INSTITUTE
OF ECONOMICS

Scuola Superiore
Sant'Anna

LEM | Laboratory of Economics and Management

Institute of Economics
Scuola Superiore Sant'Anna

Piazza Martiri della Libertà, 33 - 56127 Pisa, Italy
ph. +39 050 88.33.43
institute.economics@sssup.it

LEM
WORKING PAPER SERIES

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

Alessandro Nuvolari [a]
Michelangelo Vasta [b]

[a] Institute of Economics, Scuola Superiore Sant'Anna, Pisa, Italy
[b] Department of Economics and Statistics, University of Siena, Italy

2013/20 **September 2014**

ISSN (online) 2284-0400

INDEPENDENT INVENTION IN ITALY DURING THE LIBERAL AGE, 1861-1913

Alessandro Nuvolari - Institute of Economics, Sant'Anna School of Advanced Studies, Pisa (alessandro.nuvolari@sssup.it)

Michelangelo Vasta - Department of Economics and Statistics, University of Siena (michelangelo.vasta@unisi.it)

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: 1864-65, 1881, 1891, 1902 and 1911. We carry out the following exercises. First we examine the shares of independent, corporate and foreign inventions and their evolution over time and across industries. Second, by exploiting the peculiarities of Italian patent legislation which was characterized by a relatively cheap fees and a flexible renewal scheme, 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 in terms of number of patents but the quality of their patents was significantly lower than that of firms and of foreign patentees.

JEL codes: N73, O31

We would like to thank Sara Pecchioli for outstanding research assistance and Michele Mannucci for granting us access to the historical library of Ufficio Tecnico Ing. A. Mannucci s.r.l located in Firenze. We are particularly grateful to Lucio Barabesi, Chris Colvin, Giacomo Domini, Giovanni Federico, Gabriel Galvez-Behar, Renato Giannetti, Graeme Gooday, Anna Guagnini, Laura Magazzini, Petra Moser, Tom Nicholas, Roberto Renò and Fabio Vanni for helpful comments and suggestions. The paper has also benefited from the comments of participants at the Economic History Society Annual Conference (York, 2013), the 7th World Congress of Cliometrics (Honolulu, 2013), the European Business History Association Conference (Uppsala, 2013), the European Historical Economics Society Conference (London, 2013), the Workshop "International diversity in patent cultures. A historical perspective" (Leeds, 2014).

Following an original cue of Schumpeter, it has been frequently suggested that during the Second Industrial Revolution there was a major shift in the nature of inventive activities from individuals to the research laboratories of large firms, a process that Bernal eloquently dubbed as "the industrialization of invention".[1] This shift was determined by the complexities and the high research costs involved by the newly emerging technological systems of the Second Industrial Revolution such as chemicals, electricity and steel.[2] 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 employing specialized teams of scientists and engineers.[3]

Lamoreaux and Sokoloff have shown that the empirical evidence of the US patent records provides support to this "Schumpeterian" account.[4] The patent data studied by Lamoreaux and Sokoloff 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 relationships of long-term collaboration with firms. In a related paper, Lamoreaux, Sokoloff and Sutthiphisal provide a more "nuanced" picture by noting the co-existence of two alternative patterns of organization of invention.[5] One structured around the R&D laboratories of large firms was typical of the Middle Atlantic region and is fully consistent with the narrative outlined above. However, alongside this model it is possible to identify a second pattern of innovative activities characterized by smaller entrepreneurial dynamic firms mostly located in New England.[6]

This "Schumpeterian" tale of the rise of organized research 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 US,

[1] Schumpeter, Capitalism and Bernal, Science and Industry, p. 151. Schumpeter's thesis on the demise of individual inventors was anticipated in Schumpeter, 'Instability', p. 384: "[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".
[2] Freeman and Louçã, As Time Goes by.
[3] Von Tunzelmann, Technology and Industrial, pp 161-5; Freeman and Soete, Economics of Industrial Innovation, pp. 80-4; Mowery and Rosenberg, Paths of Innovation. For a detailed case study of the emergence of corporate research laboratories in the German chemical industry, see Meyer-Thurow, 'Industrialization of invention'.
[4] Lamoreaux and Sokoloff, 'Decline of independent inventor'.
[5] Lamoreaux, Sokoloff and Sutthiphisal, 'Reorganization of inventive activity'.
[6] On the rise of corporate intellectual property in the US, see Fisk, Working knowledge.

Germany and Britain.[7] However, it did not command a universal consensus. The most famous dissenting voice is probably the classic study by Jewkes, Sawers and Stillerman.[8] On the basis of detailed case studies evidence, they claimed that the most important breakthrough innovations of the twentieth century, were actually the outcome of the efforts of individual inventors. In their view, the bureaucratization of corporate laboratories produces a conformist approach to research which ultimately prevents the discovery of genuine radical innovations.[9] 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.[10]

Assessing the historical plausibility of the account by Jewkes, Sawers and Stillerman is by no means straightforward.[11] 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 ascertain 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 has attempted to shed new light on this issue by providing a systematic assessment of the contribution of independent inventors to technological progress using evidence from the patent records.[12] 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 significant 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

[7] Chandler, Scale and Scope; Hounshell, 'Evolution of industrial research'.
[8] Jewkes, Sawers and Stillerman, Sources of invention.
[9] For an insightful discussion of the role played by individual inventors in the generation of major technological breakthrough, see O'Brien, 'Micro Foundations'.
[10] For a similar argument, see Hatfield, Inventor, pp. 40-7. For a more 'balanced' interpretation stressing the role both of independent and corporate inventors, see Schmookler, 'Inventors'.
[11] Jewkes, Sawers and Stillerman, Sources of invention.
[12] Nicholas, 'Role of independent invention' and 'Independent invention'. Other papers have recently examined the role played by independent inventors using patents: see, Saiz, 'Social networks of innovation' for Spain in the period 1820-1939; and Basberg, 'Amateur or professional?' for Norway in the second half of the nineteenth century.

inventive activities without becoming directly involved in commercialization and production.[13]

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 dataset 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.[14] The Italian case seems particularly promising for further tackling this research question for at least three reasons.

Firstly, although Italy, in the period in question, was a "latecomer industrializer", it was able to develop autonomously a number of significant breakthrough inventions including "macroinventions" à la Mokyr:[15] Ascanio Sobrero (1812-1888), an academic chemist working in Turin, in 1847 discovered nitroglycerine; Antonio Pacinotti (1841-1912) in 1860 made a major contribution to the development of the electric dynamo; finally, most notably, Guglielmo Marconi (1874-1937) pioneered the first successful long-distance radio-transmission equipment.[16] These achievements are probably explained by a long term cultural heritage that allowed the country to remain connected with the shifts of the world technological frontier despite its relative economic backwardness.[17] In this historical phase, in Italy there was also the rise and consolidation of a number of rather innovative large firms, moving along the technological trajectories of the Second Industrial Revolution such as Edison and Ansaldo.[18] This dynamism at the micro level is confirmed by the recent estimates of Broadberry, Giordano and Zollino, which show that over the period 1881-1911 Italy was able to significantly narrow the gap in industrial labour productivity with the UK.[19]

---

[13] For a thorough appraisal of the functioning of "markets for technologies", see Arora, Fosfuri and Gambardella, Markets for Technology. 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, 'Intermediaries in the US Market'.

[14] The use of patents as a proxy measure of innovation is a widespread practice both in the economics of innovation and in the historical literature. To be sure, it must be recognized that patents data are fraught with several limitations so that other proxy measures have also been introduced in order to assess the rate and direction of technical change (for the use of exhibition data at the World Fairs, see Moser, 'How Do Patent Laws Influence'). However, on this point it is still worth quoting the seminal book by Schmookler, Invention and Economic Growth, p. 56: 'We have a choice of using patent data cautiously and learning what we can from them or not using them and learning nothing about what they can teach us'. For a recent comprehensive survey on this issue, see Nagaoka, Motohashi and Goto, 'Patent statistics'.

[15] Mokyr, Lever of Riches, pp. 13-14.

[16] For a useful survey of the major scientific and technological developments in Italy during the Liberal Age, see Maiocchi, 'Ruolo delle scienze'.

[17] Giannetti, Tecnologia e sviluppo.

[18] The 'Italian' Edison company was able to build one of the first electric power station of the world (see Guagnini, 'A bold leap'). Ansaldo, initially exploiting partnerships and licensing agreements with foreign firms, was active in several high tech sectors (for a technology history of Ansaldo, based on patent data, see Vasta, 'Innovazioni tecnologiche'.

[19] Broadberry, Giordano and Zollino, 'Productivity'.

Secondly, the Italian case is also interesting in terms of the characteristics of its patent system. In particular, in terms of the costs of patenting, Italy was an intermediate case between the "very expensive" British and German and the "very cheap" American patent system. Since the cost of patents is 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.

Thirdly, it is worth noting that Italy, mainly for the appeal of its market, was characterized by a large presence of foreign firms which operated in the most technological advanced sectors. These firms conveyed intense technology flows which resulted, also for the cheapness of the Italian patent system, in a considerable patenting activity. Instead, Italian firms − mostly of small size − were mainly focused in traditional sectors. Nevertheless, some Italian firms, also through license agreements with large foreign companies, were often able to adapt advanced foreign technology to the local context.[20]

Overall, we find that the quality of the patents taken by independent inventors in Italy was lower than that of corporate patents. Our suggested interpretation 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 could provide an important contribution to technological change, but the quality of their patents was significantly lower than that of firms and of foreign patentees. We shall argue that this phenomenon can be ascribed to the backwardness of the Italian human capital stock, which, at the time, presents a low level of literacy – with remarkable regional disparities – a limited level of schooling and a scarce and scattered diffusion of formalized technical competencies.[21]

We proceed as follows: in section I we provide a sketch of the Italian patent system in comparative perspective. Section II describes the historical sources and the methods used for the construction of the dataset. In section III 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

[20] For a recent assessment of the role of foreign technology in Italy, see Barbiellini Amidei, Cantwell and Spadavecchia, 'Innovation and foreign technology'. On the issue of firms' size, see Amatori, Bugamelli and Colli, 'Technology and firm size'.

[21] On human capital in Italy, see: A'Hearn, Auria and Vecchi, 'Istruzione' and Felice and Vasta, 'Passive modernization'. For a broad comparative perspective with other countries, see: for literacy rates, Cipolla, Literacy and development, passim; and Nuvolari and Vasta, ' Ghost in the attic', table 1; for educational attainments, Morrison and Murtin, 'Century of Education', and for stocks of engineers, Vasta, Innovazione tecnologica e capitale umano, p. 250.

proxy for the value of patents, section IV provides a systematic comparison of the relative quality of independent and corporate patents. Section V concludes.

I

The Kingdom of Sardinia (which, despite the name, consisted mainly of Piedmont and Liguria) played a major role in the process of Italian political unification culminating in 1861 with the proclamation of Vittorio Emanuele II as King of Italy. As many other laws and regulations, the Piedmontese patent system was extended to the 'new' country (Law n. 1657, 31st January 1864). The original version of this patent law (inspired by the French and Belgian examples of 1844 and 1854) had been introduced in Piedmont in 1855. In a nutshell, the main features of the Italian patent system were the following. It 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.[22] This peculiarity of the Italian patent Law allow us to have an immediate direct assessment of whether a patent is to be ascribed to an independent inventor or to a firm.

