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The Ghost in the Attic? The Italian National Innovation System in Historical Perspective, 1861-2011

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Abstract: In this paper we provide a survey of the long term evolution of the Italian “National innovation system” since the unification. . First we provide a broad reconstruction of long term trends by examining a wide range of quantitative indicators of science and technological activities in comparative perspective. Second, on the basis of this quantitative picture, we put forward a conjectural interpretation of the fundamental features of the Italian national innovation system. Our conclusion is that Italy has approached the process of Modern Economic Growth following a peculiar path characterized by a limited commitment to investments in science and technology in combination with low real wages and the intense use of unskilled labour.

Keywords: Innovation systems, Economic Growth, Italy, Science, Technology

JEL-classification: N73, N74, O14, O33

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“…I must rattle my chains, and groan through keyholes, and walk about at night, if that is what you mean. It is my only reason for existing”
“It is no reason at all for existing and you have been very wicked”

Oscar Wilde, *The Canterville Ghost,* 1887

1. Introduction

Since the unification in 1861, Italy has been a country characterized by very limited investments in scientific research and innovative activities. But, at the same time, the Italian performance in terms of economic growth, throughout this period, was nothing short of remarkable (especially if we keep in mind that Italy is a country with a very limited endowment of energy and other natural resources) and it is fully comparable with that of other major Western economies and, in particular, of successful “catching up” countries such as Germany and Japan.Angus Maddison’s estimates suggests that, over the period 1870-2008, GDP per capita in Italy has grown at the average compound rate of 1.89 % while, in the same period, Germany was characterized by an average growth rate of 1.77% and France by an average growth rate 1.8%. The growth rate of Japan is 2.5% is sensibly higher due to the low level of its starting point in 1870.[1]

Therefore, *prima facie*, the Italian case can provide us with some very interesting insights concerning the relationship between scientific and technological activities and growth performance. Is the Italian case an historical example showing that the conventional view assuming that technical change is the key-driver of economic growth is simply not warranted? Or perhaps, the Italian case shows that a country may be able to attain substantial rates of technical progress without significant efforts in R&D activities? Or maybe Italy is just a “lucky exception” to the general rule, being the example of a country that, by design or accident, was able to find some *substitute* that could replace the role played by science and technology as driver of economic growth in other countries? In this paper we shall try to answer these questions by providing a comprehensive reappraisal of the complex interactions between scientific and technological activities and economic growth in Italy since the unification. The paper is organized as follows. In the next section, we discuss the literature on technology gaps and “National Innovation Systems” (NIS) with a view to the possible application of this framework of analysis in historical studies. In section 3, we summarize and discuss the main interpretations concerning the relationship between science, technology and the Italian economic growth process. Section 4 contains an analysis, based both on quantitative

[1] Data from http://www.ggdc.net/MADDISON/oriindex.htm accessed July 5, 2012. By way of comparison, in the same period, the UK had an average growth rate of 1.46% and the USA of 1.86%. According to the most recent estimates by Brunetti, Felice and Vecchi (2011), the growth rate of Italian GDP per capita over the period 1861-2011 was just under 2%.

indicators and qualitative evidence, of the long term evolution of the Italian NIS. In particular, the Italian experience is compared with that of other major industrialized countries. Section 5 concludes.

2. Technology-gaps, convergence and National Innovation Systems (NIS).

The study of the relationship between technical change and comparative economic development represents perhaps one of the most important themes of research in economic history. Whilst (mainstream) economists have tended for a long time to conceive technology as "public good" that is, by and large, freely accessible by all countries, economic historians have instead recognized that the successful assimilation of innovations and new technologies is by no means automatic and that it requires, in most cases, significant efforts and investments in the concomitant development of new skills and competences (Mokyr 1990). Furthermore, the introduction of new technologies frequently requires a creative process of adaptation to the specific local circumstances prevailing in the importing country (Fagerberg 1994). If this is the case, then the existence of technological differences can be seen as the prime source accounting for differences in economic performance across countries.

Alexander Gerschenkron (1962) was probably the first to provide an articulated exposition of what may be called the "technology gap" approach to the study of economic growth.[2] Gerschenkron in his attempt to develop a useful historical model for nineteenth century European industrialization introduced the key-distinction between *leader* and *backward* countries. This distinction is a way to define the position of a country with the respect to the (world) technological frontier. *Leader* countries are located on the edge of the frontier of technological progress, whereas *backward* countries are situated at varying degrees of distance from this conceptual border. In Gerschenkron's view, the "backlog of technological innovations" that a backward country can import from the leader countries represents "a great promise" holding the key for achieving a prolonged acceleration of economic growth and, ultimately, for the successful "catching up" with the leader countries.[3] However, the fulfillment of this promise is far from easy requiring the construction of "institutional instruments for which there was little or no counterpart in an established industrial country" (Gerschenkron 1962: 7). Interestingly enough, Gerschenkron also noted that the "ideological climate" surrounding the process of industrialization in the backward country differs from the one that characterized the economic development of the leaders.

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[2] The original contribution was actually published in 1952, see Gerschenkron (1962:ch. 1).

[3] Landes (1969: chps. 2,3 and 4) is a classic account of the emergence of Britain's technological leadership and of the subsequent adoption and diffusion of the new technologies of the industrial revolution from the leader country to the rest of Europe.

The notion that the technological "catching up" by backward countries is not an automatic process has been further elaborated by Abramovitz (1986; 1994).[4] He argues that the successful assimilation of foreign technologies is based on the construction of a proper set of "social capabilities" in the importing country. The notion of social capabilities is used in this context rather loosely. Broadly speaking, Abramovitz's concept refers to capabilities embodied in firms and other organizations and to a broader set of factors that directly affects them such as the quality of the education system together with several other contextual dimensions. [5] Abramovitz's contribution was the root of a growing economic literature attempting to measure social capabilities empirically by means of a number of proxies (Fagerberg, Shrolec and Verspagen 2010 for a comprehensive discussion). In his paper, Abramovitz (1986: 371) pointed to another key-factor affecting the process of "catching up" which he labeled as "technological congruence". Technological congruence indicates the degree in which the leader and backward countries are similar in dimensions such as overall market size, factor supplies and resource endowments. For example, a new technology developed in the leader country may not be profitably adopted in the backward country because of different resource endowments and factor supplies.

The increasing recognition that country-specific factors shape the process of technological change at the national level was probably the main source of inspiration of the notion of NIS in the late 1980s. The concept of NIS is based on the idea that innovation is the outcome of "social" processes in which a variety of actors (individuals, business firms, public institutions, etc.) are involved. Typically, these actors are linked by means of both market and non-market interactions. According to the NIS view, the key actors and the key interactions featuring in innovation processes have a predominantly *national* character.

Interestingly enough, in the literature one can distinguish the co-existence of three broadly alternative definitions of the NIS concept, each to be ascribed to one of the three early pioneers of this approach: Chris Freeman, Richard Nelson and Bengt-Ake Lundvall (Soete, Verspagen and Ter Weel 2010).[6] According to Freeman a NIS consists in the "network of institutions in the private and

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[4] Verspagen (1991) contains an elegant formalized treatment of Abramovitz's views.

[5] "As I use it….[social capability] is a rubric that covers countries' levels of general education and technical competence, the commercial, industrial and financial institutions that bears on the abilities to finance and operate modern, large-scale business and the political and social characteristics that influence the risks, the incentives and the personal rewards of economic activity including those rewards in social esteem that go beyond money and wealth" (Abramovitz 1994: 25).

[6] The concept of national innovation system was introduced for the first time in a paper written in the early 1980s by Freeman for the OECD (Freeman 2004; see also Lundvall 2004). As recognized by Freeman himself, in historical perspective, the concept of national innovation system may be regarded as a modern elaboration of many the issues originally discussed by Friedrich List's views (1841) on the peculiar set of policies and institutions that Germany should have adopted in order to close the economic gap with England (Freeman 1995). On the intellectual connections between the national innovation systems literature and the research done at the OECD on scientific and technological activities during the 1960s and 1970s, see also Godin (2009).

public sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman 1987:1). Lundvall defines the NIS as "all parts and aspects of the economic structure and the institutional setup affecting learning as well as searching and exploring" (Lundvall 1992: 12). Finally, Nelson invokes a fairly straightforward definition of the concept, using the NIS label to indicate "a set of institutions whose interactions determine the innovative performance of national firms" (Nelson and Rosenberg 1993: 4). As noted by Soete, Verspagen, and Ter Weel (2010), these different definitions of NIS share a broadly similar outlook, but, at the same time, they contain some subtle differences concerning the scope of the concept. Nelson's use of the concept is the narrowest in its scope. In particular, the attention of Nelson and his associates (Nelson 1993) is focused on the R&D system of business firms and on the role of universities and public research laboratories in providing support to the activities of this R&D system. While the starting point of Nelson is the R&D system of business firms, Freeman takes as the starting point of the analysis the role played by the state. This is indeed not surprising when we consider that Freeman (1987) is essentially a reappraisal of the Japanese historical experience. The focus of Freeman's study is precisely the critical role played by the state and by its techno-structures in orchestrating the networks of firms and other actors involved in innovation processes. Overall, Freeman's study maintains a powerful Gerschenkronian flavor throughout since the emphasis is put on the policies and institutional arrangements that are progressively put in place in order to overcome bottlenecks and other obstacles to the introduction of new technologies in a backward country. Freeman's emphasis on the role of the Japanese state in coordinating and guiding the actions of different actors is also clearly reminiscent of the developmental state literature.[7] Finally, it is also worth noting the prominence given by Freeman to the ability of the Japanese policy-makers and technocrats in laying out sensible scenarios charting the most likely trajectories of evolution of specific technologies and industries and in employing the same scenarios in a flexible way as a guiding tool for coordination purposes.

Lundvall's definition of NIS is the broadest in its scope, as it considers as part of the NIS not only formalized R&D activities, but also the more ordinary learning processes taking place in connection with routine activities of production, distribution, marketing, etc. This broadens the NIS perspective also to small firms and to the low-technology sectors of the economy. Furthermore, Lundvall's approach, in the study of the interactions among the various actors of NIS, gives a special attention to the exchanges of information between users and producers (Lundvall 1988). In

[7] The first use of the concept of "developmental state" is the study of the MITI's experience by Johnson (1982). The book is cited in Freeman (1987). On the concept of "developmental state", see Woo-Cummings (1999). For a recent discussion on the role of institutional foundations and policies shaping successful development and catching up see Cimoli et al. (2009).

his view, detailed feedbacks from users provide a powerful stimulus to producers to further improve and refine their products. As a result, institutional arrangements and specific social conditions providing a context in which this type of user-producer relationship can flourish, may be a very important factor shaping the innovation performance of a country. This feature of Lundvall's approach to NIS is actually reminiscent of insights emerging from research on industrial clusters and on low-tech and high-tech industrial districts (Sabel and Zeitlin 1984; Saxenian 1994).

Since the early 1990s the concept of NIS has enjoyed a remarkable success in "policy making" circles both at national level and at super-national levels in particular in institutions such as the OECD and the European Commission (Sharif 2006). The main limitation of the NIS approach is the danger of assuming the existence of an ideal benchmark that all countries should emulate in order to improve their innovation performance, neglecting the Gerschenkronian intuition that backward countries are very often forced by historical circumstances to pursue development trajectories that are different from the one embarked by the leader countries. Hence historical studies should probably adopt a framework of investigation of NIS that is closer to the spirit of Freeman (1987). The key intuition is that the overall innovation performance of national economies is ultimately the outcome of the relative degree congruence or mismatching among the various constituting elements of the NIS. In other words, the historical evidence suggests that different combinations of institutional set-ups may produce equally successful outcomes in terms of catching up with the technological frontier. This perspective clearly overlaps with the *varieties of capitalism* approach (Hall and Soskice 2001). For example, Hall and Soskice argue that the structural institutional differences between Liberal Market Economies and Coordinated Market Economies should lead to the emergence of different innovation patterns across countries, suggesting implicitly the possibility a typology of different NIS (Hall and Soskice 2001: 37-44).[8] Thus, rather than looking at the Italian experience as an attempt to emulate the innovation systems of the leader countries, we think it is more fruitful to look at the Italian example as an attempt to develop an appropriate ensemble of "substitutes" aimed at overcoming the bottlenecks stifling innovative activities in a technologically lagging country. The key-interpretative issue then becomes that of assessing the peculiar Italian variety of NIS and the role it has played in shaping Italian innovation performance in long run perspective. As we shall see, in a comparative perspective, Italy seems to be the a case a country characterized by a structurally weak national innovation system. Our contention is that this weakness has forced the country to adopt a peculiar path towards modern economic growth characterized by low real wages and the intensive use of unskilled labour.

