TECHNOLOGY AND KNOWLEDGE TRANSFER IN THE MACHINE TOOL INDUSTRY – THE UNITED STATES AND GERMANY, 1870-1930

Ralf Richter
Department of History
Bielefeld University

Machine tools play a central role in the discussion about economic growth. It is widely believed that the production and use of different types of machine tools in the US and Europe indicate the predominance of different production systems on each side of the Atlantic. By examining the technology and knowledge transfer in the machine tool industry between the US and Germany, the paper challenges this dichotomous model. It can be demonstrated that, instead of fundamentally different paths of development, there was a highly interdependent machine tool community exchanging technology and knowledge on an extraordinary level.

The machine tool industry is the central branch of the metal working industry and was of paramount importance for the process of industrialization in the United States and in Europe. Machine tools themselves "have long served as one of the symbols for the gulf that separates American from European industry" in the discussion amongst experts.[1] The main thesis of this discussion is that the production and application of different types of machine tools led to different production systems on both sides of the Atlantic. Based on this approach, scientists have tried to explain different economic growth rates in the new and old world, as well as the American economic supremacy. At least since the early 1970s, the paradigm of the different development in Europe and the US has been widely accepted amongst economic and technology historians, economists and sociologists and is still repeated throughout the scientific community.[2] The paradigm also fit well with Alfred D. Chandler's analyses of big business with its economies of scale and scope that are based on large scale mass production. In accordance to Chandler's approach, researchers like Ulrich Wengenroth claimed that, on the one hand, American machine tools were generally

designed for use in mass production, as they were highly specialized and conducive to only a limited number of operations. On the other hand, the machine tools produced in Germany were characterized by a high degree of flexibility, which allowed multi-purpose use.[3] In short, it is believed that in the US there existed a predominance of single-purpose machine tools, compared to the prevalent use of general or multi-purpose machine tools used in Germany and the rest of Europe.

Interestingly, the first critics of Chandler's approach–Michael J. Piore and Charles Sabel–referred to the initially described paradigm regarding the time after the oil shock in 1973.[4] Their aim was to draw attention away from Chandler's big business and to focus on small and medium-sized companies. They argued that such companies are predominant in certain regions of Europe. Thus, the thesis of the application of different types of machinery on both sides of the Atlantic also fit to their approach. Regarding the machine tool industry in the U.S. and Germany, Garry Herrigel, one of the leading American experts on German industrialization who took up Sabel's and Piore's approach, came to the same conclusion as Wengenroth: "The Germans have a tradition of machine tool production equally as long and distinguished as that in the United States. The Germans made more flexible machine tools because they sold in very different markets than existed in the United States."[5]

This consistently stated, yet hardly corroborated thesis has been challenged by two results in recent research. First, Philip Scranton demonstrated, in his ground-breaking study on American industrialization, that the importance of mass production in the U.S. has been highly overestimated, at least for the time between 1865 and 1925.[6] With that and other similar findings, belief in Chandler's model has started to falter. Consequently, one has to ask how much influence the demand of American mass production exerted on the development of American machine tools. In addition, the thesis of the dichotomous development of the machine tool industry on both sides of the Atlantic has been fundamentally questioned by a study of Cristiano Ristuccia and Adam Tooze on the use of machine tools in the US and Germany between 1930 and 1945. In their statistical analysis, which is based on various censuses of the machine tool stock in both industries, they found no radical difference but a surprising degree of similarity in the types and numbers of machines employed. Also, the age structure of the machine tool stocks was fairly similar.[7]

Unfortunately, Tooze and Ristuccia do not possess statistical material for the German side that allowed a comparative study between the two countries for the period before 1930. However, even if we do not have German censuses of the machine tool stocks for that period, we are able to make essential statements about the development in both countries if we investigate the machine tool industry and its products. This strategy seems to be particularly justified since the United States and Germany were, for a long time, the world's leading producers of machine tools. As such, they have been the main suppliers to their national industry as well as to the world market. Consequently, the central question is: were the products of the German and American machine tool industry in the period before 1930 so different that it led to a concentration of different production systems?

In the following, this question will be answered in two steps. The first part will investigate which conclusions can be drawn from qualitative and quantitative sources

regarding the differences in the American and German machine tool industry. In doing so, it will be shown that the common assumption about the fundamentally different development in the US and Germany is the result of a misinterpretation. The second part will demonstrate that the machine tool industry in both countries was highly interdependent rather than strictly different. In hardly any other industry was there such an intensive knowledge and technology transfer between the US and Germany. This is even more interesting since machine tool enterprises on both sides of the Atlantic were not big business. These companies had no access to global organizational structures like those of large scale enterprises. Small and medium-sized regional companies were dominant in the machine tool industry and had to develop their own strategies for a successful knowledge and technology transfer.

