Independent Invention in Italy during the Liberal Age, 1861-1913

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ABSTRACT: in this paper we examine the phenomenon of independent invention in Italy during the liberal age (1861-1913).We make use of a new dataset comprising all patents granted in Italy in five benchmark years: 1864, 1881, 1891, 1902, 1911. We carry out the following exercises. First we examine the relative shares of independent and corporate and foreign invention and their evolution over time and across industries. Second, by exploiting the peculiarities of Italian patent legislation which established a maximum patent length of fifteen years and a flexible renewal scheme which allowed inventors to maintain a patent "alive" for almost any specific duration, we assess the relative quality of independent and corporate patents. Our results indicate that in Italy independent inventors provided an important contribution to technological change but the quality of their patents was significantly lower than that of large firms and of foreign patentees.

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1. Introduction

Following an original cue of Schumpeter (1942), it has been frequently suggested that during the Second Industrial Revolution there was a significant shift in the location of invention from individuals to the research facilities of large firms.[1] This shift was determined by the complexities and the high research costs involved by newly emerging technological systems such as chemicals, electricity and steel (Freeman and Louçã 2001). The search for innovations in these fields required the access to bodies of new scientific knowledge, the integration of different technological skills, the utilization of expensive pieces of equipment and long development times. All this, clearly amounted to a major increase in the scale and scope of the resources underpinning inventive activities and determined a major organizational transformation with large firms and corporations establishing dedicated in-house research laboratories (Mowery and Rosenberg 1998; Freeman and Soete 1997: 80-84; Von Tunzelmann 1995: 161-165).

Lamoreaux and Sokoloff (2012) have shown that this "Schumpeterian" account is indeed supported by the empirical evidence of the US patent records. The patent data studied by Lamoreaux and Sokoloff (2012) shows that, over the period 1870-1911, a growing share of patents were assigned at issue to large-firms and other companies. In their view, this piece of evidence indicates that inventors were increasingly carrying out inventive activities either as firms' employees or by being involved in relationship of long-term collaboration with firms. In a related paper, Lamoreaux, Sokoloff and Sutthiphisal (2009) provide a more "nuanced" picture by noting the existence of two alternative patterns of organization of invention: the first structured around the R&D laboratories of large firms that was typical of the Middle Atlantic region, the second, located in New England, characterized by smaller entrepreneurial dynamic firms.

This "Schumpeterian" tale resulted undoubtedly appealing since it was broadly consistent with narratives of business historians and historians of technology describing the rise of the corporate economy in countries such as the USA, Germany and Britain (Chandler 1990; Hounshell, 1996). However, it did not command a universal consensus. The most famous dissenting voice is probably the classic study by Jewkes, Sawers and Stillerman (1958). On the basis of detailed case studies evidence, they claimed that the most important breakthrough innovations of the twentieth century, were the outcome of the efforts of individual inventors. In their view, the bureaucratization of corporate laboratories produces a conformist approach to research which

[1] Schumpeter's thesis on the demise of individual inventors was actually anticipated in Schumpeter (1928: 370, italics in the text): "[I]n 'trustified' capitalism..[i]nnovation…is not any more embodied *typically* in new firms, but goes on, within the big units now existing, largely independently of individual persons".

ultimately prevents the discovery of genuine radical innovations.[2] As a result, there was no major shift in the "sources of invention" from the nineteenth to the twentieth century and independent inventors have continued to provide the most important contribution to technological progress.

Assessing the historical plausibility of the account by Jewkes, Sawers and Stillerman (1958) is by no means straightforward. Their work is based on detailed historical descriptions of a selection of nineteenth and twentieth century macro-inventions in different countries. Accordingly, it is hard to judge whether their sample of inventions may indeed be regarded as truly representative of historical trends in innovation both worldwide and in specific countries.

In two recent papers, Tom Nicholas (2010; 2011a) has attempted to shed new light on this issue by providing a systematic assessment of contribution of independent inventors to technological progress using evidence from the patent records. Nicholas shows that in the US, Britain and Japan independent inventors continued to account for a very significant volume of inventive activities and, more importantly, for the generation of several high-quality innovations until the late 1930s, playing a vital role for the advancement of the technological frontier. In all these countries, despite the differences in patent legislation, independent inventors could make use of relatively functioning "market for technologies" for reaping economic returns from their inventions, and they could specialize in inventive activities without becoming directly involved in commercialization and production.[3]

In this paper we expand on this line of research by looking at the role played by independent inventors in Italy during the liberal age (1861-1913). We make use of new data-set of all Italian patents granted in five benchmark years. These data allow us to examine closely the inventive output of individual inventors and firms both domestic and foreign.

The Italian case seems particularly promising for further tackling this research question for at least two reasons. First, although Italy, in the period in question, was a latecomer industrializer it was also able to generate endogenously a number of significant breakthrough inventions(radio, electric dynamo, nitroglycerin). This is probably linked to its long term cultural heritage that allowed the country to remain connected with the shifts of the world technological frontier despite its relative economic backwardness (Giannetti 1998). Second, the Italian case is also

[2] For an insightful discussion of the role of individual inventors see O'Brien (1997).
[3] For a thorough appraisal of the functioning of "markets for technologies", see Arora, Fosfuri and Gambardella (2001). For historical evidence on the consolidation of "markets of technologies" in the United States in the period we are considering here, see Lamoreaux and Sokoloff (2002).

interesting in terms of the characteristics of its patent system. In particular, in terms of the cost of patenting, Italy was an intermediate case between the "very expensive" British and German and the "very cheap" Japanese and American patent systems . Since the cost of patents is probably an important factor shaping the incentives of independent invention, the Italian evidence seems to have the potential to shed some further light on this issue.

We proceed as follows. In section 2 we provide a sketch of the Italian patent system in comparative perspective. Section 3 contains a description of the historical sources used and of the methods adopted for the construction of our dataset. In section 4 we present a statistical overview of the data examining the relative shares of independent, corporate, domestic and foreign inventions and their evolution over time, across industries and different locations. Using renewal data as a proxy for the value of patents, section 5 provides a systematic comparison of the relative quality of independent and corporate patents. This is implemented by running zero-truncated binomial regressions having as dependent variable the duration of the patent in years. Section 6 concludes.

