The Italian National Innovation System: A Long-term Perspective, 1861–2011

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Abstract

This chapter provides a survey of the long-term evolution of the Italian National Innovation System since the unification of the country in the 1860s. In the first part we sketch a broad reconstruction of long-term trends by examining a wide range of quantitative indicators of science and technological activities in a comparative perspective. On the basis of this quantitative survey, in the second part, 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 invest in science and technology, in combination with low real wages and an intense use of unskilled labour.

INTRODUCTION[1]

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 a '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. Furthermore, the introduction of new technologies frequently requires a creative process of adaptation to the specific local circumstances prevailing in the importing country.[2]

Alexander Gerschenkron was probably the first to provide an articulated exposition of what may be called the 'technology gap' approach to the study of economic growth.[3] 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 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.[4] However, the fulfilment 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'.[5] 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.

The notion that the technological 'catching up' by backward countries is not an automatic process has been further elaborated by Moses Abramovitz. Abramovitz[6] 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 large set of factors that directly affects them such as the quality of the education system together with several other contextual dimensions.[7] In his chapter, he pointed to another key factor affecting the process of 'catching up' which he labelled as 'technological congruence'.[8] 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 National Innovation Systems (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 connected 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.

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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.[9] According to Freeman, a NIS consists in the 'network of institutions in the private and public sectors whose activities and interactions initiate, import, modify and diffuse new technologies'.[10] 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'.[11] 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'.[12]

As noted by Soete, Verspagen and Ter Weel, 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.[13] Nelson's use of the concept is the narrowest in its scope. In particular, the attention of Nelson and his associates is focused on the research and development (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's book is essentially a reappraisal of the Japanese historical experience.[14] 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 flavour 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.[15] 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.[16] In his view, detailed feedback from users provides 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.

Since the early 1990s the concept of NIS has enjoyed remarkable success in 'policy making' circles both at national level and at super-national levels in particular

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in institutions such as the OECD and the European Commission.[17] 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 on by the leader countries. Hence historical studies should probably adopt a framework of investigation of NIS that is closer to the spirit of the approach outlined by Freeman in his analysis of the Japanese experience.[18] The key intuition is that the overall innovation performance of national economies is ultimately the outcome of the relative degree of 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.

In this chapter we provide a comprehensive reappraisal of the quantitative evidence on the long-term evolution of scientific and technological activities in Italy since the unification in the light of the NIS approach as outlined by Freeman. 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 a long run perspective. As we shall see, in a comparative perspective, Italy seems to be 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.

THE ITALIAN NATIONAL INNOVATION SYSTEM: A QUANTITATIVE REAPPRAISAL

The aim of this section is to provide a quantitative description of the historical evolution of the Italian NIS. We would like 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.[19]

In this context, it is possible to draw a distinction between two main typologies of indicators: input and output indicators. Input indicators refers to the resources that a country invests in innovative activities, whereas output indicators to the actual outcomes of innovation processes. The standard input indicator is the volume that a NIS dedicates to R&D. In this paper, we have decided to take a broader perspective and include in the analysis also some proxies of human capital. From a conceptual

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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 nineteenth century. 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 consideration as a contextual factor the dynamics of real wages, which, we shall argue is a crucial determinant of the rate and direction of technical change in the Italian context.

1. THE INPUT DIMENSIONS OF THE ITALIAN NIS

As already noted, the human capital endowment of a country directly affects its ability to use, adapt and develop new technologies.[20] Therefore, in this paper the structure and performance of the education system as a whole is considered as one of the broad input dimensions of NIS.[21] Table 1 shows literacy rates of the adult population in a comparative perspective. The first point that merits attention is the particular low starting point of Italy. In 1860, the Italian adult literacy rate (25 per cent) was the lowest of all countries considered, similar to that of Japan and a little lower than Spain (27 per cent). Interestingly enough, all the other countries in the table had literacy rates that were more than double 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 per cent while Germany, Sweden and the United Kingdom had already exceeded 90 per cent and other countries were very close; in 1950, Italy had not reached the literacy rates that most of the countries had achieved at the beginning of the century.

A second useful indicator of the human capital endowment of a country, charted in Figure 1, is the average years of schooling of the population (aged between

TABLE 1 Literacy rate of 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: Data kindly provided by Leandro Prados de la Escosura, *mimeo*.

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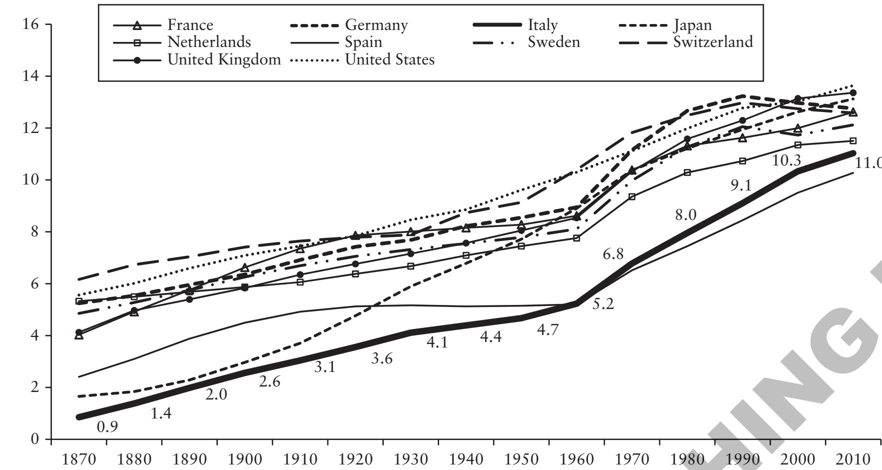

FIGURE 1: Average years of schooling on population (15–64 years) in selected countries

Source: Own elaborations on Christian Morrisson and Fabrice Murtin, 'The Century of Education', *Journal of Human Capital*, 3 (2009), pp. 1–42.