[8] For a critical discussion of Hall and Soskice application of the variety of capitalism approach to differences in innovation patterns across countries, see Akkermans, Castaldi, Los (2009).

3. Science, technology and Italian economic growth: interpretations

Science and technology are two themes that for long time have not received a great deal of attention in the classic interpretations of the economic history of Italy since the unification (Romeo 1959; Sereni 1966; Bonelli 1978; Cafagna 1989; Fenoaltea 2011). However, since the early 1990s, some Gerschenkronian suggestions have been taken up so that some more recent contributions have explicitly examined the connection between technology gaps and the peculiarities of Italian economic development (Sapelli, 1992; Giannetti 1998; Vasta, 1999).

Broadly speaking, in the literature it is possible to identify two main views about the role played by technical change in Italian economic growth. The first view, which may be labeled as the *optimist* perspective, considers the Italian pattern of technical change as a rational response to a resource endowment characterized by a scarce availability of natural resources and by a structural abundance of unskilled labour. In this context, it was pointless to invest a large amount of resources in the development of cutting-edge technologies. Rather, a more rational or suitable strategy consisted in adapting technologies developed abroad to the specificities of the Italian context.

The second view, which can be called as the *pessimist* perspective considers the Italian case as essentially a prolonged failure to develop an autonomous innovative capacity. In this view, technical change is conceived as a tool for overcoming resource constraints and, accordingly, the weak Italian performance in innovative activities is a missed opportunity for putting on a more stable and secure footing the Italian path of economic growth.

The optimist approach is well summarized in the book survey by Cohen and Federico (2001). They adopt a neoclassical perspective in which technology is akin to a public good that can be easily acquired *off the shelf* without requiring the previous development of absorptive capabilities. Accordingly, for Italian firms the best option was to invest their limited resources in adapting imported technologies: ‘Technology mixing and matching was a rational response to relative factor prices’ (Cohen and Federico 2001: 52). The relevance of the connection between factor prices and choice of techniques in the Italian case has been also elaborated in other contributions. Federico (1996: 772-773) emphasizes the relative success of Italian light industries in becoming internationally competitive relying on essentially (unskilled) labour intensive production processes and not particularly sophisticated technologies. Bardini (1998) instead argues that, in the case of Italy, the lack of coal represented a powerful obstacle preventing a fully satisfactory adoption of the technologies of the First Industrial Revolution, in particular steam power. Italy is instead much more successful in the adoption of the technologies of the Second Industrial Revolution based on electricity which are more suited to its resource endowment.

The success of Italian small firms in light industries and traditional sectors is also a theme that has featured prominently in the literature on “industrial districts”. This stream of literature has its roots in the contributions by Beccatini (1987) and Brusco and Paba (1997). According to these authors, localized clusters of small firms when closely examined display a remarkable innovative performance, which is often underestimated by traditional innovation indicators. In the Italian industrial districts, small firms are involved in continuous, cooperative, not-formalized learning processes often leading to streams of successful incremental innovations. This view suggests that Italy has followed an alternative model of development not characterized by the central role of formalized R&D activities and the growth of industries close to the technological frontiers.

A further recent development of the optimist approach is the study of the evolution of the Italian economy in the period 1950-1992, by Antonelli and Barbiellini Amidei (2011: 1-2) who suggest that “the Italian economic system had a notable capability to innovate [...]based upon the systematic valorisation of user-producer interactions between upstream producers of capital goods and downstream producers of consumer goods, within industrial districts”. This system is based on localized technological change and it is characterized by an extended capacity to reshape and adapt accessible technologies to the specific needs of the Italian firms. According to the authors, this phenomenon is able to explain the paradox of a remarkable performance of the Italian economy characterized by very high TFP growth, with a simultaneous modest performance in all technological indicators. The solution of the paradox is the “distributed” character of the system which is based on continuous interactions among large and small firms occurring either vertically within industrial filieres or horizontally within industrial districts. In this Italian model, innovations are the outcome of processes of interactive learning associated with the interactions among firms. Similarly to the industrial districts literature, the emphasis is on adaptive and non-formalized innovation activities that are not captured by traditional innovation indicators.[9]

The pessimist view which emphasizes the Italian difficulties to build a genuine autonomous innovative capacity has been declined in two versions. The contribution of Giannetti (1998) may be defined as a “moderate pessimist” picture. Giannetti (1998) maintains that Italy has been able to develop effective capabilities for the assimilation of innovations from abroad, but not for the autonomous creation of new technologies (see also Giannetti and Pastorelli, 2007). He is keen in emphasizing the repeated Italian failure of entering in a high tech sectors. However, he also emphasizes that the creation of strong absorptive capabilities allowed Italy to participate in some of the major technological trajectories of the First (although with considerable delay) and of Second

[9] In a recent paper Simoni (2012) argues that from the 1950s until the early 1990s Italy was a rather successful case “coordinated market economy” with a satisfactory innovation performance. After the 1990s the Italian system suffers from an increased lack of institutional coherence.

Industrial Revolution. Hence, according to Giannetti, Italy is like the red queen in Lewic Carroll' s *Through the Looking Glass* who must run continuously in order to stay in the same place. Also the contribution of Malerba (1993) shares the same moderate pessimist view. Malerba (1993) adopts the conceptual framework of NIS and considers the post-WWII period. Malerba argues that the Italian innovation system actually comprised two distinct innovation systems: i) a "small firm network" comprising networks of small firms operating either in traditional, low tech industries or in equipment supplier industries very often clustered in specific locations, ii) a core "R&D" system comprising large firms, public research laboratories and universities. The core R&D system is extremely fragile and with very limited capabilities in the generation of new technologies. The performance of the small firm network is satisfactory, but this produces only adaptations and incremental innovations. According to Malerba, this setting is not likely to be sustainable in the long run.

The contribution of Vasta (1999) has instead a pessimist view throughout. Vasta adopts a broader conceptualization of NIS which looks both at scientific and technology policies and at the formation of human capital, which is a crucial element of an effective *absorptive capacity*. Accordingly, Vasta contends that the construction of a successful NIS is a fundamental pre-requisite for a robust process of economic catch-up. Instead, the weaknesses of Italian NIS have, in the long run, produced a number of structural deficiencies that had many detrimental cumulative effects not easily reversible.

4. The Italian NIS: an historical profile

The aim of this section is to provide a description of the historical evolution of the Italian NIS. We wish to provide an account that is both comprehensive and comparative including a large number of indicators and proxies of scientific, technological and innovation activities not only for Italy, but also for other major industrial countries. Since the early 1960s, a suitable array of indicators capturing the most relevant dimensions of scientific and technological activities at country level has emerged and it has improved and refined (Patel and Pavitt 1995; Smith 2005). In this context, it is possible to draw a distinction between two main typologies of indicators: input and output. The standard input indicator is the volume that a NIS dedicates to R&D. Moreover, we have included in the analysis some proxies of human capital. From a conceptual point of view, it is plausible to regard the general endowment of human capital of a country as broad input for innovative activities. The indicator of innovation output most commonly used is instead, the number of patents for which there is a large availability of data since the end of the XIX century (Pavitt 1988). However, in order to provide an assessment of scientific research activities, we have also considered bibliometric indicators. The availability of indicators of output for both scientific research (publications) and technological activities (patents) gives us the opportunity of gleaning useful insights on the relative effectiveness of the technology transfer mechanisms of the Italian innovation system. Finally, we have taken into considerations a contextual factor that is the level of wages which, in our view, is crucial to determine the rate and direction of technical change.

4.1 *The input dimensions of Italian NIS*

As already noted, the human capital endowment of a country directly affects the ability to use, adapt and develop new technologies (Abramovitz 1986). Therefore, in this paper the structure and performance of the education system as a whole is considered as one of the broad input dimension of NIS.[10] Table 1 shows literacy rates of adult population in comparative perspective. The first point that merits attention is the particular low starting point of Italy. In 1860, the Italian adult literacy rate (25%) was the lowest of all countries considered, similar to that of Japan and a little lower than Spain (27%). Interestingly enough all other countries in the table had literacy rates that were more than the double of the Italian figure. It is also worth noting that it took a prolonged period of time to close this initial gap. In 1900, the Italian literacy rate was 51.8% while Germany, Sweden and United Kingdom had already exceeded 90% and other countries were very close and in 1950, Italy had not yet reached the values that most of the countries achieved at the beginning of the century.

Table 1. Literacy rate on adult population (1860-1950) in selected countries

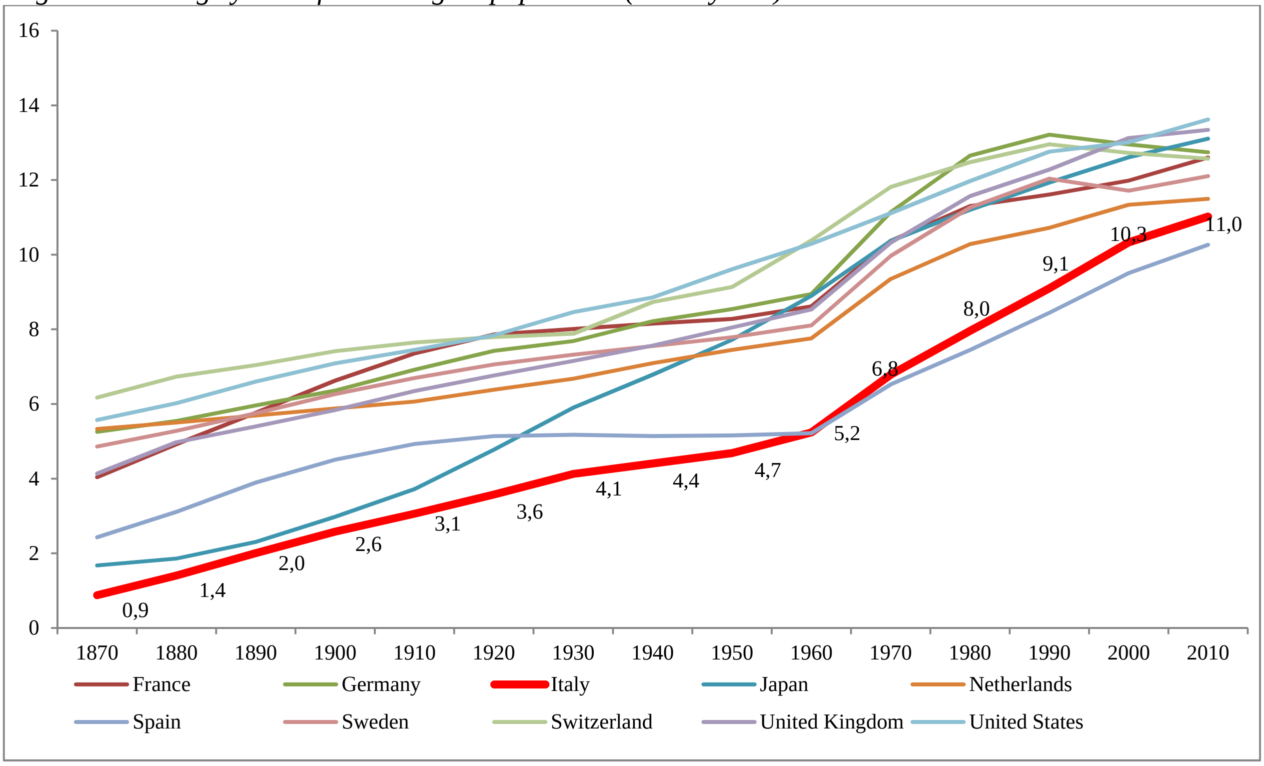
	1860	1880	1900	1913	1950
France	60.1	74.2	83.5	88.1	96.6
Germany	86.0	92.5	96.3	97.0	98.5
Italy	25.3	38.0	51.8	62.8	87.0
Japan	25.0	41.1	53.1	74.8	97.8
Spain	27.0	33.0	45.0	52.0	82.7
Sweden	91.3	94.8	97.8	98.5	98.5
United Kingdom	68.0	81.0	91.9	92.8	98.5
United States	80.3	83.0	89.3	92.3	97.4

Source: kindly provided by Leandro Prados de la Escosura, *mimeo*.

