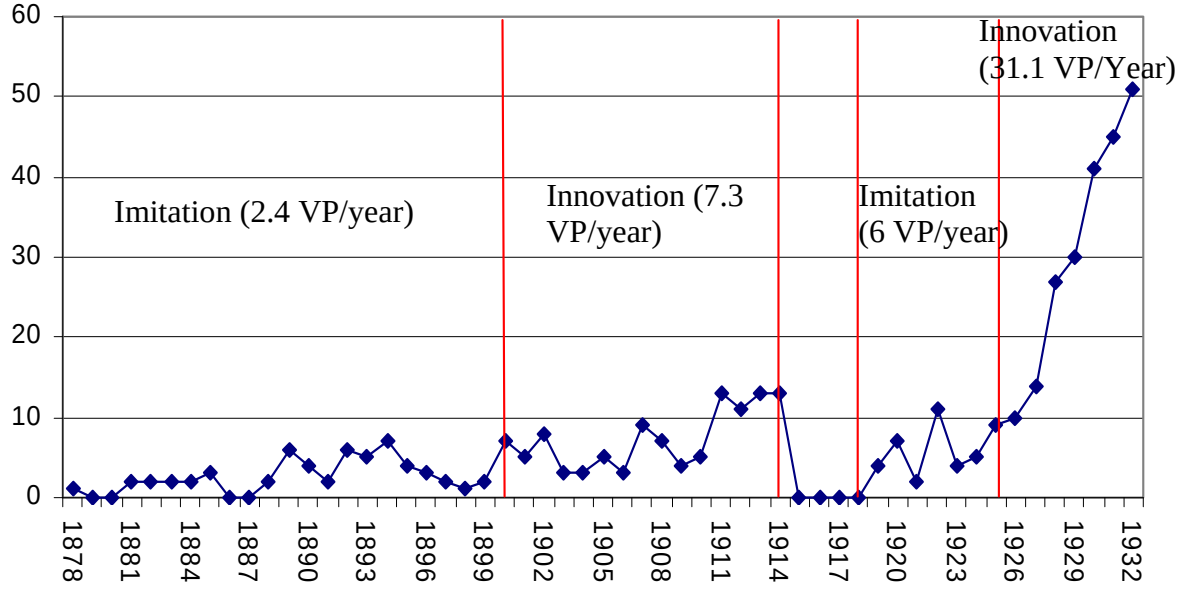
[24] See Reitschuler, S. (1963). *Die Stellung der Maschinenindustrie im Prozess der Industrialisierung*, Cologne/Opladen: Westdeutscher Verlag, p. 253.

[25] Our qualitative evidence suggests that the first imitation period already started in the late 1860. Since the German patent law was not introduced until 1877, we are not able to analyze the first decade of this imitation period with the help of patent data. Interestingly enough, however, it was apparently the growing imitating activities of German firms in the early 1870s which considerably increased the international political pressure on Germany to introduce a patent law. See Seckelmann, M. (2006). *Industrialisierung, Internationalisierung und Patentrecht im Deutschen Reich, 1871-1914*. Frankfurt/Main: Vittorio Klostermann, p. 156.

- the first innovation and diffusion period (1900 to the outbreak of the First World War) with 7.3 valuable patents per year,
- the technological setback during the First World War,
- the second imitation period (1919 to 1925) with 6 valuable patents per year, and
- the second innovation and diffusion period (1926 to 1932, which is the last year covered by our data) with 31.1 valuable patents per year.

The fact that, during the first imitation period, German machine tool makers acquired only a few patents that turned out to be worth to be prolonged for at least ten years suggest that, in the late 19th century, the German firms neglected own R&D projects but relied primarily on imitating foreign products. Obviously, however, learning-by-imitating created on the longer run the competences that were needed to develop successful innovations on one's own account. As a result, the average number of valuable patents per year of the German machine tool industry tripled in the first innovation period in comparison to the preceding first imitation period.

Figure 5 Valuable patents (VP) of German machine tool makers[a]



a Source: Baten/Streb patent data base and Richter's patent data.