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 in 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.

The third indicator we consider is tertiary education. Since the Second World War, in Italy there has been a steady growth in the number of students enrolled at 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 was not too far from that of other industrialized countries, even if completion rates were 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.[22]

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 per cent) 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 the Second World War, the share of students in science and engineering faculties has stabilized at around 25 per cent, while in the last two decades it has dropped below 23 per cent.[23]

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TABLE 2 Students enrolled by faculties (1866–2006), per cent

	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: http://Seriestoriche.istat.it (data extracted 8 July 2012)

The Italian delay in (higher) technical education is also evident if we consider the stock of engineers in the population. Comparative data on this variable are available only up to World War One 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 the levels of engineers in total population recorded in 1914 by Germany, France and the United Kingdom only during the 1950s.[24] This significant delay suggests that the degree of technological sophistication of the Italian economy was not particularly high until at least the 1950s.

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.[25] For example, Italy, in 2011, has one of the lower shares (61 per cent) of persons who have ever used a computer on all individuals aged 16–74, being the EU27 average 78 per cent and the share of the main advanced European countries around 90 per cent.

Turning our attention to more traditional input indicators, Table 3 shows the evolution of R&D expenditure on GDP for the principal industrialized 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 large amounts of resources in research (Germany, Japan and the United States), but also from South

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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 Christopher Freeman and Luc Soete, *The Economics of Industrial Innovation* (Cambridge, MA: The MIT Press, 1997), p. 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.

Sources: Our own elaborations on OECD database (OECD, Main Science and Technology Indicators Database, data extracted on 1 April 2012); for the period 1955–60 estimate based on Franco Malerba, 'The national system of innovation: Italy', in Richard R. Nelson (ed.), *National Innovation Systems. A Comparative Analysis* (Oxford, Oxford University Press, 1993); for United States in 1964, OECD, *A Study of Resources Devoted to R&D in OECD Member Countries in 1963/64*, 2 Statistical Tables and Notes (Paris, 1968); for the period 1964–1980 elaborations on OECD.

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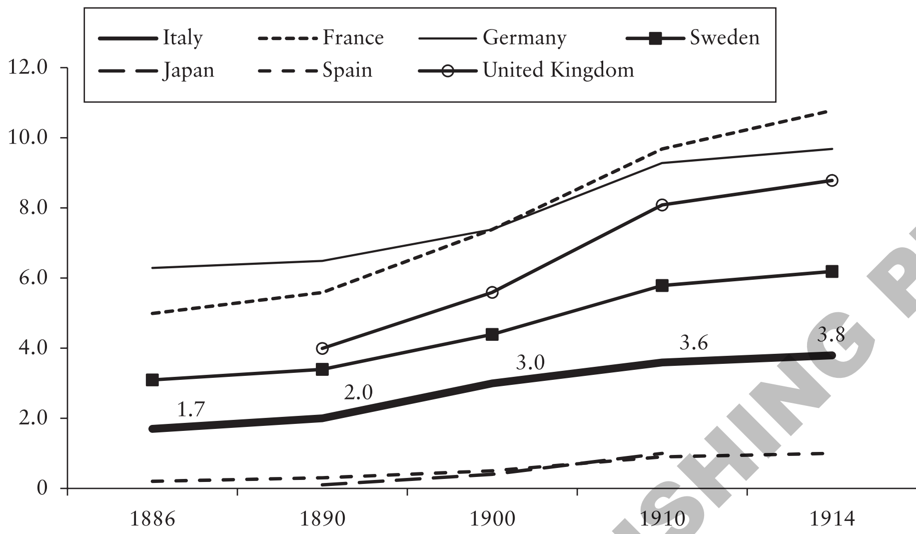

FIGURE 2: Engineers per 10,000 inhabitants (1866–1914)

Source: Own elaborations on Michelangelo Vasta, *Innovazione Tecnologica e Capital Umano in Italia (1880–1914). Le Traiettorie Tecnologiche della Seconda Rivoluzione Industriale* (Bologna: Il Mulino, 1999), p. 250.

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Korea, which now has the highest level among the countries considered, and from China that has overtaken Italy in the last decade.

In particular, in relation to Italy we can make two further observations. First, in the second half of the twentieth century the share of R&D expenditure on GPD has increased by more than six times, passing from 0.2 per cent in 1955–1960 to 1.3 per cent 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 per cent 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 the 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 reach 3.6 and 4 respectively, while Japan has 5.2 researchers per 1,000 inhabitants.