A second useful indicator of the human capital endowment of a country, charted in Figure 1, is the average years of schooling on population (with age between 15 and 64). Also in this case, the indicator shows the existence of a significant gap between Italy and the other major countries, Furthermore, the average years of schooling on population of Italy remains the lowest during all benchmark years – except for Spain in the last forty years – going from 0.9 in 1870 to 11 years in 2010.

[10] Studies of NIS typically focus only on the higher education system (which is the component of the education system that is assumed to affect directly innovative activities).

Figure 1. Average years of schooling on population (15-64 years) in selected countries



Source: our own elaborations on Morrisson and Murtin (2009).

The third indicator we consider is tertiary education. Since WWII, in Italy there is a steady growth in the number of students enrolled at the University (61 students per 10,000 inhabitants in 1962 to 147 in 1972, reaching 228 in 1989). In the early 1990s, the number of university students is not too far from that of other industrialized countries, even if completion rates are still very low: in 1991 in Italy there were only 9.2 graduates per 100 people belonging to age group for degree, compared with 29.6 in the United States, 23.7 in Japan, 18.4 in the United Kingdom, 16.3 in France, and 12.7 in Germany (Trento 1997).

Table 2 contains the shares of students enrolled at university by disciplinary groups and it shows that in the first post-unification period the scientific and engineering area is chosen by about one third of total students. This share decreases from 1881 to the end of the century; in the 1900s there is a trend reversal, with the enlargement of the faculties of engineering reaching a peak (37.2%) in 1921 due, presumably, to the expansion of the demand for engineers arising from Italy's newly emerging military-industry complex. This phase is followed by a sharp decline of students in scientific faculties during the 1920s. Finally, since WWII, the share of students in science and engineering faculties has stabilised around 25%, while in the last two decades it has declined below 23%.[11]

[11] According to Edgerton (1996: 54), the percentage of graduates in scientific and technological subjects for the major industrialized countries in 1954/55 were as follows: Germany (34%), Italy (26%), UK (44%), France (29%).

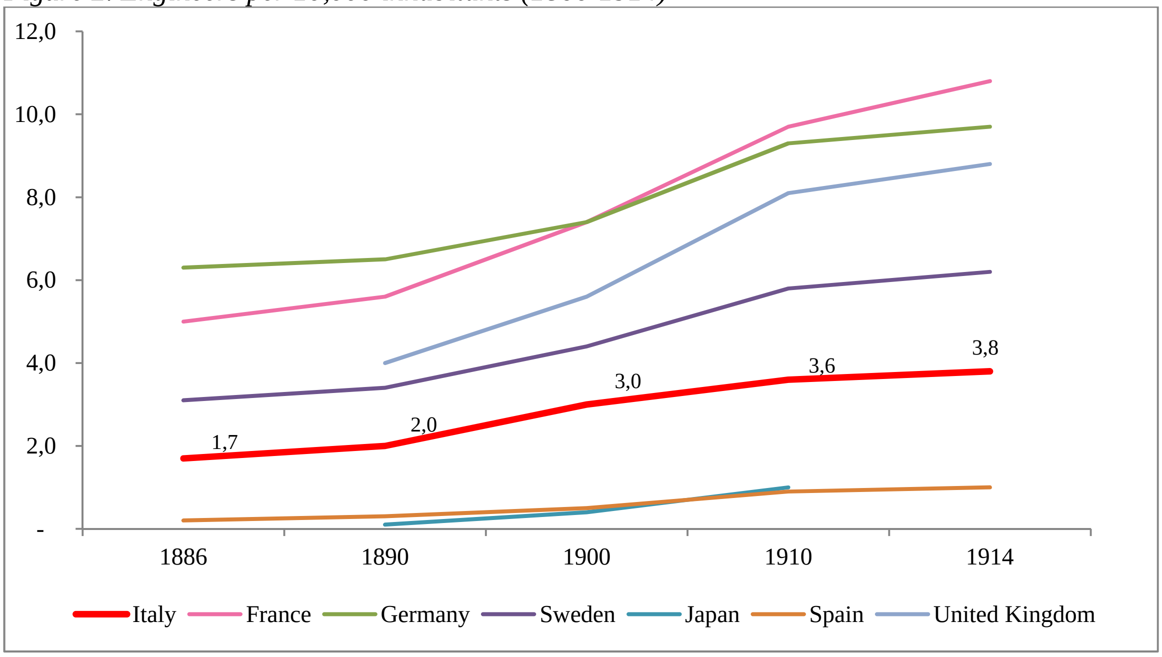
Table 2. Students enrolled by Faculties (1866-2006)

	Law and Political Science	Economics	Humanities	Medical	Science and Engineering	Others
1866	36.4	-	1.7	27.5	32.0	2.4
1871	31.9	0.8	1.4	27.1	35.6	3.2
1881	36.0	1.2	3.4	31.9	25.3	2.2
1891	29.2	1.3	6.6	34.0	25.9	3.0
1901	30.8	1.3	7.6	23.6	30.4	6.3
1911	35.7	4.9	7.9	19.8	28.5	3.2
1921	17.4	12.9	8.2	20.3	37.2	4.0
1931	21.2	19.9	11.0	23.5	21.3	3.1
1941	13.7	22.8	28.8	11.1	20.5	3.1
1951	16.9	13.1	22.2	15.0	29.7	3.1
1961	16.2	24.1	23.0	8.7	26.4	1.6
1971	9.6	15.6	31.7	12.9	28.3	1.9
1981	14.1	16.2	22.2	16.4	27.1	4.0
1991	25.1	17.8	20.9	5.3	22.8	8.1
2001	25.6	13.6	24.6	6.5	22.8	6.9
2008	22.7	13.2	24.7	8.3	23.1	8.0

Source: seriestoriche.istat.it (data extracted 8th July 2012)

The Italian delay in (higher) technical education is also evident if we consider the stock of engineers on population. Comparative data on this variable are available only up to WWI and are shown in Figure 2, which again highlights the gap dividing Italy from the other countries. Furthermore, looking at more recent data we find that Italy has reached levels of engineers in total population recorded in 1914 by Germany, France and the United Kingdom only during the 1950s (Vasta 1999a; 1999b). This significant delay suggests that the degree of technological sophistication of the Italian economy was not particularly high until at least the 1950s.

Figure 2. Engineers per 10,000 inhabitants (1866-1914)



Sources: our own elaboration on Vasta (1999a: 250).

A recent analysis on computer skills in the European Union confirms the Italian delay in technical education showing a very low share of computer science graduates. Furthermore, Italy is below the EU27 average for almost all proxies measuring even very basic computer abilities (Eurostat 2012). For example, Italy, in 2011, has one of the lower share (61%) of persons who have ever used a computer on all individuals aged 16-74, being the EU27 average 78% and the share of the main advanced European countries around 90%.

Turning our attention to more traditional input indicators, table 3 shows the evolution of R&D expenditure on GDP for the principal industrialised countries. This indicator is systematically available only from the mid-1950s, although for some countries it is possible to reconstruct some rough estimates for the 1930s. The table shows that also in this case, Italy is characterized by a very significant gap persisting throughout the entire period. Throughout the period Italy is significantly far from not only the most advanced countries that traditionally invest significant amounts of resources in research (Germany, Japan and United States), but also from South Korea, which now has the highest level among the countries considered, and from China that has overtaken Italy in the last decade.

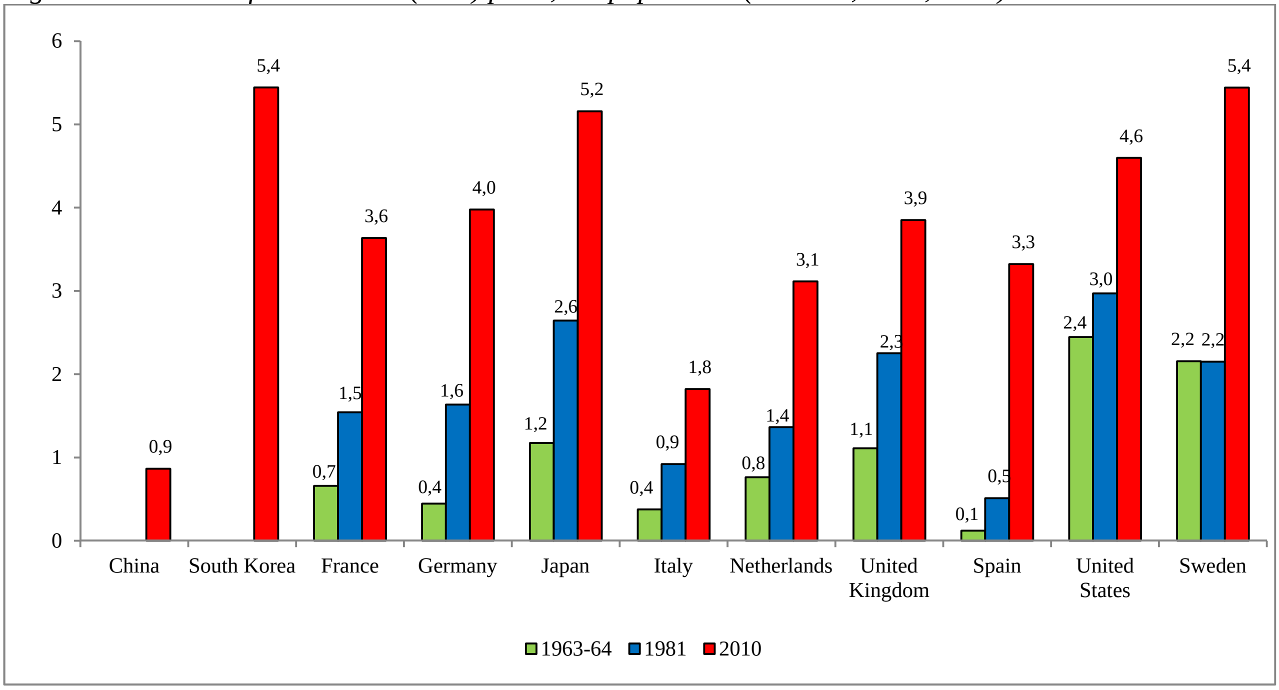
Table 3. R&D expenditure on GDP (%) for benchmark years (1934-2010)

Countries	1934	1955-60 estimate	1964	1970	1975	1980	1985	1990	1995	2000	2005	2010
China								0.7	0.6	0.9	1.3	1.7
South Korea									2.3	2.3	2.8	3.7
France		0.8	1.8	1.8	1.7	1.7	2.2	2.3	2.3	2.2	2.1	2.3
Germany		0.6	1.4	2.0	2.1	2.4	2.6	2.6	2.2	2.5	2.5	2.8
Japan	0.1		1.5	1.8	1.8	2.0	2.5	2.8	2.7	3.0	3.3	3.4
Italy		**0.2**	**0.6**	**0.8**	**0.8**	**0.7**	**1.1**	**1.3**	**1.0**	**1.0**	**1.1**	**1.3**
Netherlands			1.8	1.9	1.9	1.8	2.0	2.1	2.0	1.9	1.9	1.8
United Kingdom		1.6	2.3	2.2	2.0	2.4	2.2	2.1	1.9	1.8	1.7	1.8
Spain			0.1	0.2	0.3	0.4	0.5	0.8	0.8	0.9	1.1	1.4
United States	0.6	3.0	3.3	2.6	2.2	2.3	2.8	2.6	2.5	2.7	2.6	2.9
Sweden			1.2	1.2	1.7	2.2	2.7	2.7	3.3	3.6	3.6	3.4
OECD	0.2		1.1	1.3	1.3	1.3	1.5	1.6	1.6	1.7	1.8	2.0

Note: data for 1934 are from Freeman and Soete (1997: 300), the OECD data in 1934 refers to a weighted estimate of 12 European countries, data for Japan from 1975 to 1995 are taken from "adjusted" series; for 1964 data of Italy and Unites States refer to 1963; for 1970 data of United Kingdom and Sweden refer to 1969; for 1980 data of Germany, United Kingdom and Sweden refer to 1981; for 1990 data of China and Sweden refer to 1991; for 2010 data of China, Japan and United States refer to 2009.
Source: our own elaborations on OECD database (OECD, Main Science and Technology Indicators Database, data extracted on 1st April 2012); for 1955-60 estimate based on Malerba (1993); for United States in 1964, OECD (1968); for years 1964-1980 elaborations on OECD.

