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Innovation and Foreign Technology in Italy, 1861-2011

Federico Barbiellini Amidei*, John Cantwell and Anna Spadavecchia*****

Abstract

The paper explores the long run evolution of Italy's performance in technological innovation as a function of international technology transfer, reconstructing the different phases and dimensions of Italian innovative activity, tracking the transfer of foreign technological knowledge through a number of channels, analysing the impact of imported technology. The study is based on a newly constructed dataset, over the 1861-2009 period, composed of variables related to: innovation activity performance; foreign technology transfer; domestic absorptive and innovative capability. The analysis highlights, also by econometric assessment, the significant contribution of foreign technology both to innovation activity results and to productivity growth. Differences across channels of technology transfer and historical phases emerge, also in connection with the evolution of human capital endowment and domestic innovative capacity. Machinery imports contributed positively both to innovation activity and to productivity growth; inward FDI contributed positively to productivity growth, but not to indigenous innovation activity; the accumulation of technical human capital fuelled both. In the long Italian Golden Age, for the first time the association of foreign technological knowledge with indigenous innovation processes strengthened productivity significantly. More recently instead the dismal productivity growth is directly associated with formalised innovation activity under-performance and reduced imports of disembodied technology.

Jel Classification: N10, O31, O33, F23, O19
Keywords: Italy; Technology Transfer; Innovation; Absorptive Capability; Patenting

Contents

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1. Introduction[1]

The paper explores the evolution of Italy's performance in technological innovation since the country's political unification, as a function of international technology transfer, openness to trade and other international economic relationships.

In the 150 years under analysis, Italy moved from being a fragmented and mainly agricultural country to becoming one of the seven most industrialised countries in the world. Some researchers interpret Italian economic growth as a success story (Sapelli 1992; Federico 1996), while others point out that Italy never closed the gap in technological capabilities with respect to its main industrialised competitors, failing to emerge as an original contributor to technology generation in the world economy (Malerba and Orsenigo 1995).

One major weakness of the Italian economy has been identified in the relatively low levels of effort in the generation of technological knowledge, as measured by traditional indicators such as R&D activity or patents. Certainly, Italy does not display any significant comparative technological advantage, measured in terms of international patents (Cantwell 1991). Italian expenditure on R&D as a percentage of GDP is still much lower than the equivalent ratio in other major OECD countries; patenting activity in recent decades has been below the country's economic weight. However, this is in part explained by the fact that Italian specialisation in production and technology has remained relatively concentrated in some traditional industries, in which innovation relies more on engineering and design than it does on R&D.

Thus, owing to the accumulation of strong local capabilities in some of the longer standing fields of industrial development, more recent research on the second half of the 20th century has highlighted some important innovation achievements in Italian manufacturing, in terms of production processes and forms of organisation, product differentiation, and the development and diffusion of innovative machinery and intermediate inputs. High levels of total factor productivity growth have been mirrored by Italy's successful export performance, especially through the resilience of the "made in Italy" products and the emergence of a relevant competitive international presence in related capital goods industries. In Italy in particular R&D statistics cover only a limited part of the production of technological knowledge used for industrial innovation, by mainly small and medium-sized firms (Malerba 1993). In fact, the innovative ability of Italian firms appears to be based, at least for a significant part of the second half of the 20th century, more on creative adoption processes and the systematic development of localised learning than on the mechanism of formal research in the laboratories of large corporations.

If international trade in ideas has been recognised as a major factor in world growth in several studies (Coe and Helpman 1993; Eaton and Kortum 1996), the contribution of foreign technological knowledge in domestic technological innovation processes emerged as being particularly relevant in the Italian Golden Age of the 1950s and 1960s (Antonelli and Barbiellini Amidei 2007).

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This paper aims to reconstruct the evolution of Italian innovative effort, assessing different phases and dimensions of Italy's technological catch-up, tracking the transfer of foreign technological knowledge, and analysing the impact of imported technology on recipient innovative activity performance. We also try to assess how Italian productivity growth was related to different forms and channels of international technology transfer in some relevant periods.

The paper is structured as follows. Section 2 provides a conceptual discussion of the importance of innovation and technology transfer in economic growth. Section 3 provides historical overview of innovation and foreign technology in the context of Italian economic growth. The fourth, fifth and sixth Sections introduce and analyse the three blocks which make up the original dataset developed for this paper: variables on Italian innovative activity performance, foreign technology imports and domestic innovative capability, respectively. In these sections we discuss the evolution of the main indicators of the generation of technological knowledge; provide an analysis of the relative significance of the various channels for foreign technology imports and the characteristics of processes of absorptive and innovative capability formation in Italy in different historical phases; and place these in an international context. By doing so, these sections provide a first assessment of the magnitude and relevance of transfer of foreign technology to Italy. The seventh Section presents an econometric analysis of the impact of foreign technology on innovation and productivity growth. The last Section concludes.

2. Innovation, Economic Growth, and International Technology Transfer

The major role of innovation, be it technological or associated organisational change, in economic growth and rising living standards is almost unanimously recognised (see e.g. Scherer 1999). Technological change had a central role in the work of the classical economists such as Adam Smith, and Karl Marx. Schumpeter (1911) not only centred upon the role of technological change the explanation of economic growth, but he also, rejecting the assumption of exogenous technological change, in fact assumed that innovation and inherent transformation is an inalienable element of economic activity and therefore an indispensable interpretive element of any economic theory. The definition of innovation proposed by Joseph Alois Schumpeter in 1911 in his "Theory of Economic Development" is still a valid starting point: the introduction of new products, new processes, new final markets and new methods of organising firms as well as using new intermediate inputs. Also according to Schumpeter (1947) crucial for innovation are the conditions of access to external knowledge (to the firm, the sector, the geographical area, the country).

Schumpeter (1911) had argued that innovation necessarily provides the foundation for economic growth, since it consists of building new domains of value creation, which therefore expand the stream of values that are distributed and exchanged through the circular flow of income. The regular circular flow of income, which is the focus of most traditional analysis of markets or exchange processes in modern economics, is thereby continuously disturbed and disrupted through the establishment of new fields of value creation or production. A post-war Schumpeterian perspective has built upon this insight by contending that innovation – building new areas of value creation – relies on the localised development of technological or social capability, through problem-solving or learning activities principally within (and between) firms (see e.g. Pavitt 1999). The development of new products and processes is the outcome of a path-dependent building upon established capabilities and achievements, by the critical revision of emergent new products or methods and the search for novelty of a kind that is relevant to addressing in new ways producer problems or user needs (Dosi 2000). Hence, innovation must be understood as a continuous learning process in firms supported by other institutions, and not as a discrete event, whether an exogenous shock that gives rise to a monopoly or a flash of entrepreneurial alertness which requires no resources, nor as the implementation of a fully-defined and foreseen strategy. Innovation is a problem-solving search that creates and continually renews technological or social capability within firms, and is not a search for positions of market power as such. This Schumpeterian perspective builds upon and amalgamates the conclusions of the work of Usher (1954) and Rosenberg (1976; 1982; 1994) on the history of technology, Nelson and Winter (1982) on the evolutionary theory of economic change, and Penrose's (1959) theory of the growth of the firm. Thus, innovation depends upon the generation of new capabilities made feasible as the outcome of problem-solving and progressive experimentation, the operation of which capabilities adds new value to the existing circular stream of income, and thereby creates new profits and higher income.

In an international context, technological differences have come to be studied as prime causes of differences in GDP per capita across countries in the "technology-gap literature" – see e.g. Ames and Rosenberg (1963) and Dosi, Pavitt and Soete (1990). Gerschenkron (1962) had pointed out that "backward countries" are presented with an opportunity for great "industrial upswing." Countries that begin behind have the potential to access more advanced technologies from existing leaders (Pasinetti 1981). Yet backwardness, also in technological terms, is not just an opportunity, but one that has to confront major limiting factors, institutional, financial and socio-economic. Therefore, in Gerschenkron's interpretation of the industrialisation of European countries – among which the Italian case received considerable attention – the reduction of the gap between backward and advanced countries is far from automatic (Fagerberg 1994). The milestone work by Abramovitz (1986) focused attention on the concept of backwardness as an opportunity for catching up on technology. His explanation of the rate of productivity growth of OECD countries pointed out that differences between productivity levels across countries create potential for convergence, provided that countries have the "social capability" to absorb more advanced technologies. Abramovitz adopts the concept of "social capability" introduced by Ohkawa and Rosovsky (1973) to refer to those factors which inform a country's ability to appropriate technological and organisational change and identify them in terms of the extent of technical competence – for which education might be a rough proxy – of their political, commercial and financial institutions. Yet another limitation to the absorption of technology from leading countries is represented by limited "technological congruence" (Abramovitz 1993; 1994), i.e. economic conditions, such as market size and scale of production, in which new technology is generated and embodied (Fagerberg 1994). The (lack of) capacity for international transfer of technology is a key concept in the Gerschenkronian interpretative framework, as well as in Abramovitz and the technology-gap and catch-up stream of work.