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

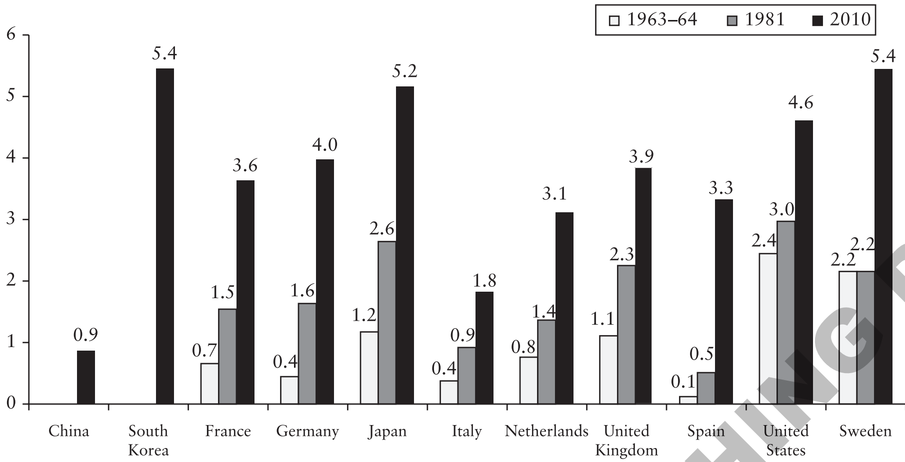

FIGURE 3: Numbers of researchers (FTE) per 1,000 population (1963–1964, 1981, 2010)

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 United States refer to 2007.

Source: Our own elaborations on Angus Maddison, *Historical Statistics of the World Economy: 1–2008 AD* (2009), http:// www.ggdc.net/MADDISON/oriindex.htm; for 1963–1964 OECD (1968), *A study of resources devoted to R&D in OECD member countries in 1963/64*, 2 Statistical Tables and Notes, Paris for 1981 and 2010 [data extracted on 30 April 2012 from OECD.Stat.]

produced by a country in a given period of time. Tables 4 and 5 show 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.[26]

Table 4 shows that the relative position of Italy with respect to the other countries did not change substantially in the long term. However, looking at Figure 4, four distinct phases can be noted: the first, of rapid growth ending at the beginning of the 1920s, when Italy reached a peak (2.5 per cent). This period was characterized by the effects of the First World War, when several industries with high technological intensity, such as steel production and chemicals, underwent a phase of rapid expansion.[27] This phase is followed by a period of relative decline that coincided with the rise of fascism, the autarchic period, and World War Two, 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.

The third phase coincides with the period of the Italian Golden Age (1950–1973), when the share reached the historical peak of 4.4 per cent in 1963. The effervescence of this historical phase is also confirmed by the 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 Perotto.[28] Subsequently, a new phase of decline ensued with a constant reduction in performance

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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

Sources: 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)

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FIGURE 4: Patents granted to Italian residents in the US on total patents granted to foreign residents (1883–2010)

Source: our own elaboration: for 1883–1962, on US Department of Commerce, Patent and Trademark Office, *Technology Assessment & Forecast*; for 1963–2010 on USPTO.GOV *Extended Year Set* [data extracted on 1 April 2012].

with an average value of 3.4 per cent during the 1970s and of 3.1 per cent during the 1980s. 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 First World War.

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. From this perspective it is particularly significant to note the marked worsening in performance during the last twenty years.

The sectoral disaggregation of patents allows the identification of the patterns of technological specialization of the Italian economy, highlighting points of strength and weakness. Vasta 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 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.[29]

Further insights on Italian innovative performance emerge from a closer look at the historical development of the patent system in Italy. Conventional economic theory suggests that, without patent protection, incentives for investment in innovative activities will be lacking. Hence, a strong and effective system of patent

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TABLE 5 Patents granted to foreign residents in the US by countries per million 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

Sources: Elaborations on Angus Maddison, *Historical Statistics of the World Economy: 1–2008 AD* (2009), http://www.ggdc.net/MADDISON/oriindex.htm; for 1883–1960 on USPTO OTAF 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).

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protection is a necessary prerequisite for the attainment 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.[30] 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 nineteenth-century patent systems contemplated the possibility of granting patents not only for new inventions, but also for importing technologies from abroad. More importantly, many nineteenth-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.[31] An illustration of discriminatory practices against foreign inventors is provided by the case study of Richter and Streb showing the obstacles raised by the German patent office against US machine tool makers during the 1920s.[32] Italy did not follow these examples and it developed a patent system that did not contemplate any systematic discriminatory rules towards foreign inventors.[33]

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 6).

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 per cent which is very similar to that of small open economies such as The Netherlands and Belgium.[34] 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. 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, 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 resources to spend in cross licensing agreements and other forms of research joint ventures and technological alliances.[35]

If we turn our attention to the generation of scientific knowledge, the most widely used output indicator is the number of scientific publications. In this paper, we use two different samples: the overall world scientific production extracted from the Scopus database (henceforth All-Scopus AS) and a 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 7 shows the average share publications of selected countries in six different periods and Table 8 shows the average number of publications per million inhabitants. In order to have some corroboration about the reliability of the Scopus dataset, in Figure 5 we also include some alternative authoritative estimates on the

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TABLE 6 Share of foreign patents in different patent systems

	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 1 July 2012].

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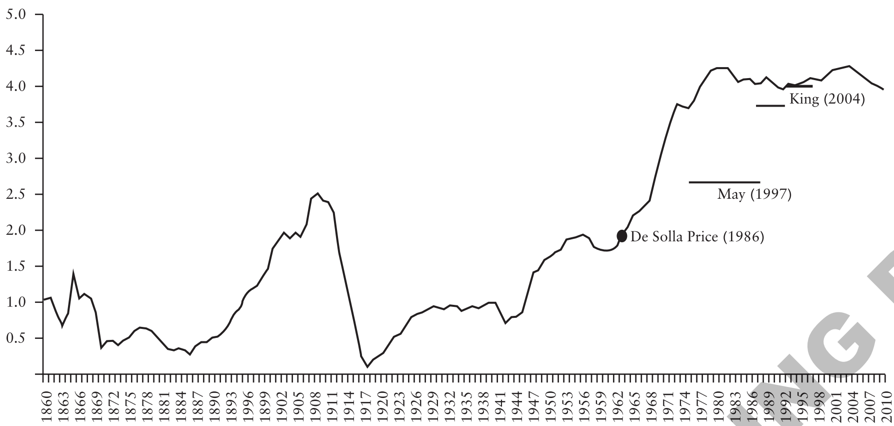

FIGURE 5: Share of Italian publications in AS (1860–2011)

Note: The series has been smoothed with a five-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.