Another important feature of a patent system is the cost of taking and maintaining a patent alive. These costs affect the choice of an inventor on whether and how long protect his invention. If a patent system is very expensive, fewer inventors will recourse 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 register a patent for a duration from 1 to 15 years according to his own choice. There was an initial fee that was proportional to the number of years for which the patent was requested (10 Italian 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 the first three years, 65 lire from the fourth to the sixth year, 90 lire for the seventh up to the ninth year, 115 lire for the tenth to the twelfth year and 140 lire for the last three years. It is

[22] The article 27 of Regolamento of the 1864 Law stated explicitly that the application for a patent could be submitted both by individuals and by corporations or other organizations.

worth noticing that the *Gazzetta Ufficiale del Regno d'Italia* regularly published the entire list of patents expired due to non-payment of the renewal fees. Furthermore, the Law gave also the possibility of "extending" the duration of a 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 an extra cost of 40 lire, 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 possible 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 20 lire.

Unfortunately, because of subtle differences in the structure of patent fees and in the actual enforcement of patent protection in different legislations, it is not straightforward to compare precisely the costs of patenting in different countries. To these difficulties, we should add the need of converting patent fees in a common currency, taking properly into account variations in the price level and properly discounting the patent fees that must be paid at different moments.

Nevertheless, in figure 1 we report the estimates of the costs of patenting (in 1998 US$) in different systems reconstructed by Lerner.[23] Figure 1 shows that the most expensive systems around 1900 were the British and the German. On the other hand, in comparative perspective, the American system was cheap and affordable. Interestingly enough, the Italian system has an intermediate position between these two models.

[Figure 1 about here]

The renewal fee structure for Britain and Germany have been recently discussed respectively by Nicholas and by Streb, Baten and Yin.[24] Figure 2 compares the structure of renewal fees in Italy, UK and Germany. The yearly fees have been measured in relation with the average weekly wages of workers in the engineering sector. Overall, this normalized measure confirms 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. Again, Italy appears to offer

[23] Lerner, '150 Years'. Note that the first national patent law in Germany was introduced in 1877.
[24] Nicholas, 'Cheaper patents'; Streb, Baten and Yin, 'Technological and geographical knowledge'.

considerably cheaper fees in comparative perspective. It is worth noting that the most expensive annual renewal fees (those for years 13, 14 and 15) are lower than the cost in year 1. For this reason, it seems very unlikely that an inventor who had been able to enter in the Italian system (paying the costs in year 1) was later on unpaired in his renewal behavior by credit constraints.[25] Of course, this argument does not exclude that some independent inventors may not have been able to access the patent system because of credit constraints. Nevertheless, these inventors are not included in our sample and consequently they do not affect the results of our work as far as patenting behavior is concerned.

Sokoloff and Khan 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").[26] Figure 2 suggests that also the Italian system was probably relatively affordable to individuals (even to those with limited financial resources). For example, according to Bosio, an authoritative legal scholar of the time, the ease of access to the system also to inventors with limited financial resources, was an explicit rationale accounting for the peculiar renewal fee structure of the Italian system.[27]

[Figure 2 about here]

After having discussed the Italian patent legislation , it is worth examining trends in patenting behavior across countries. Figure 3 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 patenting 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 figures 1 and 2.

[Figure 3 about here]

[25] Interestingly enough, this peculiarity of the Italian system supports the use of renewal data as indicator of the quality of patents.
[26] Sokoloff and Khan, 'Democratization of invention'; Khan, Democratization of Invention: Patents and Copyrights.
[27] Bosio, Privative Industriali.

The trends presented in figure 3 should not be regarded as a proxy for the innovation performances of different countries. Technology gaps across countries are instead better captured by the time series presented in figure 4 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.[28] In figure 4, 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,[29] whereas Japan is consistently at the bottom.

[Figure 3 about here]

Table 1 shows the share of foreign patents in different countries. This may be regarded as a proxy for the "openness" of national patent systems. The table shows that the system with the lowest share of foreign patents is the American. On the other hand, the Italian system is definitively the most open. This is remarkable because, as noted by Bilir, Moser and Talis, before the Paris Convention of 1883, in most countries patenting abroad was severely constrained by procedural difficulties and discriminatory clauses.[30] Overall, the large share of foreign patents in Italy is probably to be ascribed 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 appealing market.

[Table 1 about here]

II

To study the phenomenon of independent invention in Italy by means of systematic quantitative evidence, we have built a new dataset comprising all the 10,124 patents granted in Italy in five benchmark years: 1864-65 (520 patents), 1881 (941 patents), 1891 (1,618 patents), 1902 (2,987 patents) and 1911 (4,058 patents).[31] The choice of these benchmarks has been dictated by our concern of ensuring an even coverage of the entire Liberal Age period.[32]

[28] See for instance, Freeman and Soete, Economics of Industrial Innovation.
[29] This successful catching up phase can be also noticed considering the Italian performance in different European patent systems as it has been shown by Barbiellini Amidei, Cantwell and Spadavecchia, 'Innovation and foreign technology', figure 14.1.
[30] Bilir, Moser and Talis, 'Do treaties encourage'.
[31] Given the small number of patents registered in the early years after the unification, we decided to consider an initial benchmark of two years, 1864 and 1865.
[32] We have attempted to choose benchmarks corresponding to the census years, with the exception of 1864-65 (the first years of the MAIC publication) and of 1902, since in that year there is a new official publication of MAIC, which is more accurate in reporting patent descriptions and durations.

The historical sources of these data are the Italian official serial publications of Ministero di Agricoltura, Industria e Commercio (MAIC). For each patent we have collected the following 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;[33]
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;[34]
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);
11. For benchmark years 1881, 1891 and 1902 we also have information about the date in which the patent expired because the patentee did not pay the renewal fees. This allow us to determine the "real" duration of the patent.[35] The information about the expiration of patents due to missing payment of renewal fees was collected by examining the complete series of the *Gazzetta Ufficiale del Regno d'Italia* for fifteen years after each benchmark year.

In addition, we have reclassified all patents from the original administrative technological classes to a new classification mainly inspired to the International Standard Industrial Classification (ISIC) categories.

III

[33] By following patents over their lifespans, we have identified 106 patents that were initially granted to independent inventors and some years later, when prolonged, were attributed to firms. In this case, we have decided to classify these patents as corporate. Interesting enough, 12 of these patents were granted to Thomas A. Edison and prolonged few years later in the name of Compagnie Continentale Edison Societé Anonyme. In fact, for these twelve patents we were able to trace an announcement stating the property transfer from Edison to the Compagnie Continentale Edison published on *Gazzetta Ufficiale del Regno d'Italia,* n. 58, March 11, 1885, p. 1146 (we thank Anna Guagnini for pointing this reference to our attention).

[34] For each cohort, we have thoroughly checked the possible existence of extensions (prolungamento) in the official publications of the following fifteen years.

[35] It was not possible to retrieve such information for 1864-65 cohort because the Gazzetta Ufficiale del Regno *d'Italia* provided the full list of expiring patents only starting from the last trimester of 1867. At the same time, it was not possible to gather information for 1911 cohort because from 1915 the Gazzetta did not publish anymore the list of expired patents.

In figure 5 we compare the evolution of independent inventions in Italy with those of other major industrializing countries (US, Britain and Japan) using the data compiled by Nicholas.[36] We have also added data from Spain taken from Saiz.[37] Figure 5 shows that the share of independent inventions on total patents over the period 1864-1914 is characterized by a decreasing and concomitant trend in all countries. Interestingly enough, also the levels of the shares appear to be remarkably similar for US, Britain, Spain and Italy, exhibiting a decline from a share of about 90-95 per cent around 1880 to a share of about 85 per cent in 1900 and, finally declining to about 70-75 per cent 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 1910.

Overall, figure 5 suggests that a significant shift towards the growth of corporate patents, possibly consistent with Bernal's "industrialization of invention",[38] 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 development (two first comers, UK and US; and three latecomers, Italy, Japan and Spain). 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. Still, these trends are fully consistent with the "Schumpeterian" tale of the rise of corporate inventions previously discussed in the introduction.

[Figure 5 about here]

Before proceeding further, a word of caution is in order: we should take into account that, as noted by Schmookler, determining whether a patent is to be ascribed to a firm or an individual is not always straightforward.[39] 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

[36] Nicholas, 'Independent invention'. 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 5.
[37] Saiz, 'Social networks of innovation'.
[38] Bernal, Science and Industry, p. 151.
[39] Schmookler, Invention and Economic growth, pp. 25-6.

already argued by Nicholas, the data presented in figure 5 are to be regarded more as approximations rather than exact figures.[40]

Table 2 contains descriptive statistics of the patent dataset we have constructed. The first panel of the table simply shows the total number of patents and the share of independent inventors, which is decreasing along the period. The second panel gives information about the localisation of the patentees. Consistently with what we have already noticed on the degree of openness of the Italian system, we see that in all benchmark years the majority of patents were granted to foreign inventors. In 1891 they reached a peak amounting to more than two times the Italian ones. In particular, it is also worth noticing that, for the two last benchmark years, the shares of patents granted to firms are considerably higher for foreign (25.8 per cent for 1902 and 31.9 per cent for 1911) than for Italian (respectively 10.8 per cent and 14.3 per cent) residents. Moreover, it emerges that about half of the patents granted to Italian residents were taken by inventors located in the "industrial triangle" (the nearby provinces of Genova, Milano and Torino situated in the North-West of the country), which was the cradle of the Italian industrialization process.

[Table 2 about here]

The third panel of table 2 examines the average 'scheduled' length of patents, which takes also into account the extensions (prolungamento) granted to each single patent. There are two rather clear patterns: i) the average length of patents granted to firms is systematically higher than that of individuals; ii) the average length of foreign patents is considerably higher than the Italian ones. The last panel considers the behavior of patentees with respect to the extension of the patent using prolungamento. The shares of patent prolonged ranges between one-tenth in 1864-65 and one-fourth in 1911. The two categories of patentees that made most intensive use of extensions are firms and, at a somewhat lower level, foreign inventors.

In order to better illustrate the localization of inventive activity, in figure 6 we present a set of maps showing the geographical distribution of patents registered by Italian residents along the period. There is a rather clear cut divide with the distribution strongly concentrated in the Northern and in the Central areas of the country. The "Industrial Triangle" is somewhat delineated already in the first benchmark year, and it becomes clearly visible since 1881. In the later years, this centrality appears definitely much stronger. Moreover, it is worth noticing

[40] Nicholas, 'Independent invention', pp. 1001-3.

that since 1891 Roma emerges as a province with a strong density of patenting, possibly because of its administrative role as the capital of the Kingdom.

