The Berlin Stock Exchange in Imperial Germany – a Market for New Technology?

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Abstract

Analysing 474 cases of firms going public in the German capital between 1892 and 1913, we show that innovative firms could rely on the Berlin stock market as a source of financing. The data also reveal that initial public offerings (IPO) of innovative firms were characterized by particularly low underprizing, comparatively high first trading prices, and no long-run underperformance. We interpret these empirical results as evidence for the surprising fact that contemporary investors had rational expectations.

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Introduction

Economic historians associate the late nineteenth and early twentieth-century German economy with two distinct features: innovative firms that excelled in the industries of the Second Industrial Revolution such as chemicals and electrical engineering, and universal banks that supposedly provided the financial means for Germany's fast transformation from a backward country to one of the global industrial leaders she had become at the eve of the First World War. Yet there is only a small and tentative literature connecting firms' innovation with the financial system. Especially, the question is still open how innovative German firms were able to raise the venture capital needed to finance their risky R&D projects. Analysing all 474 cases of firms going public in the German capital between 1892 and 1913, we show that many innovative firms could rely on the Berlin stock market as a source of financing. The data also reveal that initial public offerings (IPO) of innovative firms were characterized by both particularly low underprizing and comparatively high first trading prices. We interpret these empirical results as evidence for the surprising facts that contemporary investors had rational expectations and were willing to take risks. Rational expectations mean here that investors were capable of identifying firms with long-term innovativeness already at the first trading day. Willingness to take risks implies that investors preferred the shares of innovative firms to those of the non-innovative ones.

In his seminal contribution *Economic backwardness in historical perspective* Gerschenkron (1962) opened discussion by claiming that Germany's industrialization was driven by the activities of large universal banks that provided the credit private firms needed to finance investment in ever-growing industrial capacities. This hypothesis which was initially hardly backed by empirical evidence inspired decades of historical research on the relationship between the financial system and economic growth. Scholars like Calomiris (1995) especially stresses the stark contrast between the German and the American financial systems during industrialization, the former being apparently dominated by universal banks, the latter basing on a well-developed stock market. However, Gerschenkron's implicit hypothesis that German universal banks also financed innovation activities has still remained in doubt.

Several case studies suggest that universal banks were rather reluctant to finance the establishment of new and potentially innovative companies but mostly dealt with already well-established companies. Pierenkemper (1990), for example, shows that the two cast steel factories *Friedrich Krupp*, and *Mayer & Kuehne*, founded in 1811 and 1842 respectively, survived their difficult set-up phase only with the financial support from family and friends. Hahn (1958)

observes that about twenty out of 150 companies which were founded in the Rhineland between 1870 and 1926 failed because of general scarcity of capital. What is more, universal banks concentrated on traditional industries. Feldenkirchen (1991), for example, points out that universal banks sustained close banking relationships primarily with companies in the heavy industry sector. According to Neuburger and Stokes (1974), banks' focus on matured industries slowed down economic growth of Germany considerably because it deprived innovative firms in the new industries chemicals and electrical engineering of capital. As a result, despite an already well-developed banking sector[1] German entrepreneurs might have been forced to finance innovation mainly from their own resources that is from private wealth or previous profits.

Quantitative studies support the assumption that universal banks played only a minor role during Germany's high industrialization. Fohlin (1991, p. 104), for example, failed to identify any causal relationship between banking and economic growth in the period from 1895 to 1913. Burhop (2006) extends the period under observation by analysing the relationship between financial depth (total assets of banks/net national product) and Germany's economic performance between 1851 and 1913. For the period from 1851 to 1882, Burhop confirms Gerschenkron's bank-led growth hypothesis: the growth of joint-stock banks' financial depth had a positive and significant impact on economic performance in Germany. For the period from 1883 to 1913, however, Burhop's results are in line with Fohlin's negative findings: the joint-stock banks lost their statistically significant impact on economic growth during Germany's high industrialization.[2] Lehmann (2014) concludes that the German stock market might have replaced bank loans as the most important source of capital in the late nineteenth century.

The question remains whether this macroeconomic shift from debt to equity also opened up new opportunities for innovative firms that had apparently found it so hard to access finance from traditional bank loans. A priori, it seems reasonable to assume that investors at the stock markets were as risk-averse as bank managers and therefore shied away from buying shares of innovative firms with very risky R&D projects. If this was true innovative firms' short-run performance at the stock market should have been considerably worse than the one of non-innovative firms with more predictable business activities.

[1] For a complete overview of the German banking system see Guinnane (2002).

[2] Interestingly enough, Burhop (2006) also finds a positive relationship between savings banks' financial depth and Germany's real capital stock for the period 1883 to 1913. This finding implies that savings banks role in financing Germany's small and medium-sized industry was more important than hitherto assumed. See also Proettel (2013).

The simplest and most often applied measure for short run performance at the stock market is the initial return which is the difference between the first trading price and the emission price at which the underwriting bank offers the shares of an IPO to potential investors. A development typically observed in modern markets is that the price of a new share shoots up at the first trading day which means that the initial return is systematically positive. This short-term price increase indicates a strong demand for the newly-traded shares implying that they could have been priced higher at emission. If the emission price had been higher, the company would have raised more capital. When an issue is in this way 'underprized', it is assumed that the company (or the underwriting bank) have left money on the table.

The phenomenon of underprizing was first documented by Stoll and Curley (1970), Logue (1973), Reilly (1973), and Ibbotson (1975).[3] Empirical studies show that on historical stock markets underpricing also existed but to a much lower extent than in modern markets where underpricing averages about 15 percent in the USA (Ritter, 2002), Germany (Ljungqvist, 1997) and France (Biais/Bossaert/Rochet, 2002). By contrast, Burhop (2011), Lehmann (2014) and Weigt (2005) observe underprizing of only about five percent at the Berlin Stock exchange between the 1880s and the First World War. Chambers and Dimson (2009) find around 10 percent in the interwar period on the London stock exchange.