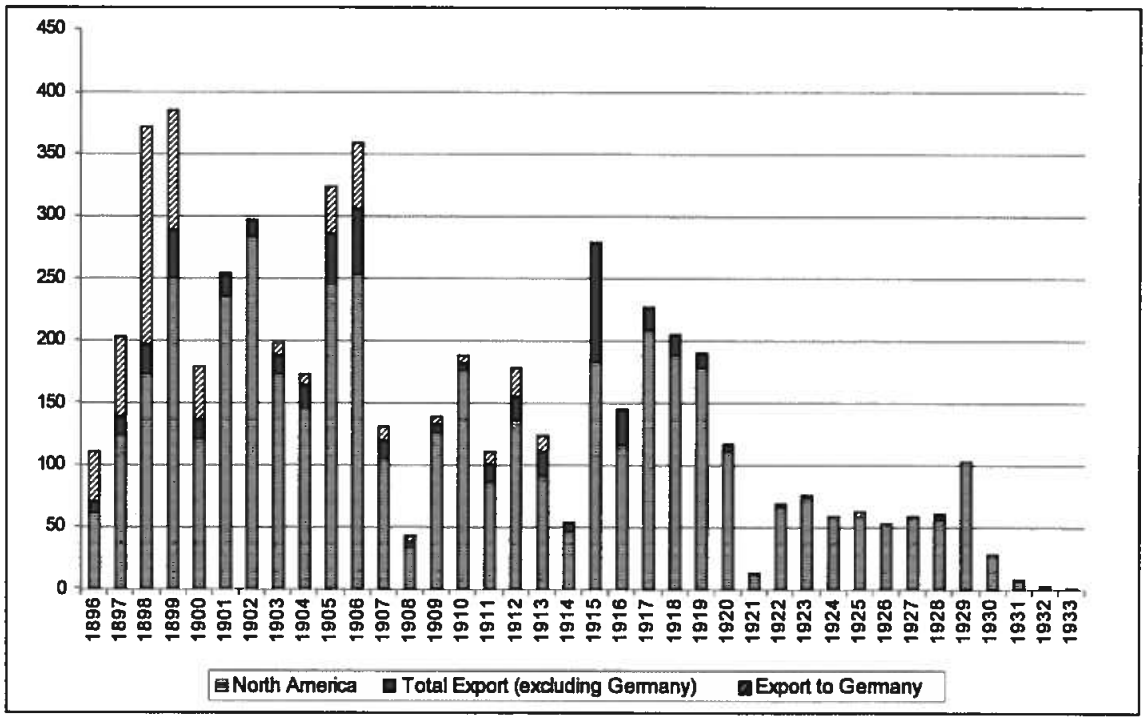
Germany's Dependency on the United States

For a long time in the nineteenth century, England set the benchmark in the construction of machine tools. Only after the American Civil War did the US machine tool designers take over technological leadership.[8] Henceforth, the most important innovations of the machine tool industry during the last third of the nineteenth century came out of the United States. Among these innovations were outstanding machines, such as the universal milling and universal grinding machines. These developments were first recognized by broader circles in Europe at the world fair in Paris in 1867. In the following years, Germany and its machine tools builders shifted their attention from England to the United States. The Prussian military, in particular, quickly realized the superiority of the American machine tools. In 1872, Prussia bought machine tools, jigs and gauges for its armories in Berlin-Spandau, Erfurt and Danzig from Pratt & Whitney of Hartford, Connecticut. This resulted in additional orders of machine tools for other armories and private manufacturers. The total sales of Pratt & Whitney amounted to $1,250,000.00. Wengenroth calculated, that this "sum was equivalent to the cost of five modern American Bessemer steel plants and certainly one of the greatest industrial contracts of that time."[9]

How important American machine tools were for Germany is demonstrated by the sales statistics of the Gray Company of Cincinnati, Ohio, 1896-1933 (Figure 1).

Until the 1920s, the Gray Company was the global technological leader for medium-sized and heavy planer machines. The significance of the German export market for this company until 1913 is obvious. Notably, during the last decade of the nineteenth century, German metal working companies stocked up on American machine tools. A contemporary witness described the 1890s as the period "when the import of American machine tools to Germany reached a threateningly high level....The machines brought in at that time stemmed only from the best American factories....The German machine tool dealers earned honor for the import of these machines and we learned extremely much from them."[10] Soon the German machine tool entrepreneurs not only followed the product innovations of the Americans but also their production methods in the machine tool industry. In autumn 1899, the *American Machinist* reported about the new work shops of the machine tool company, Ludwig Loewe & Co. of Berlin, which followed the American example. After examining the products and the implemented production methods, the author of the article came to the conclusion: "The best American tool shop is now in Germany."[11]

Figure 1: Annual Sales (Number of Machines) of the G. A. Gray Company, 1896-1933



Source: Cincinnati Historical Society Library (CHSL), Mss Bc 017, Box 21, Volume 3-8: Order Books, 1896-1940.

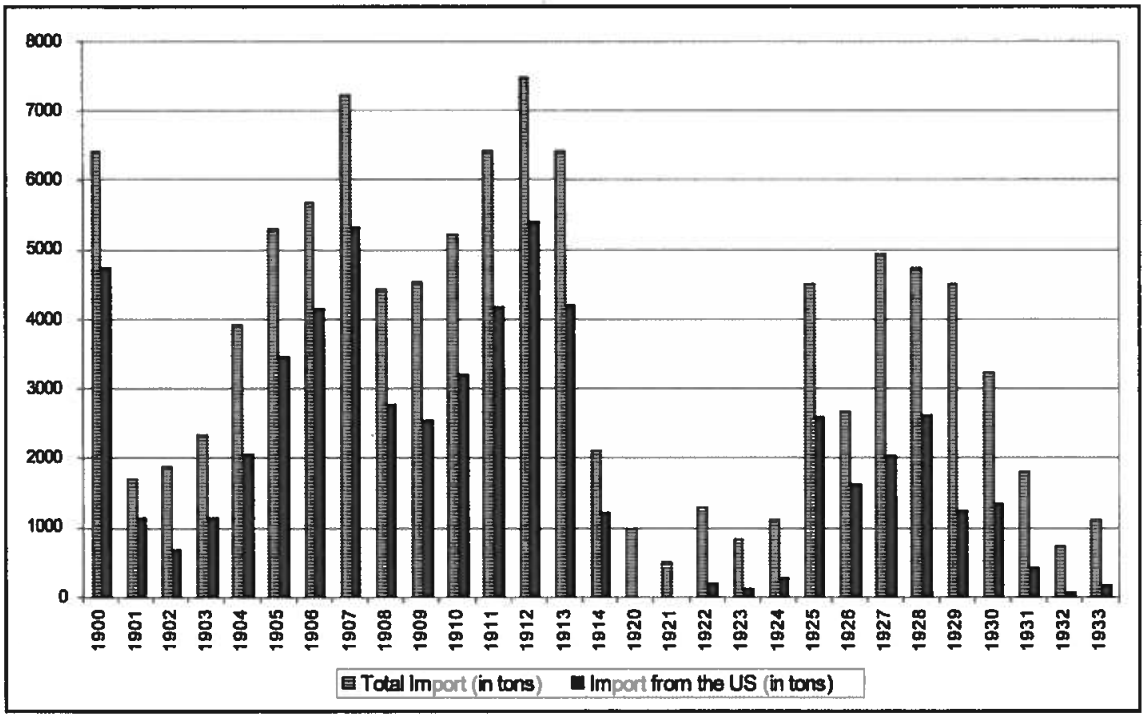
Even after the turn of the century American machine tools remained important in Germany. This is illustrated in a report by machine expert Captain Carden for the American Congress. On the behalf of the Department of Commerce and Labor, Carden spent nine months of the year 1908 in Europe in order to inspect the leading machine tool manufacturers and establishments in which such tools were used, and to evaluate the industrial conditions in Europe affecting the foreign trade in machine tools. In his extensive study, he reported that American machine tools were already in use in most of the modern German factories. In addition, Carden called attention to the fact that there were a few machine tool companies in Germany "which may be classed as really dangerous competitors of many American machine-tool firms."[12] However, there was not any indication of a fundamentally different product development in Germany. Instead, Carden's report suggests that the German machine tool industry as a whole in 1908 was still following the American example.

