Schumpeterian German Firms before and after World War I*

The Innovative Few and the Non Innovative Many

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Introduction

A well known problem in business history is the availability of firm specific data. Doing case studies can cause a bias towards well documented firms, sometimes even with their own well-organized corporate archives. The exploration of these sources often leads to very informative and detailed corporate histories, revealing a firm's historic network, not only concerning the customers, suppliers, partners and competitors, but also the social and economic environment. How important the explored firm is in its sector can be answered by the market share, but how representative a firm's specific development is, often remains unclear. The description of a whole sector by knowing only a few firms, even if they are economically important, can lead to serious misinterpretations of the real conditions. This problem of insufficient data is well known as survival bias. A few today still existing firms provide and keep al lot of information, whereas many firms never invested in keeping their history, or their information is no longer available. The isolated investigation of corporate histories is criticized by Berghoff (2004, p. 139) because of the often missing embedding into the surrounding economic and social developments. The author points out the danger that investigations of this kind could be seen as local studies, interesting only for insiders (for example former employees, customers or local officials). In addition, Plumpe (2004, p. 404) mentioned the lacking prognostic function of business history. Realizing an increasing demand for prognostics, the author is of the opinion that business history research is not able to provide it.

* I thank Jochen Streb for many helpful advices.

This examples show that business history has to face the criticism to be insufficient, often because of concentrating only on a few firms with available information. For this reason, general evidence about sectors or the whole economy is not easy to achieve.

Doing innovation history based on patent statistics, the present paper shows that concentrating only on a few firms can be sufficient to represent a whole sector. The very unequal distribution of innovations in the German Empire and the Weimar Republic gives the opportunity to infer from a very small number of firms on important aspects of the German innovation history between 1877 and 1932. In a next step, growth of the most innovative firms will be analyzed and some typical relationships between firm size and innovativeness will be discussed.

The Data

The used patent dataset built up by Streb and Baten (Streb et al 2007, Streb et al 2006, Baten et al 2007) contains more than 66.500 patented innovations for the period between 1877 and 1932.

Regardless whether the patented innovation is important or an effectless failure, general patent statistics ascribe to every individual patent the same weight. For this reason, measuring the innovativeness of a firm by the total number of its granted patents in a specific period of time can lead to serious misinterpretations. To avoid this problem, it is necessary to differ between the valuable patents with a high private utility and the worthless ones. In fact, the specification of the German patent law allows us to infer from the patents lifespan on its private utility. As 1877 the German patent law was enacted, firms became for the first time in the German history the opportunity to gain patent protection valid in the whole German Empire for new products as well as new methods. The maximum patent protection was 15 years. To keep his patent in force, the patent holder had to pay an annually, continuously increasing patent fee at the beginning of every new year. In each of the first two years the patent fee was 50 marks. After that, the patent fee increased annually in 50 mark steps up to 700 marks at the beginning of the fifteenth year.

At the beginning of every year, a patent holder had to decide, whether he wanted to renew his patent by paying the patent fee for one more year or not. The decision was based on a comparison of the future costs of the patent, i.e. the patent fee, and the expected private returns, monopoly profits or the income caused by licenses. Economically, a prolongation of the patent made only sense, when the expected private returns exceeded the costs, hence, when the

future net profits were positive. The empirical findings suggest that this condition was not fulfilled by the predominant number of the granted patents, i.e. they proved to be worthless. Seventy percent of the granted patents in the German Empire between 1891 and 1907 already forfeited after five years, only ten percent were still in force after ten years and only five percent reached the maximum lifespan of fifteen years (Streb et al, 2006, p. 353). These observations lead to the conclusion that it is possible to infer from a patents' lifespan on its private net profit (Schankerman, Pakes, 1986). The decision to differ valuable and worthless patents by defining a specific minimum lifespan was discussed in detail by Streb et al (2006). Following a study by Sullivan (1994) patents with a minimum lifespan of ten years were interpreted as the valuable ones of the German Empire and the Weimar Republic. Using this criterion, more than 66.500 valuable patents were identified out of a basic population of more than 800.000 patents. For each patent, a computer readable dataset containing information concerning the name, nationality, location, corporate form of the patent holder and the patent class was constructed. The available information concerning the year of the grant allows the exact timing of all patents.

Concerning the firm size, there are some possibilities to measure it. First, the size of a firm could be measured by revenues, second, by the number of employees, and, third by the capital stock. In this study, the size of firms will primarily be represented by the number of employees because of the better availability of this data. Important sources are for example Kocka and Siegrist (1979) as well as Fiedler (1999), because they provide employment data for the hundred largest firms in Germany for several years. The exploration of their sources, as well as the exploration of the inventories of several firm and state archives by the author of the present paper, leads to the establishment of an additional data bank, comprising information about the development of size of several hundreds of German firms.