Various theories have been developed to explain underprizing, with most of them postulating that it is the existence of some type of information asymmetry that explains underprizing at the day of the IPO.[4] The classical paper by Rock (1986), for example, assumes that the phenomenon of underprizing is caused by asymmetric information about the quality of a particular IPO among different groups of investors. This explanation is based on the assumption that IPOs considerably differ with respect to the earnings the owners of the newly-traded shares will realize in the future. Informed investors are capable of distinguishing high-quality from low-quality IPOs and will therefore buy only shares of the former. Uninformed investors cannot identify high-value IPOs but are well aware of their own incompetence. That is why they are not willing to pay a high price for an issue with unknown quality but only a price that equals the expected average value of the shares of all IPOs. If the emission bank realizes that the total demand of the group of informed investors (who are prepared to pay a high price for high quality) is not sufficient to sell

[3] For a review of studies on short-run underprizing see Ljungqvist/Jenkinson (1996).
[4] For a review of theories about the reasons for IPO underprizing see Ritter/Welch (2002).

the whole issue of a high-quality IPO it will lower the emission price below the level that is justified by quality in order to attract also uninformed investors.

Lehmann (2014) shows that German universal banks were not willing to implement the IPO of each and every firm. Instead, banks went to great lengths to determine the future business prospects of potential candidates. On the one hand, they authorized independent audit companies to scrutinize bookkeeping results before a planned IPO. The most prominent audit company employed for this purpose was the *Deutsche Treuhandgesellschaft*, which was founded by *Deutsche Bank* in 1890 and became the first official German auditing company in 1901. On the other hand, banks did also their own research, demanding reports on balance sheets and information on profits. The *Berliner Handelsgesellschaft*, for instance, had detailed guidelines about how to check the credibility and performance of industrial firms (Lehmann, 2014, table 3). Overall, German universal banks seemed to be well informed about the market value of firms that planned to go public. The comparatively low underpricing that occurred at the Berlin stock exchange during Germany's high industrialization might therefore indicate that investors' uncertainty was rather small because they knew that banks brought only those firms to the market that met certain minimum quality requirements.

From a theoretical perspective it is not clear whether we should expect underprizing to be higher or lower when it is an innovative firm that goes public. If investors shrink back from the high degree of uncertainty that comes along with extensive R&D activities banks might consider choosing an especially low emission price in order to attract a sufficient demand for the issue. Analysing about 2700 IPOs at the US market between 1980 and 1995 Guo, Lev and Shi (2006) find that R&D expenditures are in fact positively correlated with underprizing. This result, however, might not imply that investors dislike innovative firms per se but might instead mirror the fact that R&D expenditures are in general not a reliable predictor for the output of R&D processes. Depending among other things also on luck massive R&D expenditures can result in important innovations or in next to nothing. From the viewpoint of investors at the stock market, R&D expenditures are therefore not a signal for a firm's long-term profitability but primarily a significant short-term cost item. Patents are different because they document only those R&D activities that actually led to technological breakthroughs. Whereas R&D expenditures create risk, patents reduce risk and promise future economic profits. That is why investors might prefer buying shares of firms with many patents. If the bank anticipates this preference for firms with patents it can charge a comparatively high emission price and underprizing will be relatively low. Bessler

and Bittelmeyer (2008) confirm this hypothesis for modern markets. Observing the IPO activities at the German stock market for new technology (*Neuer Markt*) between 1997 and 2002, they find that initial returns were on average 20 percent smaller when the firm that went public had already patents.[5]

In the German Empire, it was obviously well understood too that patents could serve as a positive signal that increased the attractiveness of a firm's shares. The *Salinger Börsenhandbuch*, a widely-used stock market manual that provided information about existing joint-stock companies, often re-published details about firm-specific patent portfolios the companies themselves had already revealed when advertising their IPOs in listing prospectuses. In 1904, for example, *Salinger Börsenhandbuch* emphasized that the innovative wallpaper-printing machines invented by machine builder *Carl Schoening AG* (IPO in 1903) were patented in all important industrialized countries.[6] In 1911, it gave detailed information about the number and lifespans of the national and international patents held by *Carl Lindström AG* (IPO in 1910) which was engaged in precision engineering.[7]

In the remaining paper we want to find out first whether the two companies *Carl Schoening* and *Carl Lindström* were rare exceptions or part of a larger group of innovative firm that used the Berlin stock exchange as a source for financing. In a second step, we will analyse whether our hypothesis is true that, in the German Empire, the existence of patents reduced investors' uncertainty and therefore initial returns. To evaluate market's efficiency we will have also a closer look at the long-run performance of the IPO stock.

Data and descriptive statistics

In the following, we will analyse the performance of all 474 IPOs that took place at the Berlin stock exchange between 1892 and 1913, the last year of peace before the outbreak of the First World War. The starting year of our observation period is determined by the availability of a daily stock index which will be needed to evaluate the performance of a particular firm's shares in comparison to the rest of the market. We rely on the market benchmark Gelman and Burhop (2008) calculated for the years from 1892 to 1913. Information about the IPOs of the period from 1897 to

[5] Interestingly enough, Müller and Reize (2010) show that, in the 2000s, holding patents increased the probability that small and medium-sized German firm got a bank loan.
[6] See Salinger Börsenhandbuch (1904), p. 1303 f.
[7] See Salinger Börsenhandbuch (1911), p. 1501 f.

1913 was taken from the *Vierteljahrshefte zur Statistik des Deutschen Reichs* (see also Lehmann 2014). This record includes date of the issue, value of shares sold at IPO, firm name, location of headquarter, and name of the lead underwriting bank. Data about the IPOs that took place between 1892 and 1896 have been collected by Burhop (2011) using various contemporary sources.[8] Firm specific variables such as the age of a newly listed corporation and its profit in relation to the book value (current accounts) in the year before the IPO were taken from *Salinger Börsenhandbuch* and from *Handbuch der deutschen Aktiengesellschaften* (Handbook of German joint-stock companies). Prices and dividends were taken from *Berliner Börsenzeitung*.