Source: Our own elaboration on Scopus database (http://www.scopus.com/home.url) [data extracted on 7 April 2012].

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scientific impact of Italy provided by other scholars: the pioneering contribution by De Solla Price and the more recent studies by May and King.[36]

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 per cent, while starting from the beginning of the 1890s in the Giolittian era this value grew considerably overcoming the threshold of 2.5 per cent.[37] The First World War 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 per cent. Italian performance increases considerably during the Golden Age passing from 1.8 per cent in 1950 to 4 per cent in 1973. After this period the Italian share remains substantially stable around the 4 per cent mark.

The comparative perspective of Tables 7 and 8 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 its performance. In the last decades, notwithstanding Italy doubling its capacity, it is overtaken also by France. Table 8, which contains data normalized by population, shows that, in the period 1973 to 2011, the performance of Italy is higher than that of Japan and South Korea, and not so distant from those of France and Germany.

Further insights emerge from the analysis of publications that represent the research excellence in the N&S sub-sample. This analysis is possible only from 1950

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TABLE 7 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 7 April 2012].

TABLE 8 Average number of publications in Scopus per million inhabitants (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 7 April 2012].

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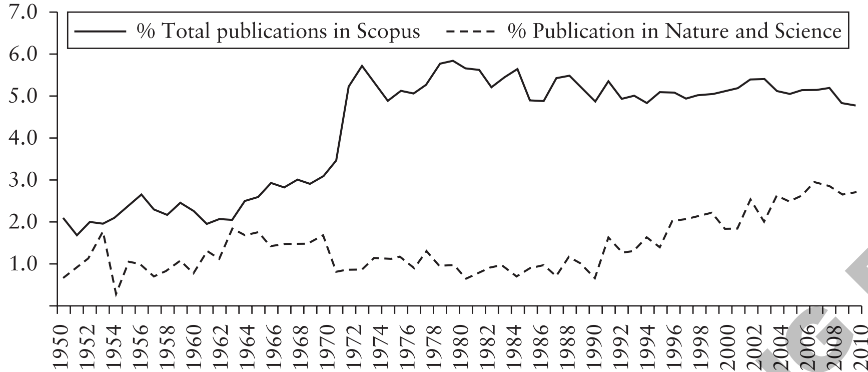

FIGURE 6: Share of Italian publications on selected countries (AS vs N&S)

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, Netherlands, Spain, South Korea, Sweden, United Kingdom, United States.

Source: Our own elaboration on Scopus database (http://www.scopus.com/home.url) [data extracted on 7 April and 26 June 2012].

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because for the previous years there the data are not fully reliable. In this case the world is represented only by a restricted number of countries and this means that the share for each country is 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 (5.8 per cent) in 1980 and then displays a decreasing trend, dropping in the last year to 4.8 per cent. The Italian publications in N&S are around 1 per cent until the early 1990s, and increase considerably in the following years reaching 2.9 per cent 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.

Finally in Figure 7 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 a proxy of the capacity of producing radical scientific breakthroughs and discoveries. The affiliations are recorded at the moment in which the prize was awarded.[38]

Several points deserve attention. The first is that in the period 1901 to 1935, the UK, France and Germany are the leading countries in terms of Nobel laureates. The leadership of the US is relatively recent and emerges only after the Second World War. The second point is that Italy lags far behind the 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 to construct

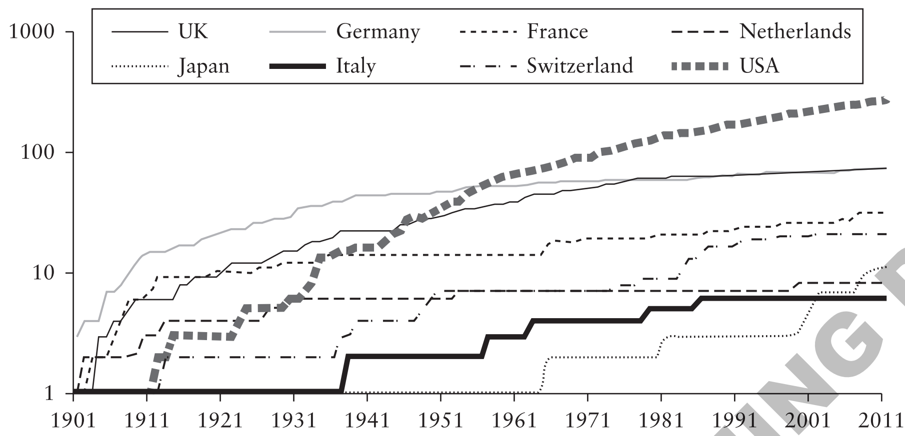

FIGURE 7: Cumulative number of Nobel laureates in Chemistry, Physics and Medicine by affiliation of the winner, 1901–2011 (logarithmic scale)

Source: Our own elaborations on data extracted from http://www.nobelprize.org [data extracted on 4 July 2012].