In Germany, experts tried to present the situation in a slightly different way. A 1911 speech Georg Schlesinger delivered at the annual convention of the German Association of Machine Builders (VDMA) played a central role.[13] Schlesinger was a professor at Technical University in Berlin. Before his appointment at the University, he had worked as an engineer at Ludwig Loewe & Co. in Berlin. Schlesinger was an internationally-known authority in technological and management matters pertaining to the machine tool industry.[14] He conceded in his speech in 1911 that the German machine tool industry had followed the American example until 1900, but after the turn of the century he claimed that a specific technological path had been developed for German machine tools. This was more an ideal than a fair analysis. In fact, only few machine tool firms created independent

advances in the 1890s. However, it was not until 1910 that the German machine tool industry as a whole became a serious competitor to America. Schlesinger generalized the outstanding development of his former employer, Ludwig Loewe, as a representation of the general situation in the German machine tool industry. As the leading German expert on machine tools, he had to know that such a statement was wrong, but here he spoke obviously as a lobbyist and a leading member of the Machine Tool Builders Association (VDW) which had always attempted, in public, to emancipate themselves from their American examples. This misdirection had far-reaching consequences. Schlesinger's student, Berthold Buxbaum, took up his interpretation in a series of influential publications between 1919 and 1921.[15] Since then, researchers refer to Schlesinger and Buxbaum's statements and follow the legend about the different development of the German and American machine tools since the turn of the century.[16]

A view on the foreign trade statistic for machine tools between 1900 and 1933 leads one to question the claim of Schlesinger and Buxbaum (Figure 2). Indeed, the exports of the German machine tool industry exceeded the imports often exponentially. Nevertheless, two-thirds of imports came from the U.S. until 1914.

Figure 2: Germany's Import (Total / US) of Machine Tools (in metric tons), 1900-1933



Source: Statistisches Reichsamt (Ed.), Monatliche Nachweise über den auswärtigen Handel Deutschlands, Berlin 1900 ff. (Note: No trade statistics were published between 1915 and 1919).

Why did Germany need so many American machine tools before World War I if German production systems were based on fundamentally different types of machine tools than those produced in the US? And why did the import of American equipment restart in the middle of the 1920s?

In a 1924 article of a leading professional journal, *Werkstattstechnik*, a manager of the Siemens-Schuckert-Works in Berlin-Spandau complained that the German machine tool

industry had lagged hopelessly behind the Americans since the end of World War I. For that reason, he was forced to buy expensive American machines for his company. In the same article, this manager of one of the biggest enterprises in Germany invited the domestic machine tool builders to catch up with American developments.[17] Also, Captain Carden, who examined the German machine tool industry for the American Congress before World War I, came to a similar conclusion during his trip to Germany in 1923. After a visit of the once praised Ludwig Loewe & Co. works in Berlin, he stated: "During the war period the Loewe shops in common with other German machine tool plants had little opportunity to develop new ideas."[18] Ironically, there also exists a corresponding statement by Georg Schlesinger in 1926. There, Schlesinger declared that the German machine tool industry had been an equal competitor of the American industry once, before World War I. Conversely, for the current situation he stated that a massive technological gap resulting from ten years of exclusion from the world market and the negative effects of war industry yielded inflation as well as deflation.[19]

However, although the Great War caused a radical disruption to the development in the German machine tool industry, the American professional press announced its comeback in 1928. Only two years after Schlesinger's statement, Germans had reclaimed their leading position on the world market alongside the American machine tool builders.[20] But also in this context there is no indication of the dichotomy regarding the production and use of machine tools in both countries.

American developments of special machine tools for mass production were discussed and praised on both sides of the Atlantic. In Germany, too, such machines were developed, though not to the same extent.[21] In this context, scholars tend to refer to the American automotive industry and its use of special purpose machine tools. However, outside the American automotive industry, these special machines were, for a long time, used only rarely because they were too expensive. Not all the automobile companies in the USA implemented a Fordistic production regime in which these machine tools were used. Compared to the national machine tool stock in the US, these rare special machine tools are statistically not significant. Additionally, special and single purpose machines[22] were reviewed in the professional press only after 1910.[23] Even in the 1920s and 1930s the pros and cons of production and use of such machines were discussed among experts.[24] Notably, these later discussions dealt mainly with the use of such machines in the automotive industry.