Our prime source for collecting patent data is the *Verzeichnis der im Vorjahre erteilten Patente* that was annually published by the Imperial patent office. This annual contains among other things an alphabetical list of all innovative firms and private inventors with information about the respective number of patents they had received in the preceding year. Having information about the name and location of the firms that went public between 1892 and 1913 we can use these annual lists to identify all patents that were assigned to these firms both before and after their respective IPO. Note, however, that our patent data are truncated at both sides of the time bar. The introduction of the first German patent law in 1877 marks the first year in which it was possible to get a German patent. Since the Imperial patent office did not reveal the name of patent holders during wartimes, the beginning of the First World War terminates the end of the period for which firm-specific patent data are available.

Our identification strategy is based on the assumption that contemporary investors used a firm's patent history to assess its future innovativeness and therefore also its future profitability. One problem with this approach is that the propensity to patent might vary considerably across industries. Whereas some industries try to appropriate the return of their innovations with the help of patenting activities, others prefer keeping them secret instead. The formula for Coca-Cola, for example, has never been patented because its public disclosure in a patent application would have allowed competitors to imitate this product after the end of the patent protection. Given these differences in industries' patenting activities, it could be misleading to interpret a particular firm's comparatively low number of patents automatically as a sign for its alleged below-average level of innovation. To assess the magnitude of this measurement problem in a historical context Moser (2012) uses an alternative source to identify innovations. She looks at the number of British and

[8] We thank Carsten Burhop for providing these data including firm specific variables.

American exhibits presented at world's fairs between 1851 and 1915. At the Crystal Palace exhibition in London in 1851, for example, about 89 percent of British exhibits and 85 percent of the American ones were without patents. In addition, Moser identifies considerable differences in industries' propensity to patent. In 1851, industry-specific patenting rates of British exhibits ranged from 30 percent in manufacturing machinery and 25 percent in engines to a mere five percent in mining and metallurgy. Moser concludes that patenting rates were especially low in those industries where innovations were difficult to imitate. In the middle of the nineteenth century this argument also applied to chemicals, because modern methods of chemical analysis that allowed chemical products to be "re-engineered" had not yet been developed. However, Streb, Baten, and Yin (2006) show that things had changed at the end of the nineteenth century when the propensity to patent was especially strong in German chemical industry. The same was true for other industries of the Second Industrial Revolution such as electrical engineering or machine building. Since German firms of these "new" industries are also dominating our sample of IPOs (see Table 2) we assume that our statistical results are not invalidated by this type of potential measurement error.

A second shortcoming of patent statistics is that pure patent counts allocate the same weight to every patent, no matter whether it had a high or a low economic value for the patentee. To deal with this problem, scholars showed that the most valuable patents of a patent population can be usually found in three non-disjoint subsets. These are the subsets of foreign patents, most-cited patents, and long-lived patents.

An inventor can apply for a patent not only in his home market, but also in foreign countries. Getting a foreign patent, however, imposes additional costs in the form of expenses for patent lawyers and translators, fees for filing and renewing, and the longer-term costs of international disclosure of the underlying technology. After weighing the costs and benefits of foreign patenting, most inventors decide to file a patent only in their home country. Only the most promising innovations will also be patented abroad. That is why foreign patents might represent an especially valuable part of a country's patent stock. Today, the so-called triadic patents that are simultaneously filed at the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO) and the Japanese Patent Office (JPO) are used to identify a country's best innovations. Economic historians usually concentrate on foreign patenting in the United States. The most comprehensive historical analysis is provided by Cantwell (1989) who analyzes the

patenting activities in the United States of sixteen industrialized countries and 27 sectors for the years 1890-1892, 1910-1912, and 1963-1983.

In academics, the value of a scientific article is often measured by the numbers of citations it received in following publications. A similar measure can be used to identify valuable patents. The idea is that the more often a particular patent is cited in subsequent patent specifications the higher inventors evaluate its technological and economic significance (Jaffe/Trajtenberg, 2002). Before the First World War, it was not common practice to refer to a preceding patent for defining prior state of the art. Nicholas (2011), however, found that some British patents of the interwar period were still cited in US patents in the decades after the Second World War. Nuvolari and Tartari (2011) exploit Bennet Woodcroft's 'Reference Index of Patents of Invention' published in 1862 which provides a list of references to technical and engineering literature, legal proceedings, and commentaries in which a patent is mentioned for each English patent granted between 1617 and 1841.

In some historical patent systems like those of Germany or the UK, where patent holders had to renew their patents regularly by paying a renewal fee, valuable patents can alternatively be identified by their individual life span (Schankerman/Pakes, 1986, Sullivan, 1994). Legislators had introduced patent renewal fees in the hope that many patent holders who were not able to profitably exploit their patents would give them up early and thereby make the new knowledge that was documented in the patent file publicly usable long before the maximum possible patent duration would have elapsed. If this mechanism worked as intended, a long life span of a historical patent can be seen as a reliable indicator of its comparatively high private economic value. In the German Empire, a patent holder had to decide annually whether he wanted to prolong his patent by another year. The renewal fee amounted to 50 Marks at the beginning of the second year and then grew steadily up to 700 Marks at the beginning of the fifteenth and final possible year of patent protection. The resulting cancellation rate was high. About seventy per cent of all German patents that were granted between 1891 and 1907 had already been cancelled after just five years. About ten per cent of all patents were still in force after ten years and only about 5 per cent reached the maximum age of fifteen years. Streb, Baten and Yin (2006) interpreted those German patents that survived at least ten years as the valuable patents within the German Empire. Their patent data set

comprises about 40,000 long-lived German patents that were granted to firm and private inventors between 1877 and the end of the First World War.[9]

However, information about a particular patent's lifespan (and about the citations it received) is ex post knowledge. Contemporary investors could not know how long a patent being issued in the years before an IPO was finally held but had to assess a firm's innovativeness on the pure patent count. That is why we decided against using available information about German firms' long-lived patents and collected instead new data on all patents granted. Table 1 provides an overview over our new data set.

Table 1: Overview: IPOs at the Berlin stock exchange between 1892 and 1913

	Share of firms with patents	Firms with patents before IPO	Firms with Patents within 5 years after IPO	Firms with patents before and after
In percent of all IPOs (474)	36.3	29.3	23.2	16.2
Total	172	139	110	77

Source: see text.