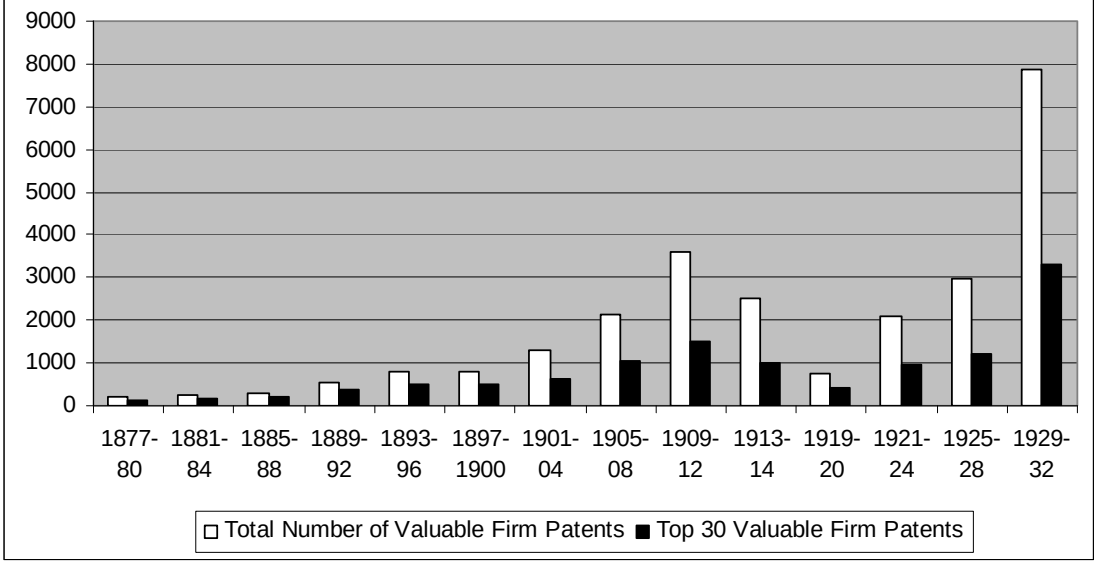
The Method and Results

In the following, I will explicate the procedure of identifying and analyzing the most innovative firms. In the first step, the dataset was separated in sub periods. Each sub period contains four years. The first period covers the time between 1877 and 1880, and the last one covers the years between 1929 and 1932. Because of missing data for the years 1914-1918, two periods have to cover only two years (1913-1914 and 1919-1920). Afterwards, rankings contain-

ing the 30 most innovative firms of every sub period were constructed[1]. Hence, for example, the first ranking contains those 30 firms with the most granted patents in the period between 1877and 1880. These rankings contain not only the rank and the name of the firms but also the number of the patents and the technological class, as well as the sector and the location of every firm in every specific period.

In total 26,078 valuable firm patents remain after separating them from the patents held by private persons. Assigned to the sub periods, figure one provides these patents as well as the number of patents held only by the 30 most innovative firms.

Figure 1: Total Number of Valuable Firm Patents and Valuable Patents of the Top 30 in Germany



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In all the years between 1877 and 1932 the share of the Top 30 is never below 40% and the average share is 54.39%. Regarding the fast increasing number of all firm patents, this seems to be a remarkable result. More detailed information provides Table one, listing all Top 30 shares per period.

Table 1: Top 30 Share in all Valuable Firm Patents in Germany

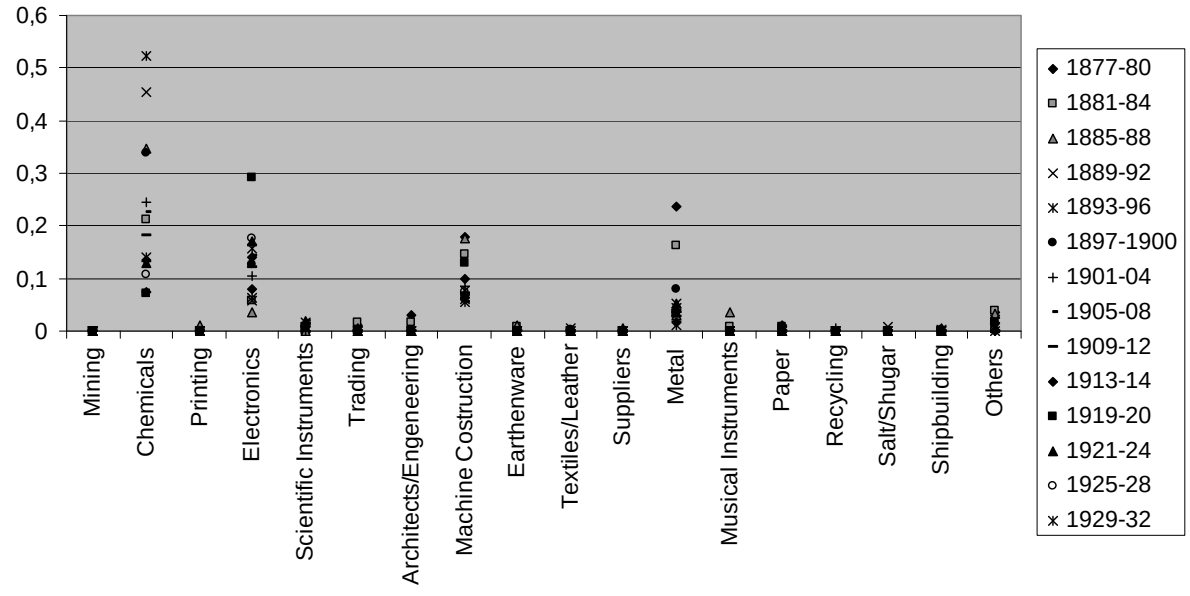
Period	1877-80	1881-84	1885-88	1889-92	1893-96	1897-1900	1901-04
Top 30 Share	65,45%	66,15%	69,87%	68,56%	66,45%	62,93%	48,15%
Period	1905-08	1909-12	1913-14	1919-20	1921-24	1925-28	1929-32
Top 30 Share	48,53%	41,47%	40,05%	55,61%	45,63%	40,67%	41,99%

[1] See, for example, the Top 10 firms of the sub period 1877-1880 in the appendix. For further information please contact the author.

It is astonishing that, from 1877 to 1900, two thirds, and, from 1901 to 1932, between 40 and 55 percent of all valuable firm patent were held by only the 30 most innovative German firms. Regarding the total number of firms in Germany, e.g. 97,163 firms with more than 5 workers in 1882 and 266,098 firms with more than 5 workers in 1930, such an extremely unequal distribution becomes even more impressive.