[Figure 6 about here]

In order to study the sectoral distribution of patents we have classified all patents according to 14 industry classes. Table 3 shows that patenting activity was concentrated in three main fields, corresponding to electricity, steam engines and transport. In all benchmark years these three industries together have a share of about one third of total patents. If we limit our attention to the two major technologies of the Second Industrial Revolution, chemicals and electricity, it is interesting to notice the contrast between the relatively large share of electricity patents in comparison with the limited share of chemicals patents.[41] These patterns are consistent with historical accounts that have remarked on the relatively success of the Italian electricity industry and the sluggish evolution of the chemical industry.

In order to provide a more systematic assessment of the patent evidence, we have identified a sub-set of patents directly related to the main "macro-inventions" of this period comprising 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 3 with an *. We have considered this particular set of patents as covering inventions with a significant degree of technological "sophistication" and, accordingly, we label this category as "high tech" patents. We have regarded 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.[42] Overall, the share of these "high tech patents" is about 40 per cent and is rather stable throughout the period. It is worth noting that independent inventors seems to be rather active in these technological fields.

[Table 3 about here]

IV

[41] See Giannetti, Tecnologia, pp. 101-12. For a more extensive discussion of inventive activities in chemicals and electricity based on patent data, see Vasta, Innovazione tecnologica e capitale umano, pp. 129-210.
[42] Fenoaltea, Reinterpretation of Italian, pp. 233-5, considers the industrial expansion of the Liberal Age in Italy as based on a peculiar combination of the technological trajectories of the First and of the Second Industrial Revolution. Vasta, 'The largest 200 manufacturing' and Giannetti and Vasta, 'Big business' point out that 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.

In his contributions, Nicholas adopts the number of citations in the US as the main indicator of the "quality" of a patent.[43] In the economics of innovation literature, both citations and renewal data have been extensively used as proxies for the quality of patents.[44] The intuition behind the use of citations is that patents covering important inventions will receive many citations by follow-up patents. The logic of using the renewal behavior is instead the idea that inventors will pay the renewal fees only as long as the economic returns of the patent would exceeds the costs of keeping it "alive". Each proxies has both advantages and disadvantages. It is unlikely that an Italian patent would be cited in US patent applications because very few US inventors or patent examiners were probably able to read patent specifications written in Italian. For this reason, the use of US patent citations to Italian patents does not seem a suitable approach. On the other hand, the Italian Law did not prescribe the use of citations for documenting prior art. Therefore, in this period, Italian patent citations did not exist. Hence, the only approach available in the Italian case is to use, as proxy measure of patent value, the renewal behavior of the patentee. The use of renewal behavior to estimate the quality of patents has been adopted as a reasonable working procedure also in other recent studies dealing with the same historical period such as Streb, Baten and Yin and Saiz.[45]

Our dataset allows us to construct two different indicators of patent value. The first is what we label the "scheduled" length of a patent (measured in years). This is computed by adding to the initial duration all the years for which the patent was prolonged. The intuition is straightforward: patents taken or prolonged for longer durations are probably seen, in the eyes of their patentees, as covering more important inventions.

The second proxy of patent value that we construct is what we label the "real" length. This proxy is measured by the full period for which the fees of the patents were regularly paid by the patentee. To sum up, the first proxy − the "scheduled" length − may be interpreted as representing an ex ante assessment of the value of the patent, with some possible revisions due to the extensions. Instead, the second proxy − the "real" length − reflects an ex post assessment of the quality of the patent.

[43] Nicholas, 'Role of independent invention' and 'Independent invention'.
[44] On patent citations as indicator of patent quality see Trajtenberg, 'A penny' and Moser, Ohmstedt and Rhode, 'Patent citations'. On patent renewals see Schankerman and Pakes, 'Estimates' and Griliches, 'Patents', pp. 1679-1682.
[45] Streb, Baten and Yin, 'Technological and geographical' and Saiz, 'Social networks of innovation'. On the basis of a detailed empirical study of a large sample of US patents granted in the 1990s, Bessen 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, see Bessen, 'Value'.

The plausibility of this approach is confirmed by comparing the length of patents registered by Italian residents in Italy with that of patents registered by Italian residents both in Italy and in the US.[46] The intuition underlying this comparison is that patents registered also in the US system, which was obviously regarded as a very large and significant market by Italian inventors, will cover innovations of higher quality. Indeed, it is not likely that an Italian inventor would have made the effort of registering a patents in the US system, unless he was convinced to own a really valuable innovation. Table 4 shows that both for "scheduled" and for "real" lengths the mean and median number of years of patents granted both in Italy and in the US are considerably higher than that granted only in Italy. A non-parametric Mann-Whitney test confirms that these differences between the two distributions are statistically significant.[47] Overall, the evidence presented in table 4 validates the adoption of Italian renewal data as a suitable proxy of the quality of patents.

[Table 4 about here]

Table 5 presents the data on the renewing behaviour of the patentees. The first panel of the table contains the share of patents that expired, because the patentees did not paid the renewal fees, before their "scheduled" duration. Overall the share of expired patents is around two/thirds of the total and it is very similar for independent inventors and firms. In the second panel of the table, we examine the average "real" duration in terms of years. As expected, we find that the average duration is higher for firms and foreign inventors. Finally, in the third panel we show the share of patents which expired within the first year of life: this might perhaps be regarded as a sort of "infant mortality rates" of patents. The mortality rate of about 30 per cent seems quite remarkable, but more importantly there is a significant difference between independent inventors and firms, the former being characterized by a much higher share of patents not surviving the first year of life.

[Table 5 about here]

Figure 7 presents the distribution of the "scheduled" patent length by type of inventor. Both for firms and independent inventors the distribution of "scheduled" patent length is concentrated on the range between 1 and 6 years. There is a peak at 6 years because the Italian Law prescribed that a patent taken for a period up to five years had to be put into practice

[46] We would like to thank Giacomo Domini for sharing with us the data of US patents granted to Italian residents.
[47] We have carried out the Mann-Whitney test because the distributions of the durations in the two samples are skewed and not normal.

within one year from the granting date.[48] This working requirement was less rigid 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, for firms and, to a minor degree, also for independent inventors, the distribution is characterized by a peak at 15 years, the maximum length of the patent.

[Figure 7 about here]

Figure 8 shows the distribution of "real" patent length by type of inventor. In this case the total distribution is left skewed with a high concentration of low quality patents, which is a pattern fully in line with similar evidence emerging from contemporary data of patent value.[49] The distribution of independent inventors and firms seems to be quite similar even if firms data present a higher peak for patents of 15 years duration.

[Figure 8 about here]

Figure 9 contains histograms of the joint distribution of the two proxy measures of patent value. It is interesting to note that the distribution it is not spread evenly on the underlying support and it is concentrated on the range of values 1-6 years with a series of additional peaks for value of 15 years.

[Figure 9 about here]

In order to fully assess the quality of the patents of independent inventors in Italy, we estimate an econometric model of the determinants of patent length. As dependent variable we consider the number of years for which each patent has been taken or renewed beyond its initial year. Since the minimum patent life for all patents is 1, we can consider as indicator of patent quality either the complete patent life ranging from 1 to 15 or the number of years of renewal beyond the initial year ranging from 0 (when a patent is not renewed beyond its initial year) to 14 (when the patent is at its maximum duration and it is renewed for 14 years beyond the initial year). Considering the number of years of renewal, beyond the initial year as a measure of patent length, has the advantage of avoiding the use of zero-truncated models. Accordingly, we estimate the following count regression model:

[48] Art. 58, Law of 30th October 1859 and art. 84 of Regolamento.
[49] Silverberg and Verspagen, 'Size distribution'.

$$E[\text{PATLENGTH} \mid X] = \exp\left[\alpha \text{INDEPENDENT} + \sum_t \beta_t \text{YEAR}_t + \sum_i \gamma_i \text{INDUSTRY}_i + \sum_c \delta_c Z_c + \varepsilon\right] \quad (1)$$

where PATLENGTH is either the "scheduled" or "real" patent length, INDEPENDENT is a dummy variable taking the value of 0 if the patentee is a firm and of 1 if the patentee is an independent inventor, $YEAR_t$ is a set of dummy variables for the different benchmark years of our patent sample, $INDUSTRY_i$ is a set of dummy variables for the different industries and Z_c is a set of control variables, including a constant.

In this case, the most suitable econometric approach is the use of a censored Poisson regression model with robust standard errors estimated with the pseudo-maximum likelihood method.[50] We consider our dependent variable PATLENGTH as right-censored since 14 years is the maximum observable value of PATLENGTH (this means that a patentee was available to renew its patent for a period of at least 14 years). However, it is possible that the assessment of the value of the patent by the patentee would have justified to renew the patent even for a longer period if the law would have allowed him this option.[51]

The results for "scheduled" patent length are reported in table 6. Our variable of interest is INDEPENDENT. 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 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 3). As mentioned, we control for industry and time effects (the baseline categories being "textiles, apparel and leather" and "1902").

[Table 6 about here]

We find that INDEPENDENT has a significant and negative effect on patent length across all the specifications, which indicates that patents taken by independent inventors were of

[50] Gorieroux, Monfort and Trognon, 'Pseudo maximum likelihood' have shown that the parameter estimates of the Poisson model are consistent even if the count is not Poisson distributed and the data are characterized by over-dispersion.

[51] For a discussion of censored count models see Hilbe, Negative binomial, pp. 387-406. We adopt what Hilbe calls the "econometric specification" of the Poisson censored model and we consider all the observations with a value of 14 as potentially right-censored, see Ibid, pp. 395-6. As additional robustness checks, we have also estimated a set of censored negative binomial and a set of ordered logit models, corresponding to the specifications reported in tables 6 and 7, obtaining fully consistent results.

lower quality than those taken by firms.[52] The estimated coefficients imply that independent inventors took patents with a "scheduled" duration that was between 45.7 per cent and 54.6 per cent shorter than that of other patentees (the percentage change is computed as [exp(coefficient)-1]x100). These results are robust across all the specifications.[53]

Moreover, we find also a positive and significant effect of the variable FOREIGN, amounting to a patent length of 87.9 per cent to 122.6 per cent higher than that of the other patentees (again the percentage change is computed as [exp(coefficient)-1]x100). It is interesting to observe from columns 2-5 that independent foreign 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. A possible interpretation of this result is that the independent foreign inventors decided to take patents in Italy only for their most valuable inventions.

An important stream of literature has suggested that urban areas constitute environments that can foster innovation and, more generally, inventive activities.[54] Table 6 shows also that these positive urban effects are significant only in the provinces of the "industrial triangle" which played a pivotal role in the early phase of Italian industrialization and not in other major Italian cities (columns 3-5). Finally, concerning the technological content of the patents, we find that high tech patents were also correlated with a longer patent life.