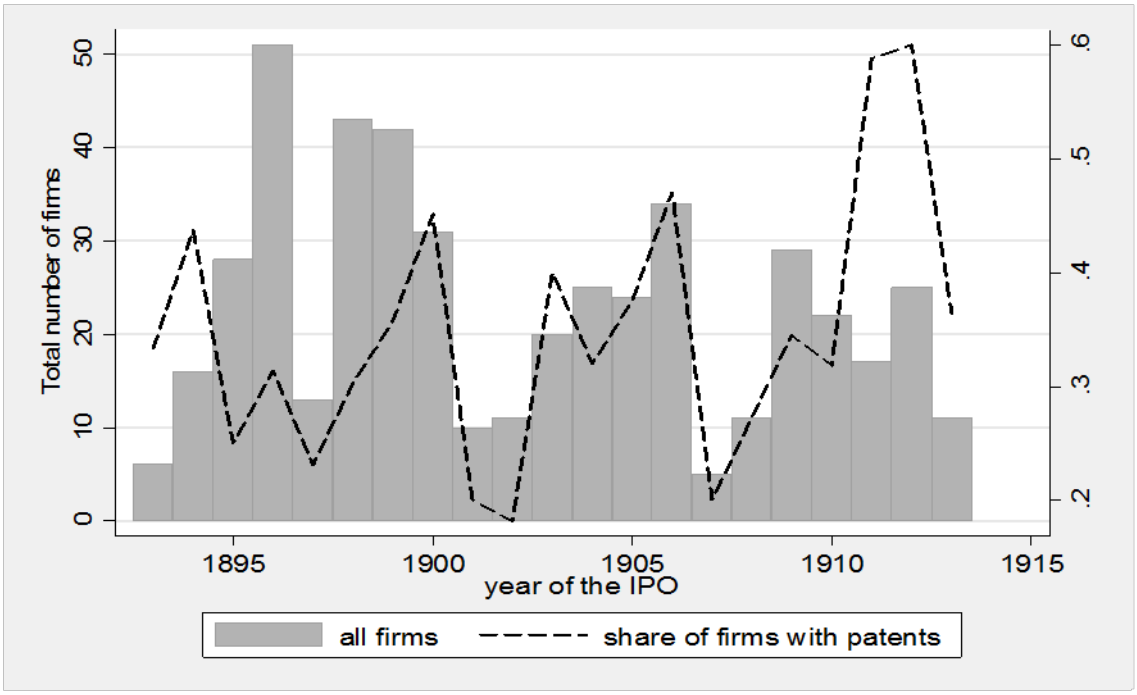
In total, we observe 474 IPOs that took place at the stock exchange in Berlin in the considered period. 36.3 percent of the firms going public received patents either before the IPO or within the first 5 years after going public. 139 firms (29.3 percent) held at least one patent at the day of the IPO and 110 (23.2 percent) firms got a patent in the first five years after they went public. The share of innovative firms in all IPOs is surprisingly high. A striking (and often neglected) feature of patent statistics is that the distribution of patents across countries, regions and also inventors is highly skewed. Degner (2009), for example, presents the astonishing result that from 1877 to 1900 two thirds, and from 1901 to 1932 between 40 and 55 percent, of all long-lived German patents granted to domestic firms were held by only the 30 most-innovative firms whereas about 266,000 firms with more than five workers existed in Germany in 1930. Against the

[9] See also Burhop/Lübbers (2010), Richter/Streb (2011), Streb/Wallusch/Yin (2007).

background of this extremely skewed distribution of innovation, it seems clear that the innovative firms' share of 36.3 percent in all IPOs was disproportionately high. In the decades before the First World War, the Berlin stock exchange was in no small part a market for new technology.

Figure 1 shows the distribution of IPOs over time. In all years, there was a reasonable number of firms with patents that went public. The numbers vary widely over time. For instance, many firms decided to go public in 1896 to avoid the new regulations of the stock market law that came into effect in January 1897. Our main conclusions are also supported by Table 2 which reveals that the distribution of patents varied widely across and within sectors. Most firms with patents can be found in key industries of the Second Industrial Revolution, such as metal working, machines and chemicals.[10] In addition, we observe very few "very innovative" firms. Only 49 firms (10.3 percent), for instance, had received more than 10 patents before the day of the IPO.

Figure 1: IPOs at the Berlin stock exchange over time



Source: see text

[10] For German machine builders innovation and imitating strategies see Richter/Streb (2011).

Table 2: Overview: IPOs of innovative firms at the Berlin stock market by sector, 1892 and 1913

Sector	Firms with patents	In percent of all IPOs in this sector	Total number of patents before IPO	Total number of patents within 5 years after IPO
Machine and Metal working	108	74.5	2226	1987
Chemicals	14	60.9	71	61
Textiles	10	27.8	69	23
Mining	11	25.6	43	16
Others	29	12.8	365	761
Total	172	36.3	2774	2848

Source: see text.

Short-run and long-run performance

Based on the daily stock market index provided by Gelman and Burhop (2008) we compute market-adjusted initial returns as a measure for IPO's short-run performance as follows:

$$IR = \left(\frac{p_{first} - p_{offering}}{p_{offering}} \right) - \left(\frac{A_{first} - A_{offering}}{A_{offering}} \right),$$

where p_{first} is the price at the first trading day, $p_{offering}$ the offering price fixed by the underwriting bank, A_{first} equals the actual stock market index on the first trading day of the IPO, and $A_{offering}$ is the stock market index at the day before the first trading day. We focus on the Berlin stock exchange and take the first trading price from the *Berliner Börsenzeitung*. Our data demands reduce the sample from 474 to 292 observations.[11]

[11] Instead of publicly offering all shares before the first day of trading, banks could start emission by privately placing shares. We assume that all IPOs for which we cannot observe the offering price were preceded by private placement. See Moral (1914), p. 49 f.