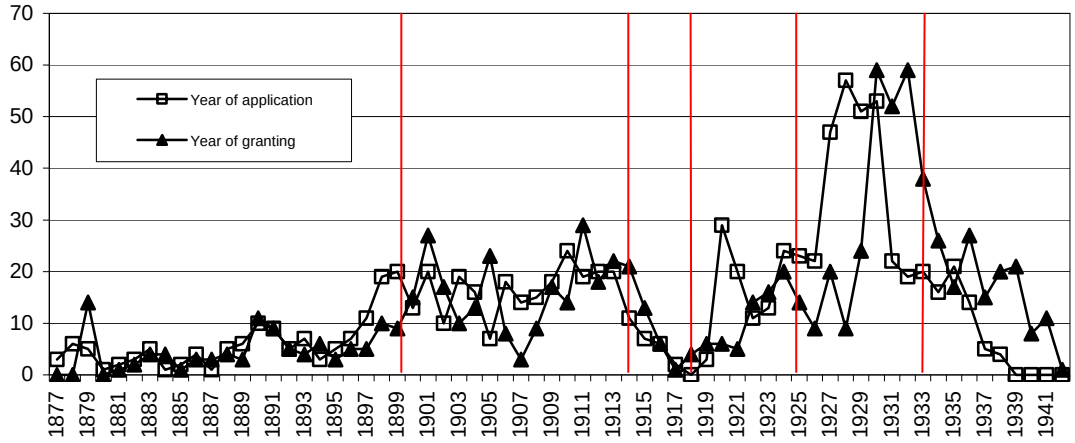
The absence of valuable German machine tool patents between 1915 and 1918 in figure 5 does not indicate the total breakdown of innovativeness in this sector but is due to the fact that the German patent office did not publish the name of any patent holder during the First World War. There are no doubts, however, that the German machine tool makers fell back into

technological backwardness again in this period because of several reasons. First, the Allied trade embargo of Germany disrupted the transatlantic stream of knowledge. Second, German firms had neither the incentives nor the resources to invest in new R&D projects because of their one-sided engagement in armament production. The German army had ordered the German machine tool makers to stop their production of high-quality machine tools and to manufacture instead high numbers of low-quality machine tools needed to produce ammunition and weapons.[26] As a result, the Association of German machine tool makers feared already in 1917 that the resulting shrinking of technological know-how would decrease their future competitiveness in the export markets.[27] Third, the firms' stock of human capital decreased because thousands of experienced machine tool makers died as soldiers. Consequently, after the war had ended, the German machine tool makers went back to their well-known imitation strategies which they had already brought to perfection in the 19th century. Any scruples which the German firms might have had regarding the violation of intellectual property rights, had diminished after the confiscation of their U.S. patents by the Office of Alien Property during the war. The American commercial attaché in Berlin summed up in 1926: "*The practice of copying American machinery has therefore extended much more widely since the war than it was even before.*"[28] Due to both their unscrupulousness and their wide experience with imitation strategies the German machine tool makers were now able to catch-up again in just a half decade. In 1926, the German machine tool industry started to pass through its second innovation period with an unprecedented average number of 31.1 valuable patents per year.

How did the American machine tool makers react against the imitating strategy of the German firms in the late 19th and early 20th centuries? We already know about the various complaints about the German imitating activities both during the first and the second imitation period. It is reasonable to assume that the American innovators did not only fight with words but tried to protect their intellectual property rights by applying for patent protection at the German market. We would therefore expect that American patenting activities in Germany were especially high during the two imitation periods.