Overall, we find that the quality of the patents taken by independent inventors in Italy was lower than that of corporate patents. Our interpretation of this result is that the phenomenon of independent invention in Italy was rather different from the cases of UK and US studied by Nicholas. In these countries, independent inventors were relatively skilled individuals able to generate high quality inventions, perhaps also with a view at their commercialization using market for technologies. On the contrary, in the Italian case, independent inventors provided an important contribution to technological change, but the quality of their patents was significantly lower than that of firms and of foreign patentees.

2. The Italian patent system in comparative perspective

After the political unification, the patent system of the Kingdom of Piedmont was extended to the entire country (Law n. 1657, 31st January 1864). The original version of this law (inspired by the French and Belgian examples of 1844 and 1854) was introduced in Piedmont in 1855. The Italian patent system was a registration system and, accordingly, there was no examination of the actual novelty of the invention patented. In practice, this meant that controversies on the novelty of patents were to be settled by means of court cases. In the Italian system, patents could be registered either in the name of individual inventors or in the name of firms. This allow us to have an immediate assessment on whether a patent is to be ascribed to an individual or firm.

One of the main features of a patent system is the cost of taking and maintaining a patent alive. These costs determine the choice of an inventor on whether and how long protecting his/her invention. If a patent system is very expensive, fewer inventors will resort to patent protection and, at the same time, it is likely that patent protection will be used mostly by firms or independent inventors with sufficient financial resources. Furthermore, in an expensive system, it is unlikely that inventions that are expected to generate limited economic returns will be patented (this because the profits of the invention may not cover the full costs of patent protection).

In Italy the system was extremely flexible: an inventor could take a patent for a duration of 1 up to 15 years according to his own choice. There was an initial fee that was proportional to number of years for which the patent was requested (10 lire for one year, 20 lire for two years…150 lire for 15 years). In addition, it was necessary to pay an annual renewal fee for keeping the patent alive. This fee was increasing over time: 40 lire for years 1-3, 65 lire for years 4-6, 90 lire for year 7-9, 115 lire for year 10-12, 140 lire for year 13-15. In addition, the Law gave also the possibility of "extending" the duration of patent initially taken for a shorter period. For doing this, the inventor had to apply for an *attestato di prolungamento*. This cost 40 lire plus all the other fees required for a normal patent of the same duration. Hence, since *prolungamento* involved and extra cost of lire 40, when the inventor was sure about the prospects of his invention, it was more convenient to take immediately the patent for the desired duration. However, when the prospects of the invention were uncertain, the possibility of taking *prolungamento* gave to the system a further degree of flexibility. Finally, it was also possibility to extend the scope of a patent, for example by adding improvements and other features to an original patent application. This was done by applying for an *attestato completivo* that cost a fixed fee of lire 20.

Unfortunately, it is difficult to compare precisely the costs of patenting in different countries. This because of subtle differences in the structure of patent fees and in actual enforcement of patent protection in different legislations. To these difficulties, we should add the need of converting patent fees in a common currency, taking properly into account the price level and the need of properly discounting the patent fees that must be paid at different moments. So far, there are two seminal contributions that have provided estimates of the costs of maintaining a patent alive for its full legal duration in different systems: Lerner (2000) and Khan and Sokoloff (2006). These estimates are presented in table 1. Khan and Sokoloff formulate their cost assessment using a discrete (1-4) scale based on the conversion of fees in current US$, whereas Lerner attempts to provide precise estimates in 1998 US$. Overall the estimates are in broad agreement.

According to table 1, the most expensive systems of the time were the British and the German. On the other side, in comparative perspective, the American system was cheap and affordable. Interestingly enough, the Italian system has an intermediate position between these two models.

[Table 1 about here]

In figure 1 we compare the structure of renewal fees in Italy, UK and Germany. The renewal fee structure for Britain is discussed in Nicholas (2011b) and that of Germany in Streb, Baten and Yin (2006). The yearly fees have all been converted in US$ using contemporary exchange rates and they refer to a patent taken in 1883 with a duration of 15 years.[4] Overall, the figure shows that (except for the initial year) the costs for keeping a patent alive is systematically lower in Italy than in Germany and UK. The last histogram on the right reports the total amount of the fees paid throughout the patent life (without discounting). Again, Italy appears to offer considerably cheaper fees in comparative perspective. Sokoloff and Khan (1990) and Khan (2005) have argued that the US system by being relatively cheap and accessible provided a large share of the population with the opportunity of exploiting their inventive activities by means of patent protection ("democratization of invention"). Figure 1 prompts the consideration that also the Italian system is probably to be regarded as relatively affordable to individuals (even to those with limited financial resources). For example, according to Bosio (1891) a legal scholar of the time, the idea of making the system accessible also to inventors with limited financial means, was an explicit rationale accounting for the peculiar renewal fee structure of the Italian system.

[Figure 1 about here]

After having presented the Italian patent legislation focusing in particular on the renewal fee structure, it is worth examining the trends in patenting behavior across countries. Figure 2 shows the number of patents per million inhabitants in different systems during the period considered. The critical effect of legislations (and in particular of patent fees) on patenting behavior is illustrated by the sharp discontinuity of the British series in 1883 (when the cost of patenting was drastically reduced). Even if Italy at the time was a latecomer country, its volume of patent activity is not distant from that of a leading country of the Second Industrial Revolution such as Germany. Of course, in drawing this comparison, it is important to keep in mind the significant lower costs of the Italian system presented in figure 1.

[Figure 2 about here]

[4] We are grateful to Giovanni Federico for providing the exchange rates series.

Therefore, the trends presented in figure 2 should not be regarded as a proxy for the innovation performances of different countries. Gaps in innovation performance across countries are instead better captured by the time series presented in figure 3 which shows the number of patents granted in the US to foreign residents normalized by population. This indeed is a proxy for national technological performance which is frequently used in the economics of innovation literature. In figure 3, Germany and UK are clearly the two leading countries, Italy is at a significantly lower level, although there is some "catching up" during the period, whereas Japan is consistently the country at the bottom.

[Figure 3 about here]

Table 2 shows the share of foreign patents in different patent systems. This may be regarded as a proxy for the "openness" of a national patent system. The table indicate that the system with the lowest share of foreign patents is the American. On the other hand, the Italian system seems to be the most open. This may be due to the combined effect of the low costs of patenting, the technological backwardness of the country and its size in terms of population, which made Italy an interesting market.