Once we allow for the fact that the transfer of technology to a new location always involves resource costs associated with the adaptation and implementation of technology in a different context, it becomes clear that these costs are often considerable (Teece 1977). The Schumpeterian approach to the internationalisation of innovation and technology transfer has drawn heavily on an evolutionary view of the firm and the industry (Nelson and Winter 1982), examining the accumulation of technology within the international networks of multinational corporations as a path-dependent corporate learning process (Cantwell 1989; 1991). This approach implies a distinctive perspective on technology transfer, being concerned with its interaction with learning processes and not just with the immediate exchange of knowledge. In particular, once technology is defined broadly as an overall system for production in line with the Schumpeterian conceptualisation of innovation outlined above, two components of technology can be distinguished (Cantwell 1991). First is the potentially public knowledge element of technology, which encompasses codifiable items as represented in the engineering blueprints and designs and the scientific knowledge that constitute the narrower definition of technology. The potentially public element of technology includes individual practitioners' knowledge of the way such scientific and engineering principles are applied, or in other words the way things work in practice (Nelson 1982a). Taken as a whole, this potentially public aspect of technology is in principle analogous to information, in that it may be exchanged between knowledgeable scientists, engineers, and practitioners or managers. However, more accurately this element of technology is only potentially public, since devices such as patents or secrecy or the specificity of the codes in which it is expressed may delay its actual entry into the public domain.

Unlike the first, the second element of technology is not akin to information but is tacit, and is specific to particular firms. This tacit element of technology is embodied in the organisational routines and collective expertise or skills of specific production teams (Nelson and Winter 1982). This part of technology is derived from and tied to the localised and collective learning experience of the teams of a given company through their own development of production. Hence, this second aspect refers to the human element of technology, which involves some received and accepted ways of achieving effective human interaction in the conduct of a productive activity, including the division of labour between actors and the coordination of their efforts (North and Wallis 1994; Nelson and Sampat 2001). The second element of technology is more often embodied in the practice of specific organisations, and sometimes in the way in which some specific organisations regularly and systematically combine their activities (whose human or social element of technology thereby may become connected), sometimes across national boundaries in the form of international business relationships.

The transmission of technology across countries therefore takes a wide variety of organisational or administrative forms, which have evolved over time. Foreign technology can be embodied in imported intermediate inputs, capital goods, or skilled migration. It can be channelled through FDI through patents registered in the host country by foreigners. It can be purchased in disembodied form or it can spread by imitation and reverse engineering (Maskus 2004; Arora, Fosfuri and Gambardella 2008). The form of international technology transfer in any given context depends upon local industrial conditions including the levels of capabilities already built and acquired by indigenous firms, and local institutional conventions and structures. These factors affect both the likely resource costs of alternative modes of technology transfer, and the potential for supportive capability building in the local recipient units that establish connections with those foreign holders of more advanced technology.

It is now better understood that firms co-evolve with their institutional environment (Murmann 2003; North 1990; Cantwell, Dunning and Lundan 2010), be it in a domestic or international context. In the catch-up experience of countries that begin behind, the importance of international business connections in a country's development has been observed repeatedly (Dunning and Narula 1996). Yet while international business linkages are part of every successful experience of technological and economic catch-up, the form of these international relationships has varied considerably (Cantwell and Zhang 2009). FDI provided a primary vehicle for international technology transfer in the US before 1914 (from Europe), in interwar Japan and post-war Europe (from the US), and more recently most notably in Singapore and China. Conversely, in the interwar US or Germany, and in post-war Japan and Korea, international trade, licensing and subcontracting were the more important mechanisms for international business connections in broad based domestic systems for innovation in which large indigenous firms or business groups spanned across industries and provided many internal technology spillovers of their own. Over the longer term, changes in the international environment influence the form of international business connections relied upon for technology transfer, and then within any given period there tends to be a good deal of cross-country variation which reflects differences in national industrial and institutional conditions.

3. Innovation and Technology Transfer in Italy

Unified Italy lost ground compared with other European countries for more than 20 years after 1861. Its first long period of rapid economic growth since the seventeenth century occurred during 1900-1913, roughly coinciding with the Giolittian period.[2] This period of growth occurred only after a regime change both in the economic and political spheres in the second half of the 1890s. This shift is regarded as allowing the preconditions for Italy to join the expansionary international cycle, but also to start catching up with more advanced economies (Rossi and Toniolo 1992, p. 544).

The innovation activity undertaken by Italian firms in this phase was mainly fed by inward FDI, investment in foreign-made equipment, and patent applications in Italy by foreigners and licensing agreements (Vasta 1999a). The military-industrial complex, a major contributor to industrialisation and, in most countries a source of technical progress, imported most of the modern technology in the Italian case (Federico 1996; Hertner 1984)

Also in the electro-technical industry Italy depended on foreign innovation. Equipment and material characterised by a high technological content was of foreign origin, particularly from Germany, until the WWI, and increasingly from Switzerland. Three out of the top five

[2] Some scholars identify a period of fast growth in the 1880s too. See Federico 1996 and Broadberry, Giordano and Zollino 2011.

patenting firms in Italy were German (Siemens & Halske; Siemens-Schukert and AEG). Only between 1909 and 1914 did two Italian corporations, CGS and Richard-Ginori, appear in the top eight patenting firms. However, these firms manufactured less technologically advanced products such as electricity meters and insulators (Vasta 1990; Hertner 1986). A similar international division of labour took place in the chemical industry, where Germany spearheaded technical progress through the application of scientific research, whereas the Italian counterpart was locked in a vicious circle of lower technology, quality and demand.

Indigenous technological development suffered from various constraints. For instance, the engineering industry suffered from a lack of adequate raw materials and limited demand for its products as neither agriculture nor the food-processing industries created any significant demand for equipment requiring new technologies. This also impeded the specialisation of engineering firms needing to produce a range of different products in order to continue their trading life (Davis 1991, pp. 98-99). An exception came from Italy's undisputed technological leadership in the most "traditional" textile industry of silk reeling. The modern reeling industry developed from the invention of the steam-reeling machine patented by the Frenchman Gensoul in 1805. Italy took the lead from France in the early 19th century and kept it for a century, introducing a long list of innovations that were implemented on domestically built machines. It suffices to mention that already in 1854, only a third of boilers in use in Lombardy were imported; fifteen years later 73 out of 75 Italian reeling firms used only domestically built machinery (Federico 1997, pp.104-109). But the weaknesses of the Italian machine tool industry were such that the industry could not provide for the expanding textile sector, which depended on foreign machinery. This also meant building their own repair shops or relying on foreign suppliers and technicians. Alessandro Rossi of the Lanificio Rossi in Schio declared in 1881 that Italian textile manufacturers had little choice but to buy abroad since foreign machines were technically superior and less expensive (Maiocchi 1980, pp. 887-888). Even the construction of the railway network, which accelerated between 1861 and 1876, did not promote a domestic engineering industry for long. Rails, engines, carriages and trucks continued to be supplied from abroad. Iron for bridges was also of foreign origin as the Italian iron and steel industry was handicapped by the lack of domestic pit coal (Cafagna 1973, pp. 287-288).

The first major breakthrough for the Italian engineering industry occurred with the railway law of 1885, which gave preference to national products, and further extensions of the railway network. A number of specialist works were established, such as Franco Tosi & Co. (1881) and Ernesto Breda & Co. (1886), while others, such as Ansaldo, were modernised. This meant important investment in machinery imported from the US. Moreover, as a result of the preferential policy for Italian-produced goods, foreign companies, German in particular, established works in Italy (Davis 1991, pp. 102-103)

Italian firms were quite proficient in adapting foreign machinery and in combining machines of different provenance and vintage - this skill was less developed in heavy industries, where plants were mostly bought turnkey (Federico 1996; Giannetti 1994). Italian engineers played an important role in this respect. They were able to deal with a variety of technologies and use them creatively due to a strong broad education in engineering rather than a specialised one (Giannetti 1991).[3] On the other hand the slow pace of technological development provided a weak demand for technical skills, thus impeding the start of virtuous circle on a large scale (Maiocchi 1980, p. 882).

In the 1920s and 1930s the growth of the Italian GDP per capita (1.6% p.a.) fell below the Western European average (1.9%) (Maddison 2010). Various trends can be identified in those two decades, from *laissez faire* policies and rapid growth in the 1922-1925 period, to severe depression (1929-1934) and recovery of industrial production in 1934-1937, driven mainly by war-related industries and those industries that benefited from the autarky (Toniolo 1980; Rossi and Toniolo 1992, pp. 545-546).

Recent work has provided a complex picture concerning the introduction of new technologies in industry in the interwar years. Overall Italian industry seems heavily dependent on foreign technology, but was able to adapt it to the Italian market. Import and imitation of technologies from abroad characterised the textile and steel industries, whereas mechanical engineering and chemical sectors saw significant investment in autonomous domestic innovation activities (Federico and Toninelli 2006; Giannetti 1999).