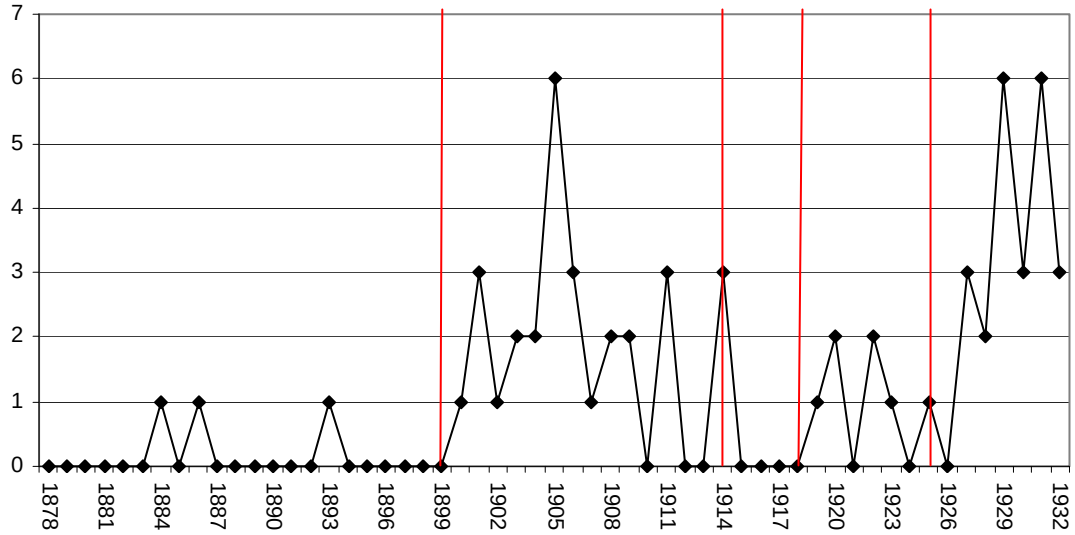
[26] See Bundesarchiv Berlin-Lichterfelde R 8099/259: Stenographischer Bericht über die Besprechung in den Geschäftsräumen des Vereins Deutscher Werkzeugmaschinenfabriken, 5. September 1916, pp. 26-32.
[27] See Verein Deutscher Werkzeugmaschinenfabriken (ed.) (1917): Jahresbericht 1917, p. 3.
[28] NARA, RG 151, 420 (Box 1950): D.P. Miller to Director Bureau of Foreign and Domestic Commerce, 8. November 1928.

Figure 6 **Patents granted (with application date) of American machine tool makers in Germany**[a]



a Source: Richter's patent data.

Figure 7 **Valuable patents of German machine tool makers in Germany**[a]

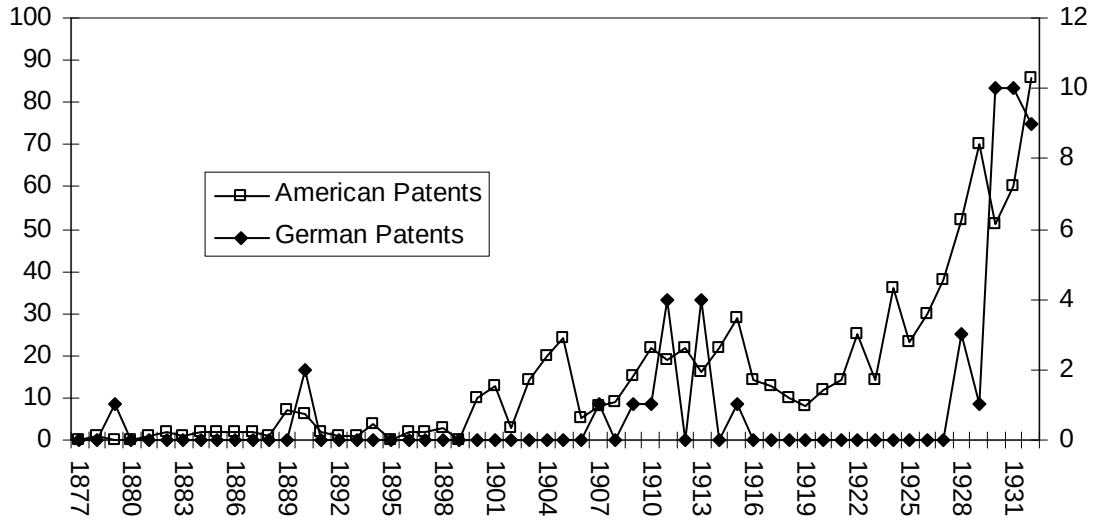


a Source: Baten/Streb patent data base and Richter's patent data.