[Table 2 about here]

3. Sources and Data

We have built a new dataset comprising all patents granted in Italy in five benchmark years: 1864 (240 patents), 1881 (941 patents), 1891 (1,618 patents), 1902 (2,987 patents) and 1911 (4,058 patents). The choice of these benchmarks has been dictated by our concern of ensuring an even coverage of the entire Liberal Age period. Furthermore we have also added to our data a 20% random sample for patents granted in 1922 (288 patents), which allow us to provide a glimpse of post-WWI situation. The historical sources of these data are the Italian official serial publications of *Ministero di Agricoltura, Industria e Commercio* (MAIC 1864-1885, 1886-1893, 1894-1901, 1902-1916, 1917-1923). For each patent we have collected the information:

1. The date in which the patent was applied (*data di deposito*);
2. The date in which the patent was granted (*data di rilascio*);
3. The official patent number;
4. The name(s) of the patentee(s): this may be an individual inventor or a firm;
5. The residence(s) of the patentee(s);
6. The initial duration of the patent;

7. The number and duration of the extensions (*prolungamento*) of the patent;[5]
8. A short description of the invention;
9. The technological category in which the patent was classified by the office;
10. Other information about the life of the patent (changes in the number and residence of patentees following a *prolungamento* or *completivo,* changes in the patent specification).

Using these data, we have computed the actual length of each patent by adding to the initial duration all the years for which the patent was prolonged. This is our main indicator of "patent quality". In addition, we have reclassified all patents from the original administrative technological classes to a new classification inspired to the ISIC (International Standard Industrial Classification) categories.

4. Independent invention in Italy

Using the data compiled by Nicholas (2011a), it is possible to compare the evolution of independent invention in Italy with that of other major industrializing countries (US, Britain and Japan). [6]

Figure 4 shows that the share of independent invention on total patents over the period 1864-1922 is characterized by a decreasing trend in all countries. The observation for 1922 for Italy shows an apparently anomalous resurgence for the share of independent inventors' patents which is in contrast with the global trend. On close inspection, this is an effect of the fall of the share of German and Austrian patents in Italy during and following WW I. Most of these foreign patents were indeed registered in the name of companies. Interestingly enough, also the levels of the shares appear to be remarkably similar for US, Britain and Italy, exhibiting a decline from a share of about 90-95% around 1880 to a share of about 85% in 1900 and, finally declining to about 70-75% during the 1910s. Japan is also characterized by a decreasing trend, but the major decline in the share of independent occurs at a later period: from 1900 to 1920.

Overall, figure 4 suggests that a significant shift towards the growth of corporate patent is actually taking place across all countries. On reflection, this is remarkable since we are considering countries characterized by different patent laws and at different stages of

[5] For each cohort, we have thoroughly checked the possible existence of extensions in the official publications of the following fifteen years.
[6] We would like to thank Tom Nicholas for providing us with the detailed data on independent inventions in US, UK and Japan used in figure 4.

development (two first comers, UK and US; and two latecomers, Italy and Japan). However, it is worth noting that in the 1910s in all countries considered, the share of independent inventors is still almost three quarters of the total. These trends are fully consistent with the "Schumpeterian" tale of the rise of corporate invention discussed in the introduction.

[Figure 4 about here]

Before proceeding further, a word of caution is in order: we should take into account that, as noted by Schmookler (1966: 25-7) determining whether a patent is to be ascribed to a firm or an individual is not straightforward. It is possible that some of the patents assigned to corporations are actually covering inventions due to the efforts of individuals (when, for example, companies have entered in agreements with individuals before the granting of the patent). In the historical context we are considering, this is not very likely with the exception of the US. On the other hand, it is also possible that patents formally granted to individuals are actually covering the formalized inventive activities taking place inside companies. This is probably a more serious source of error for the period we are considering. For this reason, as argued already by Nicholas (2011a), the data presented in figure 4 are to be regarded more as rough approximations rather than exact figures.

Table 3 contains some descriptive statistics of the patent dataset we have constructed. The first panel of the table contains the share of independent inventors and the number of patents. It is interesting to note that while the share of independent inventors' patents is decreasing, their actual number is increasing (from 226 in 1864 to 3,115 in 1911). The first panel shows the relative share of foreign *vis a vis* domestic patents. Consistently with what we have already noticed on the degree of openness of the Italian system, we find that, in all benchmark years, the majority of patents were granted to foreign inventors, reaching a share of 70% in 1891.

[Table 3 about here]

The second panel of table 3 shows that about half of the patents granted to Italian residents were taken by inventors located in the provinces of the "Industrial Triangle" (Genova, Milano, Torino). In particular, for the patents assigned to firms, the share of residents in the "Industrial Triangle" is above two/thirds of the total.

The third panel of table 3 examines the average length of patents. There are two rather clear patterns: i) the average length of patents granted to firms is systematically higher than that of

individuals (with the only exception of 1864); ii) the average length of foreign patents is considerably higher than the Italian ones. The last panel of table 3 considers the renewing behavior of patentees. The shares of patent renewed ranges between one-tenth in 1864 and one-fourth in 1911. The two categories of patentees that make most intensive use of renewals are firms and, at a somewhat lower level, foreign inventors.

In order to study the sectoral distribution of patents we have classified all patents according to 14 industry classes. We have also tried to single out a sub-set of patents directly related to the main "macro-inventions" of this period comprising roughly both the technological systems of the First Industrial Revolution (such as steam power and machine tools) and the emerging new technologies of the Second Industrial Revolution (chemicals, steel and electricity). These categories are indicated in table 4 with a *. We consider this particular set of patents as covering inventions with a significant technological "sophistication" and, accordingly, we label this category "high tech" patents. We have decided to consider as "high tech" patents also those related with the technologies of the First Industrial Revolution to take into account the status of Italy as a latecomer country.[7] Overall, the share of these "high tech patents" is about 40% and is rather stable throughout the period. It is worth noting that independent inventors seems to be rather active in these technological fields.

[Table 4 about here]

5. The determinants of patent length

In the previous section, we have shown that the contribution of independent inventors to patenting remained considerable throughout the period. Moreover, Nicholas (2010, 2011a) has argued that in the US and Britain independent inventors were also responsible for "high-quality" innovations providing significant contributions to the advance of the technological frontier. What about Italy ?