Figure 2: Underprizing and the number of patents before IPO

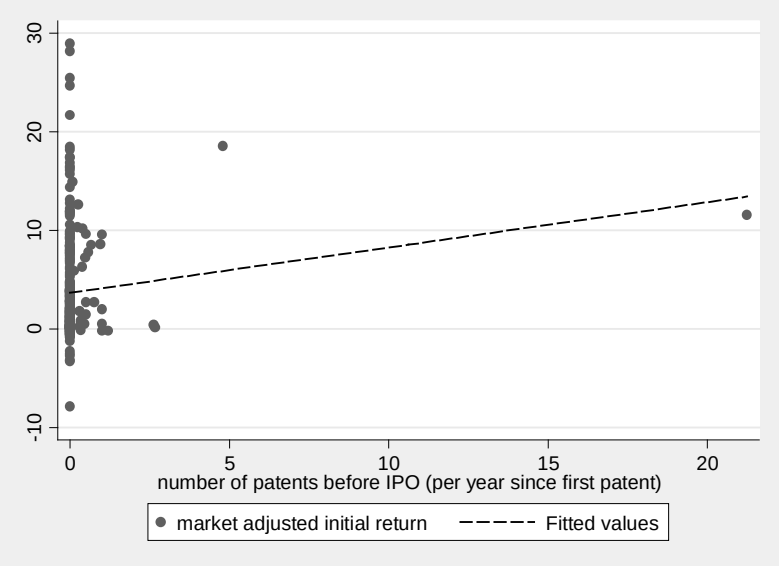


Figure 2 shows the bilateral relationship between underprizing and the number of *patents before IPO per year* a company had received before its IPO. In order to account for different time horizons, we divided the total number of *patents before IPO* by the years since the first patent. It seems that innovativeness is positively correlated with initial returns. Apparently, banks were forced to set an especially low offering price for the shares of those firms that had a large amount of patents in order to attract investors who rated innovativeness as a sign for high risk.

Previous quantitative studies on IPOs in a historical setting failed in identifying significant determinants of underprizing. In contrast to what qualitative evidence suggests, underprizing seemed to be white noise, being largely unaffected by firm-specific, bank-specific or market-specific factors (Burhop 2011, Lehmann 2014). However, patents, which might have either increased or reduced information asymmetry with regard to an IPO's future performance, have not been used yet as an explanatory variable. We will do this in the following regressions with the help of three measures: *patents before IPO, patents before IPO per year*, and *share of long-lived patents* in all patents granted before IPO. With the help of the latter variable we consider the possibility that contemporary investors were capable of identifying the most valuable patents among all patents. In addition, we control for other factors which have been identified as influential variables in modern stock markets. A high reputation of the lead underwriting bank might have dispersed investors' doubts about the quality of an IPO which implies that IPOs which have been issued by

those banks should have lower initial returns than others (see for instance Carter, Dark and Singh 1998). To take care of this reputation effect, we introduce a dummy variable (*Big Four banks*) that is set equal to one if the lead underwriter was *Deutsche Bank*, *Dresdner Bank*, *Discontogesellschaft* or *Darmstädter Bank*. These so-called D-banks were the four German joint-stock banks with the highest shares in the market for IPOs (Lehmann 2014). The intuition behind including both *size of the issue* and *age of firm*, both standardized to a mean of zero , is that investors had probably more information about large and already well-established companies than about small and young ones. Because of this additional information the problem of asymmetric information among different groups of investors might have become less important and underprizing therefore declined. The variable *SEO/IPO*, measuring the size of a firm's seasoned equity offering (SEO) in comparison to its IPO, takes care of the idea that underwriting banks might have wanted to present investors with a high initial return at the IPO in order to increase the attractiveness of an already planned large SEO in the future (Welch, 1989). *Profit per book value* at the year of the IPO informed investors about the actual profitability of the company and might have also decreased their uncertainty about expected future returns. Finally, we control for the average market return of the previous year (*past market returns*) to test Burhop's hypothesis that contemporary investors' expectations were influenced by the general economic and political climate, as well as the liquidity of the financial market (Burhop, 2011). In summary, we estimate the following OLS- regression:

$$IR_i = c + \beta_1 NumberofPatents + \beta_2 x_i + \beta_3 Pastmarketreturn + \varepsilon .$$

However, we do not solely concentrate on underprizing (initial returns) but also evaluate explanatory variables' influence on the first trading price which is a measure for the initial market-to-book ratio. Table 3 provides the results.

Table 3: IPOs' short-run performance (OLS with robust standard errors)

VARIABLES	(1) Initial return	(2)	(3)	(4)	(5) Log first trading price	(6)	(7)	(8)
Patents before IPO	0.0109	0.00901			0.000745**	0.000535*		
	(0.201)	(0.329)			(0.0161)	(0.0763)		
Patents before IPO per year			0.459***	0.436***			0.0135***	0.0105**
			(0.00592)	(0.00350)			(0.00270)	(0.0152)
Share long-lived patents		2.967		2.749		0.327*		0.361**
		(0.456)		(0.415)		(0.0624)		(0.0450)
Big Four banks	0.257	0.254	0.199	0.202	0.0683**	0.0680**	0.0657*	0.0661*
	(0.752)	(0.756)	(0.807)	(0.804)	(0.0440)	(0.0447)	(0.0519)	(0.0500)
SEO/IPO	0.0442	0.0444	0.0537	0.0531	-0.00514	-0.00513	-0.00481	-0.00488
	(0.747)	(0.747)	(0.695)	(0.699)	(0.418)	(0.422)	(0.454)	(0.452)
Size of the issue	-5.06e-08	-5.05e-08	-5.43e-08	-5.68e-08	-1.02e-09	-1.02e-09	-2.19e-10	-5.41e-10
	(0.208)	(0.209)	(0.150)	(0.140)	(0.601)	(0.602)	(0.905)	(0.762)
Age of firm	0.0373	0.0355	0.0397	0.0378	0.00514**	0.00494**	0.00524**	0.00500**
	(0.451)	(0.478)	(0.420)	(0.448)	(0.0174)	(0.0229)	(0.0154)	(0.0215)
Profit per book value	-0.0185	-0.0203	-0.0160	-0.0179	0.00864***	0.00845***	0.00878***	0.00852***
	(0.762)	(0.741)	(0.795)	(0.772)	(0.00112)	(0.00157)	(0.00107)	(0.00157)
Past market return	8.116	8.716	8.125	8.647	0.287	0.353	0.298	0.367
	(0.191)	(0.173)	(0.190)	(0.174)	(0.197)	(0.122)	(0.189)	(0.112)
Constant	0.334	0.230	0.355	0.260	4.843***	4.832***	4.843***	4.830***
	(0.756)	(0.835)	(0.741)	(0.812)	(0)	(0)	(0)	(0)
Sector and time dummies	y	y	y	y	y	y	y	y
Observations	292	292	292	292	292	292	292	292
R-squared	0.065	0.066	0.072	0.073	0.218	0.225	0.215	0.225
F	2.030	1.931	2.513	2.454	7.606	7.613	7.940	8.091

Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Similar to previous historical studies none of the usual control variables has a significant effect on underprizing. In the first two regressions we consider the absolute number of patents before IPO as measure for innovativeness; in regressions 3 and 4 we use instead the number of patents before IPO per year. Both variables are positive, but just the latter is significant at one percent. The latter result again suggests that underprizing increased with innovativeness. Though, regressions 5 to 8 also show that the first trading price of innovative firms was significantly larger than the one of non-innovative ones which implies that investors expected the shares of innovative firms not only to be more risky but also to be more profitable. Interestingly enough, investors also took into account the share of long-lived patents in all patents which suggests that they were capable of identifying the most promising patents. Models 5 to 8 also support the assumption that

investors inferred from both underwriting banks' reputation (*Big Four banks*) and actual *profit per book ratio* that the future profits of the respective firms would be comparatively large.

A closer look at the data reveals that innovative firms' patent history differs widely. We distinguish three types of innovative firms. *Permanently innovative firms* received patents before and after the IPO. *Innovative start-ups* had none or just a few patents before IPO but many afterwards suggesting that they needed investors' capital to finance their R&D activities. In contrast, the third group of innovative firms lost their traditional innovativeness after their IPO. Following Thomas Mann's famous novel in which he described the gradual decline of a family-owned company in Lübeck, we call them the "*Buddenbrooks*" of our sample. To operationalize this differentiation we introduce three dummy variables. The dummy "*innovative start-up*" will be set to one if the respective firm received at least ten times more patents in the first five years after its IPO than during its full existence before its IPO. Conversely, the dummy "*Buddenbrooks*" will be set to one if a firm's number of patents before its IPO was at least ten times as high as in the first five years afterwards.[12] All other innovative firms the patents of which were more equally distributed over time are defined as the group of *permanently innovative firms*. The group of *non-innovative firms* without any patents serves as a benchmark.

Table 4: Overview: Initial returns by different groups of firms

	Obs	Mean	Std. Dev.	Min	Max
Innovative start-ups	27	2.76	3.85	-0.62	18.47
Buddenbrooks	36	4.21	5.27	-0.55	18.20
Permanently innovative	42	4.01	4.53	-0.22	18.56
Non-innovative	187	3.73	5.68	-7.87	28.94

Source: see text.

[12] Our results are robust to changes in the demarcation between innovative start-ups, Buddenbrooks and permanently innovative firms (see appendix I)

Table 4 presents the average initial returns of the four different groups of firms in our sample of 292 IPOs. The most striking result is the comparatively low underprizing of innovative start-ups which might be explained with rational expectations. If contemporary investors were capable of identifying firms with high future innovativeness at the date of the IPO banks did not need to determine a low offering price in order to attract sufficient demand for the shares of such companies. To test whether this conclusion also holds in a multivariate setting we replace our patent variables with our new dummy variables. Table 5 shows the results.

Models 2 and 3 confirm that IPOs of innovative start-ups came along with significantly lower underprizing. The most interesting results, however, occur in models 4 to 6. The first trading prices of both innovative start-ups and permanently innovative firms were significantly higher than the one of the non-innovative firms. This finding suggests that investors associated innovativeness with higher future profits. Even more surprising, investors were also capable of distinguishing between permanently innovative firms and Buddenbrooks, which did not perform better than non-innovative firms, even though both types of firms looked very similar at the date of the IPO with respect to their patent history. This observation implies that pure patent counts that we had used in Table 3 might not be a good proxy for the knowledge that was available to contemporary investors. Obviously, they had access to additional information that allowed them to form correct expectations about the firms' future innovativeness. Since we control for the age of the firm and its actual profit per book value which have both a significant positive impact on the first trading price, this additional information is not based on easily observable data about firms' past economic performance. Reputation effects that spilled over from the lead underwriting bank are also covered.

Table 5: IPOs' short-run performance by different groups of firms (OLS with robust standard errors)

VARIABLES	(1) Initial return	(2)	(3)	(4) Log first trading price	(5)	(6)
Innovative start-ups	-1.001	-2.115**	-2.230**	0.142***	0.120**	0.137***
	(0.262)	(0.0290)	(0.0233)	(0.00276)	(0.0147)	(0.00554)
Buddenbrooks	0.383	-0.666	-0.970	0.0741	0.0488	0.0552
	(0.701)	(0.494)	(0.332)	(0.119)	(0.327)	(0.276)
Permanently innovative	0.326	-1.441	-1.556	0.144***	0.106***	0.104**
	(0.701)	(0.164)	(0.140)	(6.00e-05)	(0.00999)	(0.0110)
Big Four banks	0.288	0.106	0.248	0.0804**	0.0752**	0.0660**
	(0.708)	(0.891)	(0.759)	(0.0160)	(0.0238)	(0.0468)
SEO/IPO	-0.0121	-0.0267	0.0518	-0.0134**	-0.0116**	-0.00568
	(0.938)	(0.847)	(0.697)	(0.0318)	(0.0485)	(0.353)
Size of the issue	-2.22e-08	7.23e-10	-2.65e-08	3.26e-10	9.67e-10	4.89e-10
	(0.531)	(0.984)	(0.520)	(0.833)	(0.541)	(0.778)
Age of firm	0.0402	0.0405	0.0380	0.00506**	0.00550***	0.00525**
	(0.449)	(0.396)	(0.432)	(0.0177)	(0.00642)	(0.0158)
Profit per book value	0.0188	-0.000257	0.00202	0.00734***	0.00782***	0.00758***
	(0.769)	(0.997)	(0.974)	(0.00403)	(0.00213)	(0.00316)
Past market return	4.964	7.297	7.967	0.119	0.207	0.336
	(0.388)	(0.221)	(0.197)	(0.552)	(0.307)	(0.142)
Sektor dummies	n	y	y	n	y	y
time dummies	n	n	y	n	n	y
Constant	3.248***	2.835***	0.668	4.915***	4.930***	4.820***
	(0.000128)	(0.000877)	(0.545)	(0)	(0)	(0)
R-squared	0.011	0.048	0.076	0.158	0.199	0.243
N	292	292	292	292	292	292
F	0.581	1.562	2.130	8.052	8.886	6.606