Facing such an unequal distribution of valuable firm patents, in the next step the sectoral distribution will be analyzed. It might be an interesting question to which sectors the most innovative firms belong. Figure two provides all sectors that were covered by all the firms being among the Top 30 between 1877 and 1932. Each symbol represents a specific period and gives the share of each sector in that period. Hence, figure two provides an overview over the importance of each sector in the respective period.

Figure 2: Top 30 Share in all Valuable Firm Patents per Sector



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Regarding figure two, four sectors seem to be much more important than the others. Those four sectors, namely chemicals, electronics, machine construction and metal are obviously the dominating innovative sectors with an average share of 93.8% in all valuable firm patents of the Top 30. Among all periods, the share of those sectors was never below 84.36%.

Concerning the prognostic function of business history as well as the description of innovation history in the German Empire and the Weimar Republic, the analysis of the Top 30 firms of the mentioned four most important sectors seem to be sufficient. Regarding table two, list-

ing the periodical share of the five most innovative firms per sector in all valuable firm patents, the extremely unequal distribution among firms is still remarkable.

Table 2: Periodical Share of the Five Most Innovative Firms per Sector in all Valuable Firm Patents in Germany

Period	1877-80	1881-84	1885-88	1889-92	1893-96	1897-1900	1901-04
Machine Construction	9,95%	7,31%	8,28%	5,51%	3,33%	2,90%	4,71%
Chemicals	7,85%	18,46%	30,46%	41,03%	44,30%	25,22%	21,02%
Metal	17,80%	11,54%	3,31%	4,62%	1,92%	7,31%	4,33%
Electronics	7,85%	6,15%	4,30%	5,15%	6,66%	11,10%	9,04%
Sum	**43,46%**	**43,46%**	**46,36%**	**56,31%**	**56,21%**	**46,53%**	**39,10%**
Period	**1905-08**	**1909-12**	**1913-14**	**1919-20**	**1921-24**	**1925-28**	**1929-32**
Machine Construction	3,26%	4,15%	4,71%	7,96%	4,32%	3,44%	3,71%
Chemicals	18,45%	16,17%	11,69%	6,01%	11,82%	10,63%	14,76%
Metal	4,59%	3,54%	2,35%	3,26%	5,43%	3,71%	3,92%
Electronics	12,16%	10,49%	13,64%	25,98%	16,52%	16,47%	13,97%
Sum	**38,46%**	**34,36%**	**32,39%**	**43,21%**	**38,09%**	**34,26%**	**36,37%**