Some technological trajectories that had begun at the end of the 19th century and before the WWI came to be exploited by the Italian industry in the interwar years. The availability of hydroelectric energy made possible various instances of process innovation, such as the production of high quality iron and steel from scrap iron, aluminium from bauxite and fertilisers from acetylene. The largest Italian chemical company, Montecatini, specialised in the production of fertilisers and pesticides applying the Fauser process, i.e. electrolysis of water. Fertilisers and pesticides were an important area of growth in the Italian economy in the 1930s (Giannetti 1998, pp. 101-107). Moreover, the Fauser process and the process invented by Luigi Casale to produce synthetic ammonia and nitrogenous fertilisers were exported since the 1920s. However, systematic research and the establishment of labs in the chemical industry began only in the 1930s – still on a limited scale. Imports of foreign technology remained important, through foreign patenting in Italy, licenses and joint ventures (Giannetti 1998, pp. 112-114). The Italian oil industry, with government sponsored Agip, benefited from research by IG Farben and Standard Oil. In turn, Montecatini and Fauser agreed to transfer to the German-American cartel existing and future patents (Giannetti 1998, p. 114). A notable case of joint venture in the chemical industry was Litopane, a joint venture between Montecatini, IG Farben and Sachtleben, for the production of dyestuffs and explosives. The import of foreign technology was also very important in electro-technical where Italian firms purchased licenses and patents from foreign firms: this was the case with Cemsa and Westinghouse, and Galileo Ferraris and Tecnomasio and Brown-Boveri (Giannetti 1998, pp. 102-103).

The short period between the introduction of the autarkic policy (1935) and the beginning of the WWII witnessed the establishment of labs and research offices particularly in the chemical industry, such as the above-mentioned Montecatini, Snia and Pirelli. Developing new

[3] While Giannetti (1999) praises the education in engineering provided by Italian universities, Maiocchi (1980) stresses how such education had little practical application. A cultural discrimination against applied science was evident in mathematics and physics.

technologies was considered a matter of national interest. However, the cooperation between centres and labs was far less significant than in Germany, US and Japan.

FDI as a percentage of GDP increased sharply in the 1920s, although these did not reach the particularly high levels prior to the WWI (see Section 5.2 in this paper). By the end of the 1920s the most attractive sectors were textiles, chemicals and electro-mechanics – with examples such as the Compagnia Generale di Elettricità, the Italian branch of General Electric – rather than utilities and transport as it was the case previously. The 1930s saw a sharp decline in FDI, with "coke and petroleum," "electrical equipment" and "chemicals" being the industries with the highest share of foreign capital. Therefore, the interwar period saw a shift of FDI from utilities and transport to manufacturing, technology and capital-intensive industries (Colli 2010, pp. 93-101).

The Italian innovation activity measured in terms of Italian patenting abroad began a decreasing trend from the second half of the 1920s and remained at a relatively low level until the WWII (see Section 4.1). A weak connection between science and industry was considered a major weakness of the Italian industrial system.

In the 1950s Italy had the opportunity to reduce the gap, which had widened during the fascist autarky, and engage in the process of technological catch-up with the US (Abramovitz 1956 and 1989). The Washington-sponsored machinery imports and technical assistance programmes were an important channel of American technology. The 1950s and 1960s witnessed an expansion in internal demand that enabled the introduction of mass-production technologies. The ability to adopt such technologies depended on the considerable increase in investment and on the development of the Italian engineering industry, in particular the machine tools industry. Imported machinery as a percentage of investment increased significantly from 1950, with particularly high growth rates in the Italian economic boom of 1959-1961 (see Section 5.1). Moreover, the impact of international technology transfer has been enhanced by Italian industry's ability to acquire and diffuse foreign technological knowledge through imitation, reverse engineering and adaptation (Antonelli and Barbiellini Amidei 2007, pp. 5 and 172-173).

FDI increased sharply from the mid-1950s throughout the 1960s. The common wisdom interprets this as due to investments by American multinationals not only in Italy, but also in Western Europe. However, recent research highlighted that while American firms were the main investors, French, Swiss and British firms owned a significant share of Italian FDI in Italy (Colli 2010). Particularly relevant were foreign investments in petroleum, electrical equipment, chemical industries.

Between 1956 and 1999 the volume of transactions on patents and designs – registered in the Technology Balance of Payments (henceforth TBP) – constantly increased, clearly indicating Italy's increasing integration within a system of international technological exchange. Imports of disembodied technology exceeded markedly exports throughout the whole second half of the 20th century (Antonelli and Barbiellini Amidei 2011, pp 108-111). In the first decade of the new millennium instead, a weakening of technology transactions prevails (see Section 5.5).

Information on Italian patenting in the US by sector and technological classes (Cantwell 2002) provides a valuable insight into the innovation activity generated in the long run domestically, especially by Italy's main corporations (see Section 4.1). Patents granted in the US to Italian residents increased both in absolute and relative terms in the 1950s and early 1960s, with a growth rate almost twice the average of other foreign countries and US residents. The upward trend continued till 1972-1973 and the Italian share stabilized at rather low levels in respect to other main advanced economies. In respect to foreigner patentees only, the peak of the Italian share was already reached in mid-1960s, after which relative values declined. The absolute values resumed an upward trend after 1983, but other foreign countries' patenting in the US increased more quickly, hence the Italian decline in relative terms. The main sectors of the Italian patenting activity were "Chemicals and allied products," "Rubber and plastic products" and "Machinery, except electrical" (Antonelli and Barbiellini Amidei 2007, pp. 96-105 and 119).

If patents provide an understanding of the Italian innovative output, data on expenditure in Research and Development provide valuable information on an important input in the more formalised innovation activity of medium-sized and big Italian firms (see Section 6.2). Studying R&D expenditure (as a percentage of GDP), Italy emerges as a country that – starting from comparatively very low levels, 0.6% of GDP in 1963 – was reducing the gap with other major OECD countries in the 1960s and 1980s and reached a record 1.3% of GDP in 1990, thus progressing from one third to more than half the average figure for the other six main industrialised countries. Since the 1990s, however the gap between Italy and the other major OECD countries widened with Italy recording 1.1% in 2005, compared to 2.4% in the other six countries (Antonelli and Barbiellini Amidei 2007, pp. 55-63).

4. The evolution of Italian innovative activity performance

This section provides a quantitative analysis of the evolution of the (visible) production of technological knowledge in Italy over the past 150 years. We invested in an in-depth reconstruction of the evolution of Italian innovative effort over the period 1861-2011, which should enable us to assess Italy's relative performance in different sub-periods, and to identify phases of technological catch-up and relative lagging behind.

To stand up to the measurement challenge of accounting for innovation outputs in such a long historical time span, we build and cross-check different kinds of indicators, along the wide and evolving range of innovative dimensions/activities, trying to track also the less formalised factors typical of Italian firms. We provide quantitative evidence on both classic innovative activity indicators, such as patents, and proxies of other softer forms of innovation activity, such as trademarks, design and models, utility models. We have gathered data through access to Italian and foreign statistical and archival sources and constructed time series to be used for our subsequent estimation exercise. Depending upon data availability, in some sub-periods the time series have been broken down by sector.

This section and the following two might provide an initial assessment of the extent to which our data support the established understanding and knowledge discussed in Section 2 and the historical evidence recalled in Section 3.

4.1 Patenting activity

We built quantitative evidence about Italian patenting activity over the past 150 years, in an internationally comparative perspective, in several foreign locations, not only, as usually done, in the US, but also in various European countries (France, Germany, Spain, UK, Switzerland). We also collected data on patents granted in Italy, as well as at the European Patent Office for more recent years.[4]

Despite a great deal of theoretical and, above all, empirical approximation, it is accepted that statistics regarding patents can be considered a useful measure of the flow of prevalently scientific innovation, which bigger firms develop (along with – particularly in the past – professional individual inventors). A study of the evolution of patents can contribute to a description of the results of some ways of producing scientific and technological knowledge, but they certainly cannot be considered a comprehensive and impartial indicator. Firm size significantly influences the propensity to take out patents: in patent count statistics innovative activity results of large firms are over-represented, while those of small firms are under-estimated. Moreover patents highlight product innovation which can be copied easily, and does not adequately represent innovation processes which are protected by their complexity, compactness and the sequence of the productive process. All these caveats strongly apply to the Italian case.[5] Still patent data are a necessary complement in any innovation processes'

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[4] Our main source for what pertains pre WWII years is "La Propriété industrielle: organe officiel du Bureau international de l'Union pour la protection de la propriété industrielle", in which we found several tables with data on patents, trademarks, international trademarks, design and models applied in different countries Patents Offices with the details on foreign applicants. Other valuable historical sources were the Journal of the Patent Office Society's data reconstruction (see Federico 1964) as well as World Intellectual Property Organization (WIPO) publications (see in particular WIPO 1983), and national statistical sources (in particular for Italy see Direzione Generale di Statistica 1884-1925; Istituto centrale di statistica del Regno d'Italia 1926-1944; Istat 1949-2010. For Spain see Saiz 2005). For recent years we accessed national and international sources (United States Patent and Trademark Office-USPTO, European Patent Office-EPO, WIPO).