In particular, in relation to Italy we can make two further observations. First, in the second half of the XX century the share of R&D on GPD has increased by more than 6 times, passing from 0.2% in 1955-60 to 1.3% in 2010. Second, this growth was characterized by a two stage process: the share is increasing until the end of the 1980s and then stagnating during the last two decades. In 2010, Italy has the last place in the table, being overtaken also by Spain. Overall, the level of expenditure of the Italian innovation system remains today well below the 2% level which is the average value of OECD countries. Figure 3 shows the number of researchers (FTE) engaged in R&D activity. Again the figure points out the limited attention paid to scientific and technological research by Italian economic system. Despite the growth in the share of researchers on population, the gap between Italy and the other countries increases over time. In 1981 Italy had about 1 employee per 1,000 inhabitants employed in research activity, while France and Germany engaged 1.5 each, and Japan 2.6; thirty years later, Italy has 1.8 employees while France and Germany reaches 3.6 and 4 respectively, while Japan 5.2 researchers per 1,000 inhabitants.

Figure 3. Numbers of researchers (FTE) per 1,000 population (1963-64, 1981, 2010)



Note: data on researchers for Japan in 1981 are taken from "adjusted" series; for 2010 data of China, France and Japan refer to 2009; data of Unites States refer to 2007.
Source: our own elaborations on: Maddison [2009]; for 1963-64 OECD [1968]; for 1981 and 2010 data extracted on 30 April 2012 from OECD.Stat.

4.2. *The output dimensions of the Italian NIS*

The first output indicator we consider is the number of patents. The basic idea is that the number of patents can be adopted as a proxy for the number of innovations produced by a country in a given period of time. Tables 4 and 5 shows respectively, the percentage shares of the patents issued in the United States to residents in the major industrialized countries and the number of patents issued to residents in these countries per million inhabitants.[12]

[12] To overcome the problems originating from differences in countries' patent legislations, international comparisons typically considers patenting activity by subjects of different nationalities in a *third country*. In comparison across major industrialized countries, the most suitable choice of a *third* country is that of the United States, since they represent the most important market on a world scale. This is also the approach followed in this paper. Note that the results presented here exclude patents issued to US and Canadian subjects from the calculation.

Table 4. Patents granted in the United States (%) to foreign residents for benchmark years (1883-2010)

	China	France	Germany	Japan	**Italy**	Netherlands	South Korea	Spain	Sweden	Switzerland	United Kingdom	Others	Total
1883	-	17.8	23.3	0.2	**0.3**	-	-	0.2	1.2	2.2	43.2	11.7	100.0
1890	-	10.3	26.1	0.1	**0.3**	0.3	-	0.4	1.8	3.2	43.9	13.5	100.0
1900	0.1	10.9	34.3	-	**1.0**	0.8	-	0.2	1.5	2.5	34.1	14.4	100.0
1913	0.0	9.3	39.2	0.5	**1.5**	0.5	-	0.1	2.4	3.6	26.8	16.0	100.0
1927	0.1	11.4	33.1	0.8	**2.5**	1.7	-	0.7	3.3	4.5	25.8	16.1	100.0
1938	0.1	9.9	40.8	1.6	**1.5**	3.6	0.0	0.2	3.3	4.0	24.2	10.8	100.0
1950	0.1	17.5	0.6	0.1	**1.0**	9.1	-	0.5	7.5	11.0	40.5	12.2	100.0
1960	-	11.8	30.9	3.3	**3.6**	5.3	0.0	0.1	5.0	7.7	26.4	5.9	100.0
1970	0.0	10.6	27.3	16.1	**3.5**	3.3	0.0	0.3	3.9	6.8	18.1	9.9	100.0
1980	-	8.9	24.7	30.5	**3.4**	2.8	0.0	0.3	3.5	5.4	10.3	10.1	100.0
1990	0.1	7.0	18.5	47.5	**3.1**	2.3	0.5	0.3	1.9	3.1	6.8	8.9	100.0
2000	0.2	5.5	14.8	45.4	**2.5**	1.8	4.8	0.4	2.3	1.9	5.3	15.1	100.0
2010	2.5	4.2	11.6	41.9	**1.7**	1.5	10.9	0.4	1.3	1.5	4.0	18.6	100.0

Source: 1883-1960: elaborations on USPTO TAF mar. 1977; 1970-2010 elaborations on: USPTO.GOV Extended Year Set - Patents By Country, State, and Year Utility Patents (December 2011) (http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports.htm#by_geog).

Table 5. Patents granted to foreign residents in the US by countries per millions habitants and benchmark years (1883-2010)

	China	France	Germany	Japan	**Italy**	Netherlands	South Korea	Spain	Sweden	Switzerland	United Kingdom
1883		4.5	5.3	0.1	**0.1**			0.1	2.6	7.7	12.3
1890		4.4	9.5	0.0	**0.2**	1.3		0.4	6.7	19.0	20.3
1900	0.0	8.4	19.7		**1.0**	5.1		0.3	9.0	23.9	25.8
1913	0.0	8.2	22.0	0.4	**1.5**	3.2		0.2	15.5	33.9	21.5
1927	0.0	12.0	22.2	0.6	**2.7**	9.9		1.2	23.7	48.5	24.5
1938	0.0	12.7	32.2	1.2	**1.9**	22.5	0.1	0.4	28.7	51.3	27.6
1950	0.0	16.1	0.4	0.0	**0.8**	35.3		0.6	41.9	91.4	31.7
1960		17.9	30.2	2.5	**5.0**	32.6	0.0	0.3	47.1	102.0	35.6
1970	0.0	33.3	57.1	25.2	**10.6**	41.7	0.1	1.7	78.1	177.4	53.1
1980		37.9	73.8	61.0	**14.3**	46.3	0.2	1.7	98.9	198.3	42.7
1990	0.0	49.3	95.9	158.0	**22.2**	64.2	5.2	3.3	89.7	187.8	48.6
2000	0.1	62.5	124.5	246.9	**29.7**	78.0	70.8	6.7	177.8	181.9	61.5
2010	2.0	69.1	150.2	352.6	**30.9**	96.6	240.6	10.2	158.3	211.5	70.4

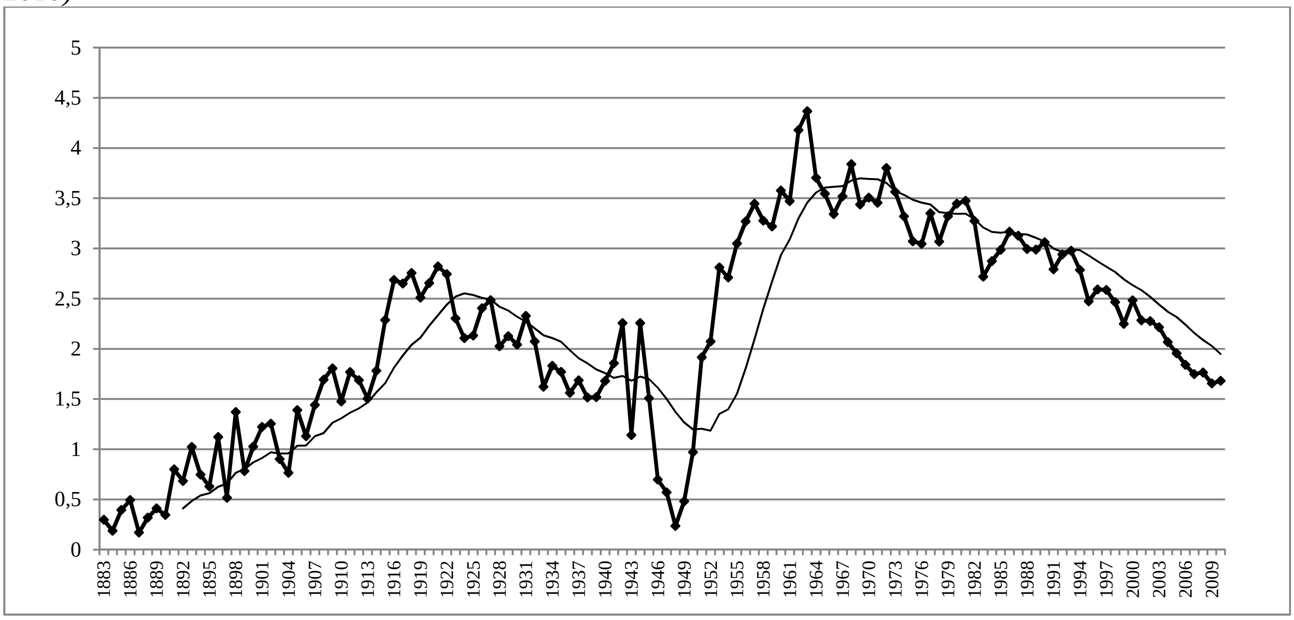
Source: Elaborations on Maddison [2009] and for 1883-1960 on USPTO TAF mar. 1977, and for 1970-2010 on USPTO.GOV Extended Year Set - Patents By Country, State, and Year Utility Patents (December 2011) (http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports.htm#by_geog).

Table 4 shows that the relative position of Italy with respect to the other countries did not change substantially in the long term. However, by looking at Figure 4, four distinct phases can be noted: the first, of rapid growth terminating at the beginning of the 1920s, when Italy reached a peak (2.5%). This period was characterised by the effects of WWI, when several industries with high technological intensity developed, such as steel production and chemicals (Zamagni 1990; Amatori 1997). This phase is followed by a period of relative decline that coincided with the rise of fascism, the autarchic period, and WWII, during which the share of Italian patents was significantly lower than in the previous period. In fact, the levels registered in the early 1920s were exceeded only in the early 1950s. This seems to contradict the interpretation of Petri who considers this historical phase as a moment of consolidation of Italian technological capabilities (Petri 2002).[13]

[13] However, it is also possible that the during the autarchic period the incentive to take patents abroad was considerably reduced.

The third phase coincides with the period of the Italian Golden Age, when the share reached the historical peak of 4.4% in 1963. The effervescence of this historical phase is also confirmed by the a number of success stories of breakthrough innovations such as the polypropylene invented by Giulio Natta during the 1950s and the *Perottina* invented in 1964 by Giorgio Perotta. It is interesting to note that 1963 is also considered as turning point by Russo and Santoni (2012: 442), Gomellini and Pianta (2007: 561) and Pivato (2011). Subsequently, a new phase of decline ensued with a constant reduction in performance with an average value of 3.4% during the 1970s and of 3.1% during the 1980s.[14] A drastic deterioration of the performance occurred from the mid-1990s, so that in 2000 the share was equal to the levels of the 1920s with a further drop to 1.7 in 2010, the level reached at the eve of the WWI.

Figure 4. Patents granted to Italian residents in the US on total patents granted to foreign residents (1883-2010)



Source: 1883-1960: elaborations on USPTO TAF mar. 1977; 1970-2010 elaborations on: USPTO.GOV Extended Year Set - Patents By Country, State, and Year Utility Patents (December 2011) (http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports.htm#by_geog).

Table 5, in which the number of patents granted per million inhabitants is reported, makes it possible to advance further conjectures. The distance with all the other countries, with the exception of Spain, remained considerable for the entire period, and the relative position did not change. In synthesis, Italian long-term innovative performance as measured using patents was in general very weak and far from that of countries with similar levels of income. In this perspective it is particularly significant the marked worsening in performance during the last twenty years.

[14] The data presented in figure 4 contradicts the interpretation of Simoni (2012) who seems to consider the Italian innovatiove performance (measured using patents) as relatively satisfactory until the early 1990s.