In his contributions, Nicholas adopts the number of citations in US patents as the main indicator of the "quality" of the patent. In the economics of innovation literature, both citations and renewal data have been extensively used as proxies for the quality of patents (Schankerman and Pakes 1986; Griliches 1990; Trajtenberg 1990). Each proxies has both advantages and disadvantages. In our case, if only for "linguistic" reasons, the use of patent citations does not

[7] As noted by Vasta (2006) and Giannetti and Vasta (2010), even the top 200 Italian joint stock companies by assets were mostly active in the sectors of the First Industrial Revolution up to the 1920s.

seem able to provide particularly significant insights and it seems preferable to look only at the renewal behavior of the patentee.[8]

Therefore, we adopt as our indicator of patent value the "real" duration of the patent in years, computed by adding to the initial duration all the years for which the patent was renewed. The intuition is straightforward, patents taken or renewed for longer durations are probably seen, in the eyes, of the patentees as covering more important inventions. Of course, it is possible that some patentee may be prevented from renewing a patent for the desired duration by financial constraints. However, as shown previously (table 1 and figure 1), one of the salient features of the Italian patent system was its relatively low cost and, therefore, we can regard the possible effect of financial constraints as a relatively minor one.

Figure 5 presents the distribution of the patent length by type of inventor. Both for firms and independent inventors the distribution of patent length is concentrated on the range between 1 and 6 years. There is a peak at 6 years because the Italian Law[9] prescribed that a patent taken for a period up to five years had to be put into practice within one year from the granting date. This working requirement was more flexible for patents taken for longer periods of time that instead had to be put into practice within two years of the granting date. Interestingly enough, both for firms and independent inventors, the distribution is also characterized by a peak at 15 years, the maximum length of the patent.

[Figure 5 about here]

In order to assess the quality of the patents taken by independent inventors, we estimate a model of the determinants of patent length. Since our dependent variable ranges from 1 to 15 and the data appear to be characterized by "overdispersion", we estimate a zero truncated negative binomial regression model.

The results are reported in table 5. Our variable of interest is INDEPENDENT (a dummy variable coded as 0 in the case of firm and as 1 in the case of independent inventors). We examine also the effects of other covariates such as FOREIGN (a dummy variable indicating a foreign inventor), INDUSTRIAL TRIANGLE (a dummy variable indicating residence of the

[8] Bessen (2008), on the basis of a detailed empirical study of a large sample of US patents granted in the 1990s, has recently argued that patent citations can be used as a (noisy) indicator of the relative technological significance of a patent, but that renewals are definitely to be preferred as indicators of the economic value of the inventions.
[9] Art. 58, Law of 30th October 1859 and art. 84 of *Regolamento*.

patentee in one of the three provinces of the Italian industrial triangle), URBAN – NOT TRIANGLE (a dummy variable indicating the residence of the patentee in one of the major Italian cities, excluding Milano, Torino and Genova, so that is Venezia, Bologna, Firenze, Roma, Napoli and Palermo), HIGH TECH (a dummy indicating a patent belonging to the high tech classes specified in table 4). In the model we control for industry and time effects (the baseline categories being "textiles, apparel and leather" and "1902").

[Table 5 around here]

Overall, we find that INDEPENDENT has a significant and negative effect on the patent duration across all the specifications, which indicates that patents taken by independent inventors were of lower quality than those taken by firms. The estimated coefficients imply that the class of independent inventors took patents with a duration that was between 26% and 33% shorter than that of other patentees (the percentage change is computed as [exp(coefficient)-1]x100). These result are robust across all the specifications.
Moreover, we find instead a positive and significant effect of the variable FOREIGN, amounting to a higher patent duration of 47% to 69% (again the percentage change is computed as [exp(coefficient)-1]x100). It is interesting to observe from columns 2-6 that independent foreign resident inventors (INDEPENDENT x FOREIGN) generate patents of higher quality. Therefore our findings suggest the existence of an important difference in the technological contribution of independent inventors, with "Italian" independent mostly producing patents of reduced quality and "foreign" independent making instead valuable innovations.

An important stream of literature has suggested that urban areas constitute environments that can foster innovation and inventive activities (Mokyr 1995). In this respect, table 5 shows also that these positive urban effect is significant only in the provinces of the "industrial triangle" which played a pivotal role in the early phase of Italian industrialization and not in the other major Italian cities (columns 3-6). Finally, concerning the technological content of the patents, we find that high tech patents were also correlated with a longer patent life.

Table 6 reports the results for regressions similar to those of table 5, but splitting the sample in two periods (1864-1881-1891 and 1902-1911). Overall, the results are consistent with those obtained in table 5 with only two very interesting differences. First, the effect of INDEPENDENT x FOREIGN is significant only in the last sub-period. Secondly, the effect of INDUSTRIAL TRIANGLE is only significant for the 1902 and 1911 benchmark years. This

finding supports the notion that the first industrialization spurt of the Italian economy was mostly driven by the growing expansion of industrial activities in the industrial triangle.

[Table 6 around here]

6. Conclusions

Independent inventors remain a critical source of innovation during the Second Industrial Revolution, alongside corporate R&D laboratories. This is shown in the case of the United States, where independent inventors were incentivized by a "democratic" and reliable patent system. However, also in the case of Britain, Nicholas (2011a) shows that independent inventors provided an important contribution to technical progress (measured in terms of "valuable" inventions), notwithstanding the high costs of patent protection.

The Italian case, documented in this paper, sheds further light on these issues. During the Liberal Age, Italy was characterized by a relatively cheap and flexible patent system which, at least in principle, appear to provide very favorable conditions for the activities of independent inventors. Accordingly, the evidence examined in this paper shows that independent inventors (both domestic and foreign) made an intensive use of the Italian patent system. However, comparing the Italian with the British case, one may note an important difference. In Britain, a significant share of the innovations patented by independent inventors were of relatively high quality, whereas in Italy independent inventors' patents were clustered on the low quality segment of the innovation quality distribution. Of course, this evidence raises the question on why Italian inventors, despite operating in a seemingly favorable context, failed to act as "a dynamic source of new technology formation" (Nicholas 2011a: 1022) as their British counterparts. Interestingly enough, our findings are in agreement with the innovation patterns in the silk industry described by Federico (1994). The silk industry was one of the few sectors, in which, during the period in question, Italy was the universally acknowledged technological leader. According to Federico, in the industry, the most valuable innovations were introduced by firms that were specialized suppliers of machines and other pieces of equipment. These firms did not resort to patent protection, but they make use of alternative appropriability strategies based on reputation, customers' service, etc. As a result, the large share of patents in this sector were taken by independent inventors. According to Federico's detailed appraisal, most of these independent inventors' patents were of limited economic and technological significance and very few of them were actually put into practice (Federico 1994: 163-5).