[5] Statistics regarding patents are a rather partial and selective indicator. Many elements need to be considered to adequately evaluate the contribution made by patents as a proxy for intensity and for the results of innovative activity (see Griliches 1990; Santarelli and Sterlacchini 1990). Above all, the evaluation must allow for the high degree of heterogeneity of the technological and economic value of the various patents. It goes without saying that, as much original knowledge is not patented for reasons of secrecy, strategy and cost, the relationship between the flows of patent approvals and the flow of new technological knowledge is rather complex and questionable. And it is equally true that the technological originality of many patents is actually little and doubtful. Further, not all innovations are patented but some tend to be broken up into a number of applications for patents (in certain countries and especially in certain sectors). On the other hand, not all patents are destined to become innovations, instead they free big multinational firms from the need to control and defend certain markets from potential competitors. Also, it is clear that only firms which are very concerned about the low level of "natural" appropriability of perfected knowledge consider it opportune to use this instrument. In fact, a different propensity to patent is seen not only for different kinds of innovation and enterprises of different size and nationality, but also for different product sectors (see Pavitt 1984).

interpretive picture over the long run, and furthermore the key ingredient of any analysis on historical periods of otherwise poor statistical coverage of technological innovation activities.[6]

The collection of evidence on patenting activity abroad other than in the US has not been explored frequently over such a long period of time and never, as far as we know, for the Italian case. It could well be that in diverse historical phases, we will find different dynamics in Italian patenting in US and in the European countries, related to Italy's trade orientation, light outward FDI, migrations destinations, and also to different host countries' patenting systems – being the particularly far and highly competitive US market not the natural first reference for smaller, only export internationalized Italian firms.[7]

We obtain interesting results. Italian patenting performance in relative terms – expressed by the share of patents granted to Italian residents on total patents granted to foreigners – appears in Europe, across the different foreign location surveyed, better than in the US over the long run – higher share levels and stronger progresses (Figures 4.1, 4.2-4.5).[8]

In particular Italy's patents share in Europe improves significantly along the first Giolittian phase: the patenting performance of this first catch-up period appears relatively more successful – a constantly increasing and higher levels at the peak and relative to Italian industrial development at the time; in the 1920s-1930s decades, the Italian gap remains mostly stable or widens. In the US instead, Italian levels and progresses were on a lower scale all over the first half of the 20th century.

At the beginning of the 1950s, in comparison with the main industrialised countries, Italian residents' patenting performance abroad was still modest both in Europe and in the United States. Since then the Italian catch-up in patenting activity abroad resumed, but it registered apparently a step back in diverse patenting locations at mid-1960s at the peak of Italian economic boom, in the middle of the so-called Golden Age (Figures 4.7a and 4.7b).

[6] Moreover patents make it possible to take account of the results of innovative activity, at least in terms of production of technological knowledge, when it is not the result of research and development activity as it is traditionally defined. Furthermore, patent statistics make it possible to consider the rather important problem of how efficiently research activity and innovation in general is managed. In fact, while R&D expenditure measures research activity cost, it certainly does not measure its output.

[7] In the first place, it is clear that the choice, consolidated in wide ranging comparative international research, to consider the patents granted by USPTO means to select a rather particular universe, represented by agents who are able to operate on the toughest international market and spend a not insignificant sum of money on defending (through this particular right of intellectual ownership) their ownership of refined knowledge. The result is that the innovative activity of large firms is over-represented, while that of foreign small firms is under-represented. Secondly, as obtaining a patent in the US is the result of expensive procedures based on merit (a rather demanding procedure which is the main reason for its documentary value) but in return for significant protection and therefore an increased degree of "artificial" ownership (guaranteed by a very effective and competent legal tradition in the main world market), it is clear that this instrument is used not only by firms which are very concerned about the low level of "natural" appropriateness of perfected knowledge, but also by firms pursuing strategies directed to the creation of intangible assets, mainly of a financial character, particularly in a highly financially sophisticated market such as the US.

[8] The comparison is within "foreign" patents. Host country resident's patents are excluded, in order to avoid evident effects of asymmetry in favour of domestic patenting activity for indigenous firms.

Interestingly the progress in Italian patenting relative performance is interrupted and partially reversed in the case of patents granted by the USPTO, while the latter recover a catch-up path in the case of European patent offices. In the 1970s-1980s period in fact, Italian patenting activity in European countries seems to be back on a moderately growing track – or on an effective defensive one relative to the relentless Japanese new champion – while Italian firms were continuously losing ground among USPTO's patentees. It is worthwhile to recall that the statistics regarding patents granted by the USPTO in the second half of the 20th century in particular can be considered a useful measure of the flow of science-based innovations, index of more formalised, laboratory-based, structured technological innovation activities, which were developed mostly by the (few) Italian large corporations.

Moreover, Italian patenting activity in Europe in the past 150 years apparently encountered relatively less difficulties – higher share levels and stronger progresses – in France, Spain and Suisse than in Germany especially over the post-WWII period (Figures 4.2-4.5): perhaps owing to less strict "Latin" patenting systems and being those countries destination of Italian typically softer and intermediate technological innovations.

Even if we look at the number of domestic patents granted to Italian residents per unit of GDP (International GK Dollars; Maddison 2010) – a proxy of innovation activities not always close to the international technological frontier – in respect to other countries' domestic performance (French residents' patents granted in France on French GDP, etc.), a lower than average Italian patenting activity output level throughout the whole period emerges, as well as a catch-up in the long run leaving a significant gap (Figure 4.6). Interesting are both the relevance of the long Giolittian phase progress and the not so remarkable Golden Age performance. In the 1950-1973 period the Italian economy was able to grow more than average, apparently "saving" more than average on domestic patenting as well as on patenting abroad.[9]

Let us now focus on the post-WWII phase (Figures 4.7a, 4.7b). The comparisons between Italian patents and other foreign patents issued in the US show: the limited number and share of Italian patents in the early 1950s; the relatively vivid growth of the Italian share during the "economic miracle years" up to the historical maximum of 4.1% in 1963 (much closer to the shares of Italian patents in Europe), and a (limited) catch-up with respect to the main industrialized countries, with the significant exception of Germany; the decline of Italy's patent share during the subsequent four decades. Certainly Italy did not experience, not even during its economic boom period, any "take-off" in foreign patent activity similar to those of Japan and South Korea (since mid-1960s and early 1990s respectively). Excluding Japan (the big winner of the post-WWII phase), however, until early 1990s the gap with respect to the other industrialized countries narrowed. In the last two decades, instead, the dynamic of Italy's patent activity in the US does not allow any further catch-up, not even against mature competitors.

Since early 1990s the relative stepping-back of Italian patents seems shared by the two sides of the Atlantic (Figures 4.8, 4.9, 4.10a, 4.10b and 4.1-4.5), in this phase the Italian

[9] The Golden Age domestic patents' pattern is substantially mirrored across Italy's main foreign patenting locations, i.e. looking at Italian patents granted in France on Italian GDP in respect to German and other main countries' patents granted in France on their own GDP (data not displayed).

performance suffer both old and new internal difficulties and structural weaknesses, as well as new successful patenting countries – the Far East industrialized tigers, South Korea in particular, and Northern Europe bouncing back, Finland first.[10] At European Patent Office, Italian patent applications share decreases less significantly and remains higher than at USPTO, while Italian share of patents granted by EPO actually increased in the past 15 years, possibly signalling a better relative performance of Italian firms – also small and medium-sized ones – in the "easier," less alien European patenting environment.

Still today the overall share of patents granted to Italian residents results rather modest, at odds with the country's economic weight, both at USPTO and at EPO.

We have also collected sectors' and technological classes' patent data in order to be able to break down by level of technological content the Italian patents granted by the USPTO over the whole period under analysis. We calculated the share of Italian sectors' patents over foreign USPTO ones and a *revealed technological advantage index* – a USPTO patent specialization index – in order to identify the relative strengths and weaknesses of Italian technological innovative performance over 120 years (Tables 4.1-4.2 and Figure 4.11).[11]

Looking at the first catch-up phase, Italian USPTO patents gained ground (*vis-à-vis* other foreigners in the 1900-1919 in respect to the 1890-1899 period) across several sectors, but in particular in the more advanced ones – in rubber, transportation equipments and electrical equipments and supplies – resulting specialized in particular in transportation and electrical equipments. In the whole interwar period instead, while total Italian patents increased their share on foreigners' ones, they retrenched in crucial advanced chemical and electrical sectors; the autarchic phase performance was particularly disappointing, as Italian patents lost ground in almost all modern sectors – with the notable exception of rubber, that thus become an area of relative specialization next to the resilient transportation equipment one.

In the second crucial post-WWII catch-up phase, in respect to the Giolittian phase, Italian USPTO patents gained significantly ground across all sectors (except a mild transport equipment decrease) and more towards traditional and technologically intermediate sectors: Italian patents increased their share on foreigners' ones in textile, machinery and chemicals in particular, prefiguring the pattern that will finally prevail in recent decades. This phase induced a shift further away from the initial technological specialization in electrical equipments – notwithstanding some (transient) 1960s-1970s progress in the more advanced areas of the electrical/electronic sector – and in transportation equipments – worsened by a drastic retrenchment of the aircraft industry (only very recently partly reversed).[12]

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[10] For the last fifteen years we refer to the Italian patents granted by the USPTO and by the European Patent Office, the EPO becoming the only sensible patenting location in Europe, apart from domestic patenting; while until mid-1990s for continental Europe in general terms we look at France, Germany, Spain and Switzerland.

[11] The index is the ratio of the relative patents share – to foreign patents – of the single Italian industries and of the Italian national share. For the 1890-1962 period we rely on the US patent database developed by John Cantwell at Rutgers University, with the support of the US Patent and Trademark Office (Cantwell 2002).

[12] Data on USPTO sub-product fields are not displayed.