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long lasting traditions of *research excellence*. It is particularly revealing that the six Italian Nobel laureates in the figure (Camillo Golgi (1906), Enrico Fermi (1938), Daniel Bovet (1957), Giulio Natta (1963), Abdus Salam (1979), Rita Levi Montalcini (1986)) all belonged to different scientific institutions. 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 few Nobel laureates show 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 reached a capability of producing what Thomas Kuhn calls *normal science* that is comparable to that of other major industrialized countries.[39] The data also indicates that there has been a recent improvement in *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 research institutions).

This quantitative picture is consistent with accounts produced by historians of science in Italy such as Maiocchi and Russo and Santoni.[40] Indeed, from the unification up to the First World War 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.[41] After the First World War 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.[42]

Another missed opportunity is the period 1950 to 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.[43] After the oil crisis, the Italian system has been systematically characterized by a structural lack of resources and by a confusing arrangement of the interaction between the CNR and the university system.[44]

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 8, 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 activity 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.

Overall this pattern suggests the existence of a 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 a research system that seems able to deliver a reasonable performance, although not outstanding, and that is more sophisticated than the system of industrial research of business firms.[45]

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 of other major industrialized countries. In our interpretation, this configuration was sustainable

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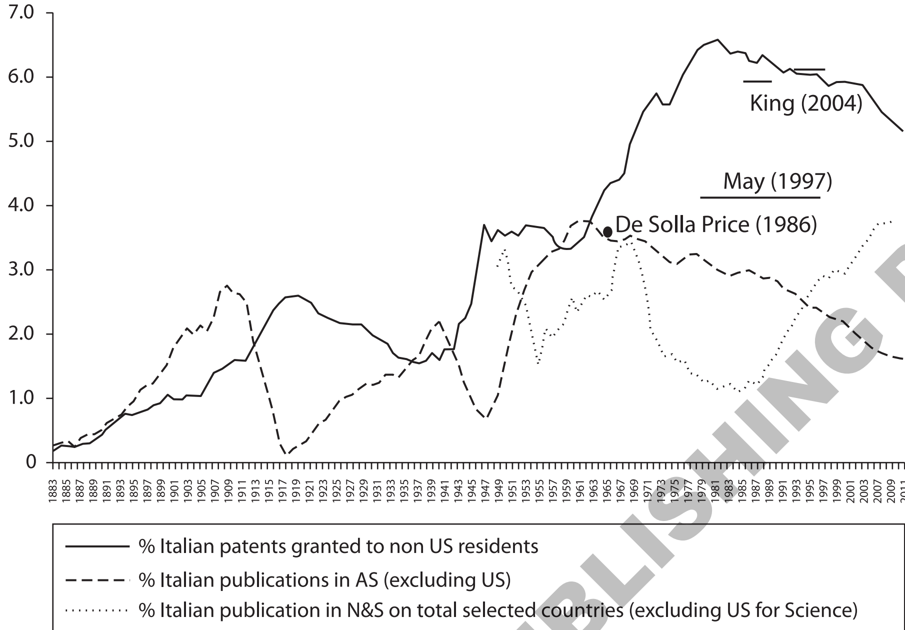

FIGURE 8: Technological activity versus scientific research activity, Italy (1883–2011)

Note: The series have been smoothed with a five-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, Netherlands, Spain, South Korea, Sweden, United Kingdom, United States.

Sources: For publication: our own elaboration on Scopus database (http://www.scopus.com/home.url) [data extracted on 7 April and 26 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).

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because the Italian economy could enjoy a relatively sluggish dynamics of real wages from the unification until at least the late 1960s.[46]

This is confirmed by Figure 9, which shows the ratios between the indices of real wages constructed by Williamson 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.[47]

Figure 10 shows instead the comparison between real wages in Italy and in the UK for the period 1870 to 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 economic historians have indeed pointed to the relatively low level of real wages as a permanent feature of the Italian process of economic growth.[48]

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

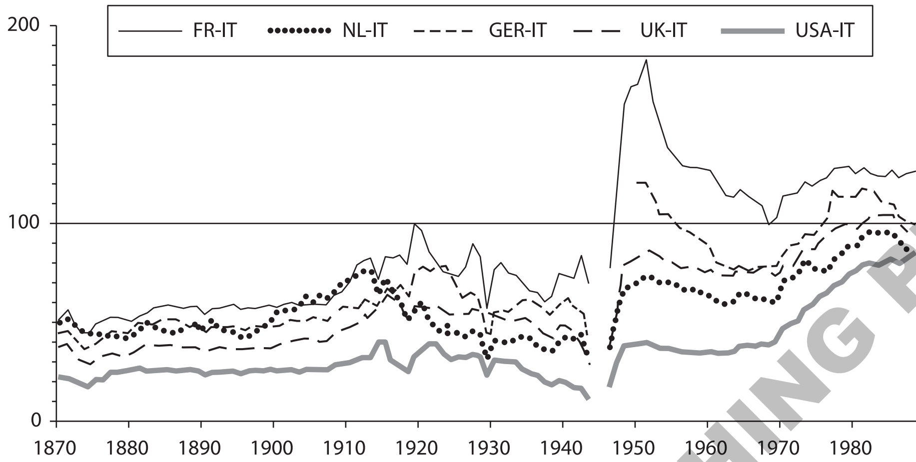

FIGURE 9: Comparative real wages, 1870–1988 (100 corresponds to Italy = foreign country)

Source: Our own elaboration is based on Jeffrey G. Williamson, 'The Evolution of Global Labor Markets since 1830: Background Evidence and Hypotheses', *Explorations in Economic History*, 32 (1995), pp. 141–96.