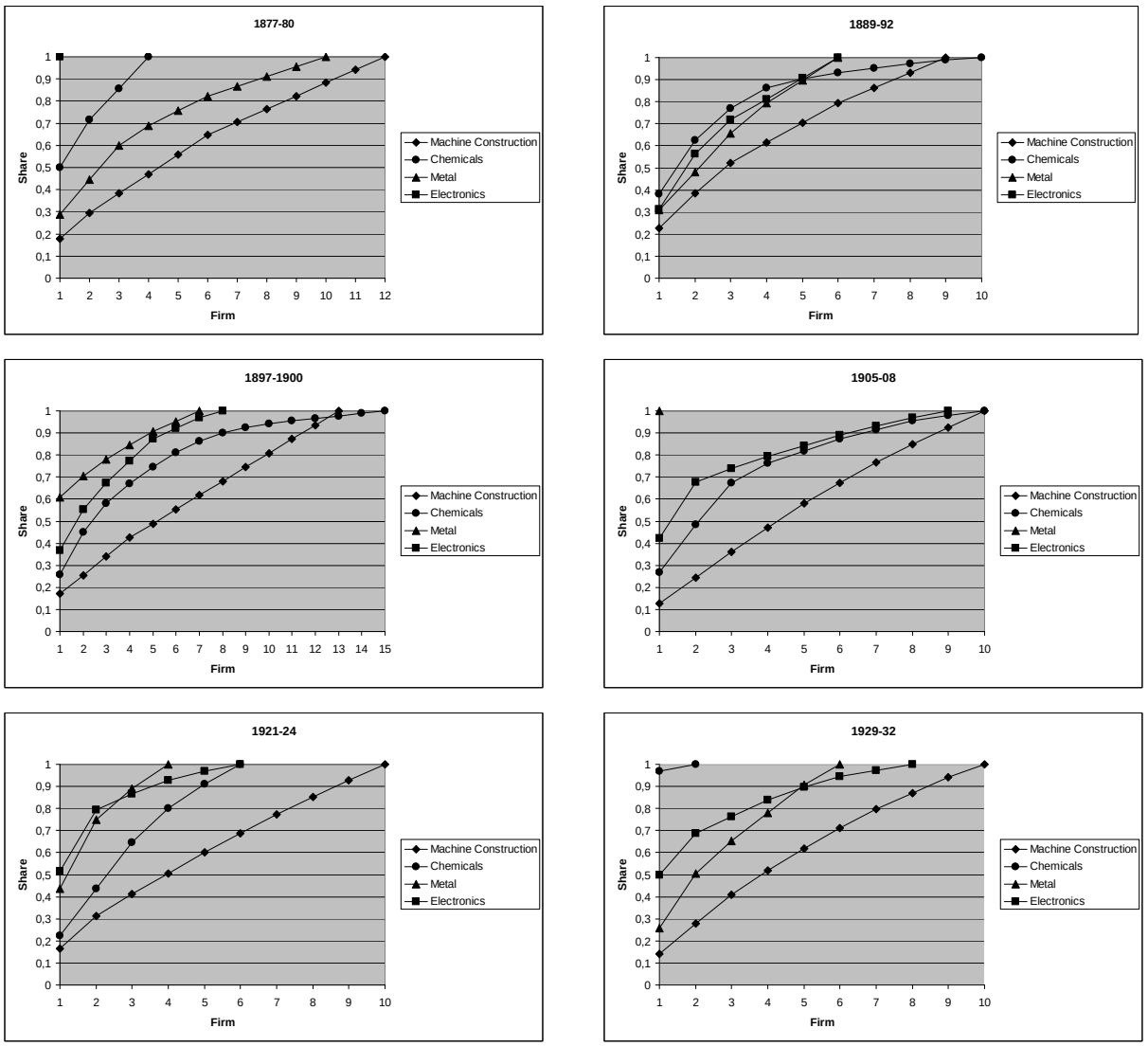
Source: see text

Only 20 firms (five per sector) have an average share of 42.04% in all valuable firm patents of the German Empire and the Weimar Republic (1877-1932). Hence, the huge inequality seems to be inter and intra sectoral. Working about innovation history based on patent statistics, this result might be a plausible argument, why it is sufficient to concentrate on a few firms. However, this kind of inequality is not only evident in innovation history. Mayer and Ottaviano (2008), analyzing European firm level data concerning the exports of 2003, found that a country's international performance is also shaped by only a few firms because, for example, the top 10% of exporters in 2003 accounted approximately 80% of all exports. Equally consistent with the results of the present paper is another interesting finding of Mayer and Ottaviano. The authors found that highly diversified and internationalized firms, exporting more than ten products to more than ten different markets, capture more than 75% of total exports (Mayer and Ottaviano, 2008, p. 139). The extreme unequal distribution is evident both in innovation history, based on patent statistics, and internationalization, measured by the exports. Possibly, unequal distribution is a general phenomenon, business history research should take care about. Bringing evidence to some more segments of the economy, the prognostic function of business history might benefit from.

After identifying huge inter and intra sectoral inequalities, in the following the four most important sectors (chemicals, electronics, machine construction and metal) in the Top 30 will be

compared in more details. The aim is to show, first, that the extension of inequality can widely differ, and, second, that the unequal distribution can have some interesting sector specific characteristics. Figure three shows this for six especially interesting sub periods of the observation period. On the horizontal axis, the firms are ranked by their sectoral share in the Top 30 patents.

Figure 3: Periodical Firm Level Distribution of Patents in the Most Important Sectors Among the Top 30



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For example, between 1877 and 1880 the share of the most innovative machine construction firm was approximately 20%. The share of the next innovative firm in this sector was about 10% and causes the machine construction curve going up to 0.3. In this period, 30% of all Top 30 innovations in the machine construction sector concentrated in the two most innova-

tive machine construction firms. Hence, the curve represents the cumulated share. Comparing the sectors concerning the distribution of innovations, three points are important. First: The share of the first (the most innovative) firm, determines the level from which the curve starts. The second important point is the question how many firms were dominating a sector. The lower the number of firms, holding all valuable firm patents of a sector, the higher the concentration of innovativeness is. For example, in the period between 1877 and 1880, all Top 30 innovations in the chemical sector were distributed among only four firms.

The third interesting detail deals with the distribution among the firms of a specific sector. The aim is to show, whether one firm has a much higher share than the others. Hence, not only the number of firms but also, their individual shares in the valuable firm patents of a sector is an important sector specific characteristic. The straighter a line, the more equal the distribution is, because the shares of the firms do not differ highly. Over all periods, the machine construction sector has the lowest inequality, because no firm, having a much higher share than the others, seems to be in a dominating position. This is a constant in the whole period of observation. With respect to the other three sectors, important differences can be discovered. In the period between 1877 and 1880, only one firm (Siemens) of the young, undeveloped and small sector of electronics was among the Top 30. Regarding the years 1889-92 in figure three, this changed rapidly. In the following time (1897-1900), the highest inequality was observable in the metal sector. Approximately 60% of all valuable innovations were developed by only one firm (Krupp). The concentration in the sector became even larger and in the period between 1905 and 1908, when only one firm remained among the Top 30. In the chemical sector, an increasing unequal distribution can be observed towards the formation of IG Farben in 1925. The huge chemical industry in Germany, producing among others pharmaceutical products, synthetic dyes and fertilizers, was dominated by this firm with a share of more than 90% in all chemical Top 30 innovations between 1929 and 1932.

Innovativeness and Growth

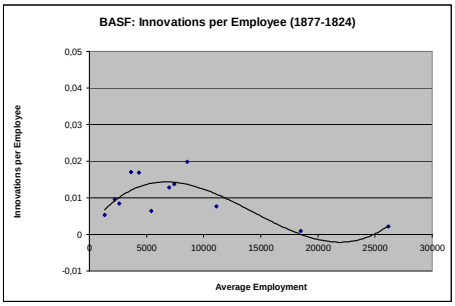
A lot of papers have been written about the relationship between firm size and innovativeness. Pavit et al (1987) investigate the distribution of the size of those firms that developed important innovations in Great Britain between 1945 and 1983. They come to the conclusions that, first, the share in all innovations of firms with less than 1000 employees was significantly