Table 7 reports the results for regressions similar to those of table 6, but using as dependent variable the "real" patent length. These regressions cover only the three benchmark years (1881, 1891 and 1902) for which we could calculated the "real" patent length using renewal data. Overall, the results are consistent with those obtained in table 6. In this case the negative impact of independent inventors on the "real" patent length is significant and higher than in the case of the "scheduled" patent length. In some specifications the coefficients for FOREIGN and INDEPENDENT x FOREIGN are not significant and that, in this case the

[52] Using a similar econometric set up, Nicholas finds a negative coefficient of independent inventors patents on renewals in Britain, arguing that, although "the quality of independent invention was high, yet renewal rates were low" (Nicholas, 'Independent invention', p. 1016) because the structure of UK patent fees was expensive and independent inventors may have been unpaired in their renewal behaviour by credit constraints. For a discussion on the issue of credit constraints for independent inventors in the UK, see MacLeod et al., 'Evaluating'. As already mentioned, the peculiar structure of the Italian renewal fees was instead not likely to represent an hindrance for the renewal behaviour of independent inventors.

[53] The negative size of the coefficient of INDEPENDENT is not likely to be affected by some possible misattributions of corporate patents to independent inventors. Since the average quality of corporate patents is higher than that of independent, biases in the direction just mentioned will in general tend to increase the average value of independent inventors' patents.

[54] See, for example, Mokyr, 'Urbanization'.

localisation of the patentee in the "industrial triangle" does not seem to exert a significant effect on patent length.

Tables 8 and 9 report the results of estimations for each benchmark year. In the case of "scheduled" patent length (table 8), the coefficients of INDEPENDENT and FOREIGN are not significant in the first benchmark (1864-65), suggesting that the pattern of innovation we have identified fully only emerges since 1881, as one would probably have expected. As far as the "real" patent length is concerned (table 9), we find a negative and significant effect: again this is higher than the corresponding effect for "scheduled" patent length in all three benchmarks (1881, 1891 and 1902).

[Tables 7, 8 and 9 about here]

V

Independent inventors remained an important source of innovation during the Second Industrial Revolution, alongside corporate R&D laboratories. This is true for the case of the United States, where independent inventors were effectively incentivized by a "democratic" and reliable patent system. In the case of Britain, Nicholas also shows that independent inventors provided an important contribution to technical progress (measured in terms of "valuable" inventions), notwithstanding the high costs of patent protection.[55]

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, seems 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 measured using renewal rates.[56] Interestingly enough, these findings are in agreement with the innovation patterns in the silk industry described by Federico. 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

[55] Nicholas, 'Independent invention'.
[56] Our results are also consistent with the recent findings reported in Nicholas, 'Technology, innovation and economic growth', table 1. Nicholas shows that during the period 1870-1918 patents registered in the United States by Italian inventors were of low quality since they received significantly less citations than patent registered in the US by German, French, British and also Japanese inventors.

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.[57]

Of course, this evidence raises the question of why Italian independent inventors, despite operating in a seemingly favorable context, failed to act as "a dynamic source of new technology formation" as their British counterparts.[58] We would suggest that two main factors are probably responsible for the relative low quality of the innovations patented by Italian independent inventors.

The first is the structural weakness, throughout this period, of the Italian innovation system (especially in terms of human capital formation) which, in general, did not represent a propitious environment for the generation and development of technological breakthroughs.[59]

The second explanation revolves more closely around the activities of independent inventors and the context in which they worked. 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 pieces of qualitative evidence suggesting that the institutional quality of these structures was largely inadequate, at least by international standards.[60] A revealing example is the case of Guglielmo Marconi (1874-1937)

[57] Federico, *Filo d'oro,* pp. 163-5.
[58] Nicholas, 'Independent invention', p. 1022.
[59] On the Italian National innovation system, see Nuvolari and Vasta, 'Ghost in the attic'. If we compare Italy with Britain in this period, we find that Italy was characterized by significantly lower literacy rates (see Cipolla, Literacy and development) and by lower number of graduates in engineering (see Vasta, Innovazione tecnologica e capitale umano, p. 250).
[60] Some suggestive evidence on the relative backwardness of "patent agency" in Italy can be gleaned by comparing the number of agents registered in the International Directory of Patent Agents published by William Reeves in London in 1901: US 2,193; Germany 418; UK 286; France 213; Spain 39 and Italy 20. We are grateful to Gabriel Galvez-Behar for providing us with these data. The relative low quality of patents of independent inventors, and the limited role played by "markets for technologies", are also pointed out by Saiz,

and the invention of the radio. Marconi developed his invention in Italy, but he was able to successfully commercialize it only after having moved to England. Guagnini 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 the successful gathering of the financial resources necessary for the entrepreneurial exploitation of the invention by means of the creation of a new company.[61]

Another enlightening case is that of Alessandro Cruto (1847-1908). He invented a highly efficient electric light bulb that in a systematic series of experiments in 1883 clearly outperformed Edison's bulb.[62] 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.[63]

To sum up, our findings may be seen as adding an important qualification to those obtained by Nicholas. Independent inventors could were 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.

'Social Networks of innovation' for Spain. Interestingly enough, according to Nicholas and Shimizu, 'Intermediary functions', markets for technologies and related institutions were instead relatively well functioning in the case of Japan, another late-comer country.

[61] Guagnini, 'Patent agents'. For a discussion of the activities of patent agents in the Britain in this period in the field of electrical technologies, see Araposthatis and Gooday, Patently contestable.

[62] Coriasso, 'Alessandro Cruto'.

[63] Other similar examples are those of Antonio Pacinotti (1841-1912) and of the partnership between Eugenio Barsanti (1821-1864) and Felice Matteucci (1808-1887). Pacinotti invented an extremely promising prototype of electric dynamo, but he was unable to attract the financial resources necessary for the commercial exploitation of his invention. Finally, Pacinotti's invention was taken up by the French company Gramme that in the late 1870s produced a rather successful electric generator. Barsanti and Matteucci developed one of the first internal combustion engines, but, despite their efforts, they did not succeed in making the invention a viable commercial option, see Maiocchi, 'Ruolo delle scienze', p. 876 and p. 890.

Footnotes references

A'Hearn, B., Auria, C. and Vecchi, G., 'Istruzione', in G. Vecchi, ed., In ricchezza e in povertà. Il benessere degli italiani *dall'Unità a oggi* (Bologna, 2011), pp. 159−206.

Amatori, F., Bugamelli, M. and Colli, A., 'Technology, firm size, and entrepreneurship', in G. Toniolo, ed., The Oxford Handbook of the Italian economy since Unification (Oxford, 2013), pp. 455-84.

Araposthatis, S. and Gooday, G., Patently contestable. Electrical technologies and inventor identities in Britain (Cambridge, MA, 2013).

Arora, A., Fosfuri, A. and Gambardella, A., Markets for technology: The economics of innovation and corporate strategy (Cambridge, MA, 2001).

Barbiellini Amidei, F., Cantwell, J. and Spadavecchia, A., 'Innovation and Foreign Technology', in in G. Toniolo, ed., The Oxford Handbook of the Italian economy since Unification (Oxford, 2013), pp. 378-416.

Basberg, B. 'Amateur or professional? a new look at 19th century patentees in Norway', Norwegian School of Economics Discussion paper 12.2012 (2012).

Bernal, J. D, Science and industry in the nineteenth century (1953).

Bessen, J., 'The value of US patents by owner and patent characteristics', Research Policy, 37 (2008), pp. 932-45.

Bilir, L., Moser, P. and Talis, I., 'Do treaties encourage technology transfer ? Evidence from the Paris convention', Working Paper Stanford University (2011).

Bosio, E., Le privative industriali nel diritto Italiano (Torino, 1891).

Broadberry, S., Giordano, C. and Zollino, F., 'Productivity', in G. Toniolo, ed., The Oxford Handbook of the Italian economy since Unification (Oxford, 2013), pp. 187-226.

Coriasso, R. (n.d.), 'Alessandro Cruto', in F. Amatori, ed., Dizionario biografico degli imprenditori italiani, mimeo.

Chandler, A. D., Scale and scope. The dynamics of industrial capitalism (Cambridge, 1990).

Cipolla, C. M., Literacy and development in the West (Harmondsworth, 1969).

Federico, G., *Il filo d'oro. L' industria mondiale della seta dalla restaurazione alla grande* crisi (Venezia, 1994).

Felice, E. and Vasta, M., 'Passive modernization? The new Human Development Index and its components in Italy's regions (1871-2007)', European Review of Economic History, forthcoming.

Fenoaltea, S., The reinterpretation of Italian economic history. From the Unification to the Great War (Cambridge, 2011).

Fisk, C., Working knowledge. Employee innovation and the rise of corporate intellectual property, 1800-1930 (Cambridge, 2009).

Freeman, C. and Louçã, F., As time goes by: from the industrial revolution to the information revolution (Oxford, 2001).

Freeman, C. and Soete, L., The Economics of industrial innovation (1997).

Giannetti, R., Tecnologia e sviluppo economico italiano (Bologna, 1998).

Giannetti, R. and Vasta, M., 'Big business (1913-2001)', in A. Colli and M. Vasta, eds., Forms of Enterprise in 20th Century Italy. Boundaries, Structures and Strategies (Cheltenham, 2010), pp. 25-51.

Gourieroux, C., Monfort, A. and Trognon, A., 'Pseudo maximum likelihood methods: Theory', Econometrica, 52 (1984), pp. 681-700.

Griliches, Z., 'Patent statistics as economic indicators: a survey', Journal of Economic Literature, 28 (1990), pp. 1661-1707.

Guagnini, A., 'Patent agents, legal advisers and Guglielmo Marconi's breakthrough in wireless telegraphy', History of Technology, 24 (2002), pp. 171-201.

Guagnini, A., 'A bold leap into electric light. The creation of the Società Italiana Edison, 1880-1886', History of Technology, 32 (2014), forthcoming.

Hatfield, H. S., The inventor and his world (West Drayton, 2nd edn. 1948).

Hilbe, J. M., Negative binomial regressions (Cambridge, 2nd edn. 2011).

Hounshell, D., 'The evolution of industrial research in the United States', in R. Rosenbloom and W. Spencer, eds., Engines of Innovation: US Industrial Research at the End of an Era (Boston, 1996), pp. 13-69.

Jewkes, J., Sawers, D. and Stillerman, R., The sources of invention (1958, rev. edn. 1969).

Khan, Z., The democratization of invention: patents and copyrights in American economic development, 1790-1920 (Cambridge, 2005).

Khan, Z., 'An Economic History of Patent Institutions', in R. Whaples, ed., EH.Net Encyclopedia (2008) http://eh.net/encyclopedia/article/khan.patents (accessed on 29 July 2013).

Khan, Z. and Sokoloff, K., 'Institutions and technological innovation during early economic growth: evidence from the great inventors of the United States, 1790-1930', in T. Eicher and C. Garcia-Penalosa, eds., Institutions and Economic Growth (Boston, 2006), pp. 123-58.

Lamoreaux, N. and Sokoloff, K., 'Intermediaries in the US Market for Technology, 1870–1920', NBER Working Paper n. 9017 (2002).

Lamoreaux, N. and Sokoloff, K., 'The decline of the independent inventor: a Schumpeterian story ?', in F. Scott Kieff and T. A. Paredes, eds., Perspectives on Commercializing Innovation (Cambridge, 2012), pp. 359-91.