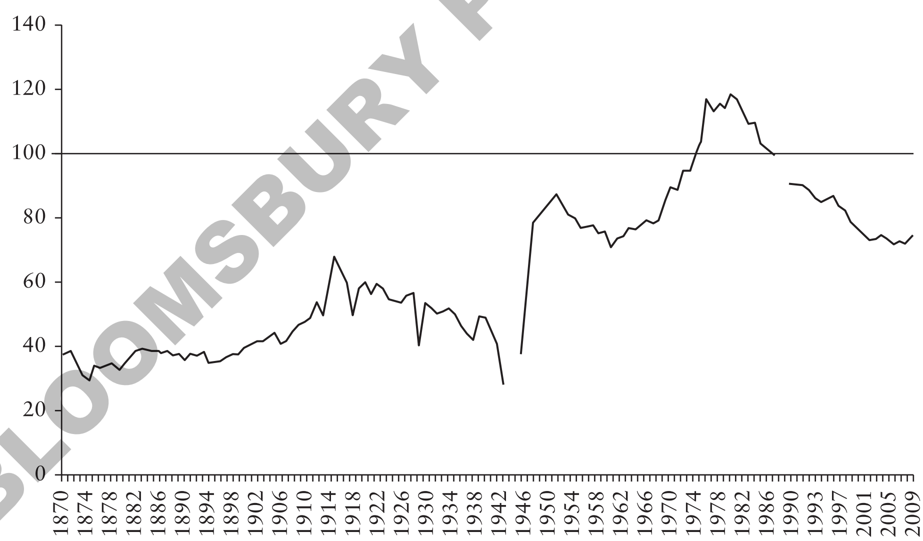

FIGURE 10: Comparative real wages, Italy/UK, 1870–2010 (100 corresponds to Italy = UK)

Sources: 1870–1988 own elaborations based on Jeffrey G. Williamson, 'The Evolution of Global Labor Markets since 1830: Background Evidence and Hypotheses', *Explorations in Economic History*, 32 (1995), pp. 141–96; 1990–2010 own elaborations on OECD data.

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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.[49]

CONCLUSION

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 of 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. Overall, this neglect of science and technology constituted a very heavy burden that could not easily be overcome even in the post Second World War 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.

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The recent evidence on the dynamics of productivity growth over the last twenty years, 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.[50] In this perspective, Italy's position among the richest countries of the world is not to be regarded as firmly secured. In other words, 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.

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NOTES

1. This paper is an extended version of Alessandro Nuvolari and Michelangelo Vasta, 'The Ghost in the Attic? The Italian National Innovation System in Historical Perspective, 1861–2011', Working Papers of the Department of Economics and Statistics-University of Siena, n. 665, 2012. We would like to thank Anna Guagnini, Ian Inkster, Luca Molà and the other participants to the workshop 'The Italian Technology in a European and Global Context, 15th–20th Centuries' (European University Institute, Florence, November, 2012) for useful comments and discussions. We are also grateful to Gabriele Cappelli for valuable suggestions.
2. Jan Fagerberg, 'Technology and International Differences in Growth Rates', *Journal of Economic Literature*, 32 (1994), pp. 1147–75.
3. The original contribution was actually published in 1952, see Alexander Gerschenkron, *Economic Backwardness in Historical Perspective* (Cambridge, MA: Harvard University Press, 1962), Chapter 1.
4. David S. Landes, *The Unbound Prometheus. Technological Change and Industrial Development in Western Europe from 1750 to the Present* (Cambridge: Cambridge University Press, 1969) 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.
5. Gerschenkron, *Economic Backwardness*, p. 7.
6. Moses Abramovitz, 'Catching Up, Forging Ahead and Falling Behind', *Journal of Economic History*, 46 (1986), pp. 385–406 and Moses Abramovitz, 'The Origins of the Post-war Catch-up and Convergence Boom' in Jan Fagerberg, Bart Verspagen and Nick von Tunzelmann (eds), *The Dynamics of Technology, Trade and Growth* (Aldershot: Edward Elgar, 1994).
7. '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' (Fagerberg, Verspagen and von Tunzelman, *The Dynamics of Technology*, p. 25).
8. Abramovitz, 'Catching Up', p. 371.