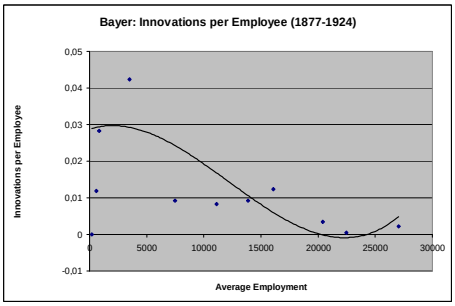
higher than their share in all research and development (R&D) expenditures. Second, firms with less than 1000 and more than 10.000 employees had an above-average share of innovations per employee. A significant negative impact of firm size (measured by the revenue squared) is found by Acs and Audretsch (1991) in their study for American firms in 1982. In their study smaller firms were more innovative. In an earlier empirical study Acs and Audretsch (1988) found a positive impact of the share of skilled workers on the innovativeness of large firms, measured by the expenditures for research and developments, and a negative one for unionized employees. Concerning the negative correlation between innovativeness and unionized employees, this indicator possibly measures the age of a firm that had passed its most innovative era. The authors explain the inconsistencies in their results with insufficient data. Van Dijk et al (1997) tried to test Acs´ and Audretsch´s results by recalculating their model using a dataset about Dutch firms. The authors often found different results, especially about the different impact of the share of skilled workers. For both, large and small firms, the authors found a positive impact, whereas Acs and Audretsch only found it for large firms. A consistently positive impact of firm size was found by Pagano and Schivardi (2003), analyzing a dataset about European firms between 1994 and 1995. Many other examples can be found, showing a positive, a negative or a mixed impact of firm size on innovativeness. Asking the other way round, i.e. about an impact of innovativeness on firm size, the same wealth of different answers can be given. Up to this day, the so called Schumpeterian hypothesis is neither confirmed nor rejected, often because of insufficient data or a too short period of observation. Many studies concentrate only on a specific region, on a specific sector or analyze a very short period of time. In contrast, this study is focused on a long term analysis of the economic and technological development of German firms.

Analyzing hundreds of firms over the 56 years between 1877 and 1932, more than one “typical” relationship between innovativeness and firm size can be identified. Regarding the two most innovative firms of the most important sectors (machine construction, chemicals, metal and electronics) in figure four, the different types can be seen. The reason, why often contradictory results are found, can now be answered. Many paper, focusing on only one sector or a short period of time, might captured only one possible curve or a segment of a curve.

Figure 4: Innovativeness and Growth
Some Typical Curves of Highly Innovative German Firms (1877-1932)

Chemicals:





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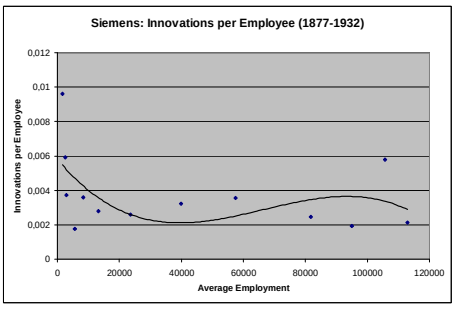
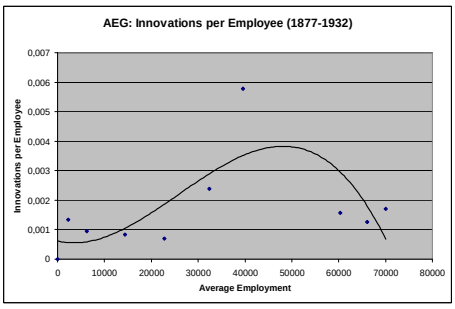
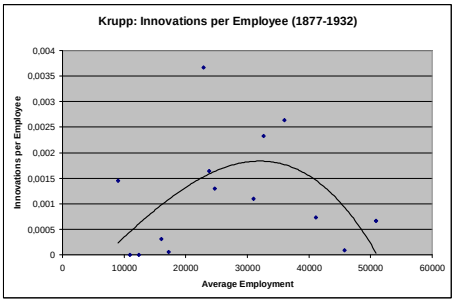
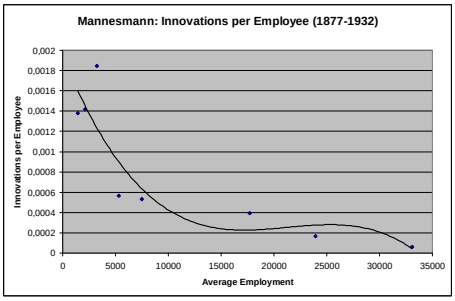


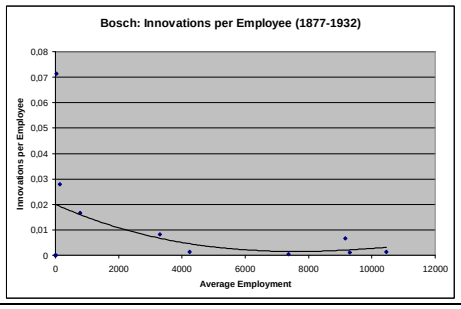


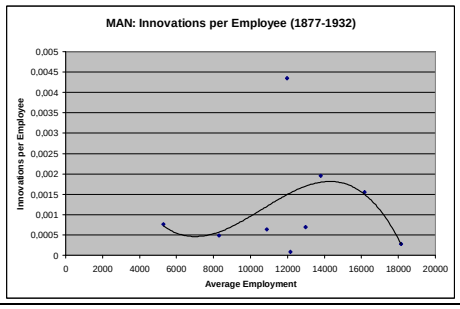
Metal:





Machine Construction:





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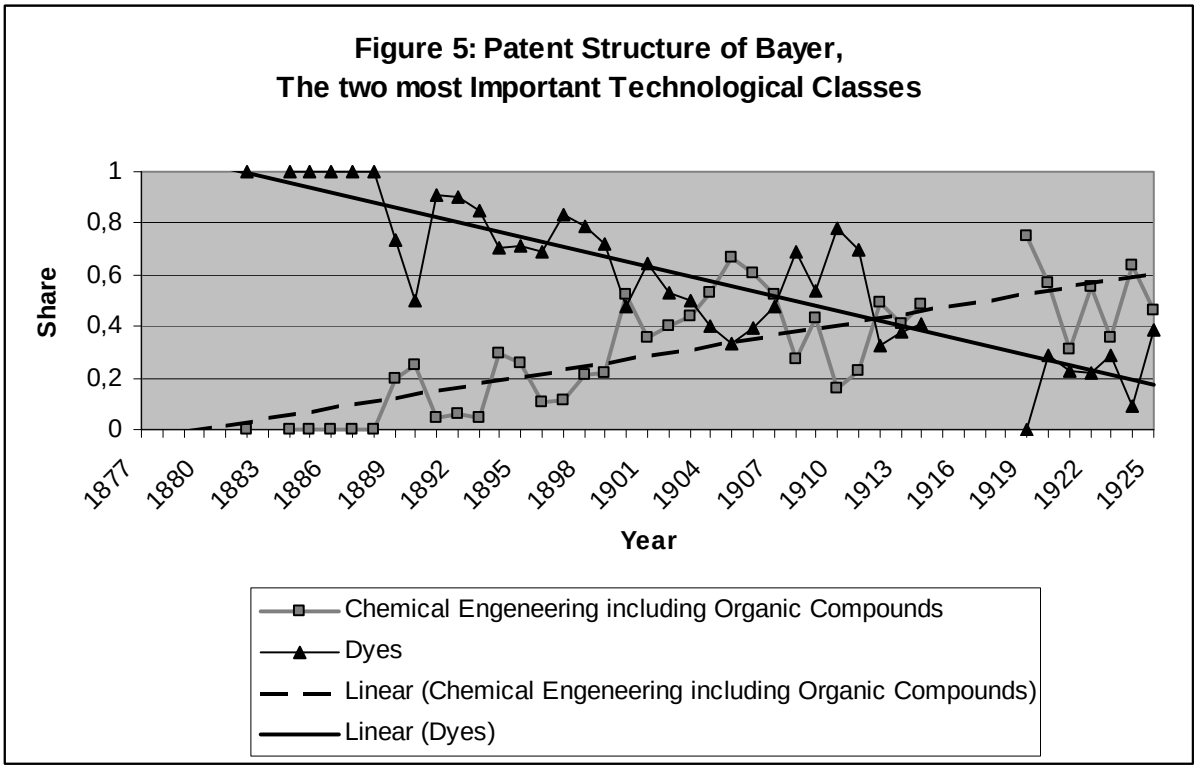
Observing for example BASF, the early development of innovations in the newly founded firm caused an increase of the innovativeness per employee. Apparently, the increase of inno-

vations per employee began already before the analyzed period. With Heinrich Caro (1834-1910) BASF started in 1868 industrial research in a newly founded R&D department, especially concentrating on synthetic dyes. Following v. Hippel (2002, p. 36) this was the beginning of BASF´s independent research and development activities. To produce and sell the innovative products, a lot of workers were needed. In addition, the increasing administration caused further employment, so that the average employment grew while the innovativeness, measured by the innovations per employee, decreased. After this period of growth (in the case of BASF after World War I), the second innovation period began. Regarding the number of patents (only 43 in 1919 and already 367 in 1925), the enormous extension of the research activities becomes evident. New research areas, like plastics, as well as the improvement of nitrogenous fertilizers were rapidly explored (v. Hippel, 2002, pp. 202-204). Hence, the second increase of the innovativeness took place after a period of growth.

Based on Schumpeter and Galbraith (Galbraith, 1957, p. 88; Schumpeter, 1950, p. 135), high earnings and high financial reserves, may foster further innovations in market dominating large firms, because they can provide voluminous research departments in which the scientific staff can concentrate on specific research activities and therefore gain specialization advantages.

The competitor Bayer shows a similar trait. As seen in the case of BASF, the exploration of new synthetic dyes came to an end before World War I. In 1906, the important Bayer chemist Carl Duisberg, wrote to Adolf von Bayer about the future possibilities concerning the production of synthetic dyes: "…in a time, the scientific and technical chemistry is on its climax, or better, on its way town towards the valley, we must not be frightened to open the eyes of the astonished people…" (Verg, 1988, p.190). Duisberg, of course thought about the new opportunities concerning the synthetic caoutchouc. Recognizing this new technological field that early, Bayer was already granted the first patent on artificial caoutchouc in 1909. After the possibilities of synthetic dyes were exhausted, Bayer concentrated on this new technology and the innovativeness increased again. Regarding the Bayer's patent structure, the reorientation away from the synthetic dyes and towards the synthetic caoutchouc can be detected. Figure five provides the decreasing share of synthetic dyes in all valuable patents of Bayer in comparison to an increasing curve, representing the share of valuable patents about organic compounds. With an average share of approximately 40% among those innovations, the patents around the artificial caoutchouc are the most important ones.



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The two linear trend lines can help to visualize the switch-over from one technological field to another. As mentioned above, before and especially after World War I, Bayer fostered innovations in the new technological field around the synthetic caoutchouc. This new innovative wave caused the reascalation of Bayer's innovativeness, shown in figure four.

The innovativeness of Siemens, the most innovative firm in the electronic sector, shows a valley around 1900. To come out of this valley, Siemens fostered the development of the technology around the telephone. For example 1909 in Munich, the first fully automated dialing station, produced by Siemens, began to work. In this time, Siemens developed many innovations for example in the fields of radio telegraphy, multiple telegraphy, radio technology and acoustic movies (Feldenkirchen, 1997, p.103). Following Mensch (1975, pp.54-55), innovations can be separated in basic innovations and further improvements. With respect to Siemens we can see that they concentrated on both basic innovations (e.g. the general technology of telegraphy) and further improvements (e.g. the different possibilities of this technology like radio telegraphy and multiple telegraphies). The innovative Period between 1900 and 1914 (telephony and telegraphy), as well as the growth period after World War I with the decreasing innovativeness, can be identified by analyzing Siemens' patent structure. Figure six provides the share of the telephony and telegraphy patents in all Siemens patents. Before World

War I, the share of innovations in these new technological fields increased and caused the increasing innovativeness between 1900 and 1914 shown in figure four.