The sectoral disaggregation of patents allows the identification of the patterns of technological specialisation of the Italian economy highlighting points of strength and weakness. For the period preceding WWI, the small number of patents registered in the United States made it impossible to express an overall judgment. However, Vasta (1999a) carried out a pioneering study on patents registered in Italy in the electromechanical and chemical sectors from 1880 to 1914. He finds that, in the first sector, innovative activity was concentrated on products that were not technologically very advanced, although if a certain capacity to gain several product niches emerged. The second sector, instead, is characterized by a considerable gap for all fields of activity and a growing dependence on foreign countries.

A comprehensive picture of the Italian pattern of technological specialisation can be gleaned from the patents issued in the US starting from 1963. By adopting a classification proposed by National Bureau of Economic Research (NBER) (Hall, Jaffe and Trajtenberg 2002), it is possible to reconstruct the evolution of the Italian specialisation pattern. The index of Revealed Technological Advantage (RTA)[15] has been calculated for each category. At the highest level of aggregation (Table 6), we can notice a certain stability during the course of the entire period. Italy is specialised in the field of pharmaceuticals and chemistry, slightly specialised in mechanics and in other classes which included many traditional products, and strongly de-specialised in computers, telecommunications, and electronics.

Table 6. Italian pattern of specialisation (RTA) by technological categories (1963-2006)

Code	Category name	1963-1975	1976-1985	1986-1995	1996-2006	1963-2006
1	Chemical	**1.398**	**1.240**	**1.203**	**1.307**	**1.309**
2	Computer &Communications	0.734	0.993	0.473	0.460	0.513
3	Drugs & Medical	0.967	**1.714**	**1.298**	0.994	**1.149**
4	Electrical & Eletronic	0.647	0.592	0.656	0.846	0.718
5	Mechanical	0.997	0.983	**1.220**	**1.469**	**1.201**
6	Others	0.938	0.878	**1.077**	**1.254**	**1.068**

Source: our own elaboration on: for period 1963-1975 NBER Patent Database; for period: 1976-2006 NBER-Google Patent Data Project database; data extracted on 22nd April 2012.

At a higher level of disaggregation (Table 7), we find confirmation of the long-term stability of the Italian pattern of specialisation. The category with the highest index value was, for all the sub-

[15] The RTA index is used to make cross-country comparisons by utilizing a third country as scenario. This index is calculated in the same way as the RCA (Revealed Comparative Advantage) index, first used by Bela Balassa for the analysis of international trade. In the case of the RTA, the index measures the comparative advantage in innovative activity rather than the comparative advantage in trade. The index uses patents as a proxy measure of technological capability, and it has been applied to technology for the first time by Luc Soete in 1980.
The index for a certain country and in a certain product is given by the country's share of foreign patents in the *third country* taken out by foreigners in that product, divided by the country's share of foreign patents for all the products:

$$RTA_{ij} = (P_{ij}/\Sigma_j P_{ij})/(\Sigma_i P_{ij}/\Sigma_i \Sigma_j P_{ij})$$

Where P_{ij} is the number of patents in given country for the product *i* granted to residents in the country *j*. Clearly, an index > 1 reveals a comparative advantage, and an index < 1 a comparative disadvantage.

periods identified, that of textiles and clothing. At the same time, organic compounds and pharmaceuticals also continued at the top of the classification. Instead, all the products connected with the trajectory of Information and Communications Technology (ICT) and those relative to the biotechnologies were found to be greatly de-specialised. In interpreting these trends, we should also take into account that patents granted in the United States are likely to provide a more positive picture of Italian specialization, due to the greater difficulties faced by small-size firms – specialised in the traditional sectors – to patent abroad. Still, Italian specialisation remains predominantly dominated by traditional low-tech sectors as shown also by Breschi and Mancusi (1995) using European Patent Office data. It is interesting to note the relative specialisation in chemical and pharmaceuticals emerging from table 6 and 7. According to Boldrin and Levine (2008: 222-223), one of the factors accounting for the success of the Italian pharmaceutical industry until the early 1980s was the peculiarity of Italian patent law which preclude the patenting of drugs. Accordingly, a number of Italian pharmaceutical firms and laboratories did emerge during the 1950s, first imitating and then improving on existing products and drugs.

Finally, it is worth noting that the picture of technological specialisation emerging from Table 6 and 7 is broadly consistent with the picture of revealed comparative advantage constructed using trade data (Table 8).

Table 7. Ranking of Italian top specialized and despecialized sub-categories (1963-2006)

Rank	1963-1975	1976-1985	1986-1995	1996-2006	1963-2006
top specialized sub-categories					
1	Apparel & Textile (2.750)	Apparel & Textile (3.477)	Apparel & Textile (4.140)	Apparel & Textile (3.673)	Apparel & Textile (3.501)
2	Resins (2.217)	Drugs (2.595)	Organic Compounds (2.360)	Receptacles (2.880)	Organic Compounds (2.208)
3	Organic Compounds (1.977)	Organic Compounds (2.244)	Drugs (2.011)	Organic Compounds (2.222)	Receptacles (1.698)
4	Biotechnology (1.568)	Computer Periphericals (1.268)	Receptacles (1.705)	Mat. Proc & Handling (1.895)	Resins (1.663)
top de-specialized sub-categories					
1	Semiconductor Devices (0.319)	Amusement Devices (0.037)	Amusement Devices (0.110)	Electronic business methods and software (0.094)	Electronic business methods and software (0.122)
2	Electrical Lighting (0.361)	Surgery & Med Inst. (0.285)	Electronic business methods and software (0.127)	Amusement Devices (0.096)	Amusement Devices (0.190)
3	Earth Working & Wells (0.392)	Semiconductor Devices (0.379)	Information Storage (0.325)	Computer Periphericals (0.214)	Computer Periphericals (0.317)
4	Surgery & Med Inst. (0.453)	Nuclear & X-rays (0.391)	Nuclear & X-rays (0.348)	Communications (0.337)	Surgery & Med Inst. (0.445)

Source: our own elaboration on: for period 1963-1975 NBER Patent Database; for period: 1976-2006 NBER-Google Patent Data Project database; data extracted on 22nd April 2012

Since the end of the XIX century, as shown in Table 8, Italy has been relatively specialized in the export of manufactured goods with a rather limited degree of technological sophistication (mainly textiles, spirits and tobacco, apparel, footwear, ceramics glass and bricks, etc.).

Table 8. Top 3 RCA sectors for manufactured products

	1899	1913	1929	1950	1970	1998	2005
1	Spirits & Tobacco (4.60)	Spirits & Tobacco (4.04)	Ceramics, glass and bricks (2.50)	Textiles (2.60)	Textiles, clothing and footwear (2.25)	Footwear (5.53)	Leather products (4.00)
2	Finished goods n.e.s (2.68)	Finished goods n.e.s (2.18)	Textiles (2.37)	Apparel (1.88)	Non-metallic mineral manufactures (1.85)	Leather products (4.88)	Footwear (3.76)
3	Ceramics, glass and bricks (2.16)	Ceramics, glass and bricks (1.73)	Spirits & Tobacco (2.11)	Spirits and Tobacco (1.36)	Electrical machinery (1.52)	Furniture, fixtures (3.44)	Furniture, fixtures (2.64)

Source: our own elaboration on Vasta (2010).

Further insights on Italian innovative performance emerge from a closer look at the historical development of the patent system in Italy. Conventional economic theory suggest that, without patent protection, incentives for investment in innovative activities will be lacking. Hence, a strong and effective system of patent protection is a necessary pre-requisite for the attainments of substantial levels of innovative activities. The historical evidence instead suggests a much more complicated picture, especially for countries that are catching up with the world technological frontier (Odagiri, Goto, Sunami and Nelson, 2010). In fact, many successful catching up countries adopted judicious policies concerning intellectual property rights, in order to make sure that patents could act not only as an incentive, but also as a tool for transferring technologies from abroad. Thus, many XIX century patent systems contemplated the possibility of granting patents not only for new inventions, but also for importing technologies from abroad. More importantly, many XIX century patent systems contained discriminatory measures against foreign inventors sometimes explicitly, sometimes in the actual practice of the legal procedures. For example, in the US patents were initially restricted to American citizens (a ban that was gradually relaxed) and until 1861 foreign applicants were required to pay higher fees (Mowery 2010: 36).[16] An illustration of discriminatory practices against foreign inventors is provided by the case study of Reichter and Streb (2011) showing the obstacles raised by the German patent office against US machine tool makers during the 1920s. Instead, Italy in generally refrained from developing a patent system that could serve as a tool from the importation of technologies from abroad.

The original patent law of the Kingdom of Sardinia enacted in 1855, which is the ancestor of the Italian legislation, did contain a discriminatory fee for foreign inventors (50% more than the

[16] More precisely, the reform of 1836 stated the foreign inventors could be granted a US patent paying a fee of $300 ($500 if they were British). The patent fee for US inventors was $ 30 (Khan 2005: 57).

domestic inventors). However by 1878 every type of discrimination was *de facto* removed (Giannetti 2010).[17] The lack of discrimination in the Italian system is visible when we look at the relative *openness* of the patent system. This may be measured by considering the share of patents granted to foreign applicants in the total number of patents granted (Table 9).

Table 9. Share of foreign patents in total patents granted

	a. 1880	a. 1901	a. 1914	1927	a. 1938	a. 1963	1979	a. 1991	a. 2010
Belgium	69.3	78.4				89.5	89.1	53.6	20.3
France		51.4	50.8	42.8	55.0	65.3	72.2	31.2	11.3
Germany	31.1	37.1	30.1	24.4	19.2	37.2	51.7	38.1	29.6
Italy		64.4	61.5	62.8	57.7	72.2	77.2	25.5	10.7
Japan				27.7	17.4	35.9	21.0	15.6	15.9
Netherlands			80.2	80.0	76.9	81.1	86.8	88.8	15.7
Switzerland	39.1	67.3	62.0	59.3	55.9	66.3	75.2	45.6	37.8
United Kingdom		53.2	-	53.3	55.6	74.7	79.9	64.6	58.5
United States of America		13.3	11.5	11.8	15.2	18.6	37.4	47.0	50.9

Source: our elaborations on data from http://www.wipo.org, extracted 1st July 2012.

It is interesting to note that until 1979 the Italian system seems to be extremely open with a share of patents granted to foreign inventors that exceeds the 50% which is very similar to that of small open economies such as the Netherlands and Belgium.[18] The general impression is that of a system that is particularly open in order to stimulate the transfer of technologies from abroad, but it is surely less suited in stimulating the use of foreign technologies as a base for autonomous innovations. The ability of the Italian innovation system in importing and adapting foreign technology is the focus of the study of Barbiellini Amidei, Cantwell and Spadavecchia (2011). On the basis of various indicators, they suggest that Italy at least up to the 1960s is largely dependent on technologies imported from abroad. Later on Italian firms were able to adapt foreign technologies to local conditions.

As a final notation, we may observe that the Italian weak patenting position both nationally and internationally is going to represent a future obstacle to the access to sophisticated knowledge bases of high tech sectors. As noted by Hall and Ziedonis (2001), one of the reasons underlying the growth of international patenting activities since the late 1980s is the need of firms of accumulating sizable patent portfolios in order to have enough chips to spend in cross licensing agreements and other form of research joint ventures and technological alliances.