9. An insightful survey of the NIS literature is provided by Luc Soete, Bart Verspagen and Bas Ter Weel, 'Systems of Innovation' in Bronwyn H. Hall and Nathan Rosenberg (eds), *Handbook of the Economics of Innovation*, Vol. 2 (Elsevier: Dordrecht, 2010). The concept of NIS was explicitly introduced for the first time in a paper written in the early 1980s by Freeman for the OECD; see Christopher Freeman, 'Technological Infrastructure and International Competitiveness', *Industrial and Corporate Change*, 13 (2004), pp. 541–69. See also Bengt-Åke Lundvall, 'Introduction to "Technological Infrastructure and International Competitiveness" by Christopher Freeman', *Industrial and Corporate Change*, 13 (2004), pp. 531–9. As recognized by Freeman himself (Christopher Freeman, 'The "National System of Innovation" in Historical Perspective', *Cambridge Journal of Economics*, 19 (1995), pp. 5–24), in historical perspective, the concept of national innovation system may be regarded as a modern elaboration of many of the views put forward by Friedrich List on the peculiar set of policies and institutions that Germany should have adopted in order to be able to close the economic gap with England (Friedrich List, *The National System of Political Economy* (London and Totowa, NJ: Frank Cass, 1983, 1st edition 1841)). 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 Benoît Godin, 'National Innovation System: The System Approach in Historical Perspective', *Science, Technology and Human Values*, 34 (2009), pp. 476–501.
10. C. Freeman, *Technology Policy and Economic Performance: Lessons from Japan* (London: Pinter, 1987), p. 1.
11. Bengt-Åke Lundvall (ed.), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning* (London: Pinter, 1992), p. 12.
12. Richard R. Nelson and Nathan Rosenberg, 'Technical Innovation and National Systems' in Richard R. Nelson (ed.), *National Innovation Systems. A Comparative Analysis* (Oxford: Oxford University Press, 1993), p. 4.
13. Soete, Verspagen and Ter Weel, 'Systems of Innovation'.
14. Freeman, *Technology Policy.*
15. The first use of the concept of 'developmental state' is the study of the MITI's experience by Chalmers Johnson, *MITI and the Japanese Miracle* (Stanford: Stanford University Press, 1982). The book is cited in Freeman, *Technology Policy*. On the concept of 'developmental state', see Meredith Woo-Cumings (ed.), *The Developmental State* (Cornell: Cornell University Press, 1999).
16. Bengt-Åke Lundvall, 'Innovation as an Interactive Process: From User-producer Interaction to the National Innovation System' in Giovanni Dosi, Christopher Freeman, Richard R. Nelson, Gerald Silverberg and Luc Soete (eds), *Technical Change and Economic Theory* (London: Pinter, 1988), pp. 349–69.
17. Naubahar Sharif, 'Emergence and Development of the National Innovation Systems Approach', *Research Policy*, 35 (2006), pp. 745–66.
18. Freeman, *Technology Policy.*
19. Keith Smith, 'Measuring Innovation', in Jan Fagerberg, David C. Mowery and Richard R. Nelson (eds), *Oxford Handbook of Innovation* (Oxford: Oxford University Press, 2005), pp. 148–77.

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20. Abramovitz, 'Catching Up'.
21. 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).
22. Sandro Trento, 'Il Grado di Scolarizzazione: Un Confronto Internazionale', in Nicola Rossi (ed.), *L'Istruzione in Italia: Solo un Pezzo di Carta?* (Bologna: Il Mulino, 1997), pp. 21–66.
23. According to David Edgerton, the percentage of graduates in scientific and technological subjects for the major industrialized countries in 1954–1955 were as follows: Germany (34 per cent), Italy (26 per cent), UK (44 per cent), France (29 per cent). David Edgerton, *Science and Technology and the British Industrial 'Decline'* (Cambridge: Cambridge University Press, 1996), p. 54.
24. Michelangelo Vasta, *Innovazione Tecnologica e Capitale Umano in Italia (1880–1914). Le Traiettorie Tecnologiche della Seconda Rivoluzione Industriale* (Bologna: Il Mulino, 1999) and Michelangelo Vasta, 'Capitale Umano, Ricerca Scientifica e Tecnologica', in Franco Amatori, Duccio Bigazzi, Renato Giannetti and Luciano Segreto (eds), *Storia d'Italia. Annali*, Vol. 15, *L'Industria* (Torino: Einaudi, 1999), pp. 1041–24.
25. Eurostat, *Computer Skills in the EU27 in Figures* (Brussels: Eurostat Press Office, 2012).
26. 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 inventors from the calculation.
27. Franco Amatori, 'Italy: The Tormented Rise of Organizational Capabilities between Government and Families', in Alfred D. Chandler Jr., Franco Amatori and Takashi Hikino (eds), *Big Business and the Wealth of Nations* (Cambridge, MA: Cambridge University Press, 1997), pp. 246–76; and Vera Zamagni, 'L'Industria Chimica in Italia dalle Origini agli Anni' 50', in Franco Amatori and Bruno Bezza (eds), *Montecatini 1888–1966. Capitoli di Storia di una Grande Impresa* (Bologna: Il Mulino, 1990), pp. 69–148.
28. It is interesting to note that 1963 is also considered a turning point by Lucio Russo and Emanuela Santoni, *Ingegni Minuti. Una Storia della Scienza in Italia* (Milan: Feltrinelli, 2012), Matteo Gomellini and Mario Pianta, 'Commercio con l'Estero e Tecnologia in Italia negli anni Cinquanta e Sessanta' in Cristiano Antonelli, Federico Barbiellini Amidei, Renato Giannetti, Matteo Gomellini, Sabrina Pastorelli and Mario Pianta (eds), *Innovazione Tecnologica e Sviluppo Industriale nel Secondo Dopo Guerra* (Bari: Laterza, 2007); and Marco Pivato, *Il Miracolo Scippato. Le Quattro Occasioni Sprecate dalla Scienza Italiana negli Anni Sessanta* (Rome: Donzelli, 2011).
29. Vasta, *Innovazione Tecnologica*.
30. Hiroyuki Odagiri, Akira Goto, Atsushi Sunami and Richard R. Nelson (eds), *Intellectual Property Rights, Development and Catch Up. An International Comparative Study* (Oxford: Oxford University Press, 2010).