None of this information leads one to the conclusion of a fundamentally different development of the machine tool industries in each country, but it provides evidence of a bitter trade competition on worldwide market shares between the US and Germany. The larger part of the essential innovations came from the US, and Germany managed again and again to catch up with this backlog in a considerably short time.

Catching up American development

When searching for explanations for this impressive catching up process within the German machine tool industry, one can find in American and German publications and archives countless complaints about the German competitors that simply continued to copy or imitate American machine tools.[25]

Already in the 1890s, an American consul in Chemnitz wrote to the State Department in Washington that not only the latest American developments of machine tools were imitated but also copied in the Saxon industrial center.[26] The editor of the *American Machinist* reported about his journey to Germany: "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 therefrom, as well as bought a good line of the best standard machines from which to copy or to vary, in the productions of his own line, I noticed that every solitary American machine, whether from Providence, or New Haven, or Cincinnati, had had the name chipped off and the place painted over."[27] It was in this way that the Germans concealed the American origin of the machine tools when showing their plants to German clients, so that these customers would not realize that the company offered simple copies of American machine tools. The changes implemented by the Germans were negligible. Only the German cast iron, which was stronger than American, forced them to slightly thicken up the frames. "But so far as the central idea and the means of carrying it out [were] concerned, these tools [were] simply American out and out, 'corrected for the longitude of Germany', as the astronomers would say."[28]

Other companies were even less scrupulous. The *American Machinist* reported regularly about such cases. For instance, a German machine tool dealer in Belgium had sold horizontal boring machines claiming that they had been made by the Newark Machine Tool Company in New Jersey. In fact, it had been made in Chemnitz (Saxony) "in an exact imitation of the Newark machine."[29] Since German production costs had been far below the American costs, this strategy promised a huge profit for the dealers and the producer. In another case, a milling machine was being manufactured by a different company in Chemnitz "in imitation of the Brown & Sharpe to the minutest details, and even the cuts in the catalog describing it."[30] Not only did the professional press observe the similarities in Germany, but American machine tool producers, in reviewing and meticulously analyzing product catalogs and advertisements found similarities as well. For that purpose, Gray Company in Cincinnati, for example, had several scrapbooks to collect German product illustrations. With the help of this monitoring they found their machines being copied by several German companies.[31]

German copying was a long-running issue in the US. In 1912, there was a Senate hearing regarding the cutting of tariffs for metal working machinery. The argument of the American machine tool producers was based on the claim that, first, only German products constituted real competition. Second, there should be no lowering of the tariffs since the German firms would only copy American machine tools and carry out unfair competition. Furthermore, Frederick Geier, president of the Cincinnati Milling Machine Company, who spoke in the hearing for the American producers, stated that the Germans not only copied machine tools but also production, organization and distribution methods. Copying could even mean cloning the layout of an entire factory.[32] Behind this argument was also the fear of the rapid advancement of the German machine tool companies and American attempts to keep German machine tools away from US market. By that time, there had been reports by American experts stating that the Germans began to close the technological gap.[33]

Yet, there were countless German machine tool producers who stuck with American

machine designs. An internal report by the mechanical engineer Friedrich Nickel of the Technical State College in Chemnitz about his field trip to diverse German machine tool firms in the Rhineland during the summer of 1912 is illuminating. Several entrepreneurs that he visited confessed behind closed doors that they still kept to American designs and stressed that the Germans in the past learned, and continued to learn from the Americans with respect to precision and serviceability.[34]

The presented facts clearly demonstrate that in German factories, not only thousands of American machine tools were in use, but also the same amount or even more German copies of these tools. Yet the few German achievements in this field should not be forgotten. Actually, leading German machine tool producers emancipated themselves step by step from American designs with the help of a strong theory-based research at universities and technical colleges. Among German engineers evolved a growing self-confidence which led some of them to break their silence and to publicly confess the shameless German copying that had taken place over the last years.[35] Furthermore, some German firms even registered their patents in the United States where they sold small numbers of their machines. Others negotiated licensing contracts with American producers.[36] There are also examples of U.S. and German developments being constructed at the same time, which gives similar evidence toward "path dependence" of technical developments in the machine tool industry on both sides of the Atlantic. After all, copying as a specific kind of transnational technology transfer should not be referred to as a dull re-building. Even when the Germans copied, imitated or adapted American machine tools, they quite often tried to advance and specify the machines for certain applications. Historians of the history of technology call this phenomenon "re-engineering." Consequently, the technology transfer closely connected to an extensive process of learning.

This process of learning and the corresponding necessary competition with the US was terminated with the outbreak of the First World War. Due to the war economy, German machine tools were in high demand in the German domestic market. There was no time for further developments because the companies were busy with the military orders and a large part of the highly qualified work force was commanded to the front battle lines. Therefore, World War I caused a severe break in the product development of German machine tool producers.

This was surprising even to the Americans, who were able to continuously develop their machine tools during wartime, though they were also extremely busy with war orders. In 1919 a German expert noticed in the *American Machinist:* "All in all, the German machine tools are much the same as they were before the war."[37] Germany was dependent on the American market as a source of inspiration, which was lost during wartime. Georg Schlesinger also shared this opinion. In a confidential report of the Olympia machine tool exposition in London for the German Machine Tool Association, he concluded that even English tools were superior to the Germans'. Also, he noted the English-followed American machine tool designs.[38] This was somehow the starting signal for the second wave of German enterprises' copying of American machine tools.