Lamoreaux, N., Sokoloff, K. and Sutthiphisal, D., 'The reorganization of inventive activity in the United States during the early twentieth century', NBER Working Paper n. 15440 (2009).

Lerner, J., '150 years of patent protection', NBER Working paper n. 7478 (2000).

MacLeod, C., Tann, J., Andrew, J. and Stein, J., 'Evaluating inventive activity: the cost of nineteenth-century UK patents and the fallibility of renewal data', Economic History Review, 56 (2003), pp. 537-62.

Maddison, A., Historical Statistics of the World Economy: 1-2008 AD (2009) http://www.ggdc.net/MADDISON/oriindex.htm 2009 (accessed on 7 Dec. 2011).

Maiocchi, R, 'Il ruolo delle scienze nello sviluppo industriale italiano', in G. Michele, ed., *Scienza e Tecnica nella cultura e società Italiana dal Rinascimento a oggi, Storia d' Italia,* Annali, vol. 3, (Turin, 1980), pp. 865-999.

Meyer-Thurow, G., 'The industrialization of invention: a case study from the German chemical industry', Isis, 73 (1982), pp. 363-381.

Mokyr, J., The lever of riches. Technological creativity and economic progress (Oxford, 1990).

Mokyr, J., 'Urbanization, technological progress, and economic history', in H. Giersch, ed., Urban Agglomeration and Economic Growth (Berlin, 1995), pp. 3-37.

Morrisson, C. and Murtin, F., 'The century of education', Journal of Human Capital, 3 (2009), pp. 1-42.

Moser, P., 'How do patent laws influence innovation? Evidence from nineteenth-century World Fairs', The American Economic Review, 95 (2005), pp. 1214-36.

Moser, P., Ohmstedt, J. and Rhode, P. W., 'Patent citations and the size of patented inventions - evidence from hybrid corn' (2013) http://ssrn.com/abstract=1888191 (accessed on 10 Mar. 2014).

Mowery, D. and Rosenberg, N., Paths of innovation. Technological change in twentieth century America (Cambridge, 1998).

Nagaoka, S., Motohashi, K. and Goto, A., 'Patent statistics as an innovation indicator', in B. H. Hall and N. Rosenberg, eds., Handbook of Economics of Innovation, vol. 1 (Amsterdam, 2010), pp. 1083-1127.

Nicholas, T., 'The role of independent invention in US technological development, 1880-1930', Journal of Economic History, 70 (2010), pp. 57-82.

Nicholas, T., 'Independent invention during the rise of the corporate economy in Britain and Japan', Economic History Review, 64 (2011), pp. 995-1023.

Nicholas, T., 'Cheaper patents', Research Policy, 40 (2011), pp. 325-39.

Nicholas, T., 'Technology, innovation and economic growth in Britain since 1870', Harvard Business School Working Paper (2012).

Nicholas, T. and Shimizu, H., 'Intermediary functions and the market for innovation in Meiji and Taisho Japan', Business History Review, 87 (2013), pp. 121-49.

Nuvolari, A. and Vasta, M., 'The ghost in the attic? The Italian national innovation system in historical perspective, 1861-2011', Working Paper n. 665, Department of Economics and Statistics, University of Siena (2012).

O'Brien, P.K., 'The micro foundations of macro invention: the case of Reverend Edmund Cartwright', Textile History, 28 (1997), pp. 201-33.

Saiz, P., 'Social networks of innovation in the European periphery: exploring independent versus corporate patents in Spain circa 1820-1939', Historical Social Research, 37 (2012), pp. 348-69.

Schankerman, M. and Pakes, A., 'Estimates of the value of patent rights in European countries during the post-1950 period', Economic Journal, 96 (1986), pp. 1052-76.

Schmookler, J., 'Inventors past and present', Review of Economics and Statistics, 39 (1957), pp. 321-33.

Schmookler, J., Invention and economic growth (Cambridge, MA, 1966).

Scholliers, P. and Zamagni, V., eds, *Labour's reward. Real wages and economic change in* 19th and 20th century Europe (Aldershot, 1995).

Schumpeter, J. A., 'The instability of capitalism', Economic Journal, 8 (1928), pp. 361-86.

Schumpeter, J. A., Capitalism, socialism and democracy (New York, 1942).

Silverberg, G. and Verspagen, B., 'The size distribution of inventions revisited: an application of extreme value statistics to citations and value measure of patent significance', Journal of Econometrics, 139 (2007), pp. 318-39.

Sokoloff, K. and Khan, Z., 'The democratization of invention during early industrialization: evidence from the United States, 1790-1846', Journal of Economic History, 50 (1990), pp. 363-78.

Streb, J., Baten, J. and Yin, S., 'Technological and geographical knowledge spillover in the German empire, 1877-1918', Economic History Review, 59 (2006), pp. 347-73.

Trajetenberg, M., 'A penny for your quotes: patent citations and the value of innovations', RAND Journal of Economics, 21 (1990), pp. 172-87.

Vasta, M., Innovazione tecnologica e capitale umano in Italia (1880-1914). Le traiettorie tecnologiche della seconda rivoluzione industriale (Bologna, 1999).

Vasta, M., 'Le innovazioni tecnologiche', in V. Castronovo, ed., *Storia dell'Ansaldo*, vol. 9 (Roma-Bari, 2002), pp. 225-59.

Vasta, M., 'The largest 200 manufacturing firms (1913-2001)', in R. Giannetti and M. Vasta, eds., Evolution of Italian Enterprises in the 20th Century (Heidelberg, 2006), pp. 87-110.

Von Tunzelmann, G. N., Technology and industrial progress (Cheltenham, 1995).

Official publications

Gazzetta Ufficiale del Regno d'Italia, various years.

Ministero di Agricoltura, Industria e Commercio [MAIC], Bollettino delle privative *industriali del Regno d'Italia* (Torino, 1864-1885).

Ministero di Agricoltura, Industria e Commercio [MAIC], Bollettino delle privative *industriali del Regno d'Italia* (Roma, 1886-1893).

Ministero di Agricoltura, Industria e Commercio [MAIC], Elenco degli attestati di privativa industriale, di prolungamento, completivi, di importazione e di riduzione (Roma, 1894-1901).

Ministero di Agricoltura, Industria e Commercio [MAIC], Bollettino della proprietà intellettuale (Roma, 1902-1916).

US Patent and Trademark Office [USPTO], Technology assessment & forecast, Seventh Report, Mar. 1977.

US Patent Office, Annual report of the Commissioner of Patents, various years, http://catalog.hathitrust.org/Record/002138126 (accessed on 9 Dec. 2013).

US Patent Office, Index of patents issued from the United States Patent Office, various years, http://catalog.hathitrust.org/Record/003928306 (accessed on 9 Dec. 2013).

US Patent Office, Official gazette of the United States Patent Office, various years, http://catalog.hathitrust.org/Record/000498155 (accessed on 9 Dec. 2013).

WIPO, Statistics Database, various years, http://www.wipo.int/ipstats/en/ (accessed on 7 Dec. 2011).

Table 1. Degree of Openness (percentage of non-residents on total) of patent systems (1871-1914)

Countries	1864/65	1880	1901	1914
Germany		31.1	37.1	30.1
Italy	50.7	64.9	64.9	61.5
United Kingdom			53.2	
United States			13.3	11.5

Source: own elaboration on WIPO, Statistics Database (accessed on 7 Dec. 2011); data for Italy from MAIC, various years.
Note: for Germany 1883 instead of 1880.

Table 2. Italian patent sample (descriptive statistics)

	1864-65	**1881**	**1891**	**1902**	**1911**
Type of patentee					
Total	520	941	1,618	2,987	4,058
Firm (%)	4.0	14.5	18.4	20.6	24.1
Independent (%)	96.0	85.5	81.6	79.4	75.9
Localization					
Foreign	263	603	1,132	1,965	2,264
Firm (%)	3.0	15.1	18.8	25.8	31.9
Independent (%)	97.0	84.9	81.2	74.2	68.1
Italy	257	338	486	1,022	1,794
Firm (%)	5.1	13.3	17.5	10.8	14.3
Independent (%)	94.9	86.7	82.5	89.2	85.7
Industrial triangle cities (Genova, Milano, Torino)	151	176	233	501	990
Firm	6.0	18.8	25.3	14.2	18.1
Independent	94.0	81.3	74.7	85.8	81.9
Average "scheduled" length (years)					
Total	6.8	6.2	7.3	6.3	5.6
Firm	7.5	8.3	9.0	8.7	8.1
Independent	6.7	5.8	6.8	5.6	4.7
Foreign	7.7	7.1	8.4	7.6	6.7
Italy	5.8	4.5	4.6	3.8	4.1
% of patents prolonged (excluding patents with original length = 15)					
Total	10.7	17.9	17.5	23.8	24.1
Firm	22.2	39.7	27.6	36.2	38.1
Independent	10.2	14.4	15.5	21.0	20.0
Foreign	11.9	19.8	15.3	27.1	25.2
Italy	9.5	14.7	21.4	18.3	22.7

Source: MAIC, various years.

Table 3. Distribution of patents across industries

	1864-65	1881	1891	1902	1911
Distribution (%) of patents across industries					
Agriculture	3.3	6.6	5.6	3.3	2.9
Chemicals*	8.5	6.8	5.5	5.8	4.7
Construction and construction materials	7.1	3.9	5.7	6.3	7.7
Electricity*	12.1	13.5	14.9	19.3	14.8
Food and beverages	6.0	7.7	3.6	3.7	1.8
Machine tools, machinery, components and metalworking*	19.4	3.8	3.2	4.2	4.2
Steam engines*		8.0	10.1	11.0	14.2
Mining	4.0	2.8	3.5	2.5	1.6
Other manufactures	6.0	15.3	14.1	7.2	9.2
Paper and printing	4.8	3.5	3.2	4.2	3.8
Scientific instruments	2.7	7.7	4.3	6.2	6.4
Textiles, apparel & leather	7.3	8.2	9.8	10.5	8.2
Transport	11.9	8.9	10.9	12.3	18.0
Weapons*	6.9	3.4	5.8	3.6	2.5
Total	100.0	100.0	100.0	100.0	100.0
High-tech patents*	46.9	35.5	39.4	43.9	40.4
% of high-tech patents granted to firms	9.5	41.9	49.3	52.9	51.9
% of high-tech patents granted to independent	48.5	34.4	37.2	41.6	36.7

Source: MAIC, various years.

Table 4. Duration (years) of patents granted to Italian residents

"Scheduled" length (years)	**All patents (3,630)**	**Patents granted only in Italy (3,519)**	**Patents granted also in US (111)**
Mean	4.1	4.0	8.2
Median	3.0	3.0	7.0
Mann-Whitney test (z)= 9.749***			
"Real" length (years)	**All patents (1,846)**	**Patents granted only in Italy (1,781)**	**Patents granted also in US (65)**
Mean	2.5	2.4	5.7
Median	1.0	1.0	5.0
Mann-Whitney test (z)= 7.730***			

Source: for Italy, MAIC, various years and *Gazzetta Ufficiale del Regno d'Italia*, various years; US patent data retrieved from US Patent Office, Annual report of the Commissioner of Patents, various years; US Patent Office, Index of patents issued from the United States Patent Office, various years; US Patent Office, Official gazette of the United States Patent Office, various years. All US sources have been accessed on 9 December 2013 through http://catalog.hathitrust.org.