Over the long run some light and some pre-eminent dark areas emerge: i) specialization in the machinery sector progressed significantly in the long run, crossing the critical level of one after WWII and overcoming the 1.5 value in recent years; ii) the process of technological specialization in the chemical, rubber and plastic industry, after having proceeded vigorously in the 1950s-1960s (with some trouble in the subsequent decades), approached relatively high levels for a broader and more advanced set of fields in 2001-2008; iii) the Italian food industry and the textile industry reached levels of relative technological specialization after WWII, but became areas of high specialization only in recent years, when these two product fields gained the highest (and increasing) shares of USPTO patents granted to foreigners (3.5 and 4.2% respectively in 2001-2008), in front of the chemicals and machinery fields (with a 3.0% share of foreign patents each); iv) started with significant levels of specialisation, the transportation equipment industry went through a process of relative technological de-specialisation after the 1950s, in particular as result of the non-automotive area disappointing performance; v) finally, in the sphere of electric and electronic a long run trend of de-specialization prevails with the index constantly well below one after WWII, particularly the free-fall of the increasingly crucial Information and Communication Technology area – within a generalized retrenching, with the only exception of household appliances – hurting in the past three decades.

Overall, the mechanical industry emerges as having faced the problem of technology and made a more than average effort to equip itself with levels of technological skills and innovative capacity to sustain its successful presence on national and international markets; industrial machinery, in particular, developed a well-structured technological base, establishing itself as an area of relative national technological strength (as we will better see in following sections). The rejuvenated traditional industries (largely in the area of "made in Italy," with the branches of textiles and clothing, leather and footwear, wood products and furniture, ceramics, food, etc.), while increasing the quality content of their output, apparently also increased in recent years their involvement in a somehow patent-rewarding innovation activity. The chemical industry – notwithstanding an industry downsizing with important casualties – was able in the end to broaden its technological specialization over an higher number of product fields, while sharpening its technological participation in products niches. Instead, Italy's patenting profile remained seriously inadequate in the ICT field – where Italy had only 19% of its USPTO patents in 2001-2008, whereas here 46% of all patents granted by the USPTO, in the same period, were concentrated – so that the 1960s Italian firms failed attempt to make their mark in the high- tech electronics industry was apparently a serious and persistent problem for the evolution of the technological strategies of Italian industry.[13]

4.2 Softer and less formalised innovative activity

We have also collected data on designs & models and utility models, in order to detect the less formalised factors typical of Italian firms: the output of their softer, lower grade technological innovative activities. We then try to track Italian trademarks registered abroad – in

[13] See Malerba 1988; Malerba, Torrisi and Bussolati 1996; Antonelli and Barbiellini Amidei 2007; Barbiellini Amidei and Goldstein 2012.

different foreign locations – as also trademarks in fact can be a useful complementary indicator to the more traditional measures of formalised innovative activity such as patents.

4.2.1 Design & models and utility models

As soft innovative indicators, design & models applications at the different European patent offices should proxy the investment by firms in industrial design activities and light product innovation.[14] Apparently in the long run Italian firms were better performing in relative terms in these simpler innovative activities. Still since late 19th century until 1930s, the Italian share of industrial designs and models deposited in France (Figure 4.12) appears modest in respect to other main foreign countries.[15] This not so brilliant Italian firms' performance up to the 1930s is re-enforced when we look at utility models registered in Germany (Figure 4.13). These were lower grade patents – with less stringent patentability requirements, shorter term and lower fees than patents – whose protection was usually sought for innovations of a marked incremental nature, which might not meet the patentability criteria of "inventive step," but still were a junior patent, an intellectual property right (IPR) in need of complying the "novelty" requirement.

Since 1960s instead, the Italian shares of industrial designs deposited and recorded by foreigners in the main European countries (Figures 4.14 and 4.15), as well as the total number of Italian domestic design and models (data not displayed), appear much closer to its industrialized competitors ones, than what emerged for patenting activity. This result might also signal an increasing Italian SME's (light) innovative contribution, partly substitute of a gradually weakening more formalised and structured corporate-centred innovation.

4.2.1 Trademarks

To better assess the Italian innovative performance in the long run we have also collected data on trademarks registered domestically and abroad (France, Germany, UK, US, Switzerland and International trademarks registered in Berne).

Trademarks convey information, telling the customers about new products and their qualities (Wilkins 1992). As such, trademarks can be a useful complementary indicator of firms' innovative activity – an underused one in economic history as well as in economics of innovation – in particular for analysing product innovation and innovation activities performed by smaller firms in low-tech and intermediate industries. In fact innovation studies have shown that, as means of appropriating innovation returns, patents tend to rank lower in many firms' preferences, with the exception of a few industries in which they play a really strategic role

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[14] An industrial design is the independently created, original and industrially reproducible ornamental aspect of an industrial product, while an industrial model is any original three-dimensional form which gives a special appearance to and can serve as a pattern for industrially producing a good.

[15] Our main sources were "La Propriété industrielle: organe officiel du Bureau international de l'Union pour la protection de la propriété industrielle" as well as WIPO publications (see in particular WIPO 1983) and national statistical sources (for Italy in particular see Direzione Generale di Statistica 1884-1925; Istituto centrale di statistica del Regno d'Italia 1926-1944; Istat 1949-2010).

(Mendonca, Pereira and Godinho 2004). Trademarks are correlated with innovative efforts, and while showing some similarities to patenting patterns, they may be able to reveal many aspects of innovation activities otherwise not covered. On the one hand, trademarks are used by a wider set of firms, than are patents, especially among small and medium-sized enterprises, since SMEs are more likely to be involved in applying for trademark rights, being cheaper and not requiring a technological breakthrough, in particular in traditional and intermediate industries. On the other hand, the filing of new trademarks, been used by firms as means of reinforcing the differentiation of their products and of marketing innovations, may reflect the introduction of light design-based product innovations. A trademark-based indicator can significantly contribute in capturing relevant outcomes of Italian firms innovation processes not revealed by other indicators of innovative activity.

Notwithstanding its first mover joining of the International Trademarks agreement in 1883, Italy's share of international trade marks remained for many decades rather low, being until 1930s one tenth of the main players' ones, France and Germany, less than 4% of total trademarks recorded in Geneva (Figure 4.16).[16] It is otherwise true that legally-backed trade marks, as an essential intangible asset initially, in particular as company names, were at the time "providing the basis" for the rise and establishment of the modern large international corporations (Wilkins 1992, p. 87), an area of structural weakness of the Italian business environment.

Italian investment in trademarks revealed innovation activities increased along the post-WWII decades (Figures 4.17, 4.18, 4.19 and 4.20). Italy's relative positioning was destined to improve in particular since 1970s, both in domestic trademarks registered by residents (on GDP), and in trademarks registered by Italians abroad (USPTO, France and Community Trade Marks).[17] Italian trademarks' performance appears again (as for designs & models) much closer to its main competitors' one, than what emerged for patenting activity. Within the EU-15 countries, in the 2003-2008 period Italy's Community trademark applications were ranking third, after Germany and the UK. Interestingly, while the correlation between the two time series of trademarks and patents (registered at home and abroad, expressed as number and share) was positive for the most part of the past century, in recent years this correlation turned negative (looking at trademarks and patents registered by Italians both at the USPTO and at the European Offices).

[16] Our main sources were "La Propriété industrielle: organe officiel du Bureau international de l'Union pour la protection de la propriété industrielle" as well as WIPO publications (see in particular WIPO 1983), and national statistical sources (for Italy in particular see Direzione Generale di Statistica 1884-1925; Istituto centrale di statistica del Regno d'Italia 1926-1944; Istat 1949-2010).

[17] The Community Trade Mark came into being with the establishment of the OHIM, Office for Harmonization in the Internal Market, a EU institution, in 1994.

5. The import of foreign technologies

In this section we explore the inflow of foreign technology to Italy through different channels, through the production of new empirical evidence on the international transmission of technology over the period 1861-2011. We gathered data and build time series of: imports of capital goods, differentiated by type and country of origin; inward foreign direct investment; patent applications in Italy by foreigners; payments for the purchase by Italian firms of foreign disembodied technology.

5.1 Imports of capital goods

If investment in new machinery has generally represented in the 20th century one of the main channels for the introduction of new technologies for the most part of the industrialized countries, this was especially true for Italy through investment in foreign produced machinery for a relevant part of its 150 years since Unification.[18]

Thanks to the new Italian import and export 1862-1950 Federico *et al.* (2011) database, and relying on different modern national (Istat 1953-1987; Istat and Ice 2000-2009) and international sources (OEEC 1951-1958; 1959-1961; OECD 1997; 2011), we are now able to build long time series on machinery imports in Italy.

New data show that machinery imports have a higher and increasing weight as a ratio on national investments in machinery (as well as on GDP and on industry value added), during the Giolittian phase in respect to the 1920s and 1930s (Figure 5.1). Also in the first period the weight of machinery imports appears, *mutatis mutandis*, higher than the one prevailing after WWII (as we will show in Section 6.3), when taking into account the 1950s opening of the domestic market with European integration and international commercial liberalizations, as well as the new scale of intra-industry trade characterizing the second half of the 20th century.