In a more general perspective , two factors are probably responsible for the relative low quality of the innovations patented by Italian independent inventors. The first is the structural weakness of the Italian innovation system (especially in terms of human capital formation) throughout this period which, in general, did not provide a favourable context for the generation and development of technological breakthroughs making Italy (Nuvolari and Vasta, 2012). The second explanation revolves more closely around the activities of independent inventors. A recent stream of literature has highlighted the critical role played by institutional arrangements that are complementary to the functioning of the patent system such as patent agents and other intermediaries that allows the functioning of "markets for technologies". These institutions promote the successful commercial implementation of the innovations generated by independent inventors either by facilitating transactions on the "markets for technologies" (licensing or sales of the invention) or by helping to raise the capital for the creation of new companies.
Although the activities of patent agents and other intermediaries in Italy have not been yet studied systematically, it is possible to point to some shreds of qualitative evidence suggesting that the institutional quality of these structures was largely inadequate, at least by international standards.[10] In this respect, a revealing example is the case of Guglielmo Marconi (1874-1937) and the invention of the radio. Marconi made the invention in Italy, but he was able to successfully commercialize its invention only after having moved to England. Guagnini (2002) has documented the key-role played by *Carpmael & Co.* (Marconi's patent agents in London) in ensuring both the international appropriability of the invention and in contributing to the successful gathering of the financial resources necessary for the entrepreneurial exploitation of the invention by means of the creation of a new company.
Another instructive case is that of Alessandro Cruto (1847-1908). Cruto invented a highly efficient electric light bulb that in a systematic experiment in 1883 clearly outperformed Edison's (Coriasso, n.d.) . After the experiment Cruto tried to exploit the invention by taking a patent and creating a new company. However, the commercial success of the firm, also because of its inability of exploiting the patents on international markets, was short-lived and the firm, after several vicissitudes, was finally bought by Philips in 1927.

To sum up, our findings may be seen as adding an important qualification to those obtained by Nicholas. Independent inventors could remain a critical source of invention also during the Second Industrial Revolution period, but it is likely that they could play such a role only when they were supported by an appropriate institutional framework.

[10] Interestingly enough, according to Nicholas (2011a), markets for technologies and related institutions were instead relatively well functioning in the case of Japan, another late-comer country.

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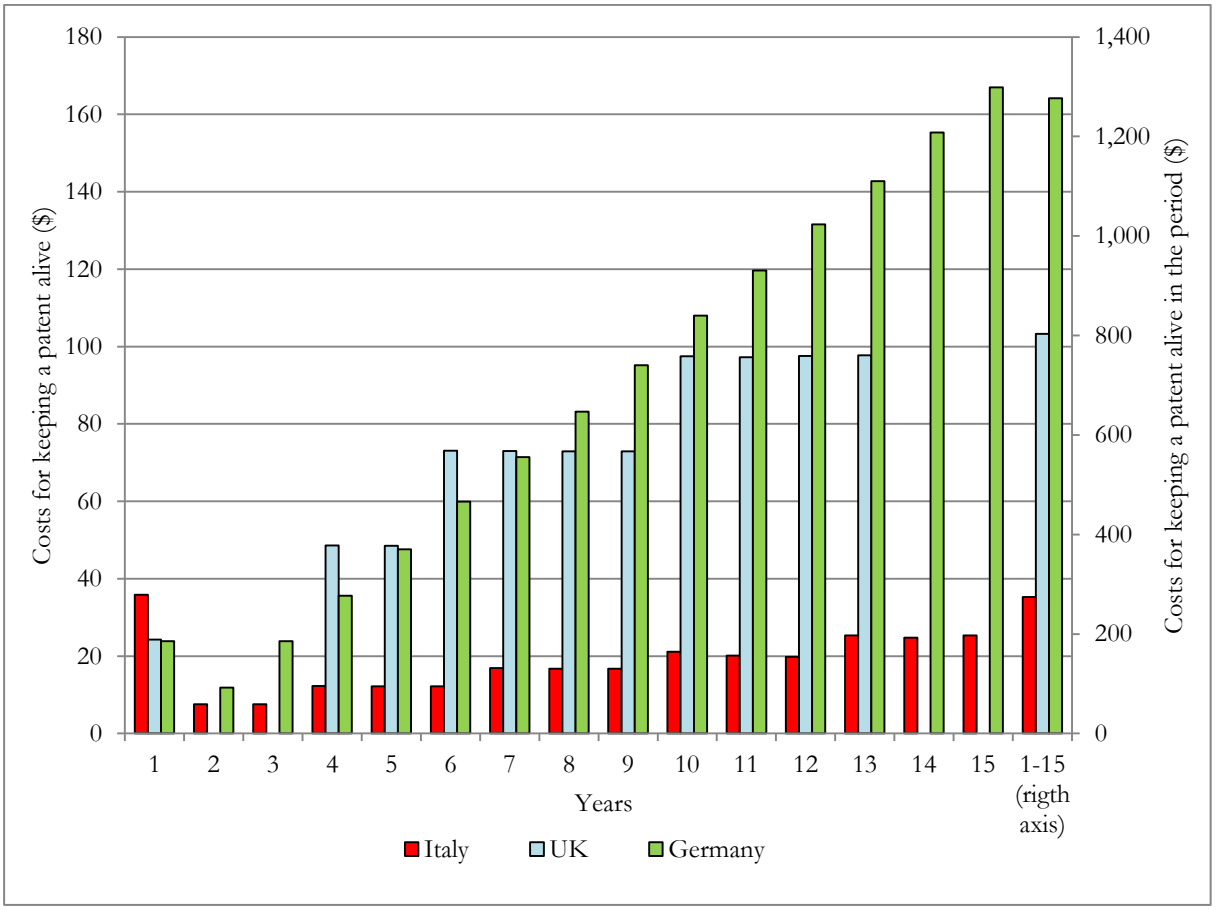
Tab. 1 Cost of patenting (to keep a patent alive for full legal term) in different countries

Countries	1871/1875		1891	1899/1900	
	a	*b*	*a*	*A*	*b*
Germany		19	$$$$	$$$$	22,694
Italy	$$	2,665	$$$	$$$	4,341
Japan				$$	2,356
United Kingdom	$$$$	10,195		$$$$	6,612
United States		546		$	720