Since they could not catch up on their own, Germans relied very intensively on copying after the war. When a Dutch manager of a metal working company visited the

Leipzig fair in 1922, he deridingly told a German producer: "You Germans try to copy and when you are ready with your copy the American again has escaped and looks only upon it as of bygone days."[39] Most likely, many German machine tool firms survived in the 1920s only because they copied so unscrupulously. Chronically short of capital, the last reserves of these endeavors were melted away by the inflation and hyperinflation in the first half of the 1920s. To copy American products helped to assure competitiveness and keep costs of development down. In a special report of the American embassy in Berlin, it was remarked "that the copyist escapes all of the costs involved in pioneering work, the development of the design, and its subsequent refinement."[40]

In the mid 1920s, the copying by the Germans was regarded by the US government to be so threatening that the staff of the Industrial Machinery Division in the Department of Commerce started to analyze and systematically collect information and knowledge about German machine tool producers. For this purpose, they arranged a library with German product catalogs and patent rolls. Economical data about the German firms were provided by Credit Rating Agencies. In addition, American experts were sent to Germany to prepare field reports. The results were impressive. The American embassy in Berlin sent a list of the fifty-six most notorious copyists in 1926 to the Department of Commerce, which contained most of the important German machine tool producers.[41] Another report mentioned that sixty-four different American machine tools had been copied by up to twelve different German firms.[42] In the documentation, there is no summary of the types of the copied machines, but a list of the fifty American firms with the most copied products.[43] The list reflects the innovative elite of the American machine tool industry, including those companies that equipped large scale companies which were based on mass production.

The uninhibited German copying in the 1920s was well known throughout Europe. The French journal *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 it in the United States." They continued: "The copying of American types of machine-tools has always been more or less practiced in the world, but it is, at the present time, more active than ever....At one of the latest German shows, we where thus able to see four German firms exhibiting copies of the same American machine."[44]

In contrast to the first wave of copying, even small and unimportant firms started copying American machine tools in the 1920s.[45] In 1926, the American trade commissioner in Berlin stated: "That American equipment is constantly copied here, is a German by-word. An expression which is often heard, is that one way to get rich quickly in Germany, is to find and copy some American equipment."[46] The outstanding effort of the Germans was also recognized in the Soviet Union, which was in the process of industrialization. The Russian trade mission in Berlin even ordered American machines in Germany, sending American product catalogs to German firms and marking the wanted machines in order to get an exact copy of them.[47]

Only in 1928 did the massive wave of copying start to abate. With the help of the Americans, Germany caught up to the world market. As in the pre-wartime period, the Germans now focused more on theoretical research on machine tools. In 1930, Schlesinger noted in the *American Machinist* that he found it truly astonishing that American machine tool research was still in a "Kindergarten-stage" and that American producers obviously were not interested in research carried out by universities and colleges.[48] But even this German research development would soon find an end by the starting armament economy and the displacement of many machine tool scholars. Among them was Georg Schlesinger.

Why did the Americans not fight this copying? There are several reasons for that. Many American firms did not protect their products with patents. This was caused by the high costs of patent enrollment in Germany and the low chance of protection offered by such an enrollment. Even with a slight change in the construction of the American machine tool, a German replica was not regarded as an infringement. Another reason was the technological development in the machine tool industry, unlike that of the chemical, iron and steel industry, development occurred in small steps only. Therefore, a high cost patent protection abroad was, in most cases, not profitable. Hence, the machine tool producers hesitated to take on the costs to protect their rights on foreign markets. Finally, American machine tool producers often blocked each other by not cooperating in fighting against German copying. Sometimes, American producers even complained about German copiers, while having secret license agreements with these Germans.

To sum up, the Germans closed their development gap in two waves of copying. The first wave started in the 1890s and lasted until the eve of World War I. The second wave started after the First World War and ebbed away in the late 1920s.[49] During both waves, the distance between the developments in the United States and Germany were continuously reduced. This matches the thesis of Tooze and Ristuccia, "that over the 1920s the US and German metal-working industries became more similar in terms of the machine tools they employed."[45] The interruption of the process of convergence and the emergence of a second wave of copying was because of the disastrous effects of the First World War.

What were the channels for this asymmetrical transnational technology transfer, which allowed long-lasting adoption, imitation and copying of American machine tools so quickly?[51] Most important was the concerted purchase of machines, then disassembly and analysis to create a good replica. A statistic of the machine inventory at the J. E. Reinecker Works in Chemnitz from 1915 reveals a continuous purchase of American machine tools since 1877. In fact, each time only one to two machines of the same type were bought. That was enough to grasp the construction and design of the machine and to copy it if required. All in all, the firm bought nearly one hundred American machines within thirty-eight years.[52] This is also remarkable since J. E. Reinecker Works belonged to one of the very few German companies who held patents in the U.S., and which sold some of their machines there successfully.

The Germans learned from product catalogs and journals which machines were worth ordering. Already in 1897, one single company subscribed to over sixty international technical and trade journals and hired a translator for them.[53] American journals were

not only a platform for the domestic machine tool industry, but rather, they took an international perspective. For instance, the *American Machinist* reported in 1898 extensively about the new workshops of the Reinecker Company. The articles in the American professional journals were normally far more extensive and more thorough than their German counterparts. With the help of the journals, the machine tool builders on both sides of the Atlantic were fairly well informed of the upcoming developments on the other side. The popularity of the American journals in Germany is reflected by the German edition of the A*merican Machinist (Zeitschrift für praktischen Maschinenbau)* starting in 1910.

Furthermore, American patents and drawings were exchanged among German entrepreneurs. The *American Machinist* alerted its readers at the turn of the century to take special precaution against such practices.[54] In addition, American patents were also spread by German license holders. The Reinecker Company, for example, assigned a professor for mechanical engineering in 1905 to analyze and describe a special patent of an American firm in order to "get maximum attention."[55] It turned out to be a study of 136 pages. The strategy was clear; after Reinecker signed the license contract, it had to find customers for the new machine.