The increasing share of machinery imports on total manufactured products imports since 1890s –18% reached in 1908 – highlights the investment effort in foreign machinery of Italian firms during the Giolittian era (Figure 5.2). The imports of specialized machinery, other than agricultural machines, became relevant since late 19th century as an amount and a share of total machinery imports (Figures 5.3 and 5.4). Interestingly the imports of machine tools, the machines needed to make machines, started to grow since 1920s, reaching a significant amount and almost 30% of machinery imports at the end of 1930s.[19]

[18] Classical economic theory from the time of Smith, and Marx has centered the analysis of economic growth on the theme of the production of machinery because of its role in the processes of accumulation and innovation. In the last decades especially through the historical research on the technological evolution of industry, the understanding of the role of capital goods in the growth of the economy and in the innovative processes has improved (see Rosenberg 1963; 1982; Rosenberg and Mowery 1998).

[19] We collected soft data, historical evidence on the development of the specialized machinery industry in Italy and its relation with machine tools imports, as a national machine tools industry mostly developed in Italy later in the 1960s (see Section 6.3). The machine tool industry has been seen in economic historians analyses as a crucial mechanism in the spread of technological innovation: in the US industry, in particular, in the 19th century for the

Even in the second catch-up phase the ability to adopt external foreign knowledge depended initially on imports of foreign machinery. In the first two decades after WWII, however, a process of quantitative and qualitative growth of the rising Italian machinery industry was set in motion (as we will see in Section 6.3) as a result of the tremendous increase of foreign capital goods purchases of early 1950s and 1960s, when machinery accounted for historically high 25% of all Italian manufactured goods imports (Figure 5.2). Subsequently this percentage in fact fell over time down to only 10% in recent years, Italian machinery exports grew strongly in the long run and the balance of specific commercial trade in capital goods was positive from 1965 onwards.

5.2 Inward Foreign Direct Investments

We also produced new time series on FDI inward in Italy in the past 150 years, working on data from various historical and contemporary sources.[20] From these new estimates we see: i) in the first half of the 20th century a relatively high weight of FDI on GDP during the Giolittian phase; ii) after WWII, a FDI ratio increasing only until mid-1970s – from the historically low levels reached at the end of the fascist period; iii) since 1990s with the new globalised environment, a shifting of inward FDI to levels of a higher scale (Figure 5.5). In order to evaluate recent Italian FDI figures, we looked at data for different advanced countries for the last three decades: while until the 1980s the Italian experience as an FDI recipient was not so different in a international comparison, since 1990 – notwithstanding the sharp rise of the FDI/GDP index – Italian inward FDI remains anchored at much lower levels than its main trading partners, as especially relative to France (Figure 5.6), Spain and the UK, but also in respect to Germany.

5.3 Patent applications in Italy by foreigners

Another relevant indicator of foreign technology influx in Italian technological set is the number of patents applied by foreigners at the Italian Ufficio dei brevetti.[21] The number of foreign patents per unit of Italian industry value added increases since 1880s, reaching at the end of the Giolittian phase its historically highest values (Figure 5.7). It is notable that the ratio of foreigners' patents on the share of Italy's GDP (as well as foreigners' share of domestic total patents) has been mostly higher than other countries' ones (US, France, Germany and Spain) for most of the time up to the 1930s, again quite high in the 1950s-1960s, while it decreased to lower than average levels in the 1970s (Figure 5.8).

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expansion of productive technology based on interchangeable components; at the beginning of the 20th century for the advent of methods of mass production.

[20] Direzione Generale di Statistica 1884-1905, for the 1884-1905 period; Colli 2010; UIC 1995; International Monetary Fund 1948-2010; Unctad 1991-2009.

[21] Our main sources were "La Propriété industrielle: organe officiel du Bureau international de l'Union pour la protection de la propriété industrielle" as well as WIPO publications (see in particular WIPO 1983 ; Direzione Generale di Statistica 1884-1925; Istituto centrale di statistica del Regno d'Italia 1926-1944; Istat 1949-2010).

5.4 *Foreign technical assistance and the Marshall Plan after WWII*

The European Recovery Program (ERP) – or Marshall Plan , a milestone in the history of Europe after the WWII – is particularly relevant to this paper in that it was an important channel for transferring American technology to European countries.[22]

Funds made available under the Marshall Plan came in the form of grants, loans and conditional aid, with this last type of aid intended to support trade within Europe and facilitate the operation of the European Payment Union. Grants and loans were to be used to import goods and services procured mostly in the US, that would be sold in the country of destination. The funds raised by selling the products would constitute the counter-part fund.[23]

In this context, we want to focus in particular on the composition of goods and services transferred to Italy. Table 5.1 clearly indicates the surge in the importance of shipments of foreign machinery and vehicles since 1950. Table 5.2 below confirms this and provides more detailed information on the type of machinery imported, showing the increased weight of metal working machinery and machine tools in 1952 the most relevant kind of ERP funded imports.

The appearance of “technicians, designers and patents” in 1950 in Table 5.2, indicates the inception of the Technical Assistance and Productivity Program (TAP). The TAP was introduced in the ERP in 1949 as the productivity gap between the US and Western Europe was perceived as widening. Italy benefited of 26 mlm US Dollars of US funds committed to the Technical Assistance Program (not including matching funding from Italy’s authorities), as the third major world wide recipient, after France and Germany with 29 and 28 millions respectively (Comin and Hobijn 2010; Tiratsoo 2000). The TAP involved the lending of US specialists to Europe and study visits to the US of European teams. Over the period 1949-1969 the average number of industrial trainees per year that visited the United States from Italy was 63, less than half those sent by France and Germany, and ranked only eight over all countries (Comin and Hobijn 2010).

The counterpart funds represented an important reserve of domestic currency and could be used either for modernization of economic sectors or for some other goals (subject to the approval of the ECA); various countries decided to use them in various ways. Interestingly, Italy used a relevant share of its counterpart funds (over 15% and 80 mln US Dollars; see Table 5.3) – and much more than other countries – to promote domestic production of machinery, making this its third more relevant destination of funds (after investment in transport and

[22] One of the main factors behind the launch of the ERP in April 1948 was the awareness that the economic reconstruction of Europe required an extensive American contribution, if the US wanted to pursue its paramount economic aim of building a multilateral world trading system (Milward 1984, pp. 90-93). The fear that an impoverished Western Europe would be more likely to turn to communism was a further important trigger behind the ERP (Tiratsoo and Tomlison 1997). According to the US Secretary of State, George Marshall, the reconstruction of Europe aimed at creating a political and social environment in which “free institutions” could prosper (Killick 1997, pp.80-81).

[23] Countries submitted their long-term plan to the Organisation for European Economic Cooperation (OEEC) and the Economic Cooperation Administration (ECA), and in turn annual and quarterly plans were agreed with the relevant government (Brown and Opie 1953, pp. 177-213; Fauri 2010, pp. 157-165; Zamagni 2003, pp. 325-336).

communications infrastructures and agriculture).[24] A significant amount of money, and more than Germany and France, was also devoted to sustain Technical Assistance programs (5.6 mln US Dollars almost 1% of the total Italian Funds).

5.5 The purchase of foreign disembodied technology

We collected data on the transactions in the Italian Technology Balance of Payments (TBP) since 1956 from Italian official sources (Ufficio Italiano dei Cambi and Banca d'Italia) so as to build time series of Italian purchases of disembodied technological knowledge developed abroad.[25]

The purchases by Italian firms of not-incorporated foreign technological knowledge appear to be significant since mid-1950s (when national data become available) and have experienced a dramatic increase during the early 1960s Italian economic boom (Figure 5.9). Until mid-1980s, Italian technological acquisition registered in the TBP experienced a sustained growth, reaching a value equal to 0.35% of GDP. Up to early 1990s, Italy's effort to purchase technology abroad stands out among OECD countries (Figure 5.10). When we consider that the national R&D/GDP ratio was under 1% for the most part of the period, it is then clear that the disembodied foreign technology imported was a crucial input of Italian innovative activity over the second half of the 20th century, during the Golden Age era and beyond. Since the beginning of the new millennium instead, the investment in disembodied foreign technology as a share of GDP dropped to the levels prevailing at the beginning of the 1960s, without signs of any significant "technological emancipation" on the receipts side of the TBP (see below, Section 6.4).[26] Also the Italian share of total TBP expenses of main OECD countries decreased significantly.

6. Absorptive capability and domestic innovative capacity

We then collected data and built time series of four set of variables able to illustrate the building process of the national absorptive capacity – i.e. the capability to adapt and adopt foreign technologies – and the development of a domestic innovative system: technical human capital; R&D expenditures; sales abroad of disembodied technological knowledge; domestic production of industrial machinery.

[24] France and Germany used them for investment mainly in the energy sector (see Table 5.3) and Great Britain and Norway to reduce their public debt (Fauri 2010, p. 173).

[25] Our main sources were: since 1990s, UIC 1996, Banca d'Italia 1997-2009; for previous years, see Antonelli and Barbiellini Amidei 2007. The Technology Balance of Payments records expenses and income related to international transactions of disembodied technology, such as patents, trademarks, designs and technical assistance.

[26] Recent developments of the Payments side of the TBP could even be related to the lower and weakened involvement of foreign multinational and their subsidiaries in the Italian productive and technological system in recent years.

6.1 Technical human capital

We firstly collected data on engineers enrolled in Italian universities over the past 150 years so as to proxy the accumulation of higher technical skills. From the new time series of the number of enrolled engineers as a percentage of university students since 1862 – built accessing different historical and contemporary official sources – three main results emerge (Figure 6.1):[27] i) the remarkable growth and weight reached by the share of engineers on total university students during the Giolittian phase until 1920; ii) the subsequent dramatic decline, following Gentile's reform of the fascist period;[28] iii) the not so impressive growth of engineering students in the post-WWII period that result after having subtracted – as almost never is done – the students enrolled in engineering universities but following architectural studies.