Figures 6 and 7 prove that this expectation is wrong. American firms had a comparatively high number of both German patents granted and valuable German patents not during the two imitation periods but during the two innovation periods. How can this discrepancy between our theoretical expectation and the empirical observation be explained? There are two necessary preconditions for patenting activities in a foreign market. First, an innovator will only be prepared to apply for patent protection in a foreign market after he has learned how to

use this instrument in his home market. Second, an innovator has to expect to sell his products in the foreign market at a sales volume that justifies the costs that come along with the patenting activities abroad.

Figure 8 Patents granted of the American machine tool makers from Cincinnati in the American and German jurisdictions[a]



a Source: Richter's patent data.

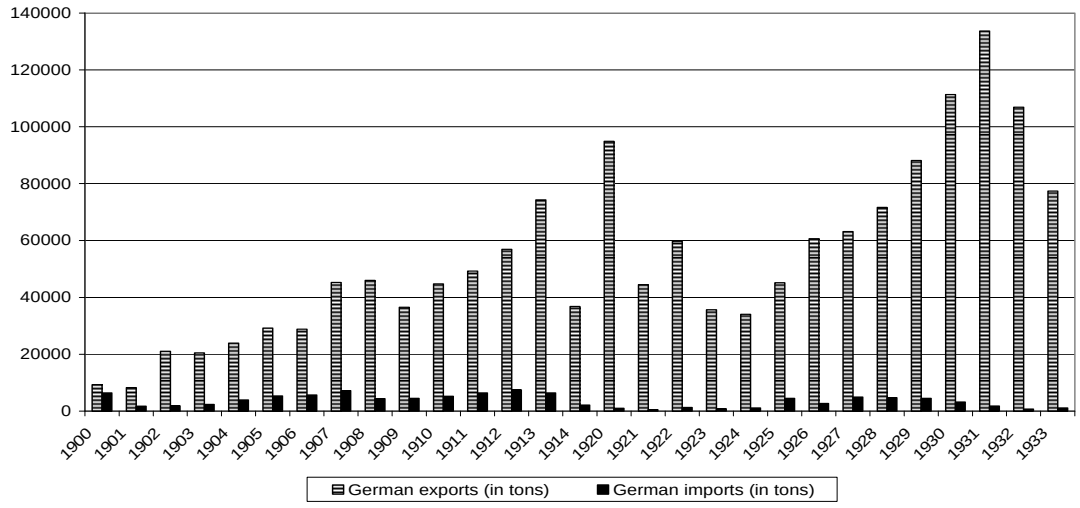
Both preconditions were not satisfied during the first imitation period. Figure 8 shows that the newly founded American machine tool makers of the industrial district in Cincinnati intensified their patenting activities in their home market not before the turn of the century. Their inexperience with respect to patenting at home might explain why they also abstained from patenting activities in Germany before 1900. However, the increasing number of German patents held by American machine tool makers after 1900, proven by figures 6, 7 and 8, is not only the result of growing experience but is probably also owed to the fact that, in this period, Germany has become one of the most important foreign market for American machine tool makers who delivered about one quarter of their total exports to German customers.[29] The increased German demand for their products obviously convinced American

[29] See Robertson, R. M. (1966). Changing Production of Metalworking Machinery, 1860-1920. In Brady, D. S. (ed.). *Output, Employment, and Productivity in the United States after 1800.* NBER Books, New York: Columbia University Press, pp. 479-496, here p. 493; Penrose, B. and Williams, J. S. (1912): *Duties on Metals and Manufacturers of Metals.* Committee on Finance, United States Senate, Washington: Govt. Print. Off., p. 236.

machine tool makers that it has become profitable to get their innovations patented in the German jurisdiction.[30]

Interestingly enough, we found no evidence that three of the most notorious German imitators of the first imitation period, namely J. E. Reinecker, Pfauter, and Wanderer Works, maintained their imitation strategies during the first innovation period when these three firms also held patents in the American jurisdiction. As these German firms now had a strong interest that their own patents were respected in their American export market, they abstained in return from violating the intellectual property rights of American firms before the First World War. Figure 9 proves that German machine tool makers increased their exports considerably during both innovation periods.

Figure 9 German Exports and Imports of Machine Tools, 1900-1933[a]



a Statitisches Reichsamt (ed.). *Monatliche Nachweise über den auswärtigen Handel Deutschlands.* Berlin 1900-1933.