To evaluate stock market's efficiency we will have now a closer look at firms' long-run performance. If investors anticipated future returns correctly at the first trading day the long-run performance of the different types of newly-listed corporations should not significantly deviate from the general market development. We calculate both the buy-and-hold-ratio (BHR) and the buy-and-hold abnormal returns (BHAR) as follows:

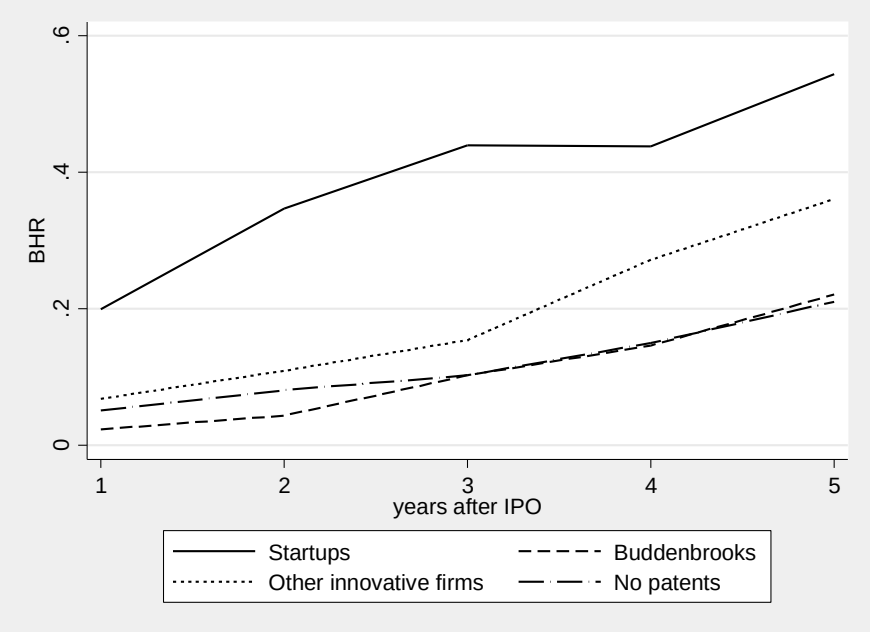
$$BHR_{i,T} = \left[\prod_{t=1}^{T}(1 + R_{i,t})\right] - 1$$

where $R_{i,t}$ is the return of stock i at time t, including dividends and *Stückzinsen*,[13] and T is the time period for which the BHR is determined. To compute the buy-and-hold abnormal returns, the return of the stock market index $R_{M,t}$ is subtracted from the IPO return.

$$BHAR = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\prod_{t=1}^{T}(1+R_{i,t})\right)-\left(\prod_{t=1}^{T}(1+R_{M,t})\right)\right]$$

Figure 3 displays the buy-and-hold-ratios over a five year period for the four different types of IPOs we distinguish. At least in appearance, innovative start-ups performed comparatively better which suggests that these firms' first trading price was still too low to anticipate all above-average future gains. According to the t-values (see Table 6), innovative start-ups had indeed a significantly larger BHR than non-innovative firms after one, three, and five years. The Wilcoxon rank-sum test, however, rejects this hypothesis for the one-year and three-year period. The long-run performance of both Buddenbrooks and permanently innovative firms does not differ significantly from the one of non-innovative firms. These findings imply that most of the differences in future profitability across the four types of IPOs were already covered by the first trading price.

Figure 3: IPOs BHR by different groups of firms



[13] *Stückzinsen* were a fixed yearly dividend payment of four percent of the face value which was paid at the beginning of the trading year.

Table 6: IPOs BHR by different groups of firms

	1 year			3 years			5 years		
	Obs	**Mean**	**t-mean**	**Obs**	**Mean**	**t-mean**	**Obs**	**Mean**	**t-mean**
Start-ups	27	0.175	3.0***	24	0.440	3.3***	22	0.544	1.6**
Buddenbrooks	60	0.043	-0.08	47	0.103	-0.00	39	0.221	-0.26
Perm. innovative	64	0.042	-0.06	57	0.154	0.86	46	0.331	0.58
Non-innovative	285	0.045		258	0.103		209	0.255	
	Obs	**Median**	**z-mean**	**Obs**	**Median**	**z-mean**	**Obs**	**Median**	**z-mean**
Start-ups	27	0.08	1.4	24	0.10	1.3	22	0.305	1.7*
Buddenbrooks	60	0.025	-0.22	47	0.4	0.05	39	0.25	0.57
Perm. innovative	64	0.045	-0.33	57	0.11	0.47	46	0.19	0.38
Non-innovative	285	0.03		258	0.08		209	0.2	

Note: t-mean: t-value of test for difference between groups; z-mean: z-value of two-sample Wilcoxon rank-sum (Mann-Whitney) test.