Only prior and during the first Italian catch-up, the Italian educational system made a significant selective investment in science-based educated technical human capital.[29] Yet at the middle of the 20th century Italy had accumulated an adequate stock of high technical human capital as a result of its post-Unification investments in engineering graduate studies. After the Golden Age mild growth of the investment in engineering education, the 1970s and 1990s engineers' enrollment relative retrenching has probably been increasingly hurting in recent years.[30]

We then looked at the evolution of the intermediate technical skills endowment as proxied by the number of technicians educated in Italian schools over the long run. From the new time series on students enrolled in technical schools since 1861 interesting results emerge as well (Figure 6.2).[31] Firstly, the early and significant growth of the share of students enrolled in industrial lower secondary schools was not matched by a similar investment in intermediate technical education. The students enrolled in technical high schools lagged behind and started to grow significantly only in the first decade of the 20th century, when the Giolittian catch-up was already well in motion, becoming a relevant share of secondary education only in the 1920s and for a brief period. Moreover technical high schools of the Giolittian phase were more focused on commercial professions' education than on industrial production needs. Interestingly, a small but qualified part of industrial lower secondary schools, often sponsored by local firms and business institutions, resulted a key element in the development of local endowments of manufacturing skills in scattered areas of North and Centre Italy regions (notably Lombardia

[27] Our main sources were: Direzione Generale di Statistica 1884-1925, Istituto centrale di statistica del Regno d'Italia 1926-1944, Istat 1949-2010; 1950-1972; 1973-1990; 1987-1998.

[28] See Bertola and Sestito 2011 for a description of Gentile reform.

[29] See Lacaita 1973; Zamagni 1978; Vasta 1999a; 1999b.

[30] Net of the architecture and building field, the share of students enrolled in engineering on total university students in 2009 was lower (and decreasing) in Italy (9%), relative to (the not too much dissimilar educational systems of) France, Germany (10.5 and 11.9% respectively, both increasing in recent years), and European Union (10.1%); see Eurostat 2010.

[31] Our main sources were: Direzione Generale di Statistica 1884-1925, Istituto centrale di statistica del Regno d'Italia 1926-1944, Istat 1949-2010; 1950-1972; 1973-1990; 1989-1998.

and Marche).[32] Secondly, following the establishment of Gentile's new educational system, a decline of all kind of technical education prevailed. Thirdly, strong and continuous growth of a new technical high school education (*Istituti tecnici superiori*), with a broader and deeper epistemic base and more focused on business production needs, marked the second half of the 20th century. [33]

After WWII structural change in Italy was accompanied on a much lesser scale by a general increase in the investment in human capital (classified according to the levels of education) with respect to other industrialised countries, as well as relative to the investment in physical capital. In early 1950s, Italian workforce had low levels of human capital acquired by means of formal training and education, not only with respect to the US, but also to many European countries and Japan.[34] Italy had a qualitatively good supply of engineers and a trained on-the-job workforce. The average level of education rose dramatically during the fifty years after WWII, but the most significant quantitative progress took place since mid-1950s for what pertains high school education, only since late 1960s in terms of university education (Figures 6.1 and 6.2).[35]

Prior and during the second Italian catch-up a relevant investment was done in intermediate technical human capital. The increased investment in the technical secondary education was important in this phase for the development of the national absorptive capacity. In this period Italian industry, and the mechanical sector in particular, benefited from the new relative abundance of technicians educated and trained in the *Istituti tecnici industriali* (Figure 6.3).[36] This educated human capital, endowed with good structured technical skills with some epistemic base, fruitfully matched the industry's internal development of skilled labor, and was pivotal to develop and successfully exploit technological innovations along vertical manufacturing filieres (Antonelli and Barbiellini Amidei 2011, pp. 126-127 and 174-175). However at mid-1960s, after two decades of dramatic growth, the industrial technical high schools – driving force and core component of the new technical education – stopped gaining weight within total technical education (Figure 6.2); the decline of the share of students enrolled in industrial technical high schools, evident since mid-1970s, combined with an increasingly damaging quality loss, brought the industrial section of higher technical education to

[32] See Zamagni 1996; Moroni 2002; Lacaita 2009.

[33] See Genovesi 1998; Vasta 1999a; 1999b; Zamagni 2002.

[34] See Maddison 1995.

[35] Moreover, up to the end of the 1960s, scientific studies at university were in decline both for enrolled and graduates. Despite improvements, large gaps remained in the area of formal education. Even as late as 1977 little more than 40% of those employed had finished middle school and the percentage of graduates in the working population remained comparatively low (see Vasta 1999b). See Bertola and Sestito 2011.

[36] The "Istituto tecnico industriale" was developed in the post-WWII educational system as a 5 year secondary school teaching technical-scientific subjects relevant for industrial technology development (mechanical engineering, electrical engineering, measures, fluid dynamic, automation, material technology, etc.). The number of "Istituti tecnici industriali" increased from 89 in 1949, to 434 in 1969, and to 636 in 1979. In the course of 1950s among Italian firms emerged the tendency to use educated technicians – in addition to skillful heads of units coming from rows of the workers – to cover the chief technician (*capo tecnico*) functions in the production lines.

progressively lose its leading role. In the 1990s the ratio of industrial high schools students on industry's employees started to retrench. The need for a new technical high school was recognised since 1970s, but for decades the institutional answer was not able to meet this need, never going beyond the project stage.[37]

6.2 Research and development investment

The statistical data on R&D expenditures – available for Italy as well as for other main industrialised countries only since early 1960s – confirm that in Italy both the public sector and above all the business sector historically invested few resources in research activities.

The overall volume of Italian R&D expenditure (gross domestic expenditure on R&D or GERD), starting from a rather modest figure, increased both in absolute terms and relative to GDP in the 1960s and 1980s in particular, due to a higher R&D activity taking place both in the business and the public sector (Figures 6.4 and 6.5): R&D passed from 0.6% of GDP in 1963, compared to an average 1.9% for the six main OECD countries, to 0.8% in the mid-1970s to a record 1.3 in the early 1990s, compared to an average international value of 2.0% and 2.3% respectively.

Since the 1990s instead the gap between Italy and the other major OECD countries widened with Italy down to 1.2% in 2008, when the international counterpart recorded 2.4%. The gap to the other main industrialized countries is still considerable and the R&D/GDP ratio remains anchored at rather low levels, incompatible with Italy's economic position on the international scene.[38]

The extreme character of these figures suggest that, in Italy in particular, R&D expenditures cover only a limited part of the production of technological knowledge useful for industrial innovation.[39] Such expenditures reflect in fact a kind of behaviour and operational criteria typical of large firms active in sectors with a strong scientific base, with laboratories and scientific staff quite rare in the Italian industrial landscape. Most of Italian industry is characterized – increasingly since 1970s – by a completely different kind of firms, more often small to medium, active in traditional and technologically intermediate sectors. The particular dimensional structure of the Italian industrial system is, in fact, the main determinant of the low

[37] One of the few new accomplishments in this area is perhaps the start in 2011-12 of a new non-academic technical higher education institution (*Istituti Tecnici Superiori*) supposed to train specialized technicians closer to the business needs of new high-tech or otherwise innovative Italian industries.

[38] Also limiting the comparison to R&D civil programmes, a significant gap persists.

[39] It is nowadays generally acknowledged that R&D data can document only a part, a rather specific and limited part, of the more complex range of activities aimed at producing technological knowledge and eventually the introduction of technological and organisational innovation. The size of the firm, the sector and product specialisation must be considered very carefully when R&D is analysed as an indicator of activities directed towards innovation, being product or process innovation, the introduction of new kinds of intermediate inputs, the development of new organisational models or the exploration of new territorial and product markets. This indicator, covering activities mostly carried out by large firms and in large state and private research laboratories and favouring formalised heavily science oriented research activity, in fact can describe the evolution of a rather limited sub-group of innovative initiatives, especially in the Italian case.

level of R&D activity; the original specialization model, biased towards traditional sectors, being the second major determinant of the low involvement of domestic firms in R&D activity.[40]

The investment effort of Italian private enterprises has a crucial part in explaining the long run evolution of Italian R&D. The weight of business enterprise sector R&D expenditure (BERD), notwithstanding the initial long upward trend, remained relatively modest in comparison to the other most industrialized countries (Figure 6.6). While in the phase of closing the gap, the corporate system acted as the driving force of R&D growth, with a particularly relevant role of state enterprises in the 1980s, the re-opening of the gap since early 1990s had much to do with the weakening of R&D investment of Italian private and privatized business sector, as well as with the shrinking of the corporate part of it.[41]

The evolution of the pattern of R&D expenditure by sector reveals some interesting trends: while the 1960s and 1970s were characterized by the growth of R&D in sectors at the technological frontier (in the fields of electronics, chemicals, nuclear power); since the 1980s there has been a relative fall in research activity in high-tech industries and an intensification in intermediate technological industries (automotive industry, machinery, electrical appliances).[42] In the long run, the mechanical industry, in particular, made up ground and machine tools and robotics were among the very few Italian industries showing R&D/turnover ratios in line with foreign competitors.[43]

6.3 Domestic machinery industry

After 80 years in which Italian industry (and agriculture) depended decisively on machinery and equipments imported from abroad, innovation and structural change after WWII fulfilled the opportunity to develop a domestic machinery industry, crucial in the emerging Italian innovation system.[44] Since mid-1950s domestic production started to overcome internal investment in machinery and equipments (Figure 6.7). If in the first phase of Italian post-WWII catch-up a significant part of investment passed through the purchase of capital goods produced abroad, imported machinery, while allowing the access to external foreign knowledge, provided an important impulse and was an important input in the process of imitation, creative adoption

[40] Up to 1985, the number of firms involved in Istat's annual census on R&D activity was below number 1000 units. Recent European Community Innovation Surveys on innovation, taking into account a broader set of firms and innovation activity indicators, show more similarity in the share of Italian "innovative" firms recorded by size with those of the European partners.