In the light of the increasing success of German firms in the American market, the German government was now also willing to make some concessions to the American patent holders. Section 11 of the German patent law of 1891 ruled that a patent could be revoked when the patent holder did not manufacture the patented good within the borders of Germany.[31] The purpose of this stipulation was to avert that a foreign patent holder used his German patent only to secure his monopoly in this country but did not employ German labor and did not

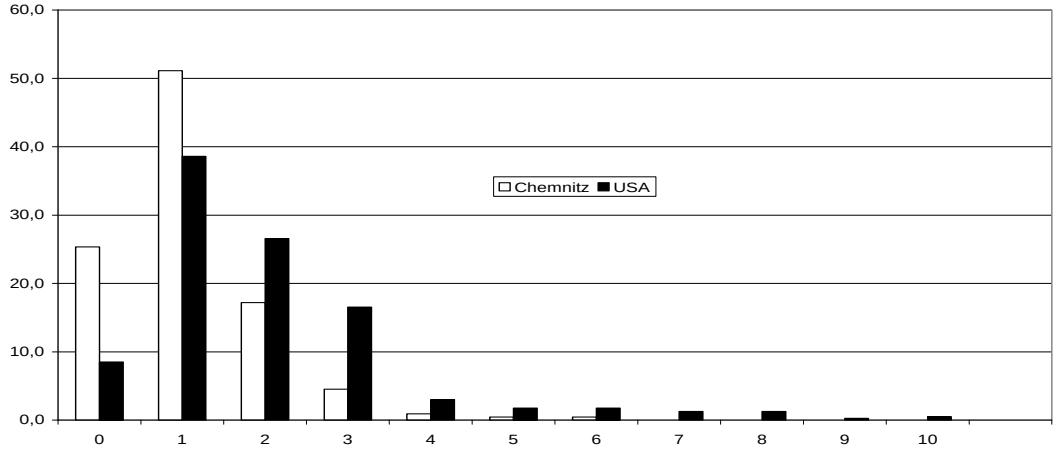
[30] The average time span the American machine tool makers let pass between the patent application in their home market and the one in the German market decreased from 2.3 years before the First World War to 0.9 years after the First World War.

[31] A similar ruling can be found in section 27 of the British Patents and Design Act of 1907.

stimulate German industry. Since the German firms used their American patents in the United States exactly in this unwanted way, the German government arranged with the American government in 1909 that section 11 of the German patent law was in return not applied to American firms.[32]

However, as we have already seen, the German firms reverted fast to their traditional imitation strategies after they had lost their American patents during the war and faced again a technological gap between themselves and their American competitors in the early 1920s. The Americans were well aware of the revitalized imitating activities of the German firms in the 1920s. In 1925, the American trade commissioner Theodor Pilger authored a report in which he listed 64 American machine tool makers whose products were copied by German firms and who were then squeezed out of the German and other export markets by their imitators. Pilger suggested as a countermeasure to apply for patents in the German jurisdiction.[33] The American firms obviously followed this advice. Figure 6 shows that the patent applications of American firms in Germany reached a record high in the late 1920s. However, given the fact that the German patent office needed in this decade on average about three and a half years to grant a patent for which an American machine tool maker had applied for, the number of patents granted increased not until 1930.

Figure 10 Time span between the application and the granting of patents of machine tool makers from the US and from Chemnitz, 1877-1918, in years[a]