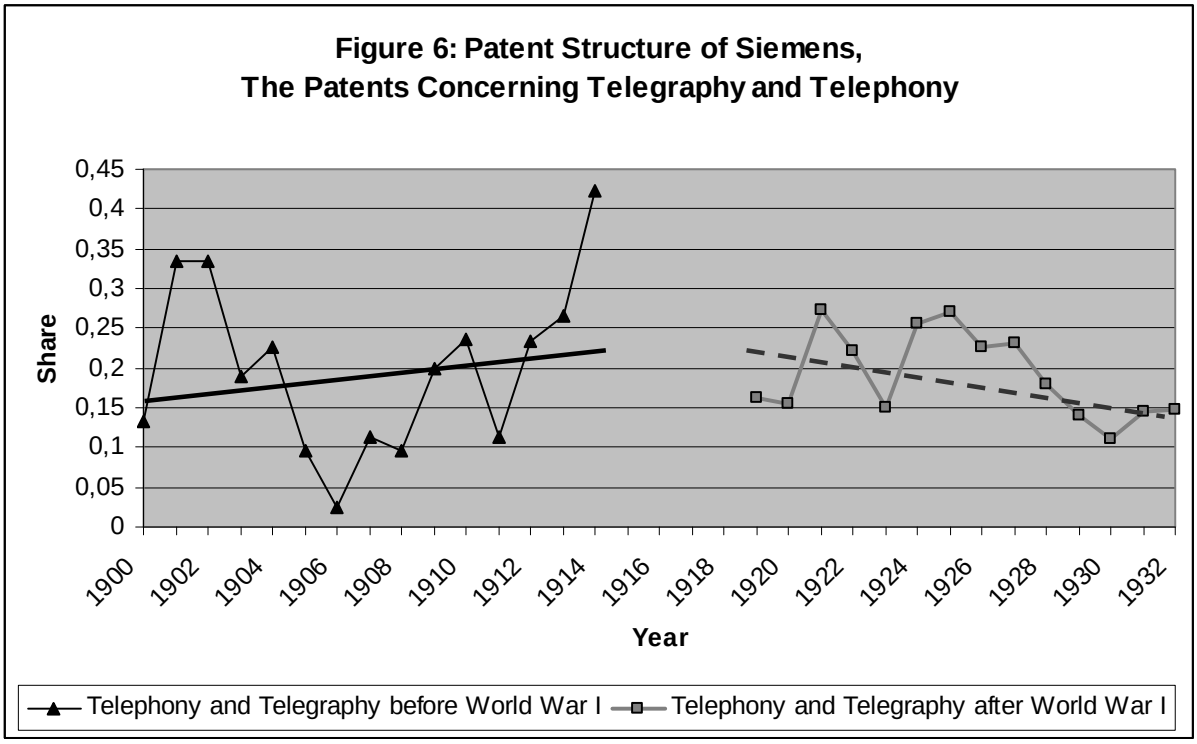

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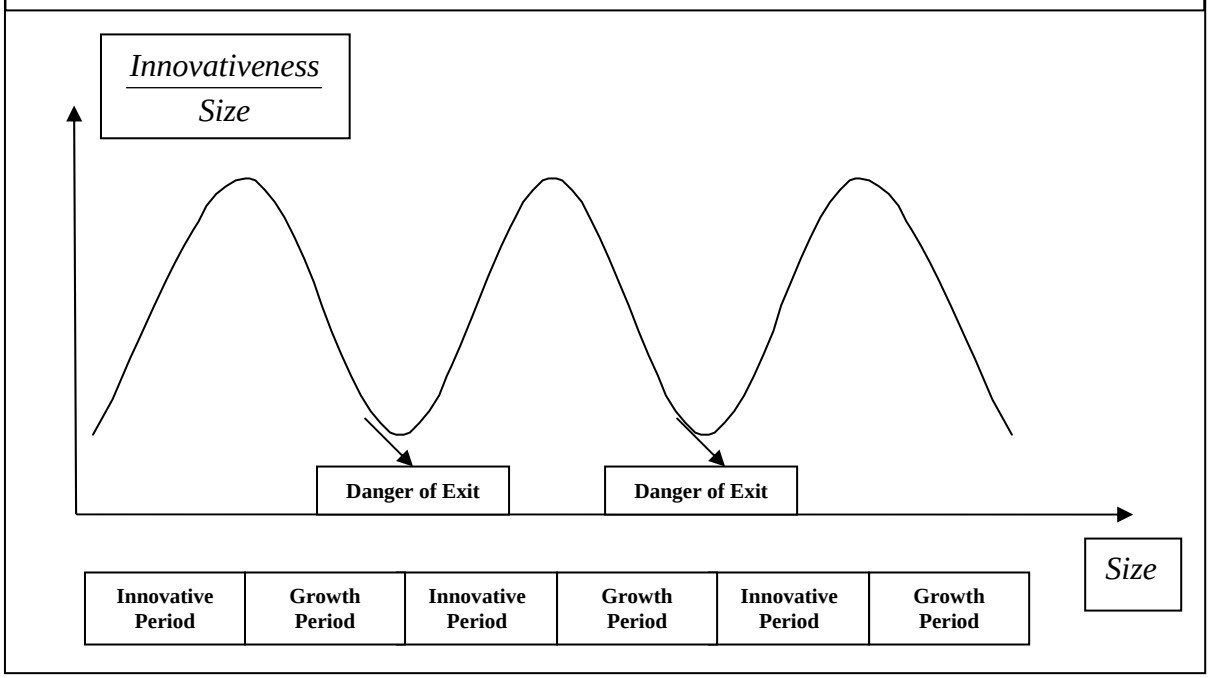
Figure six shows first, the period, in which Siemens developed many innovations around telephony and telegraphy, and, second, the period of exploiting them. After World War I, a decreasing innovativeness, together with an increasing number of employees (more than 100,000) is observable causing the trend downwards in figure four.