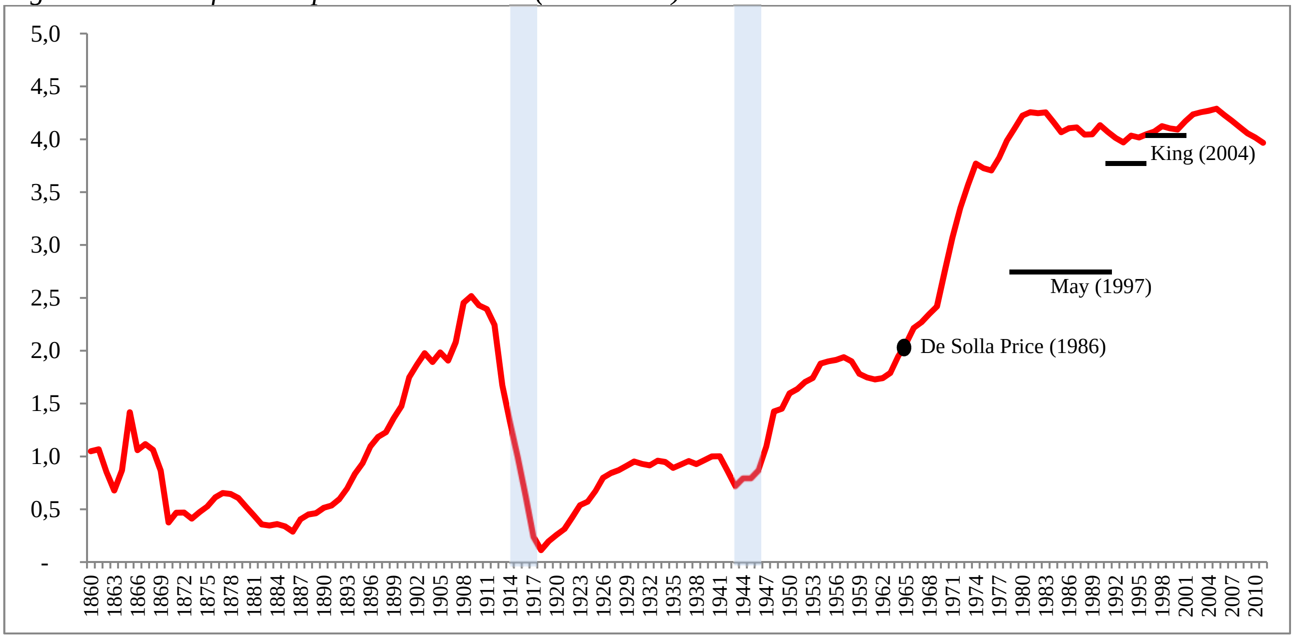
If we turn our attention to the generation of scientific knowledge we consider as output indicator the number of scientific publications. For this purpose, we use two different samples: the overall world scientific production extracted from the Scopus database (henceforth All-Scoupus AS) and a

[17] The other distinguishing feature of the Italian patent system from 1859 to 1939 was that it did not contemplate an examination procedure. The system was simply a registration system. For a compact overview of the Italian patent system, see Vasta (1999a:121-126)

[18] The decline in the share after 1979 is probably due to the creation of the European Patent Office.

sub-sample of this database, which should approximate the excellence of research activity, represented by the two leading "generalist" scientific journals in the world: the English *Nature* and the American *Science* (henceforth N&S). Figure 5 shows the share of Italian publications in AS, while Table 10 shows the average share publications of selected countries in six different periods and Table 11 shows the average number of publications per millions inhabitants. In order to have some confirmation about the reliability of the Scopus dataset, in the figure we also include some alternative authoritative estimates on the scientific impact of Italy provided by other scholars: the pioneering contribution by De Solla Price (1986) and the more recent studies by May (1997) and King (2004).

Figure 5. Share of Italian publications in AS (1860-2011)



Note: the series has been smoothed with a 5-period moving average; all documents in AS concerning areas of Life Sciences, Health Sciences and Physical Sciences. De Solla Price data refer to the number of scientific authors, while May and King data are relative to publications.
Sources: our own elaboration on Scopus database (http://www.scopus.com/home.url); data extracted on 7th April 2012.

Figure 5 shows the existence of different phases in Italian performance in scientific research. In the first phase, running from the unification up to the end of the 1880s, the Italian share is around 0.6%, while starting from the beginning of the 1890s in the Giolittian era this value grew considerably overcoming the threshold of 2.5%.[19] The WWI produced a drastic decline and, during the interwar period, even if characterized by a positive trend, the Italian share on world scientific production remained under 1%. Italian performance increases considerably during the Golden Age passing from 1.8% in 1950 to 4% in 1973. After this period the Italian share remains substantially stable around the 4%.

[19] In the study by Forman, Heilbron and Weart (1975) which contains a comprehensive survey on the state of academic physics in the world around 1900, Italy appears to lag behind Germany, France and UK both in terms of funding and in terms of scientific production.

Table 10. Average % by countries of total publication in Scopus (1860-2011)

	Italy	United Kingdom	France	Germany	United States	Japan	Spain	Netherlands	China	South Korea	Sweden	Others
1860-1889	0.6	73.6	0.9	8.8	5.7	0.1	0.0	0.2	0.0	-	0.0	10.0
1890-1914	1.6	46.6	1.1	22.2	9.2	0.5	0.0	0.4	0.0	0.0	0.3	18.0
1919-1938	0.7	11.3	0.3	34.2	27.3	1.3	0.1	1.4	0.2	0.0	0.6	22.5
1950-1972	2.1	9.6	1.6	12.0	49.3	4.0	0.1	1.5	0.0	0.0	1.1	18.6
1973-1995	4.0	8.9	5.8	8.1	35.7	7.8	1.3	2.0	0.8	0.2	1.7	23.7
1996-2011	4.1	7.9	5.6	7.7	28.9	8.2	3.1	2.3	9.5	2.3	1.7	18.6

Note: all documents in Scopus database concerning areas of Life Sciences, Health Sciences and Physical Sciences.
Sources: our own elaboration on Scopus database (http://www.scopus.com/home.url); data extracted on 7th April 2012.

Table 11. Average number of publications in Scopus per millions habitants (1860-2011)

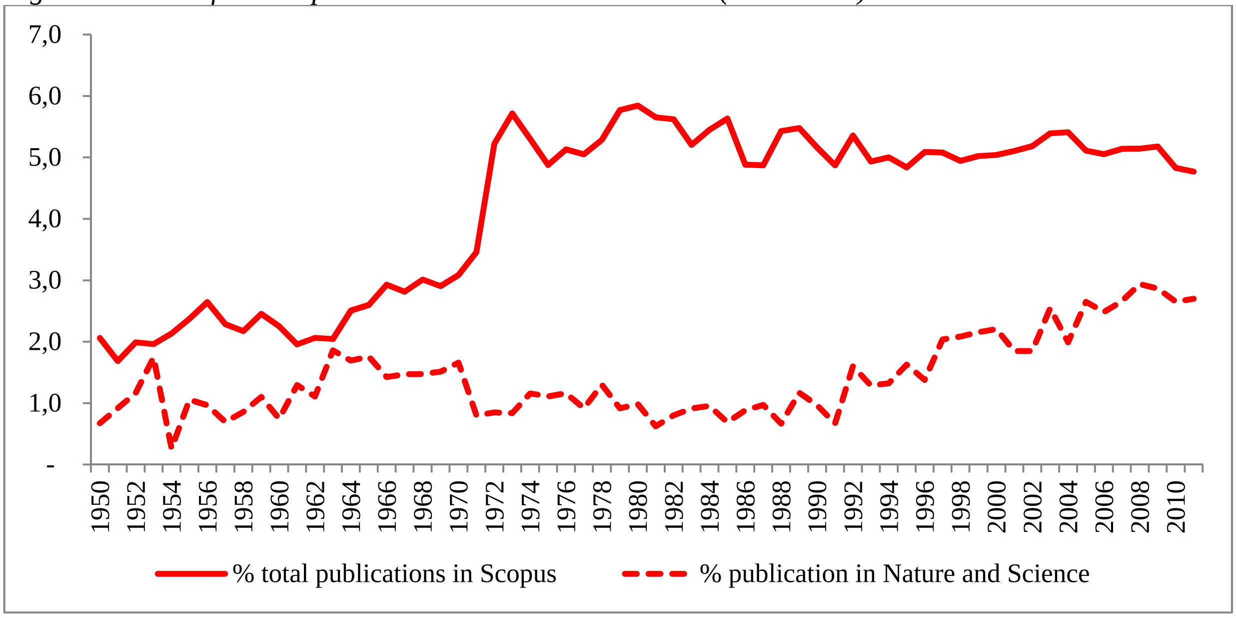
	Italy	United Kingdom	France	Germany	United States	Japan	Spain	Netherlands	China	South Korea	Sweden
1860-1889	0.1	15.6	0.2	1.7	0.9	0.0	0.0	0.3	0.0	-	0.0
1890-1914	0.8	18.8	0.5	6.9	2.0	0.2	0.0	1.4	0.0	0.0	1.1
1919-1938	1.1	10.6	0.4	28.0	12.5	1.3	0.2	9.4	0.0	0.0	5.7
1950-1972	17.3	69.1	16.5	53.5	97.4	18.1	1.9	49.9	0.0	0.3	57.2
1973-1995	284.9	621.1	404.4	399.9	593.3	270.0	155.7	572.2	3.6	24.9	817.2
1996-2011	890.7	1,608.9	1,092.6	1,152.7	1,200.6	777.2	980.7	1,739.7	104.4	635.3	2,241.9

Note: all documents in Scopus database concerning areas of Life Sciences, Health Sciences and Physical Sciences.
Sources: our own elaboration on Maddison [2009] and Scopus database (http://www.scopus.com/home.url); data extracted on 7th April 2012.

The comparative perspective of Tables 10 and 11 provides further insights on the historical dynamics of Italian scientific performance. In the period 1890-1914, Italy is ranked above France, Japan and Spain. During the Golden age, Italy remains constantly above France and is overtaken by Japan who increased considerably his performance. In the last decades, notwithstanding Italy doubled her capacity, it is overtaken also by France. Table 11 which contains data normalized by population shows that, in the period 1973-2011, the performance of Italy is higher than that Japan and South Korea, and not so distant from those of France and Germany.

Further information comes from the analysis of publications that represent the research excellence in the N&S sub-sample. This analysis is possible only from 1950 because for the previous years there the data are not fully reliable. In this case the universe is represented only by a restricted number of countries and this means that the share for each country are calculated on this more limited sample. In Figure 6, two curves for Italy are plotted: the share of total publications of selected countries in AS and in N&S. In the first case, the share of Italian publications grows with a fluctuating behaviour until the end of the 1960s, it reaches its peak (5.84%) in 1980 and then displays a decreasing trend dropping in the last year to 4.8%. The Italian publications in N&S are around 1% until the early 1990s, and increase considerably in the following years reaching 2.9% in 2008. These data seem to indicate that, since the early 1990s, there has been a significant increase in the Italian ability to produce excellent research converging towards the level of performance in AS publications.

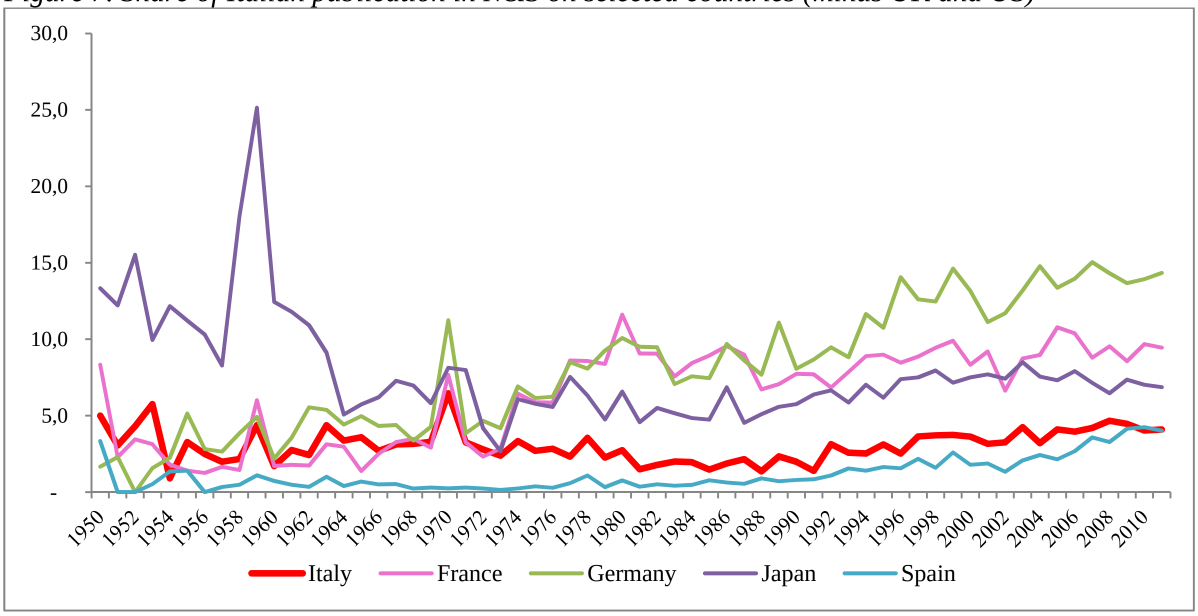
Figure 6. Share of Italian publications on selected countries (AS vs N&S)



Note: all documents in Scopus database concerning areas of Life Sciences, Health Sciences and Physical Sciences. The countries considered are: China, France, Germany, Japan, Italy, Netherland, Spain, South Korea, Sweden, United Kingdom, United States.
Sources: our own elaboration on Scopus database (http://www.scopus.com/home.url); data extracted on 7th April and 26th June 2012.