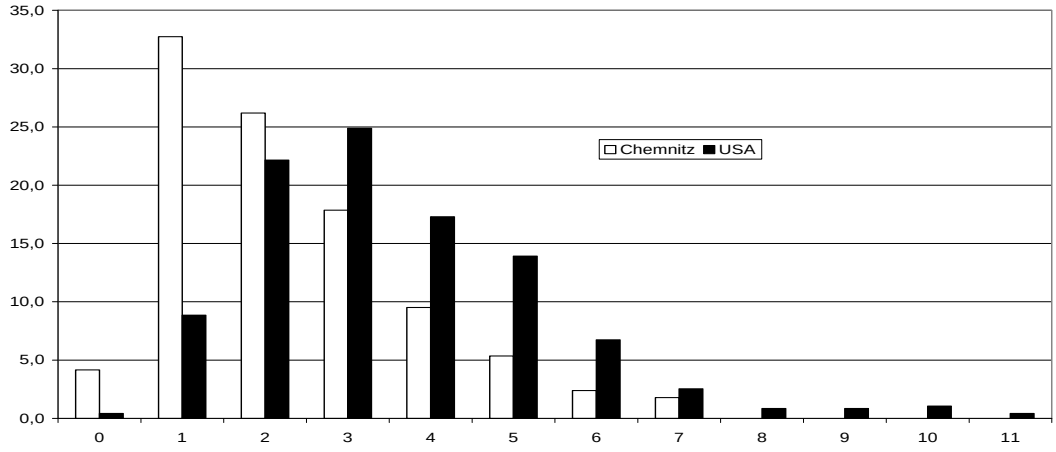


a Source: Richter's patent data.

[32] See „Abkommen zwischen dem Deutschen Reiche und den Vereinigten Staaten von Amerika, betreffend den gegenseitigen gewerblichen Rechtsschutz vom 23. Februar 1909." Blatt für Patent-, Muster- und Zeichenwesen, 25. August 1909, Nr. 7/8.
[33] See NARA, RG 151, 420 (Box 1950): W.H. Rastall to Julius Klein, 11. January 1926.

Figures 10 and 11 illustrate that the German patent office needed actually much more time to process the American patent applications in the period after than in the period before the First World War. Given the parallel increase in the duration between application and granting dates for the patents of the German machine tool makers from Chemnitz after the First World War, this fact might be explained by the growing complexity of the new products.

Figure 11 Time span between the application and the granting of patents of machine tool makers from the US and from Chemnitz, 1919-1940, in years[a]



a Source: Richter's patent data.

However, since the average time which passed between application and granting was considerably lower for the German firms than for the American firms in both periods, with 1.1 years versus 2.0 years between 1877 and 1918 and 2.3 years versus 3.5 years between 1919 and 1940, a possible alternative interpretation is that the German patent office deliberately delayed the application process of American patents to give the German firms the time they needed to complete their catching-up process. In addition, some American machine tool makers needed more than ten years to fight their cases through the German patent court because several German companies joint in order to prevent American patent applications.[34] The problems, American manufacturers had to face when dealing with the German patent office in the 1920s, is illustrated by the experiences of Sol Einstein, design engineer of the Cincinnati Milling Machine Company: "*It was difficult to get a German patent granted due to the opposition from German manufacturers. I therefore was sent to Germany to straighten out the difficulties our attorney experienced. When our opponents found out that I was in*

[34] See Cincinatti Historical Society Library (CHSL), Milacron, Series: Misc. Folders (Schwartz), Box 1, Folder Litigation Compilation; Landesarchiv Berlin, Bestand Ludwig Loewe, A. Rep. 250/01/18/Karton 110 u. 130.

Germany to attend a hearing before the patent office, from month to month they postponed the hearings in the hope I would not stay in Germany. Finally after three months of delaying, the hearing was set. With preparation of having a demonstration of an up-to-date centerless grinder at the Singer Sewing Machine Plant and three prior art machines [...] *set up to the experimental room at the patent office, our opponents were willing to withdraw their position if we would grant them a license for using all twelve machines they had built. I insisted, however, on a ruling by the patent office which finally granted the patent with very broad claims.*" However, "*through the united effort of a large number of German companies, the patent, after four years in existence, was declared invalid. In England, our patent was declared invalid by a judge who stated frankly that he was particularly interested in maintaining the interest of the English people.*"[35] In Germany, it was the Association of German machine tool makers which coordinated the German firms' fight against the American patentees by collecting and encouraging patent appeals.[36]

We claimed at the beginning of section 3 that the two innovation periods were also periods of knowledge diffusion in which the competences to develop and produce innovative machine tools spill-over to more and more German firms. To check this assumption we calculated for every year *t* the following Herfindahl-Index *H* with respect to the valuable patents *VP* owned by firms *i=1...n*:

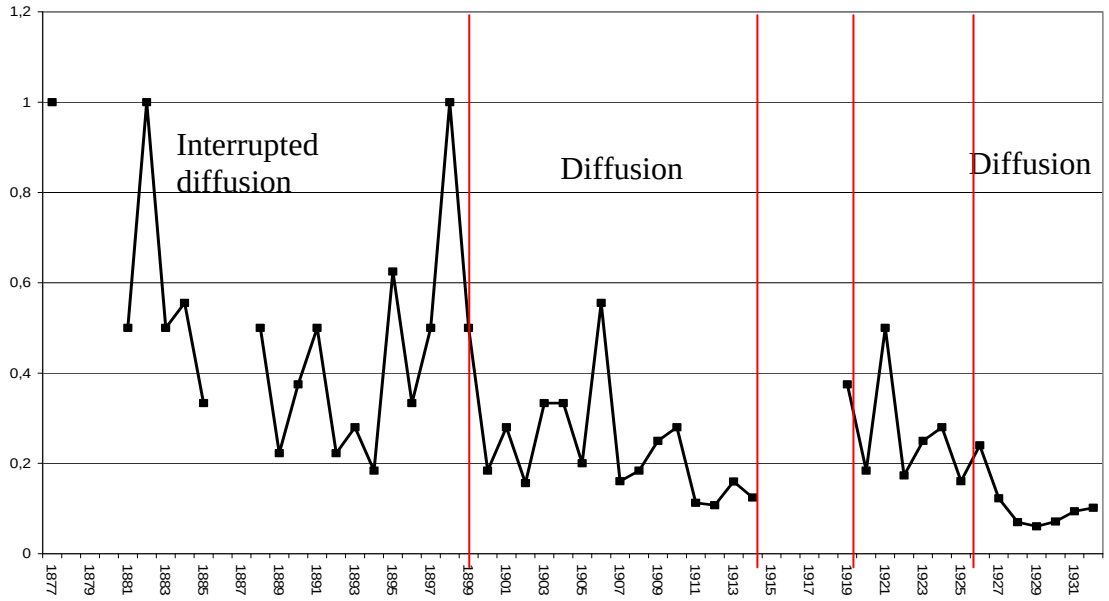
$$H_t = \sum_{i=1}^{n} \left(\frac{VP_{i,t}}{VP_t}\right)^2$$

The smaller the Herfindahl-Index the more equal is the distribution of valuable patents among those German machine tool makers firms which actually held valuable patents. The Herfindahl-Index comes to one in the case of maximum concentration and to 1/n in the case of an equal distribution of valuable patents. We interpret periods in which the Herfindahl-Index is decreasing as diffusion periods. Figure 12 shows that the Herfindahl-Index is in fact decreasing during the two innovation periods (1900-1914, 1926-1932) which implies that an increasing number of German machine tool makers were able to develop profitable innovations in these periods. Interestingly enough, the Herfindahl-Index first also falls in the

[35] CHSL, Milacron, Series: Executives Personal History (Schwartz), Box B-H, Folder Sol Einstein: Einstein, Sol, I do remember – men, machines, and the plants behind the Cincinatti Milling Machine Company, August 1972, p. 7.
[36] See Staatsarchiv Chemnitz, Bestand Wanderer-Werke, 31030/WW3617: VDW to Wanderer-Werke, 23. January 1931.

first imitation period which might reflect the general growth of the number of firms in the still young machine tool industry. During the intensification of the imitation period at the end of the 19th century, however, the Herfindahl-Index increases again. This indicates the interruption of the former diffusion process and might be explained by the fact that most of the German machine tool makers lacked the resources to engage successfully in the learning-by-imitating process.[37]

Figure 12 Herfindahl-Index of the distribution of valuable patents among German machine tool makers[a]