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31. More precisely, the reform of 1836 stated that foreign inventors could be granted a US patent by paying a fee of $300 ($500 if they were British). The patent fee for US inventors was $30; Zorina Khan, *The Democratization of Invention: Patents and Copyrights in American Economic Development, 1720–1920* (Cambridge: Cambridge University Press, 2005).
32. Ralf Richter and Jochen Streb, 'Catching Up and Falling Behind: Knowledge Spillover from American to German Machine Toolmakers', *Journal of Economic History*, 71 (2011), pp. 1006–31.
33. Lerner in his comparative study of the structure of worldwide patent systems claims that in Italy around unification there was a discriminatory fee (+ 50%) for foreign applicants which was later removed; see: Josh Lerner, '150 years of Patent Protection', NBER Working paper n. 7478 (2000), Table 5. However, this does not appear confirmed by the text of the Law (Legge 28 Febbraio 1826, n. 1899, Regno di Sardegna, and Legge 31 Gennaio 1864, n. 1657, Regno d'Italia). 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, *Innovazione Tecnologica*, pp. 121–6.
34. The decline in the share after 1979 is probably due to the creation of the European Patent Office.
35. Bronwyn H. Hall and Rosemarie Ziedonis, 'The Patent Paradox Revisited: An Empirical Study of Patenting in the US Semiconductor Industry, 1979–1995', *Rand Journal of Economics*, 32 (2001), pp. 101–28.
36. Derek J. De Solla Price, *Little Science, Big Science . . . and Beyond* (New York: Columbia University Press, 1986); Robert M. May, 'The Scientific Wealth of Nations', *Science*, 275/5301 (1997), pp. 793–96; David A. King, 'The Scientific Impact of Nations. What Different Countries Get For Their Research Spending', *Nature*, 430 (2004), pp. 311–16.
37. Paul Forman, John L. Heilbron and Spencer Weart, 'Physics circa 1900: Personnel, Funding and Productivity of Research Establishments', *Historical Studies in the Physical Sciences*, 5 (1975), pp. 1–185 contains a comprehensive survey on the state of academic physics in the world around 1900, in which Italy appears to lag behind Germany, France and the UK both in terms of funding and in terms of scientific production.
38. Of course, several Italian scientists received Nobel prizes while being affiliated with foreign institutions, so it is possible that the results of Figure 7 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 fully plausible.
39. Thomas S. Khun, *The Structure of Scientific Revolutions* (Chicago: Chicago University Press, 1962).
40. Roberto Maiocchi, 'Il Ruolo delle Scienze nello Sviluppo Industriale Italiano', in Gianni Micheli (ed.), *Storia d'Italia. Annali 3. Scienza e Tecnica* (Torino: Einaudi, 1980) and Russo and Santoni, *Ingegni Minuti*.
41. According to Maiocchi, 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

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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). Maiocchi, 'Il Ruolo delle Scienze', p. 924.

42. Maiocchi, 'Il Ruolo delle Scienze'; Arturo Russo, 'Italian Science Between the Two World Wars', *Historical Studies in the Physical and Biological Sciences*, 16 (1986), pp. 281–320; Vasta, 'Capitale Umano'. For a comprehensive study of technological development in military applications at the beginning of the Second World War which shows that, despite some noteworthy successes, Italy was characterized by a fundamental gap in military equipment, see Vera Zamagni, 'Italy: How to Lose the War and Win the Peace' in Mark Harrison (ed.), *The Economics of World War II. Six Great Powers in International Comparison* (Cambridge: Cambridge University Press, 1998).
43. Renato Giannetti and Sabrina Pastorelli suggest that since the mid-1960s it is possible to detect a 'progressive involution in the innovation strategy of the country'. Giannetti and Pastorelli, 'Il Sistema Nazionale di Innovazione negli Anni Cinquanta e Sessanta', in Antonelli *et al.* (eds), *Innovazione Tecnologica e Sviluppo Industriale*.
44. Vasta, 'Capitale Umano'.
45. Pier Angelo Toninelli and Michelangelo Vasta, show that the Italian case is characterized by a structural shortage of genuine Schumpeterian entrepreneurs. Pier Angelo Toninelli and Michelangelo Vasta, 'Opening the Black Box of Entrepreneurship: The Italian Case in a Historical Perspective', *Business History* 56/2 (2014), pp. 161–86.
46. 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, 'Il Ruolo delle Scienze', pp. 918 and 970.
47. Jeffrey G. Williamson, 'The Evolution of Global Labor Markets since 1830: Background Evidence and Hypotheses', *Exploration in Economic History*, 32 (1995), pp. 141–96.
48. See in particular Vera Zamagni, 'La Dinamica dei Salari nel Settore Industriale', in Pierluigi Ciocca and Giuseppe Toniolo (eds), *L'Economia Italiana nel Periodo Fascista* (Bologna: Il Mulino, 1976) and Vera Zamagni, 'The Daily Wages of Italian Industrial Workers in the Giolittian Period (1898–1913), with an International Comparison for 1905', *Rivista di Storia Economica*, 1 (1984), pp. 59–93.
49. The potential role of low real wages in inhibiting innovation is discussed in Alfred Kleinknecht, 'Is Labour Market Flexibility Harmful to Innovation?', *Cambridge Journal of Economics*, 22 (1998), pp. 387–96. For some evidence on the Italian case during the 1990s and 2000s, see Federico Lucidi and Alfred Kleinknecht, 'Little Innovation, Many Jobs: An Econometric Analysis of the Italian Labour Productivity Crisis', *Cambridge Journal of Economics*, 34 (2010), pp. 525–46.
50. Stephen Broadberry, Claire Giordano and Francesco Zollino, 'A Sectoral Analysis of Italy's Development: 1861–2010', Working Paper 62-011 (2011), University of Warwick.

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