All these measures, which could be handled in Germany, were not enough for the intensive knowledge and technology transfer that occurred in the machine tool industry. Therefore, regular visits to fairs and exhibitions were compulsory for progressive entrepreneurs. After each trip, extensive reviews by experts circulated, discussing the latest developments and tendencies of the industry. Already in the 1860s, Professor Franz Reuleaux, one of the key figures of German scientific mechanical engineering, traveled to the world exhibitions and industrial fairs in order to write special reports on the latest machine constructions. He was relentlessly criticized of German backwardness.[56] Moreover, American experts were often hired by German companies. For example, when Ludwig Loewe Loewe & Co. reorganized its machine tool production in 1897, three American mechanical engineers were employed.[57]

German entrepreneurs not only hired American experts for their factories, but also traveled to the United States. Many machine tool builders spent several years themselves in the American machine tool industry before founding their own companies in Germany.[58] Other businessmen sent their sons across the Atlantic to let them gain experience in the profession.[59] Shorter study trips to competitors were an important part of the knowledge and technology transfer. Germans benefited from the open-heartedness of Americans, whose doorways were adorned with the sign "visitors welcome". Before World War I German entrepreneurs normally traveled alone or in small groups. Later the associations organized study trips. Richard Winklhofer, one of the founders of the Wanderer Works in Chemnitz reported about his journey to America in 1904: "In Providence I visited the world famous tool and machine tool factory Brown & Sharpe with about 2,000 employees. In Hartford: [I visited] also the internationally known firm Pratt & Whitney, machine tool company. At the later one I bought a thread milling machine at the exhibition in St. Louis, which later the Wanderer Works built themselves."[60] During the trips the companies in Germany were informed about the latest developments in the States and got suggestions for the improvement of their machines at home. Especially in

the 1920s, study trips in the US became crucial. Experts at the Ludwig Loewe & Company spent many months in North America during the years of 1924 and 1929. Their extensive reports are impressive examples of knowledge and technology transfer. And again, the transfer was not only about machines but also about labor relations, education and advanced training, marketing and sales organization. The managers of Loewe stressed at the end of their reports the need for study trips to the US every three years to keep pace with the latest developments.[61] Unlike in the iron and steel industry, these study trips in the 1920s were still a kind of industrial espionage.[62] The iron and steel industry manufacturing facilities were large, complex, and difficult to understand, while the machine tool industry remained simple, allowing one to quickly catch up with the improvements of the competitor. Many engineers drew sketches after plant tours of machines and parts of machines that seemed important to them.[63]

Also very important was the growing and finally world-wide dealer network. Roberto Mazzoleni demonstrated how successfully American machine tool companies sold their products in Europe through agencies on the ground until the First World War.[64] The machine tool dealers, who often sold American and German products at the same time, communicated about the latest developments and demands between the continents and the different markets in Europe. For instance, the French sales partner of the Wanderer Works from Chemnitz urged the directorate in 1903 to improve their milling-machines in accordance with the machines of Brown & Sharpe and the Cincinnati Milling Machine Company.[65] Often German entrepreneurs acted initially as traders, but quickly mutated to producers selling copies of products which they just recently distributed.[66] All in all, the American export of machine tools to Europe was organized by a small group of machine tool dealers. German dealers especially controlled continental business and were of outstanding importance to the technology transfer. It was certainly an advantage for many American machine tool entrepreneurs born in Germany or linked to a German background, as they were able to speak German and understand German business attitudes.

Not only Germans benefited from the transfer. The Americans also took advantage of information coming from Germany. After an evaluation of the future market for planing machines by the dealer DeFries, a new company in Cincinnati was founded to meet the demand on the German market.[67] World War I caused a complete collapse of most German machine tool dealer companies, such as the famous Schuchardt & Schütte, which had offices from Barcelona to St. Petersburg. The war interrupted one of the most important channels of knowledge and technology transfer in the machine tool industry. After the Great War, it took several years before new dealer companies were established, which were specialized for the import of American machines. The dealers not only had to make new contacts, but also had to train their staff by sending them for several months to American factories.[68] Finally, the end users of machine tools were important for knowledge transfer. They also were well informed about American developments and had high standards for their machine tools.

Comparing transfers before and after World War I, it is obvious that the participants during both periods used about the same strategies. However, in the 1920s the German interest in American developments in the machine tool industry broadened and intensified. In contrast to other industries, the machine tool industry's transfer was above

average. This transfer was not purely a one-way street, although it tended to go mainly in one direction.

The presented findings and examples lead to the conclusion that the thesis of a different development in the German and American machine tool industry is not maintainable. Instead of the dichotomous situation of fundamentally different production and use of machine tools on both sides of the Atlantic, one can find a highly interdependent international market. On the German side there was always a concern about keeping pace with American developments. When the German machine tool builders could not provide high-end machinery like their American competitors, German metalworking companies would buy American machinery. The only exception was the interruption of the First World War, yet the importance of this event and its constraining impact on innovations has not been discussed enough by researchers up to now. Finally, it seems that Tooze and Ristuccia are correct with their rejection of an explanatory model, which explains the different productivity rates in the US and Germany during the first half of the 20th century by the use of different machine tools.

NOTES

1. Cristiano Ristuccia and J. Adam Tooze, "The Cutting Edge of Modernity. Machine Tools in the United States and Germany 1930-1945," *Working Paper,* http://www.econ.cam.ac.uk/dae /repec/cam/pdf/cwpe0342.pdf (accessed September 2003), 3.
2. For instance Harm Schröter refers to the paradigm in his recently published book on the Americanization of Europe. Harm G. Schröter, *Americanization of the European Economy. A Compact Survey of American Economic Influence in Europe since the 1880s* (Dordrecht: Springer Press, 2005).
3. Ulrich Wengenroth, "Germany: Competition Abroad – Cooperation at Home, 1870-1990," *Big Business and the Wealth of Nations,* ed. Alfred D. Chandler, Franco Amatori and Takashi Hikino (Cambridge: Cambridge University Press 1997), 147-148.
4. Michael J. Piore and Charles F. Sabel, *The Second Industrial Divide: Possibilities for Prosperity* (New York: Basic Books, 1984), 194-250.
5. Gary Herrigel, "Industry as a Form of Order: A Comparison of the Historical Development of the Machine Tool Industries in the United States and Germany," *Governing Capitalist Economies: Performance and Control of Economic Sectors,* ed. J. Rogers Hollingsworth, Philippe C. Schmitter and Wolfgang Streeck (New York & Oxford: Oxford University Press, 1994), 113. See also Gary Herrigel, *Industrial Constructions: The Sources of German Industrial Power* (Cambridge: Cambridge University Press, 1996).
6. Philip Scranton, *Endless Novelty: Specialty Production and American Industrialization, 1865-1925* (Princeton: Princeton University Press, 1997).
7. Ristuccia and Tooze, *Cutting Edge,* 30-31; See also J. Adam Tooze, "'Punktuelle Modernisierung.' Die Akkumulation von Werkzeugmaschinen im 'Dritten Reich'," *Jahrbuch für Wirtschaftsgeschichte,* vol. 1 (2003): 79-97.