In Figure 7 we have eliminated from the total publications of selected countries the publications of UK in Nature and those of US in Science (in order to mitigate the potential bias of these sources towards UK or US authors) At the beginning of the period, the Italian share is similar to that of other European countries, but since the 1970s France and Germany have grown faster, and in last years also Spain reaches the Italian share.

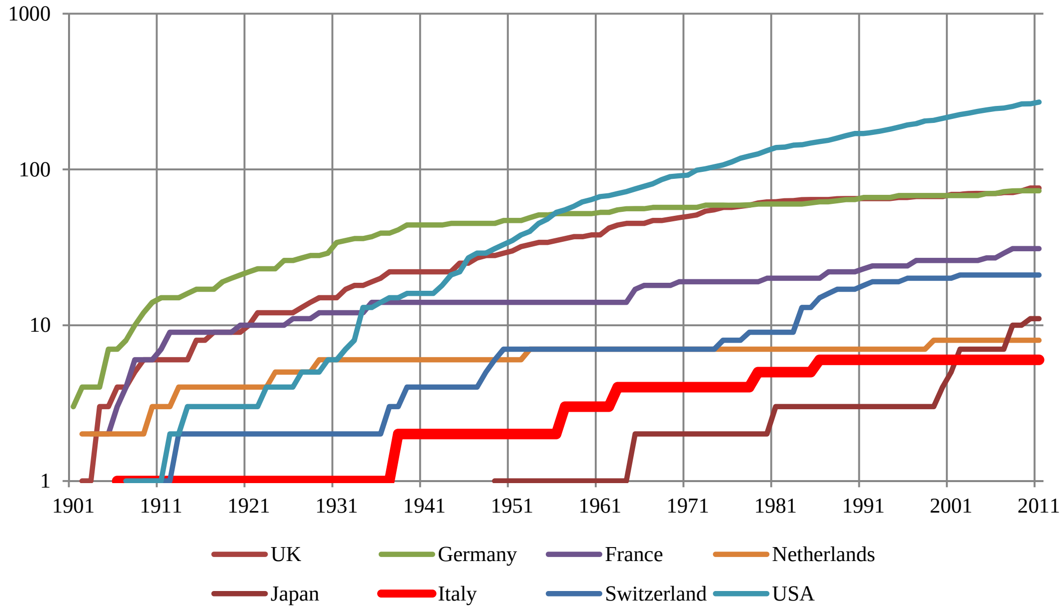
Figure 7. Share of Italian publication in N&S on selected countries (minus UK and US)



Note: The countries considered are: China, France, Germany, Japan, Italy, Netherland, Spain, South Korea, Sweden; United Kingdom only for Science and United States only for Nature.
Sources: our own elaboration on Scopus database (http://www.scopus.com/home.url); data extracted on 26th June 2012.

Finally in Figure 8 we consider another dimension of research excellence, the cumulative number of Nobel laureates in physics, medicine and chemistry by research affiliations. This should be considered as measure of the capacity of producing radical scientific breakthroughs and discoveries. The affiliations are recorded at the moment in which the prize was awarded.[20]

Figure 8. Cumulative number of Nobel laureates in Chemistry, Physics and Medicine by affiliation of the winner, 1901-2011 (logarithmic scale)



Source: our own elaborations on data extracted from http://www.nobelprize.org (data extracted on 4th July 2012).

Several points merits attention. The first is that in the period 1901-1935, UK, France and Germany are the leading countries in terms of Nobel laureates. The leadership of the USA is relatively recent and emerges only after WWII. The second point is that Italy lags far behind UK, France and Germany throughout the period. Finally, Nobel laureates with Italian affiliations are rather evenly scattered throughout the entire period and there is no particular clustering in specific periods of time. Overall, the figure points to a significant weakness of the Italian NIS in the domain of scientific research namely, the inability of constructing long lasting traditions of *research excellence*. It is particularly revealing that the six Italian Nobel laureates in the figure (Rita Levi Montalcini (1986), Giulio Natta (1963), Abdus Salam (1979), Daniel Bovet (1957), Camillo Golgi (1906), Enrico Fermi (1938)) did all belong to a different scientific institution. In other European countries, instead, it is possible to identify a restricted number of research institutes that account for more than a single Nobel laureate. Even smaller countries like the Netherlands and Sweden with

[20] Of course, several Italian scientists received Nobel prizes while being affiliated with foreign institutions, so it is possible that the results of figure 8 contain a downward bias. Still, we would maintain that if one is interested in getting a sense of the structural performance of a country in science, the approach adopted here is reasonable,

few Nobel laureates shows a certain tendency towards the concentration of research excellence in specific institutions.

Considered together, the indicators measuring the capacity of the Italian NIS of generating scientific knowledge show that Italy, starting from very low levels, has reach a capability of producing what Kuhn (1962) calls *normal science* that is comparable to that of other major industrialized countries. The data also indicates that there has been also a recent improvement in the ability scientific findings of sizable impact (as measured by the articles published in *Nature* and *Science*). Finally, the data on the Nobel laureates seems instead to indicate a lack of ability in the construction of research traditions of excellence (in particular the incapacity of concentrating resources and talents in key institutes).[21]

This quantitative picture is consistent with accounts produced by historians of science in Italy (Maiocchi 1980; Russo and Santoni 2012). From the unification up to WWI there was no real integration of the system of scientific research and industrial applications, so that the growth of scientific research was due, by and large, to the expansion of the university system and to the sporadic initiative of some talented scientists such as Vito Volterra. [22] After WWI a major restructuring of the system of scientific research took place leading to the creation in 1923 of Consiglio Nazionale delle Ricerche (CNR).This was a major institutional reform adopted by the Fascist regime for allegedly boosting the performance of the Italian scientific system and increasing its connections with industrial firms, especially in military applications. In fact, most historians agree in considering this reorganization as a missed opportunity, because it was carried out with a very limited amount of resources and more with a view to propagandistic goals than to the real support of promising research projects (Maiocchi 1980; Russo 1986; Vasta 1999b).[23]

Another missed opportunity is the period 1950-1963 when the experience of CNR was fraught by an excessive fragmentation of resources and by a political inability to focus on the most promising projects as shown by the case of the lukewarm support to research in nuclear power systems (Russo and Santoni 2012).[24] After the oil crisis, the Italian system has been characterized

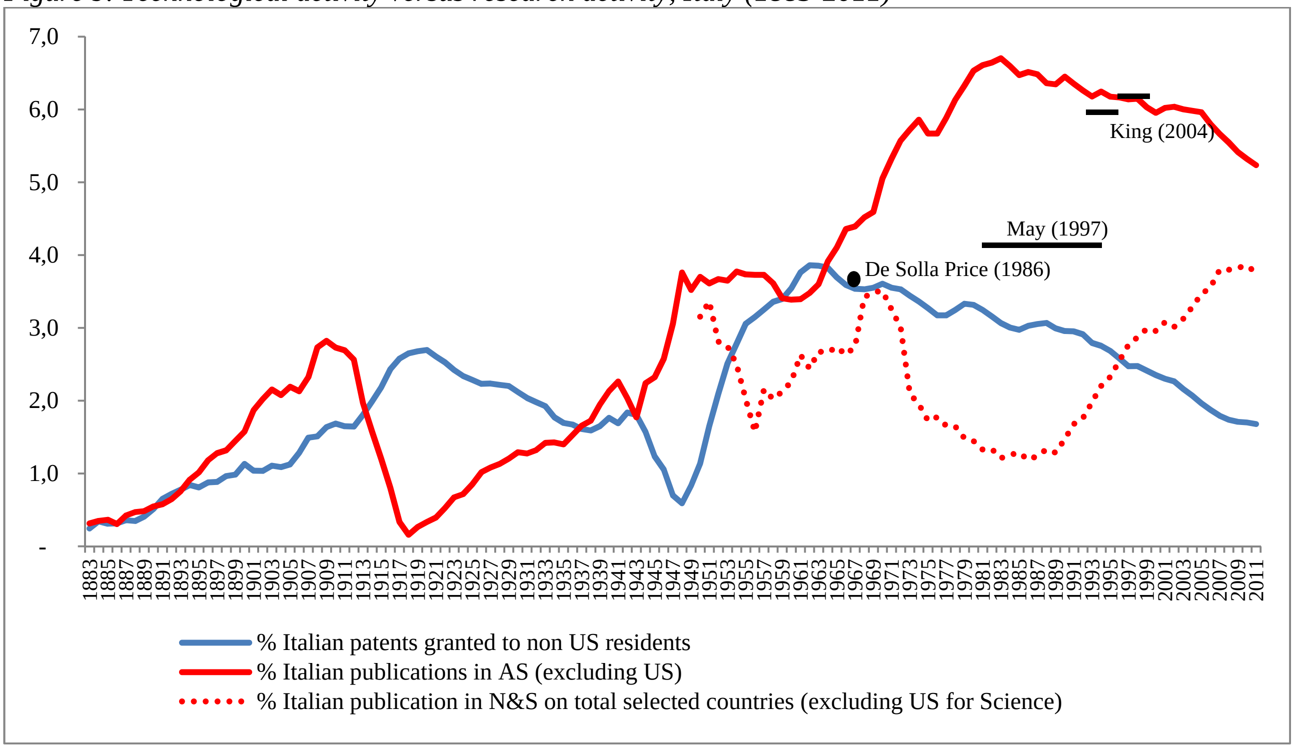
[21] This is confirmed by Shangai university ranking where the top Italian university in 2011 is ranked below the 100th position, see http://www.shangairanking.com (data extracted on 22nd July 2012).
[22] According to Maiocchi (1980: 924) during the liberal age in the parliamentary discussions it is very common to find statements like these: “In Italy we should work more and study less. We should first become a wealthy and powerful national and later on we shall become a learned and science-minded nation” [statement to Parliament of MP Rizzetti in 1894)”
[23] For a comprehensive study of technological development in military applications at the beginning of WWII which shows that, despite some noteworthy successes, Italy was characterized by a fundamental gap in military equipment, see Zamagni (1998).
[24] Giannetti and Pastorelli (2007: 611) suggest that since the mid 1960s it is possible to detect a “progressive involution in the innovation strategy of the country”.

by a structural lack of resources and by a confusing arrangement of the interaction between the CNR and the university system (Vasta 1999b).

4.3. *A mismatch between science and technology?*

The comparison between the share of scientific publications of Italian researchers and the share of patents granted to Italian residents in the US, provided in Figure 9 points to an important peculiar characteristic of the Italian innovation system. First, looking at the whole period, scientific activity performs better than patent activity. Second, scientific activity increases considerably in the early 1960s when, on the contrary, the share of patent production starts to decline. Third, the “mismatch” between science and technology becomes even more apparent after the 1980s, when the share of Italian publications in N&S grows rapidly while the share of patents drops. This latter trend is probably due to the growing internationalization of the Italian academic system, at least in hard sciences.

Figure 9. Technological activity versus research activity, Italy (1883-2011)



Note: the series have been smoothed with a 5-period moving average; all documents in AS concerning areas of Life Sciences, Health Sciences and Physical Sciences. The countries considered are: China, France, Germany, Japan, Italy, Netherland, Spain, South Korea, Sweden, United Kingdom, United States.
Source: for publication: our own elaboration on Scopus database (http://www.scopus.com/home.url); data extracted on 7th April and 26th June 2012; for patents: 1883-1960: elaborations on USPTO TAF mar. 1977; 1970-2010 elaborations on: USPTO.GOV Extended Year Set - Patents By Country, State, and Year Utility Patents (December 2011) (http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports.htm#by_geog).