Krupp, the most innovative firm in the metal sector, shows an approximately perfect Kuznets-Curve. Such a curve, originally describing the inverted U of the relationship between income and inequality (Kuznets, 1955), can also be used describing the innovation process over time. Caused by an important basic innovation and following related innovations, the curve rises to an optimum level. The curves´ decline after reaching the highest point can be explained by growing complacency and inactivity. Extension of firm size beyond the optimum often causes immense bureaucracy and other negative effects, e.g. slowly decision making, laming the innovativeness of firms (Mensch, 1975, p. 66). It is interesting, why Krupp did not have success in creating further innovations or did not want to develop them. With the main business areas, defense and railway, maybe more than others, Krupp was able to benefit from World War I. During the war, the revenue increased form 478 Million to 1.5 Billion Marks. In the same time, the share of the defense products climbed from 52% to 82%. Concentrating on military

products obviously caused a negligence of facilities needed to produce new civil goods. After the war, Krupp's management had to decide between accepting the new time of the Republic, i.e. to develop new civil products, and hoping that former, profitable times will come back (Gall, 2000, p.343). Krupp tried to overwinter the time of the Republic with its restrictions caused by the lost war. After World War II, Krupp decided to create the firm's future on their own by developing new innovations. In our period, however, only the inverted U is observable.

Such an inverted U can be interpreted as a part of long term curve, describing innovativeness and growth. Regarding the six curves, in the long term, the relationship between innovativeness and firm size might be described as a lying S curve. Even if a firm is successful for years with only one innovation, at some point of time (e.g. after loosing patent protection) competitors will win market shares because of advancements or cheaper prices. Hence, the firm has to develop new innovations or exit the market. Developing new innovations can cause an increasing innovativeness up to the next maximum. In general, because of the possibility of creating new innovations, a growing firm can repeat the S shaped curve. Hence, in the long run, the relationship between innovativeness and the size of long-living firms can be a reiterating lying S like it is shown in figure five. The amplitude however, is not fixed, it can differ both, among sectors and firms.

Figure 7: Relationship between Innovativeness and Size of Long-Living Firms
A Reiterating Lying S-Curve



How long the movements upwards and downwards takes time, i.e. how fast an upwards movement turns downwards (i.e. the frequency), of course depends on customers' needs and the speed of technological change. Getting through a valley with its danger of exit is a very important aspect about a firm's long-term survival. The segment, in which the curve rises, is marked as "innovative period" in figure seven. The following "growth period" with the curve moving downwards, is defined as the period, when the innovativeness per employee decreases because of the higher number of workers needed for the production and for administrative work. In this period, the firm may gain a higher market share.

How often a firm can repeat its specific S curve can be an indicator of long-term success. To conquer the inverted U´s unavoidability is an important precondition for long term success. This leads to the general discussion about possible causes of firm's longevity. The necessity to adapt the production program to both technological progress and changing customer's needs, is pointed out by Streb (2007, 170). However, this author mentioned as well the problem that the implementation of such a general concept might be very difficult for a firm. The reason, however, why and how long a specific firm was in fact able to repeat the S curve, depends on a wealth of both, processes and decisions in the firm, and environmental circumstances the firm has to deal with. Hence, helping to explain a firm's long term success or failure, detailed business history research is needed.

Conclusions

Based on a newly developed dataset containing every long-lived patent granted in the German Empire and the Weimar Republic between 1877 and 1932, the 30 most innovative firms per 4-year period were identified. With an average share of 54.39% in all years between 1877 and 1932, the extremely unequal distribution towards those few firms has been discovered. More than a half of all innovations were developed by only a few firms. In a next step, the four most important sectors (chemicals, electronics, machine construction and metal) were identified. Focusing only on 20 firms (five per sector), the remarkable inequality becomes even more apparent. Regarding those sectors, the extension of inequality can widely differ and the unequal distribution can have some interesting sector specific characteristics.

Facing the criticism that case studies in business history are not always representative, the present paper shows that concentrating only on a few firms might be in some fields sufficient to represent a whole sector. Doing innovation history based on patent statistics, the very un-

equal distribution of innovations in the German Empire and the Weimar Republic gives the opportunity to infer from a very small number of firms on important aspects of the German innovation history between 1877 and 1932. However, the firm specific differences shown in figure three must be taken into account. Hence, business history can not be replaced but the possibility to estimate general tendencies of sectors and innovativeness can provide assistance.

In the next step, the present paper tried to explain why the empirical findings about the relationship between size and innovativeness of firms are often contradictious. In a long term analysis of hundreds of firms, some typical, often recurring relationships have been discovered. The results lead to the conclusion, that in general, the long term relationship between firm size and innovativeness is apparently a reiterating laying S-shaped curve. This curve, divisible into innovative periods and growth periods, can make a contribution to explain a firm‘s long term success. However, the reason why every firm specific curve has its own interesting characteristics has still to be investigated by detailed business history research.

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Appendix

1877-1880		
Firm	**Number of Valuable Patents**	**Sector**
Siemens	15	Electronics
Krupp	13	Metal
Rheinische Stahlwerke	7	Metal
Hörder Bergwerks- & Hüttenverein	7	Metal
BASF	7	Chemicals
Proell & Scharowsky	6	Engeneering
Gasmotorenfabrik Deutz	6	Machine Construction
Moeller & Schreiber	4	Metal
Buss, Sombart & Co.	4	Machine Construction
Schulz, Knaudt & Co.	3	Metal