8. See Nathan Rosenberg, "Technical Change in the Machine Tool Industry, 1840-1910," *The Journal of Economic History* 23 (1963): 414-443.
9. Ulrich Wengenroth, "Industry and Warfare in Prussia," *On the Road to Total War,* ed. Stig Förster and Jörg Nagler (Cambridge: Cambridge University Press, 1997), 258.
10. Georg Schlesinger, "60 Jahre Edelarbeit," *Ludw. Loewe & Co. Actiengesellschaft Berlin 1869-1929* (Berlin: VDI Verlag, 1930), 83.
11. Ibid. 42.
12. Godfrey L. Carden, *Machine Tool Trade in Germany, France, Switzerland, Italy, and United Kingdom* (Washington, D.C.: GPO, 1909), 26.
13. Georg Schlesinger, *Die Stellung der deutschen Werkzeugmaschine auf dem Weltmarkt,* (Düsseldorf: Bagel, 1911).
14. For Schlesinger see Günter Spur and Wolfram Fischer, *Georg Schlesinger und die Wissenschaft vom Fabrikbetrieb* (München & Wien: Hanser Verlag 2000).
15. Bertold Buxbaum, *Die Entwicklungsgrundzüge der industriellen spanabhebenden Metallbearbeitungstechnik im 18. und 19. Jahrhundert* (Berlin: Springer Verlag, 1920); Bertold Buxbaum, "Der deutsche Werkzeugmaschinen- und Werkzeugbau im 19. Jahrhundert," *Beiträge zur Geschichte der Technik und Industrie. Jahrbuch des Vereins deutscher Ingenieure* 9 (1919): 97-129; Bertold Buxbaum, "Der amerikanische Werkzeugmaschinen- und Werkzeugbau im 18. und 19. Jahrhundert," *Beiträge zur Geschichte der Technik und Industrie. Jahrbuch des Vereins deutscher Ingenieure* 10 (1920): 121-154.
16. See for example Volker Benad-Wagenhoff, *Industrieller Maschinenbau im 19. Jahrhundert. Werkstattpraxis und Entwicklung spanabhebender Werkzeugmaschinen im deutschen Maschinenbau 1870-1914* (Stuttgart: Franz Steiner Verlag 1993), 377-379.
17. W. le Vrang, "Neue Aufgaben der deutschen Werkzeugmaschinen-Industrie," *Werkstattstechnik* (WT), 1 September 1924, 449-452.
18. Godfrey L. Carden, "Changed Machine Tool Shops of Germany," *The Iron Age* (IA), 4 January 1923, 33.
19. Georg Schlesinger, "Die Arbeitsstätten des deutschen Werkzeugmaschinenbaues," *WT,* 1 March 1926, 5.
20. See for example Anonymous: "Germany Recovers Old Place in Machine Tool Industry," *IA,* 19 April 1928, 1097.
21. A. Julius Klostermann, "Deutsche Massenfertigung im Auge des Amerikaners," *WT,* 15 December 1920, 641-643; George Chambeau, "Vierspindlige Ganzautomatische Senkrechtbohrmaschine," *WT,* 15 July 1921, 412-413.
22. Both terms were not clearly separated in the contemporary discussion.
23. See for example Anonymous: "Special Purpose Machine Tools," *American Machinist (AM),* 31 March 1910, 609-610; Robert Pierpont, "Machine Tools in Auto Manufacture," *AM,* 9 June 1910, 1079-1080; John Riddell, "A User's View of Machine Tools," *AM,* 10 November 1910, 862-863.
24. See for example Ralph E. Flanders, "Progress in Machine Tool Industry in 1923," *AM,* 17 January 1924, 77; Frank C. Hudson, "Special vs. Standard Machines," *AM,* 19 June 1924, 936; R. M. Heidey, "Machine-Tool Needs of the Automotive Industry," *AM,* 1 October 1925, 533-535; Douglas T. Hamilton, "Standard vs. Special Machines," *AM,* 9

July 1931, 53-56.