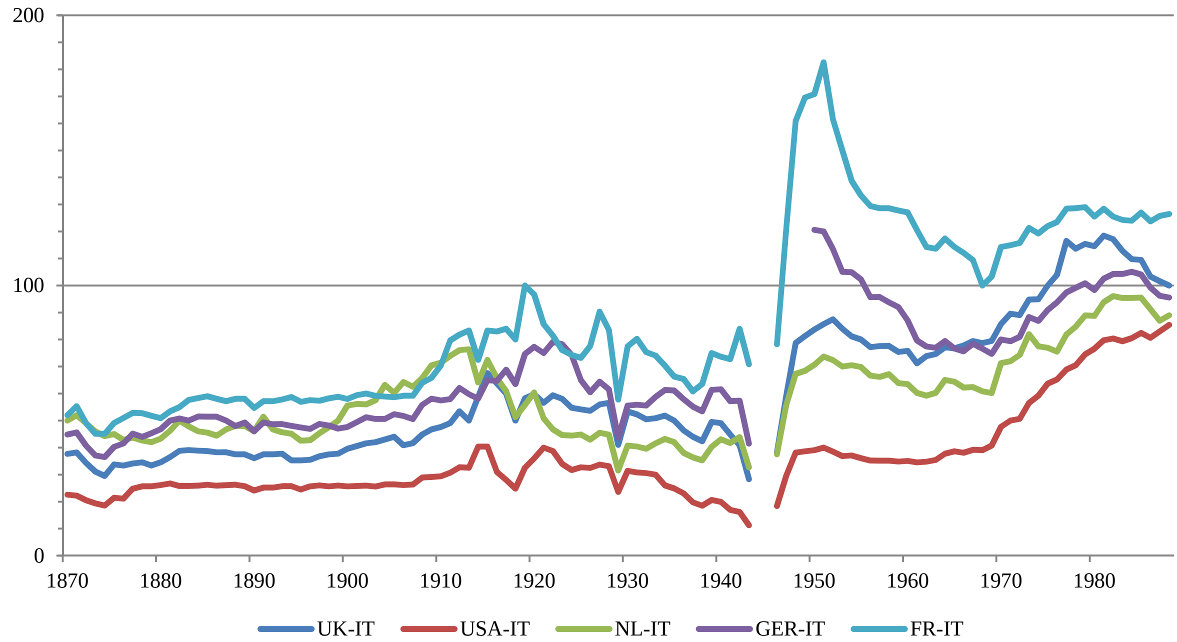
Overall this patterns suggest the existence of serious lack of congruence between the two key elements of NIS. In particular, the diverging performance between scientific and technological activities reveals major difficulties in the technology transfer of scientific results from universities to firms (lack of bridging institutions), and, more generally, the existence of research system that seems able to deliver a reasonable performance, although not outstanding, and that is more sophisticated that the system of industrial research of business firms (Malerba 1993).[25]

4.4. *Contextual factors: the dynamics of real wages*

The final element of our quantitative overview of the Italian NIS is represented by what we consider an important contextual factor. In general terms, the indicators we have considered so far provide the picture of a country characterized by a very limited investment of resources in scientific and technological activities and by a relatively marginal position in these areas when compared with that other major industrialized countries. In our interpretation, this configuration was sustainable because the Italian economy could enjoy a relatively sluggish dynamics of real wages from the unification until at least the late 1960s.[26]

This is confirmed by Figure 10 which shows the ratios between the indices of real wages constructed by Williamson (1995) for all the major industrialized countries and the Italian level. If the ratio is higher than 100 then Italy has a higher real wage than the other country.

Figure 10. Comparative real wages, 1870-1988

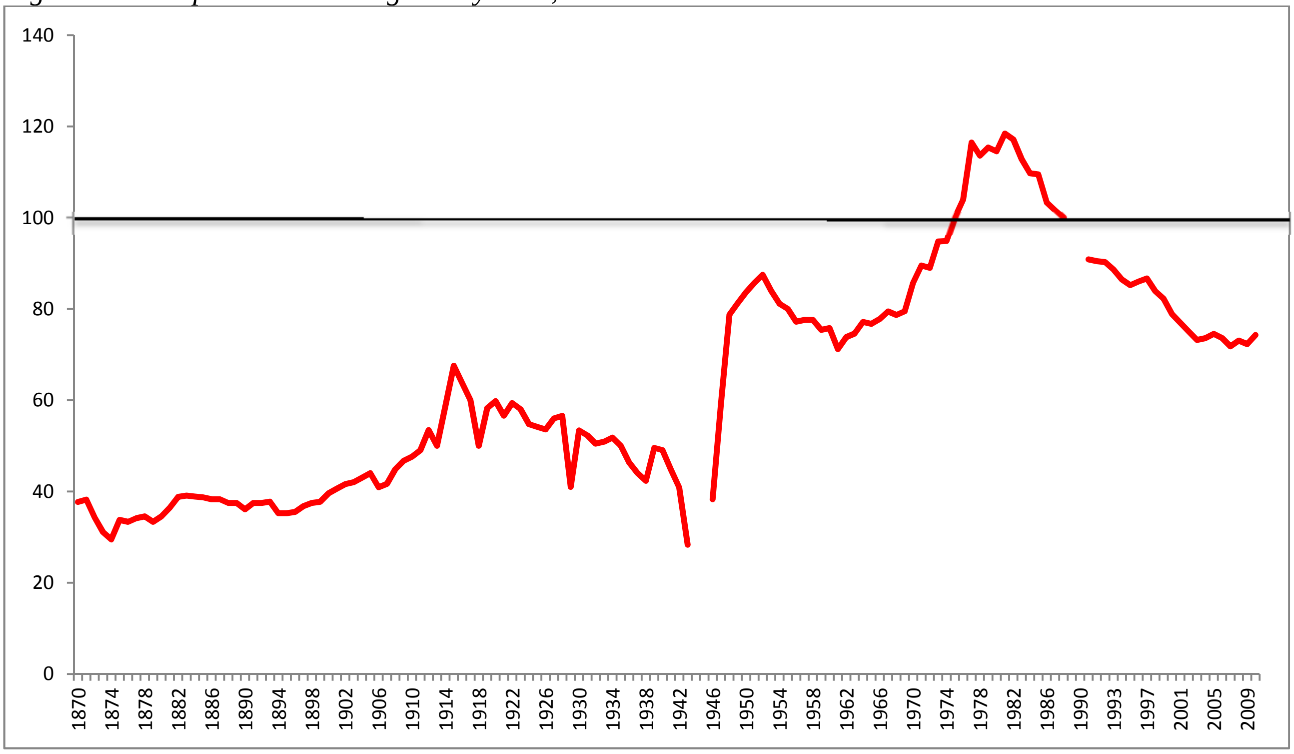


Source: own elaborations on Williamson (1995)

[25] Toninelli and Vasta (forthcoming) show that in the Italian case is historically characterized by a structural shortage of genuine Schumpeterian entrepreneurs.
[26] The connection between real wages and the lack of investments in scientific and industrial research by firms is also suggested by Maiocchi in particular in relation to the Giolittian period and the period 1950-1970 (Maiocchi: 918 and 970).

Figure 11 shows instead the comparison between real wages in Italy and in UK for the period 1870-2010. It shows that period in which Italy is characterized by levels of real wages higher that the UK is just a relatively brief interlude (1975-1990). Several historians have indeed pointed to the relatively low level of real wages as a permanent feature of the Italian variety of capitalism (Zamagni 1976; 1984).

Figure 11: Comparative real wages Italy / UK, 1870-2010



Source: 1870-1988 own elaborations on Williamson (1995), 1990-2010 own elaborations on OECD data.

Here, we would like to draw attention to the potential connection between real wages and innovative activities. In our view, it is plausible to assume that low real wages did represent a powerful compensating factor for the structural weaknesses of the innovation system. In other words, low real wages were a safety valve that Italian firms and entrepreneurs could activate to counterbalance the lack of a sound contribution to their competitiveness arising from their own ineffective innovation activities. Furthermore, it is also likely that in the long run this lethargic dynamics of real wages might have exerted further negative effects by discouraging the systematic search for improvements in labour productivity and the substitution of capital equipment for labour.[27]

[27] The potential role of low real wages in inhibiting innovation is discussed in Kleinknecht (1998). For some evidence on the Italian case during the 1990s and 2000s see Lucidi and Kleinknecht (2010). The possible connection between high wages and innovation is also discussed by Allen (2009) in the context of the British industrial revolution.

5. **Conclusions**

Our reappraisal has confirmed that the Italian pattern of modern economic growth is indeed a peculiar one, structurally characterized, on the one hand, by limited investments in R&D activities and in the broader educational system, and, on the other hand, by a limited capacity of generating innovations and being competitive in high tech industries. Our study shows that the origins of this structural weakness have deep historical roots. In the liberal age, there was a substantial lack of appreciation of the key-role that scientific research. During the fascist period, it is possible to see a more concerted attempt of constructing a system of scientific research capable both of generating scientific results and of developing new industrial applications, but the fascist contribution to the construction of a modern system of scientific research was more rhetoric than real.[28] Overall, this neglect of science and technology constituted a very heavy burden that could not easily be overcome even in the post-WWII phase. While in this period it is surely possible to identify a number of success stories both in scientific research and industrial R&D, this historical phase remained a missed opportunity for an effective consolidation of the Italian NIS. One may also be tempted to speculate whether, since the 1980s, the rhetoric of the *industrial districts* and the anti-Chandlerian "small is beautiful" literature may also account for the complacency concerning the failure of the Italian NIS. However, at closer inspection, it is probably useful to distinguish between two different dynamics with the Italian NIS. If we consider the two main output indicators (papers and patents), it is possible to claim that up to approximately the early 1960s, the performance of the NIS in the sphere of scientific production was roughly aligned with that in terms of generation of industrial innovations. Since then, the dynamics of the two indicators are characterized by a divergent pattern. In particular, the Italian NIS seems to deliver a somewhat satisfactory performance, as far as the production of scientific publications is concerned while losing ground in the generation of innovations. In our interpretation, this diverging pattern suggests that one of the major weaknesses of the Italian NIS is the lack of suitable *bridging institutions* for ensuring an effective knowledge transfer from science to industrial applications. Finally, it is worth noticing that the performance of the Italian system in the production of high-quality scientific publications is characterized by a significant improvement from the early 1990s. This is probably an outcome of the stimulus raised by the growing internationalization of the Italian academic system as far as hard sciences are concerned. Still, the general impression arising from the evidence collected here is that of a NIS that is structurally weak when compared with those of the other major industrialized countries.

[28] It is particularly instructive to compare the Italian approach towards the construction of technological capabilities in the liberal and Fascist periods with the Japanese case of technological modernization (Nicholas 2011).

The recent evidence on the dynamics of productivity growth over the last twenty years (Broadberry, Giordano and Zollino 2011), in our view, shows clearly that a fully developed NIS capable of contributing both to the assimilation of technologies from abroad and to the generation of new technologies is a key-ingredient of a successful process of catching-up. In this perspective, Italy's position among the richest countries of the world is not to be regarded as firmly secured. In our view, the evidence discussed in this paper clearly supports the pessimists' view. In fact, the Italian model of development characterized by a scarce attention to innovative performance and by an in-built tendency to rely on a compression of the dynamics of real wages appears as an inherent fragile construction.

To sum up, our historical appraisal, suggest that Italian NIS, since the unification until today, was characterized by a peculiar shadowy or *ghostly* nature. In Italian economic history, it has been largely invisible forcing the country to adopt a peculiar road towards modern economic growth based on the combination of low real wages and the intensive use of unskilled labour. We should, of course, recognize that along specific dimensions such as the assimilation and adaptation of foreign technologies the Italian NIS provided a significant contribution and that, in few historical moments, the Italian NIS was also, against all odds, capable of generating important advances both in scientific research and industrial applications. But, on further reflection, also these sporadic appearances - that are more due to lucky accidents than to planning and design - fit the analogy of the *ghost* rather well. In this perspective, one may even be tempted to extend the analogy to the frail and ineffectual ghost that, according to Oscar Wilde, was living in Canterville Chase.

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