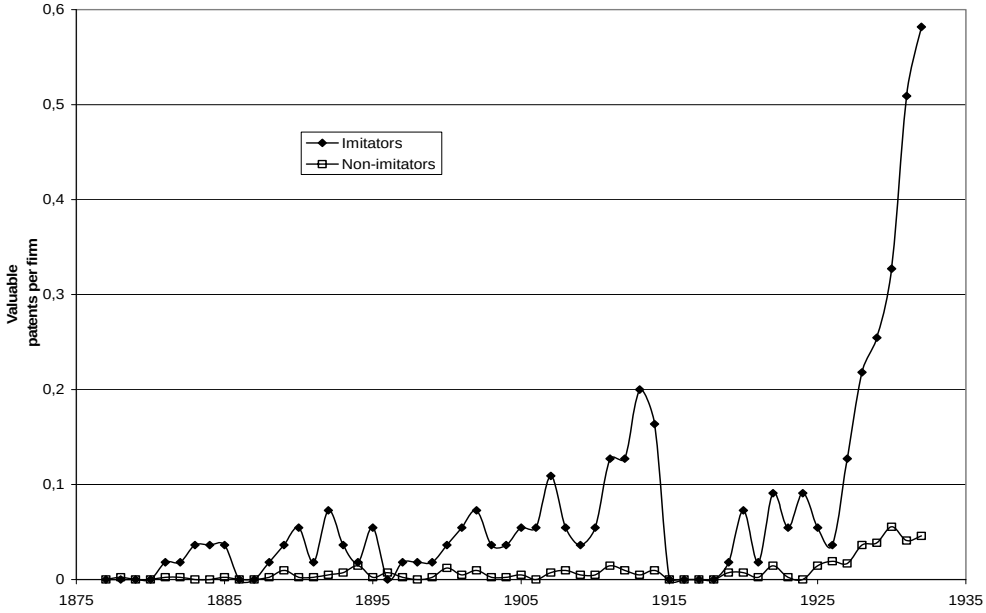
a Source: Baten/Streb patent data base and Richter's patent data.

To prove this last conclusion we have to show that the German imitators were more innovative than the German non-imitators. Fortunately, the Industrial Machinery Division of the American Department of Commerce and the National Machine Tool Builders Association compiled a list of the 55 most notorious German imitators.[38] To answer the question whether these imitators were more innovative than the "non-imitating" (or less-imitating) other German machine tool makers we calculate the annual number of valuable patents per firm for each of these two groups. The results of this calculation are shown in figure 13. The notorious imitators were far more innovative than the non-imitating firms, especially in the innovation and diffusion periods. We conclude from this finding that the competence to develop

[37] William Brown claims "that innovations occurs when the demand for machine tools falls". See Brown, W. (1957). Innovation in the Machine Tool Industry. *Quarterly Journal of Economics* 71, pp. 406-425. However, we found neither in the German nor in the American case any evidence for this hypothesis.
[38] See NARA, RG 151, 420 (Box 1950): D.P. Miller to Director Bureau of Foreign and Domestic Commerce, 8. November 1926.

profitable innovations diffused first and foremost within the group of imitating firms. To spend resources for imitation was an excellent strategy to secure long-term growth and survival.

Figure 13 Valuable patents per imitating and non-imitating firm[a]



a Source: Baten/Streb patent data base and Richter's patent data.

4 Conclusions

The technologically backward German machine tool makers successfully used imitating and counterfeiting activities in the late 19th century and the 1920s to catch-up to their American competitors. The German administration supported this strategy by stipulating a patent law that discriminated against foreign patent holders and probably also by delaying the granting of patents to foreign applicants. Parallel to the growing international competitiveness of German firms, however, the willingness to guarantee intellectual property rights of foreigners was also increasing because German firms had now to fear retaliatory measures in their export markets when violating foreign property rights within Germany.

We interpret this development of the German machine tool industry as a model for other historical, contemporaneous and even future catching-up processes. Developing countries may learn from this example that the strict compliance to the international rules of law with respect to intellectual property rights can slow down the speed of technological and economic

progress in their domestic industry.[39] Advanced countries may understand, first, that the owed their own development similar imitating strategies in the past, and, second, that illegal imitation usually only takes place during a transitional period. We predict that the copying and counterfeiting activities of the Chinese machine builders which were momentarily tolerated by the Chinese government will end as soon as the Chinese firms will be able to sell advanced and innovative machinery abroad.

[39] See the similar conclusion in Boldrin, M. and Levine D. K. (2008). *Against Intellectual Monopoly*. Cambridge: University Press, p. 281.

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