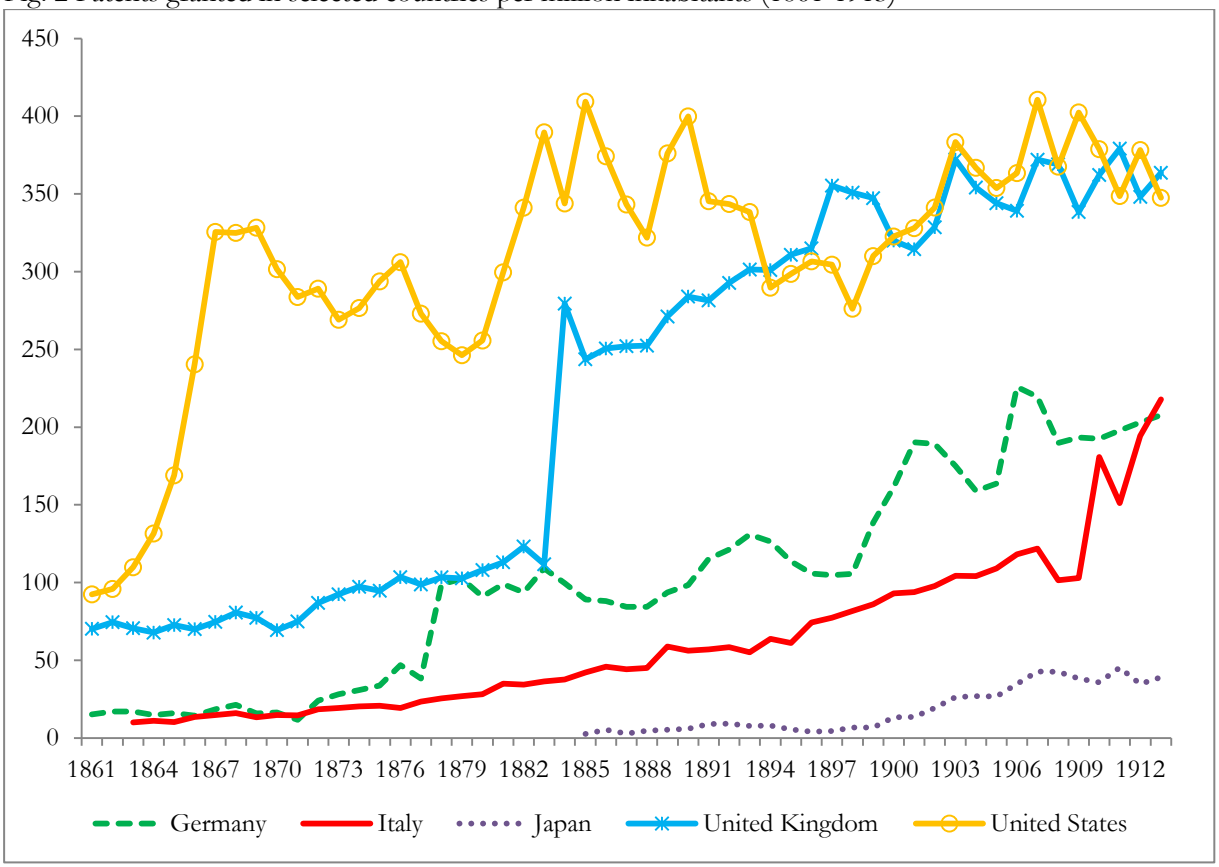
Source: *a*: Khan and Sokoloff (2006, tab. 5.6); *b*: Lerner (2000, tab. 3).
Note: *a*: $ ($ 0-100), $$ ($ 100-250), $$$ ($ 250-500), $$$$ > $ 500 in current US$; *b*: in 1998 US$.

Fig. 1 Annual renewal fees of patenting in Germany, UK and Italy (1883)



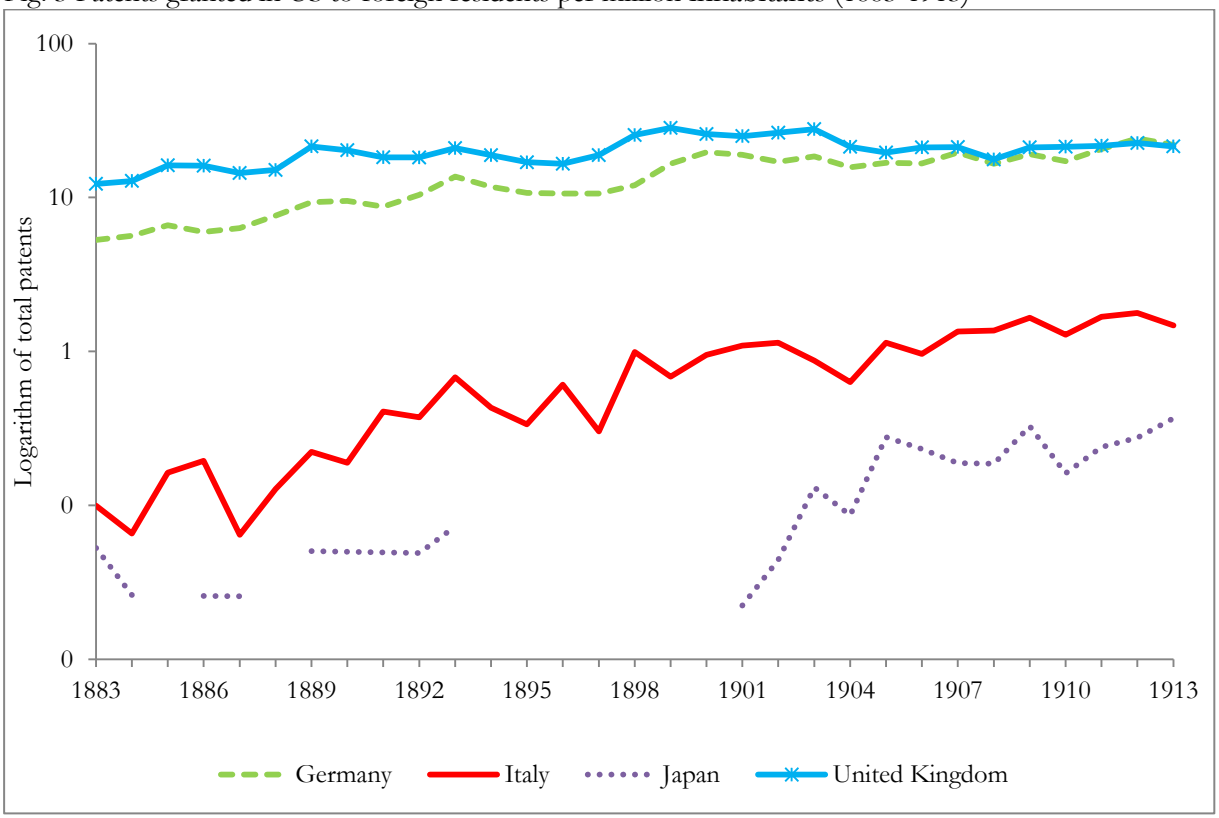
Source: own elaboration based on: UK, Nicholas (2011b), Germany, Streb, Baten and Yin (2006) and Italy Italian Law nr. 1657, 31st January 1864. Exchange rates kindly provided by Giovanni Federico.
Note: years from 1 to 15 in the lest axis; total period 1-15 in the right axis.