Loughran and Ritter (1995) show that, in modern markets, IPO stocks performed significantly worse than shares of more seasoned firms in the first five years after going public. This result seems to suggest that investors are in general too optimistic about the future prospects of IPOs. Table 7 shows that this was not true with respect to innovative start-ups and permanently innovative firms at the Berlin stock exchange in the German Empire. Both groups performed more or less like the stock market index. Non-innovative firms, on the other hand, performed significantly worse than the market which is in line with Guo, Lev and Shi (2006) who observe that long-run underperformance of IPOs only occurred in those cases when non-innovative firms went public at the US stock exchange between 1980 and 1995. Interestingly enough, at the Berlin stock exchange, Buddenbrooks also began to underperform after three years. This finding suggests that their sharp decline in innovativeness became fully visible only after some trading years. Though, investors were able to distinguish between Buddenbrooks and permanently innovative firms at the date of the IPO they still overestimated the former's future profitability at the first trading day. Despite this last observation, the Berlin stock exchange was surprisingly efficient when it came to identifying IPO's future innovativeness.

Table 7: IPOs BHAR by different groups of firms

	1 year			3 years			5 years		
	Obs	**Mean**	**t-mean**	**Obs**	**Mean**	**t-mean**	**Obs**	**Mean**	**t-mean**
Start-ups	27	0.090	1.1	24	0.198	0.95	22	0.125	0.81
Buddenbrooks	60	0.013	0.59	47	-0.083	-2.32**	39	-0.124	-2.2**
Perm. Innovative	64	0.000	0.01	57	-0.137	-0.21	46	-0.007	-0.06
Non-innovative	285	-0.018	-1.2**	258	-0.975	-4.4***	209	-0.110	-1.9**
	1 year			**3 years**			**5 years**		
	Obs	**median**	**z-mean**	**Obs**	**median**	**z-mean**	**Obs**	**median**	**z-mean**
Start-ups	27	0.10	0.45	24	-0.60	-0.48	22	-0.09	-0.06
Buddenbrooks	60	0.00	0.18	47	-0.09	-2.68***	39	-0.12	-2.70***
Perm. Innovative	64	-0.00	-0.71	57	-0.06	-1.31	46	-0.12	-1.17
Non-innovative	285	-0.03	-4.1***	258	-0.11	-5.90***	209	-0.14	-5.90***

Note: t-mean: t-value of test for difference between groups; z-mean: z-value of two-sample Wilcoxon rank-sum (Mann-Whitney) test.

Conclusions

In the decades before the First World War Germany changed from a comparatively backward country to one of the global industrial leaders, especially excelling in new and innovative industries such as chemicals, electrical engineering, or machine building. Until now, however, the question has remained widely unanswered how German firms were able to finance their very risky innovation activities. This paper closes this gap of knowledge at least partly by showing that, since the 1890s, many innovative companies relied on the Berlin stock exchange as a source of financing. Even more surprising is the fact that innovators were not penalized by relatively high underprizing or low first trading prices. In the opposite, innovative start-ups that needed equity capital to run their risky R&D projects realized comparatively high offering prices, and, in the longer run, they did not perform worse than more seasoned corporations. These findings not only suggest that contemporary investors associated innovativeness with higher future profits. It is also strong evidence for the assumption that contemporary investors had rational expectations. In particular, they were capable of distinguishing between permanently innovative firms and firms with sharply declining innovativeness (Buddenbrooks), even though both types of firms looked very similar at the date of the IPO with respect to their patent history. This observation implies that pure patent counts that are often used in cliometric studies of innovation might not be a good proxy for the

knowledge that was available at the date of an IPO. To conclude, in the decades before the First World War, the Berlin stock exchange worked as an efficient market for new technology.

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Appendix I

Table A1: underpricing regressions with other firm type specifications

VARIABLES	(1) Initial return	(2) Log first trading price	(3) Initial return	(4) Log first trading price
Innovative Startup (sp. 1)	-2.032**	0.133**		
	(0.0423)	(0.0104)		
Buddenbrooks (sp.1)	-0.710	0.0703		
	(0.488)	(0.179)		
Permanently innovative (sp.1)	-1.983*	0.0890**		
	(0.0520)	(0.0231)		
Innovative Startup (sp. 2)			-2.258**	0.133***
			(0.0176)	(0.00521)
Buddenbrooks (sp.2)			-1.240	0.0589
			(0.198)	(0.216)
Permanently innovative (sp.2)			-1.119	0.108**
			(0.306)	(0.0124)
Big Four Banks	0.254	0.0651*	0.280	0.0657**
	(0.752)	(0.0503)	(0.728)	(0.0471)
Size of the issue	-2.20e-08	6.43e-10	-3.05e-08	4.43e-10
	(0.597)	(0.711)	(0.450)	(0.798)
Age oft he firme	0.0369	0.00512**	0.0395	0.00515**
	(0.441)	(0.0193)	(0.415)	(0.0176)
Profit per book value	0.00118	0.00758***	0.00303	0.00750***
	(0.985)	(0.00316)	(0.961)	(0.00341)
Past market return	8.143	0.322	8.347	0.322
	(0.187)	(0.158)	(0.175)	(0.155)
sector and time dummies	y	y	y	y
Constant	0.593	4.819***	0.653	4.819***
	(0.596)	(0)	(0.551)	(0)
R-squared	0.078	0.239	0.076	0.242
N	292	292	292	292
F	1.713	6.586	1.728	6.823

Table 1 shows that our results are robust to other specification of firm types. In specification 1 the dummy "*innovative start-up*" will be set to one if the respective firm received no patents before the IPO, but at least one in the first five years after it went public. The dummy "*Buddenbrooks*" will be set to one if a firm had patents before the IPO, but none within the first five years after the IPO. In specification 2 the dummy "*innovative start-up*" will be set to one if the respective firm received five times more patents in the first five years after its IPO than during its full existence before its IPO. Conversely, the dummy "*Buddenbrooks*" will be set to one if a firm's number of patents before its IPO was at least five times as high as in the first five years afterward.

All other innovative firms are defined as firms with patents before and after the IPO, which do not fulfil the criteria of either *"innovative start-up"* or *"Buddenbrook"*. The group of *non-innovative firms* without any patents serves as a benchmark in all specifications.