25. Particularly in early publications, the terms "imitation" and "copy" are not clearly separated from one another.
26. U.S. National Archives and Records Administration (NARA), RG 59, T 380-7: J. C. Monaghan to E. J. Uhle, 4 February 1894; See also J. C. Monaghan, "Opportunities for American Trade in Germany," *AM,* 17 November 1898, 852.
27. Hudson, "German Machine Copying," *AM*, 11 February 1897, 116.
28. Ibid.
29. Anonymous: "Rights of Foreign Manufacturers in Germany," *AM*, 8 March 1900, 214.
30. Anonymous: "German Criticism on the Machine Tool Trade with America," *AM*, 14 February 1901, 175.
31. CHSL, Mss 017, Box 25: Scrapbook, around 1900.
32. Committee on Finance, United States Senate, *Duties on Metals and Manufactures of Metals. No. 4 & 5 Hearings before the Committee on Finance, United States Senate. Sixty-Second Congress on H. R. 18642* (Washington, D.C.: GPO, 1912), 173-236.
33. See for example Anonymous: "Germany's Commercial Advance," *AM*, 21 February 1907, 246.
34. Universitätsarchiv Chemnitz, 100/152: Friedrich Nickel. Bericht über die Besichtigungsreise in den Sommerferien 1912.
35. Johannes Luserke, "Amerikanische Vorbilder im Werkzeugmaschinenbau einst und jetzt," *Der Deutsche Werkzeugmaschinenbau*, 7 January 1912.
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37. Anonymous: "The German Machine-Tool Industry During and After the War," *AM*, 11 September 1919, 537.
38. Wirtschaftsarchiv Baden-Württemberg (WABW), B 17, Bü 112: Vertraulicher Bericht über die Zweite Olympia-Werkzeugmaschinen-Ausstellung in London, December 1920.
39. Dirk de Vries, "A Hollander's View of Leipzig Fair," *AM*, 27 April 1922, 636.
40. NARA, RG 151, 420 (Box 1950): W. H. Rastall tn Dr. Klein, 11 January 1926.
41. Ibid: D. Miller to Director of Foreign and Domestic Commerce, 8 November 1926.
42. Harless D. Wagoner, *The U.S. Machine Tool Industry from 1900 to 1950* (Cambridge, MA and London: MIT Press, 1968), 203.
43. NARA, RG 151, File 420 (Box 1950): E. F. DuBrul NMTBA-Circular, 21 February 1926.
44. NARA, RG 151, 413 (Box 1806): W. H. Rastall to Erik Oberg, 2 May 1927.
45. Ibid: F. W. Allport to Director Bureau of Foreign and Domestic Commerce, 26 April 1927; Ibid: W. H. Rastall to Boston District Office, 26 May 1927; Ibid: Harvey A. Sweeter to Industrial Machinery Division, 3 June 1927.
46. NARA, RG 151, 420 (Box 1950): D. F. Miller to Director Bureau of Foreign and Domestic Commerce, 7 December 1926.
47. NARA, RG 151, 413 (Box 1806): W. H. Rastall to A. R. Wilfley & Son, 14 March 1927.
48. Georg Schlesinger, "Scientific Machine Tool Research," *AM*, 9 October 1930, 575.
49. Freyberg analyzed a second wave only for the years between 1923-1925. Thomas von Freyberg, *Industrielle Rationalisierung in der Weimarer Republik. Untersucht an*

Beispielen aus dem Maschinenbau und der Elektroindustrie (Frankfurt/M.: Campus Verlag, 1989), 40. Conversely, Benad-Wagenhoff sees the apparent copying of American machines by Germans a mere propaganda created by Americans. This is also certainly wrong. Benad-Wagenhoff, *Industrieller Maschinenbau*, 379.

50. Tooze and Ristuccia, *Cutting Edge*, 41.
51. Regarding a 'transnational technology transfer', I refer to the approach by David J. Jeremy, "Some of the Larger Issues posed by Technology Transfer," *International Technology Transfer. Europe Japan and the USA, 1700-1914*, ed. David J. Jeremy (Aldershot: Edward Elgar, 1991), 1-5.
52. Staatsarchiv Chemnitz (StAC) 31007, Nr. 131: Schätzungsprotokolle über Betriebsgegenstände, 1915.
53. Fred J. Miller, *American and Other Machinery Abroad: Being a Study of the European Field for the Introduction of American Machinery* (New York: 1897), 72.
54. Anonymous: "Rights of Foreign Manufacturers in Germany," *AM*, 8 March 1900, 214.
55. Theodor Pregél, *Bilgram's Kegelrad-Hobelmaschine* (Chemnitz: J. E. Reinecker, 1905), 1.
56. Franz Reuleaux, "Bericht von F. Reuleaux zur Pariser Weltausstellung 1867," *Bericht über die allgemeine Ausstellung zu Paris 1867* (Berlin: Steinthal, 1868).
57. Schlesinger, "60 Jahre Edelarbeit", 68.
60. Johann Winklhofer, *Erinnerungen aus meinem Leben* (München: Mühlthaler, 1940), 24.
58. Festschrift J. E. Reinecker Chemnitz 1859-1909 (Chemnitz: J. E. Reinecker 1909), 15.
59. Winklhofer, *Erinnerungen*, 72.
60. Landesarchiv Berlin A Rep. 250-01-18, Nr. 14: Bericht über die Reise der Herren Direktor Hegner und Dr. Loewe nach USA, Oktober-Dezember 1929.
61. For the iron and steel industry see Christian Kleinschmidt and Thomas Welskopp, "Amerika aus deutscher Perspektive. Reiseeindrücke deutscher Ingenieure über die Eisen- und Stahlindustrie der USA, 1900-1930," *Zeitschrift für Unternehmensgeschichte* 39 (1994): 73-103.
62. For example WABW B10, Bü 111: Reisebericht USA (Cincinnati) von Rolf Böhringer, 10 September 1935.
63. Roberto Mazzoleni, "The Agency System in the International Distribution of U.S. Machine Tools, 1900-1915. Social Norms and Contracts," *Business and Economic History* 27 (1998): 420-430; Roberto Mazzoleni, "The Organisation of US Machine Tool Distribution in Europe (1890-1916)," *Industrial and Corporate Change* 11 (2002): 53-84.
64. StAC 31030, rot 201: Schreiben der Wanderer-Direktion to Winklhofer, 23 December 1903.
65. Historical files of the Cincinnati Inc.: Sales book and product catalogs, 1898-1905.
66. Ibid: "Planer Planet" (employees journal of the Cincinnati Planer Company), 5 March 1945.
67. CHSL, Mss 982, Box 31: Visitors Register 1920-1959. And Box 25: Employee Entrance/Exit Journals 1927-1928.