Fig. 2 Patents granted in selected countries per million inhabitants (1861-1913)



Source: own elaboration on 1883-1922: WIPO Statistics Database, December 2011; 1861-1882: Khan (2008); data for Italy from MAIC (various years).

Fig. 3 Patents granted in US to foreign residents per million inhabitants (1883-1913)



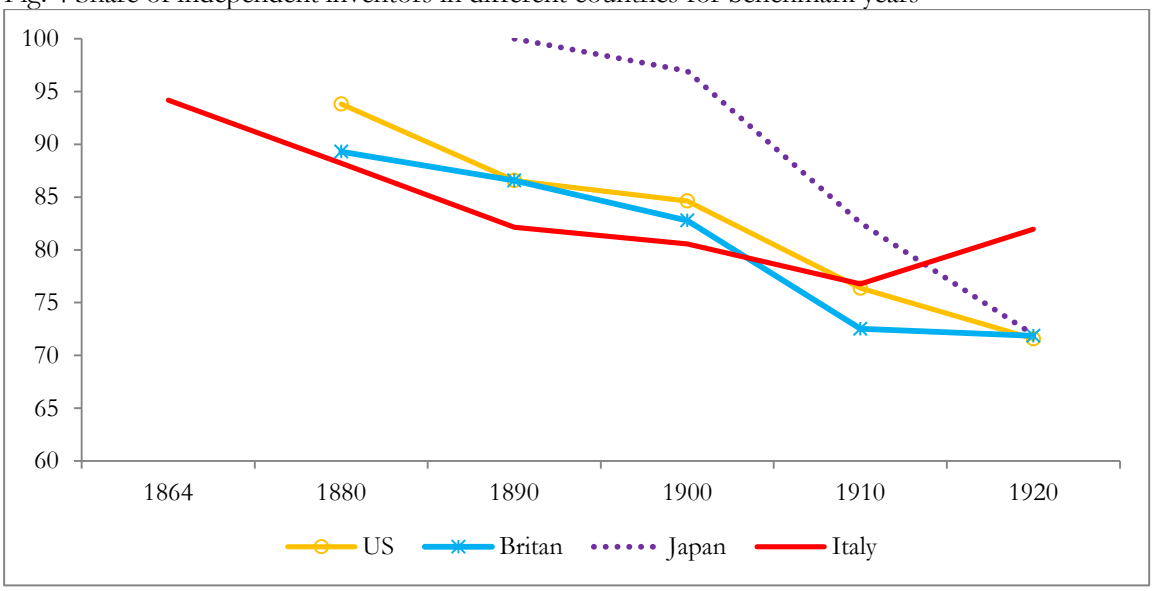
Sources: own elaboration on Maddison (2009) and on USPTO TAF mar. 1977.

Tab. 2 Degree of Openness (% of non-residents on total) of patent systems (1871-1922)

Countries	1871	1880	1901	1914	1922
Germany		31.1	37.1	30.1	25.5
Italy	35.6	64.5	64.5	61.3	56.0
Japan					30.8
United Kingdom			53.2		44.2
United States			13.3	11.5	11.6

Source: own elaboration on WIPO Statistics Database, December 2011; data for Italy from MAIC (various years).
Note: for Germany 1883 instead of 1880; for Japan 1923 instead of 1922; for United Kingdom 1921 instead of 1922.

Fig. 4 Share of independent inventors in different countries for benchmark years



Sources: own elaboration on data kindly provided by Nicholas (2011: Figure 3); for Italy our own elaborations.
Note: for Italy the benchmark years are: 1881, 1891, 1902, 1911, 1922.

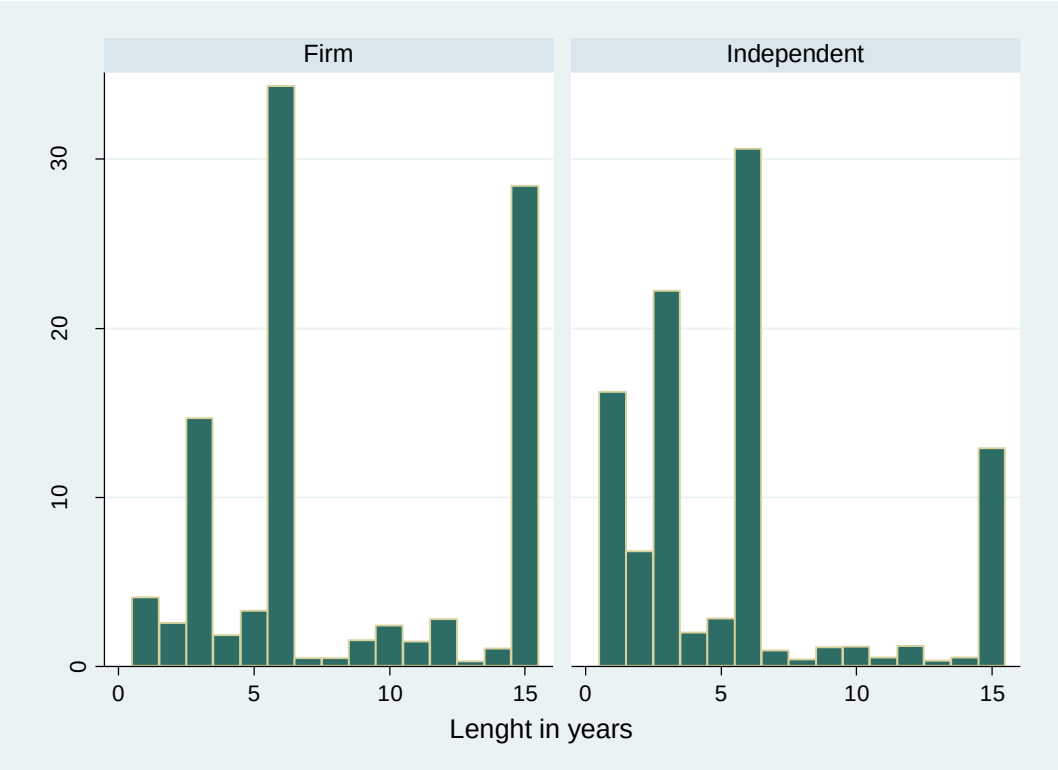
Tab. 3 Italian patent sample (descriptive statistics)