Table 5. *Patents expired before "scheduled" length (1881*-1902)

	1881	1891	1902
Total			
Total number of patents	941	1,618	2,987
Expired	627	1,144	1,909
%	66.6	70.7	63.9
Firm			
Total number of patents	136	298	616
Expired	84	213	402
%	61.8	71.5	65.3
Independent			
Total number of patents	805	1320	2371
Expired	543	931	1507
%	67.5	70.5	63.6
Average "real" length (years)			
Total	3.5	3.4	3.7
Firm	5.4	4.9	5.7
Independent	3.2	3.1	3.2
Foreign	4.0	3.6	4.4
Italy	2.7	2.8	2.5
% expired in the first year (with "scheduled" length >1 year)			
Total	30.3	32.1	29.7
Firm	19.3	22.7	15.1
Independent	32.3	34.5	34.2

Source: MAIC, various years and *Gazzetta Ufficiale del Regno d'Italia*, various years.

Table 6. *Determinants of "scheduled" patent length (1864*-1911)

	(1)	(2)	(3)	(4)	(5)
Independent	-0.610***	-0.789***	-0.754***	-0.777***	-0.763***
	(0.0469)	(0.0692)	(0.0757)	(0.0713)	(0.0174)
Foreign	0.800***	0.646***	0.777***	0.631***	0.789***
	(0.0667)	(0.106)	(0.132)	(0.106)	(0.133)
Independent x Foreign		0.213**	0.178*	0.201**	0.162**
		(0.0961)	(0.0981)	(0.0982)	(0.0718)
Industrial Triangle			0.185*		0.162**
			(0.103)		(0.0804)
Urban not Triangle				-0.117	
				(0.0739)	
High Tech					0.294***
					(0.0107)
Year dummies	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	No
Constant	0.831***	0.965***	0.834***	0.980***	0.813***
	(0.0643)	(0.0744)	(0.115)	(0.0742)	(0.0449)
Log-likelihood	-29441	-29423	-29404	-29418	-29837
Observations	10,101	10,101	10,101	10,101	10,101

Note: censored Poisson regressions (dependent variable is "scheduled" patent length in years), robust standard errors in parentheses, clustered by industries for regressions 1-4 and by high-tech sectors for regression 5 (*** p<0.01; ** p<0.05; * p<0.1). Baseline reference is 1902 for year and textiles, apparel & leather for industry.

Table 7. *Determinants of "real" patent length (1881*-1902)

	(1)	(2)	(3)	(4)	(5)
Independent	-0.799***	-1.086***	-1.023***	-1.024***	-1.049***
	(0.113)	(0.147)	(0.169)	(0.152)	(0.0791)
Foreign	0.469***	0.252	0.501	0.160	0.498***
	(0.112)	(0.185)	(0.345)	(0.177)	(0.0567)
Independent x Foreign		0.344	0.281	0.282	0.310***
		(0.228)	(0.240)	(0.234)	(0.0213)
Industrial Triangle			0.350		0.333
			(0.326)		(0.400)
Urban not Triangle				-1.286**	
				(0.541)	
High Tech					0.292***
					(0.0158)
Year dummies	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	No
Constant	0.394***	0.581***	0.331	0.680***	0.209
	(0.129)	(0.143)	(0.333)	(0.141)	(0.138)
Log-likelihood	-6408	-6400	-6390	-6361	-6496
Observations	5,546	5,546	5,546	5,546	5,546

Note: censored Poisson regressions (dependent variable is "real" patent length in years), robust standard errors in parentheses, clustered by industries for regressions 1-4 and by high-tech sectors for regression 5 (*** p<0.01; ** p<0.05; * p<0.1). Baseline reference is 1902 for year and textiles, apparel & leather for industry.

Table 8. Determinants of *"scheduled" patent length by benchmark year (1864*-1911)

	1864-65	1881	1891	1902	1911
Independent	-0.344	-0.620***	-0.373***	-0.614***	-0.752***
	(0.449)	(0.119)	(0.0899)	(0.106)	(0.0749)
Foreign	0.196	0.563***	0.959***	1.080***	0.702***
	(0.147)	(0.166)	(0.0841)	(0.137)	(0.111)
Industry dummies	Yes	Yes	Yes	Yes	Yes
Constant	1.122***	1.117***	0.850***	0.528***	0.553***
	(0.404)	(0.121)	(0.0927)	(0.178)	(0.105)
Log-likelihood	-1727	-2774	-5919	-8876	-9628
Observations	520	941	1,618	2,987	4,035

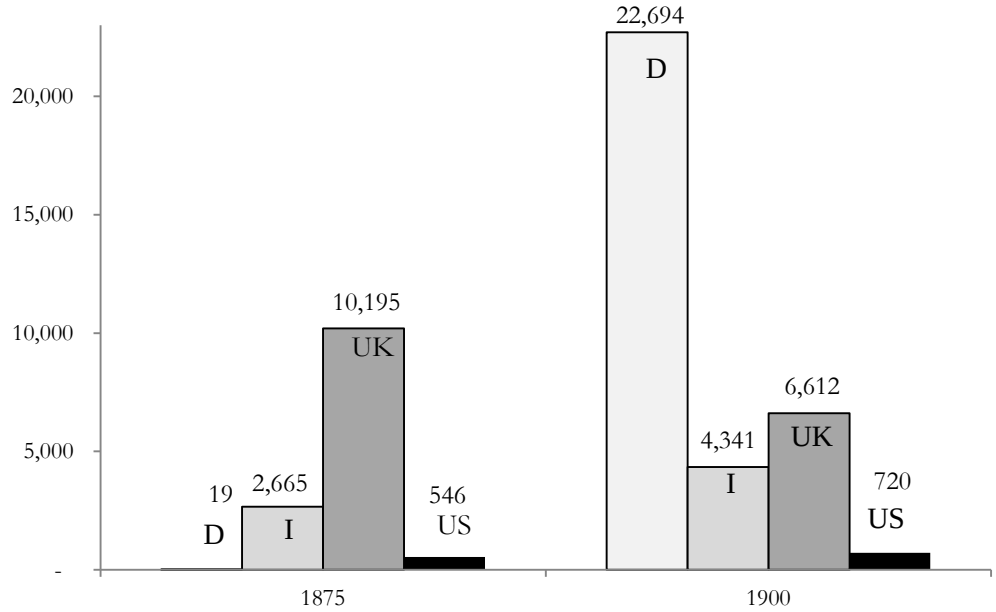
Note: censored Poisson regressions (dependent variable is "scheduled" patent length in years), robust standard errors in parentheses, clustered by industries (*** p<0.01; ** p<0.05; * p<0.1). Baseline reference is textiles, apparel & leather for industry

Table 9. *Determinants of "real" patent length by benchmark year (1881*-1902)

	1881	1891	1901
Independent	-1.284***	-0.556***	-0.817***
	(0.221)	(0.159)	(0.161)
Foreign	0.650	0.248	0.523***
	(0.427)	(0.218)	(0.108)
Industry dummies	Yes	Yes	Yes
Constant	0.107	-0.0434	0.214
	(0.341)	(0.197)	(0.152)
Log-likelihood	-600.8	-1389	-4309
Observations	941	1,618	2,987

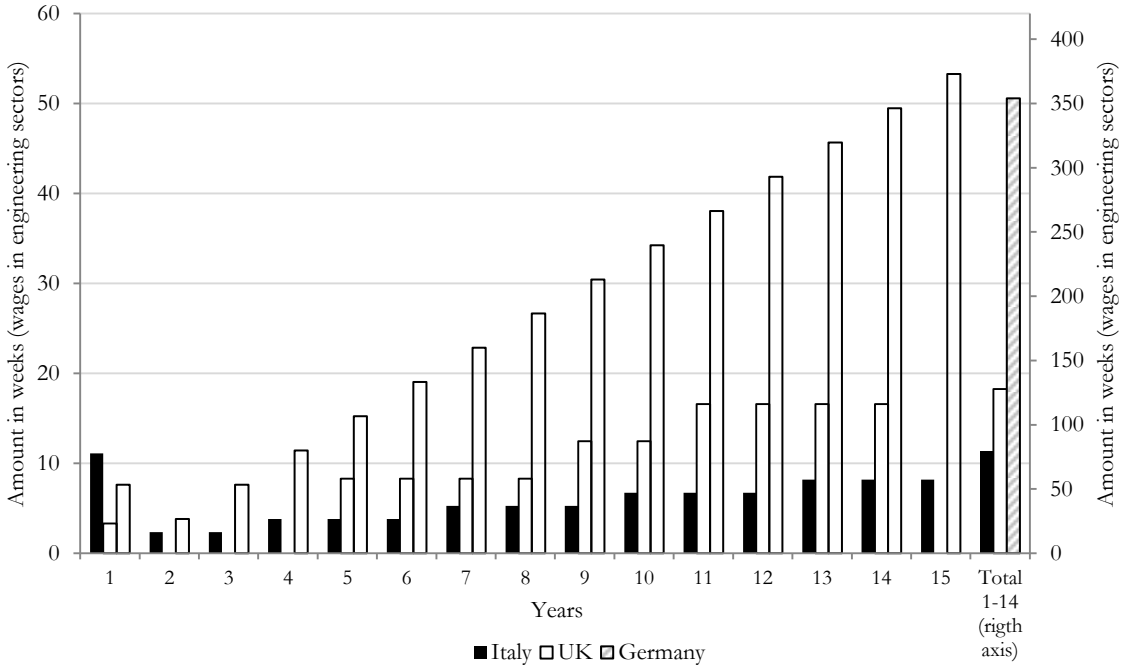
Note: censored Poisson regressions (dependent variable is "real" patent length in years), robust standard errors in parentheses, clustered by industries (*** p<0.01; ** p<0.05; * p<0.1). Baseline reference is textiles, apparel & leather for industry.

Figure 1. Cost of patenting (to keep a patent alive for full legal term) in different countries, 1998 US$



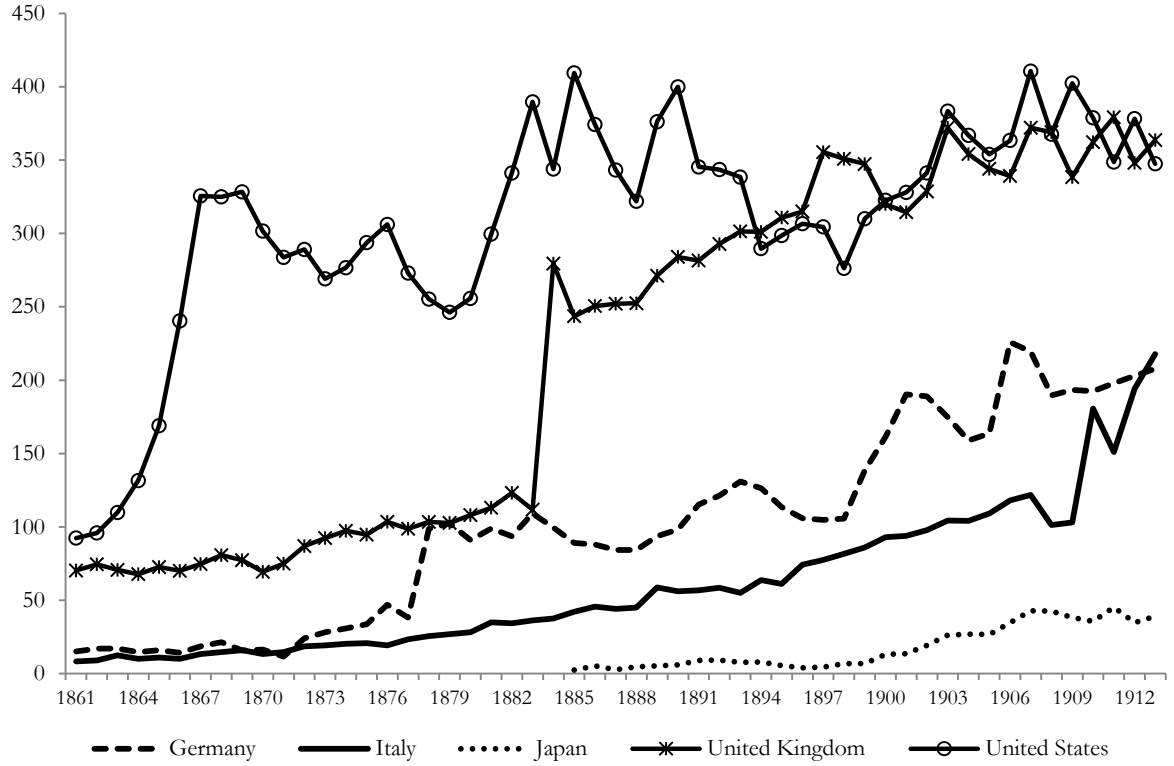
Source: Lerner, '150 Years', table 3.

Figure 2. Annual renewal fees of patenting in Germany, UK and Italy (1880s)



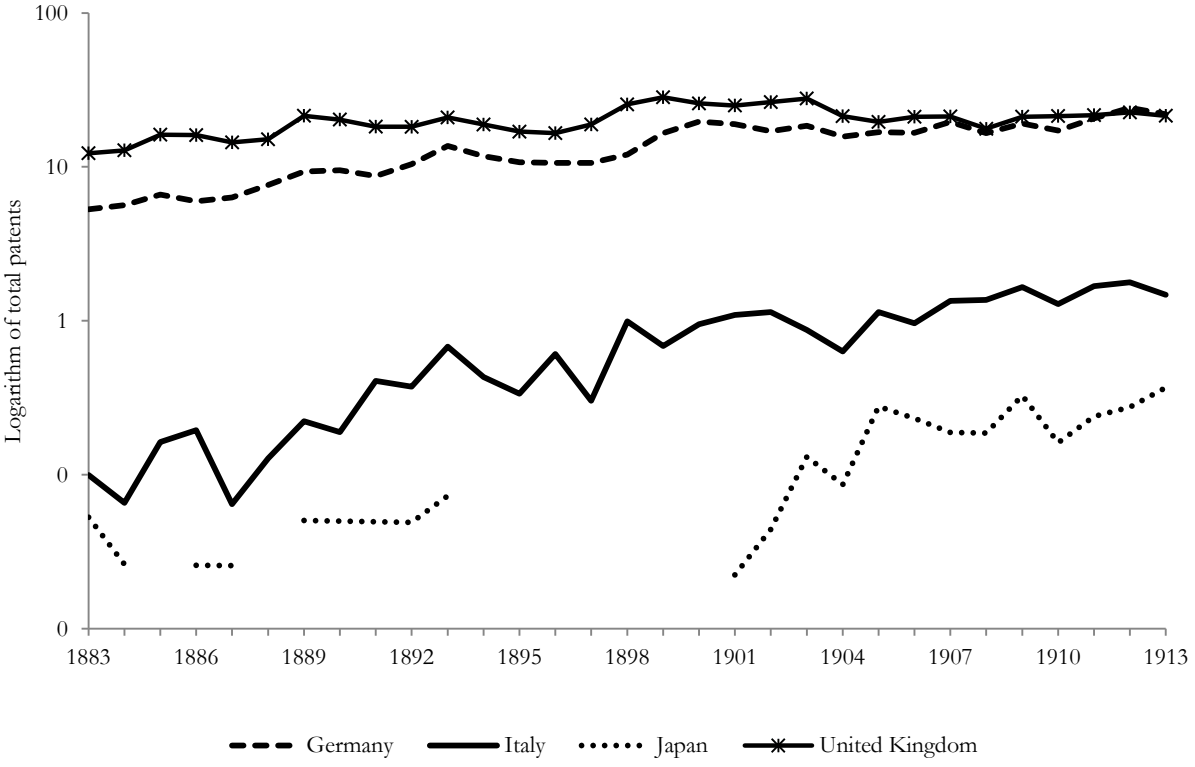
Source: own elaboration based on patent renewals data for UK: Nicholas, 'Cheaper patents'; Germany: Streb, Baten and Yin, 'Technological and geographical'; Italy: Italian Law nr. 1657, 31st January 1864 and on wages from Scholliers and Zamagni, Labours reward, pp. 210-9 (Germany), pp. 231-233 (Italy), pp. 258-66 (UK).
Note: years from 1 to 15 in the left axis; total period 1-14 in the right axis.

Figure 3. Patents granted in selected countries per million inhabitants (1861-1913)



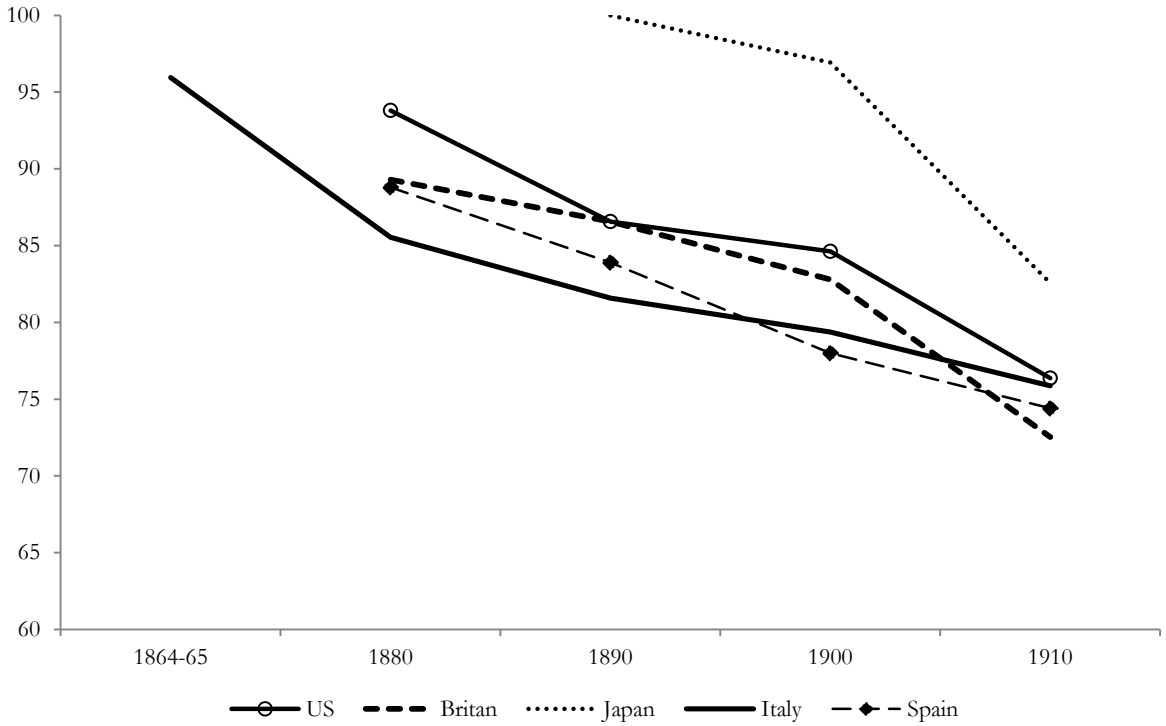
Source: own elaboration 1861-82: Khan, 'An Economic History of Patent' (accessed on 29 July 2013); on 1883-1913, WIPO, Statistics Database (accessed on 7 Dec. 2011); data for Italy from MAIC, various years.

Figure 4. Patents granted in US to foreign residents per million inhabitants (1883-1913)



Sources: own elaboration on USPTO, Technology assessment, and on Maddison, Historical Statistics (accessed on 7 Dec. 2011).

Figure 5. Share of independent inventors in different countries for benchmark years



Sources: own elaboration on data kindly provided by Nicholas, 'Independent invention', figure 3 for US, Britain and Japan and for Spain on Saiz, 'Social networks', table 1; for Italy our own elaborations on MAIC, various years.
Note: for Italy the benchmark years are: 1881, 1891, 1902, 1911; for Spain data corresponds to 10 years average centred on 1884, 1894, 1904 and 1914.

Figure 6. The geographical distribution of patents in Italy for benchmark years (share per province on total)