	1864	1881	1891	1902	1911
Number of patents					
Total	240	941	1,618	2,987	4,058
Firm (%)	5.8	11.8	17.9	19.5	23.2
Independent (%)	94.2	88.2	82.1	80.5	76.8
Foreign (%)	50.0	64.1	70.0	65.8	55.6
Italy (%)	50.0	35.9	30.0	34.2	44.4
Industrial triangle cities (Genoa, Milan, Turin) (%)					
Total	60.8	52.1	47.9	49.0	55.0
Firm	85.7	78.0	72.0	66.0	70.6
Independent	59.3	48.5	43.1	47.2	52.5
Average length (years)					
Total	6.5	6.2	7.2	6.3	5.6
Firm	6.2	7.2	9.0	8.5	8.0
Independent	6.5	6.0	6.9	5.7	4.8
Foreign	7.3	7.1	8.4	7.5	6.7
Italy	5.6	4.5	4.6	3.8	4.1
% of patents renewed (excluding patents with original length = 15)					
Total	10.8	17.9	17.5	23.8	24.0
Firm	25.0	23.1	24.9	31.3	35.7
Independent	9.9	17.3	16.1	22.2	20.8
Foreign	10.8	19.8	15.3	27.0	25.0
Italy	10.9	14.7	21.4	18.3	22.8

Tab. 4 Distribution of patents across industries

	1864	1881	1891	1902	1911
Distribution of patents across industries					
Agriculture	5.0	6.6	5.6	3.3	2.9
Chemicals *	10.4	6.8	5.5	5.8	4.7
Construction and construction materials	7.9	3.9	5.7	6.3	7.7
Electricity *	7.1	13.5	14.9	19.3	14.8
Food and beverages	11.7	7.7	3.6	3.7	1.8
Machine tools, other machinery and components *	2.5	2.8	3.2	4.2	4.2
Mining & Metallurgy *	8.3	3.8	3.5	2.5	1.6
Other manufactures (furniture, decorative items, etc.)	10.8	15.3	14.1	7.2	9.2
Paper and printing	3.8	3.5	3.2	4.2	3.8
Scientific instruments	2.9	7.7	4.3	6.2	6.4
Steam engines *	4.6	8.0	10.1	11.0	14.2
Textiles, apparel & leather	7.5	8.2	9.8	10.5	8.2
Transport	12.1	8.9	10.9	12.3	18.0
Weapons *	5.4	3.4	5.8	3.6	2.5
Total	100.0	100.0	100.0	100.0	100.0
% of high-tech patents *	35.4	38.3	39.4	43.9	40.4
Independent	37.6	38.8	37.2	41.6	36.6
Firm	-	34.2	49.8	53.4	52.8

Fig. 5 Distribution of patent length by type of inventor



Tab. 5 Determinants of total patent length (1864-1911)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Independent	-0.307***	-0.406***	-0.383***	-0.394***	-0.389***	-0.323***
	(0.0162)	(0.0384)	(0.0387)	(0.0384)	(0.0389)	(0.0706)
Foreign	0.502***	0.393***	0.471***	0.382***	0.473***	0.525***
	(0.0165)	(0.0379)	(0.0427)	(0.0380)	(0.0430)	(0.0688)
Independent X Foreign		0.133***	0.109***	0.121***	0.101**	0.0492
		(0.0419)	(0.0422)	(0.0419)	(0.0424)	(0.0726)
Industrial Triangle			0.107***		0.0937***	0.183**
			(0.0281)		(0.0281)	(0.0789)
Urban - not triangle				-0.101***		
				(0.0355)		
High Tech Sectors					0.144***	
					(0.0142)	
Independent X Industrial triangle						-0.0868
						(0.0844)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	No	Yes
Constant	1.623***	1.705***	1.627***	1.713***	1.654***	1.572***
	(0.0313)	(0.0426)	(0.0469)	(0.0427)	(0.0428)	(0.0713)
Observations	9,810	9,810	9,810	9,810	9,810	9,810

Note: zero truncated negative binomial regressions (dependent variable is total patent length in years), robust standard errors in parentheses (*** p<0.01; ** p<0.05; * p<0.1). Baseline reference is 1902 for year and textiles, apparel & leather for industry.

Tab. 6 Determinants of total patent length per sub-periods

Variables	Years 1864, 1881, 1891			Years 1902, 1911	
	(1)	(2)	(3)	(4)	(5)
Independent	-0.223***	-0.137*	-0.220***	-0.319***	-0.472***
	(0.0326)	(0.0780)	(0.0326)	(0.0185)	(0.0436)
Foreign	0.490***	0.595***	0.487***	0.601***	0.443***
	(0.0436)	(0.0867)	(0.0439)	(0.0256)	(0.0484)
Independent X Foreign		-0.118			0.180***
		(0.0854)			(0.0476)
Industrial Triangle	-0.00398	0.00614	-0.0208	0.161***	0.131***
	(0.0573)	(0.0580)	(0.0576)	(0.0313)	(0.0317)
High_Tech			0.124***		0.149***
			(0.0268)		(0.0166)
Industry Dummies	Yes	Yes		Yes	
Constant	1.665***	1.590***	1.704***	1.512***	1.649***
	(0.0673)	(0.0918)	(0.0511)	(0.0386)	(0.0467)
Observations	2,798	2,798	2,798	7,012	7,012

Note: zero truncated negative binomial regressions (dependent variable is total patent length in years), robust standard errors in parentheses (*** p<0.01; ** p<0.05; * p<0.1). Baseline reference is textiles, apparel & leather for industry.