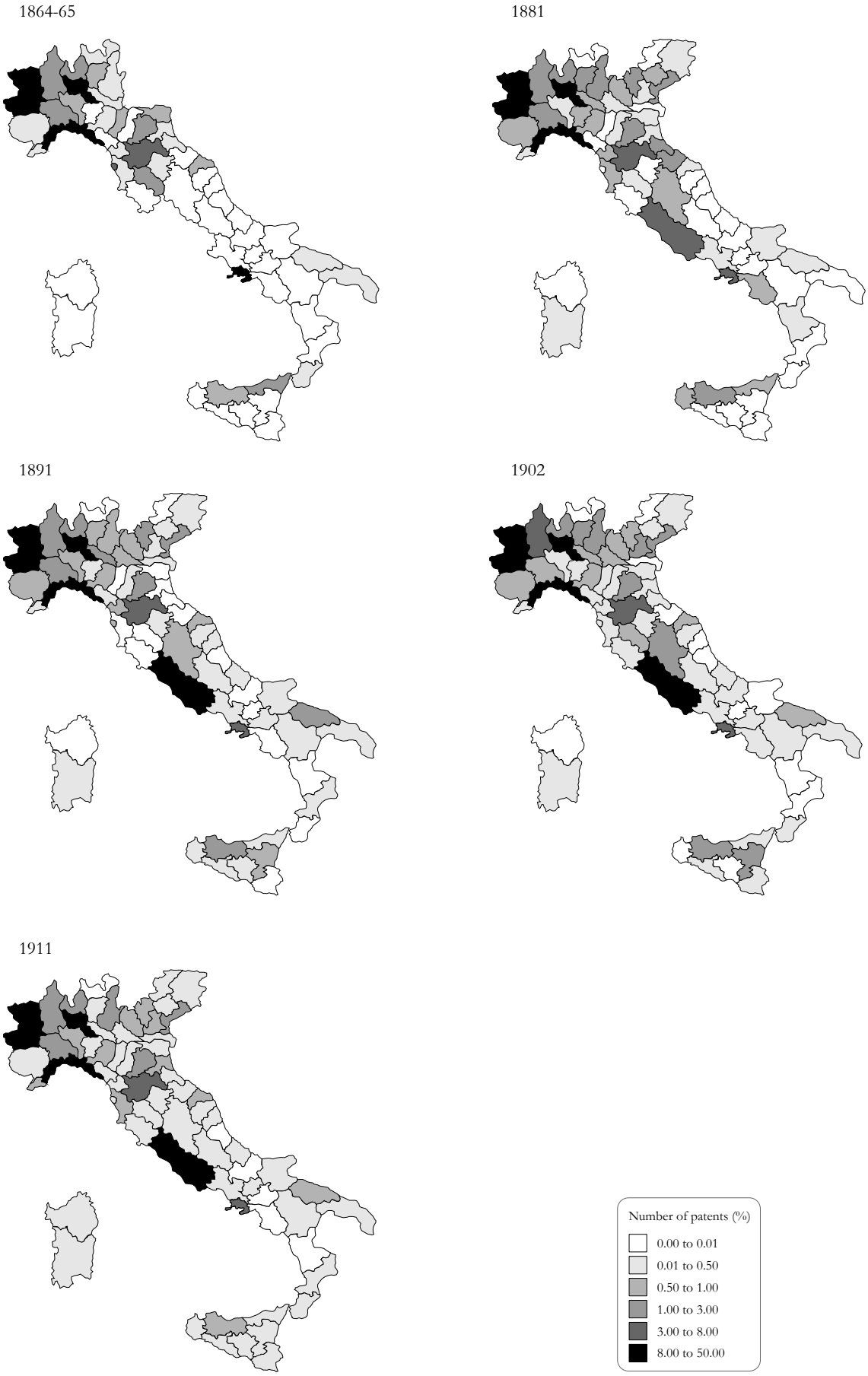
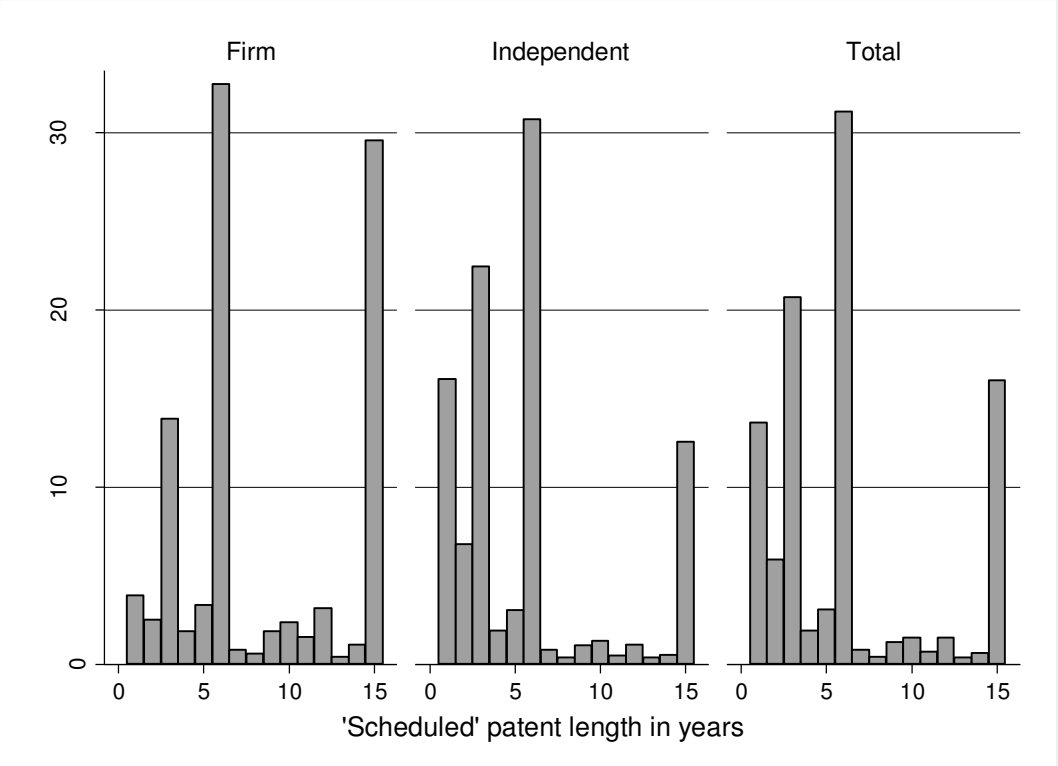
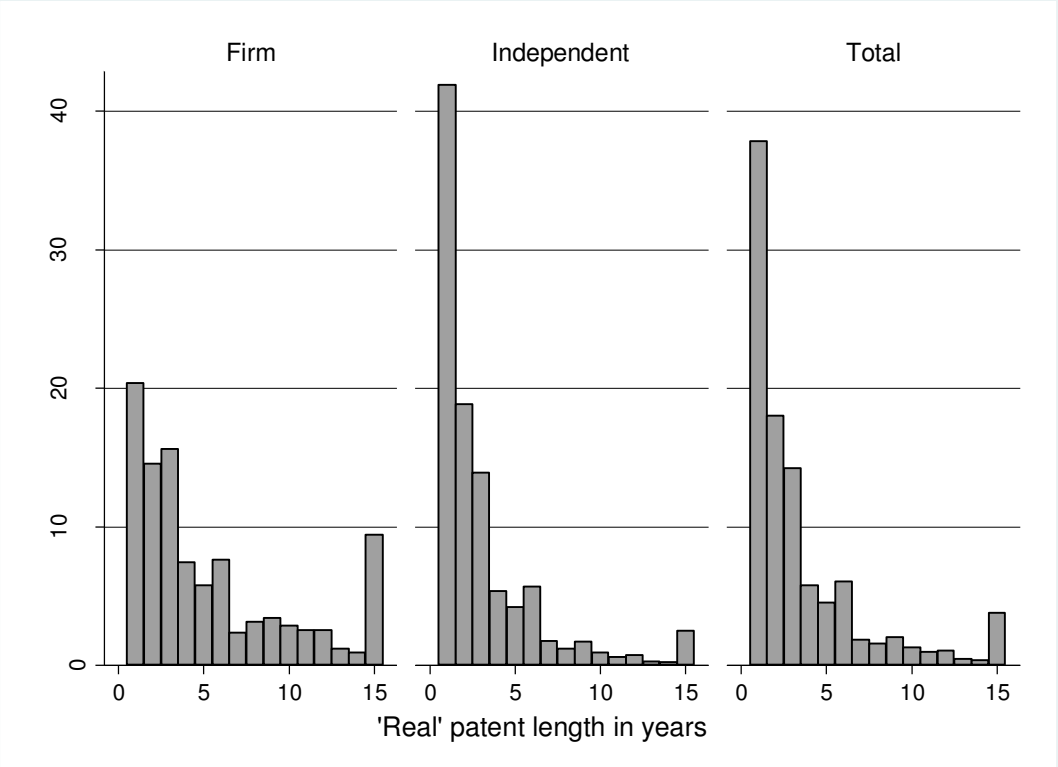


Figure 7. *Distribution of "scheduled" patent length by type of inventor (1864/65*-1911)



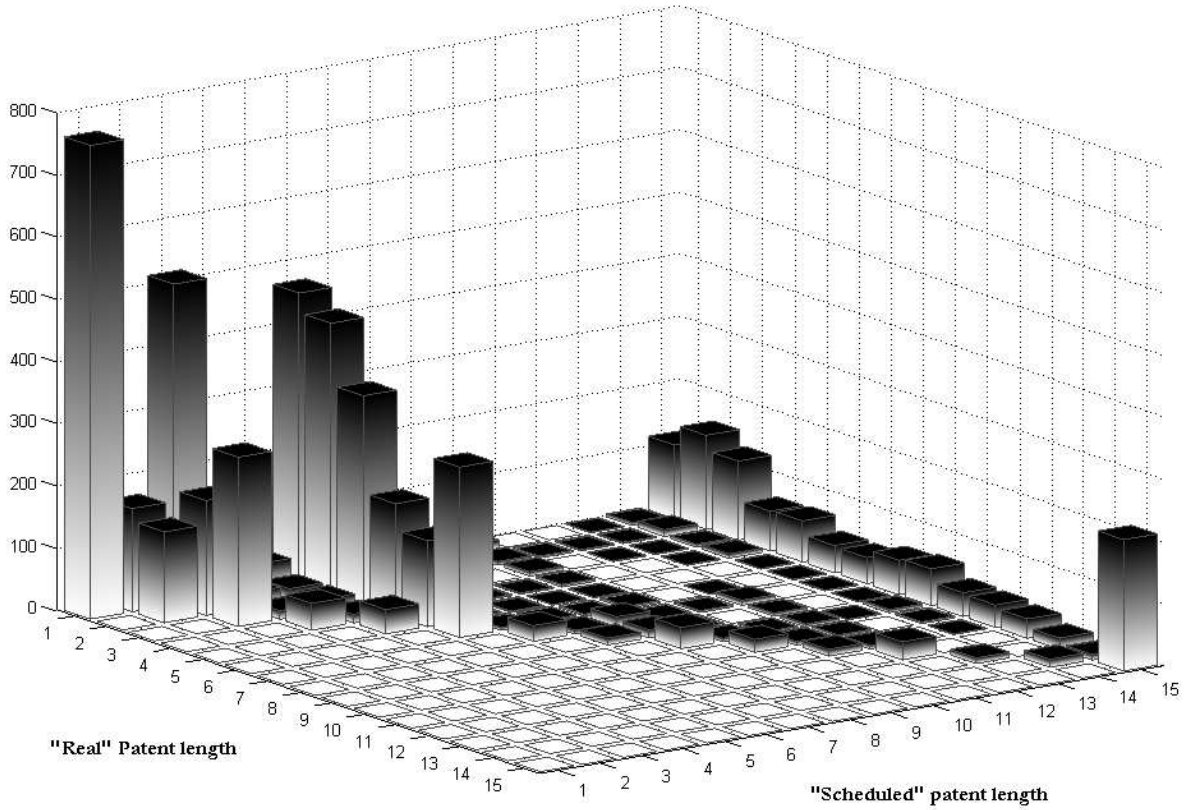
Source: MAIC, various years.

Figure 8. *Distribution of "real" patent* length by type of inventor (1881-1902)



Source: MAIC, various years and *Gazzetta Ufficiale del Regno d'Italia*, various years.

Figure 9. *Distribution of "scheduled" patent length vs. "real" patent length (1881*-1902)



Source: MAIC, various years and *Gazzetta Ufficiale del Regno d'Italia*, various years.