[41] The role of State enterprises was particularly interesting, in that it was a real tool of public research policy and played a central role in the (failed) building process of a national innovation system. In Italy, state action to support research carried out by (private) firms began only at the end of the 1960s (Law 1076 of 1968, Fondo IMI-Ricerca Applicata). See Antonelli 1989; Giannetti and Pastorelli 2007; Antonelli and Barbiellini Amidei 2011.

[42] See Antonelli and Barbiellini Amidei 2011, pp. 93 and 99.

[43] See Onida and Malerba (eds.) 1990; Parolini 1991.

[44] Since the final part of the Giolittian catch-up until early 1930s a mild trend towards a higher domestic coverage of internal machinery needs – but still with a ratio below one – prevailed.

and technological innovation for investing Italian industries as well as for domestic producers of capital goods. A part in this process was probably also played by the significant foreign direct investments in the machinery and equipments sector (see Colli 2010, p. 106). Increasingly, investing industrial firms targeted domestically produced machines. It was with the economic boom of early 1960s that internal demand for capital goods exerted decisive pressure on domestic industry: the strong and prolonged growth of investment, while initially finding the domestic productive structure unprepared and inadequate, set off significant up-grading, innovation and development of the sector. As can be seen from the data, since 1965 domestic production of capital goods exceeded significantly internal absorption and the balance of specific commercial trade in capital goods turned structurally positive. Exports grew strongly in the long run and Italy gained in this sector a new significant and long-lasting competitive advantage (Figures 6.8 and 6.9).[45] Machinery industry has become one of the main contributor of Italian trade surplus: its weight on total manufactured goods exports passed from 3% at the eve at the WWII, to 15% in the 1950s and to over 30% in the 2000s (Figure 6.10).

The emergence of a domestic machinery industry competitive in developing specialized machinery, tailored on the needs of the users, resulted a crucial competitive factor for Italian industry in the second half of the 20th century (Antonelli and Barbiellini Amidei 2011). Through creative adoption, increasingly reshaping foreign technologies so as to enhance their technological congruence with respect to the needs and characteristics of the industrial domestic users, the development of the Italian capital goods industry resulted in fact in a reduction in the price of capital goods, feeding capital deepening, in a decisive boost to the diffusion of technological innovation and to productivity growth in important domestic manufacturing sectors.

Starting in the 1960s, domestic demand for investment goods increasingly concerned more specialized and technologically sophisticated machinery, stimulating and feeding innovations by the national suppliers, shaped through interaction processes with the industrial users. The impulse of the demand of the growing Italian consumer durables industries (white goods, cars, motorcycles, typewriters, etc.), was important, stimulating more formalised innovative activity, through the purchase of licences abroad and the formation of joint research centres.[46] In the 1970s, the Italian machine tool industry entered a new and important phase of growth, with the development of the production of automated numerically controlled machines.[47] In a few years,

[45] The Italian share of world exports of machine tools doubled, passing from 2.5% in 1955 to 5.4% in 1965. Italian exports of machine tools, despite some dips, continued to increase their share of the international market between the 1970s and the 1990s, passing from 7.4% in 1975 to 9.1% in 1990 (in front of the US, while Japanese exports managed to gain a quarter of the world market, as more or less the German ones; Mazzoleni 1999).

[46] Notably, the experimental centre UCIMU (Unione Costruttori Italiani Macchine Utensili) and the joint research institute RTM (Istituto per le ricerche di tecnologia meccanica e per l'automazione) of Fiat, Finmeccanica and Olivetti. In the mid-1960s, while the ratio of R&D to total sales in the Italian mechanical industry was still modest, the purchase of know-how from abroad was already considerable.

[47] After WWII, the US machine tool industry (technological and commercial leader from the middle of the 19th century, when it replaced British industry) opened a new path of technological innovation: the development of automated systems to control the movement of machine tools with high levels of precision (as a result of research carried out in the early 1950s at the Servomechanism Laboratory of MIT, with financing from the US Department

as a result of the access to new foreign technology and of incremental localised innovations, it was increased the spectrum of manufacturing processes where the use of numerically controlled machine tools was efficient. In particular, numerically controlled machines became attractive for small and differentiated production batches, helping the search for productive flexibility.[48] These technological and productive developments of the machine tool sector favoured the spread of decentralization and articulation of manufacturing industry's productive processes across different production units. During the 1980s, Italian producers were increasingly competitive in adapting and applying the new technology to their typically specialized and customized machinery for traditional industries, thanks to the relationships linking producers, users and suppliers of components.[49] Also, since the 1970s the reliance of mechanical industry on foreign licences decreased and sales of know-how and technical assistance increased; at the end of the 1990s, the machinery sector accounted for a significant share of Italian international patenting activity, R&D and sales abroad of not incorporated technology (as seen in Sections 4.1 and 6.2, see also Section 6.4).

The innovations incorporated in machinery contributed significantly to increase productivity, to improve quality and to widen the variety of products in the downstream manufacturing sectors. In particular, the innovative capacity of the Italian machinery industry made a significant contribution to the competitiveness of the country's traditional rejuvenated manufacturing sectors.[50] As a result, the machinery sector played a central role in post-WWII Italian industry innovative dynamics, as a growing advanced branch of Italy's productive system, as a supplier of goods, vector of technological change, and as a lever for technological and organizational innovation in users industries. Machinery industry resulted crucial for the diffusion of foreign and indigenous technological innovation through the domestic industrial

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of Defence). Numerically controlled machinery was produced and used in the United States essentially from the early 1960s and quickly reached an appreciable diffusion even among Italian firms. In the 1960s, some Italian firms (notably Olivetti and San Giorgio), who were active in the electronics field, developed control systems for domestic machine tool producers (see Barbiellini Amidei, Goldstein and Spadoni 2010). Wider diffusion of numerically controlled machine tools was reached in the mid-1970s worldwide (see Antonelli and Garofalo 1978). It is estimated that in 1978 numerically controlled machinery accounted for 10% of total Italian production compared to a little higher share for Germany and double that percentage for the United States and Japan (see Mazzoleni 1999).

[48] Thanks to the improvements in performance and the lower costs made possible by the introduction of control systems based on the new technology of the microprocessor and by specific localized innovations. In the subsequent years, the growing application of the innovations in microelectronics and information technology made available machinery characterized by increasingly flexible automation (typically, flexible automation systems and CAD- CAM systems). See Carlsson and Jacobsson 1991.

[49] It is estimated that numerically controlled machines accounted for 38% of all Italian machine tools production in 1988, compared to a similar share for the United States, a 50% share for Germany and a share of almost 60% for Japan (see Mazzoleni 1999).

[50] See Antonelli and Barbiellini Amidei 2011. Strong empirical evidence has emerged from numerous sector studies; consider, for example, the analysis of the role of textile machinery in the growth of the textile industry by Antonelli, Petit and Tahar 1992; Antonelli and Marchionatti 1998, Belussi and Pilotti 2002 for garment and fashion industry; Carlesi, Lanzara and Sbrana 1983 for furniture and paper industry; Bursi 1984 and Russo 1985 for ceramic industry; Patrucco 2005 for plastic products industry.

fabric in the second half of the 20th century. Most recent globalization trends may have weakened machinery centred innovation and diffusion processes, as the small size of firms, on the one hand, makes it difficult to recreate at an international level, in a global production structure, those mechanisms of virtuous interaction between users and producers; on the other hand, does not allow to increase investment in formal research and human capital.

6.4 Exports of disembodied technology and technological recombination

Tracking exports of disembodied technology and the balance of the Technology Balance of Payments since 1950s, we are also able to study the evolution of the Italian relative degree of "technological dependence" and the process of technology recombination.

The TBP was constantly negative until 2005 as imports exceeded markedly exports throughout the whole second half of the 20th century. The TBP shows a increasing deficit until 1973, after which date the deficit decreased partly due to an increase in exports of disembodied technology and partly due to a slowdown in the purchase of foreign technology. Since mid-1970s Italy was increasingly integrated within the system of international technological exchange also as a technology supplier. Italian exports of disembodied technology almost reached imports and a value of 0.3% of GDP in the second half of 1990s, starting from less than 0.07% in 1972 (Figures 5.9 and 6.11). The balance turned for the first time positive in recent years more as result of a weakening of Italy's disembodied technology transactions – in a dramatically enlarging international market for technologies – than for a truly increased role as provider of disembodied technology, as receipts of TBP were again down to 0.2% of Italian GDP.

If we compare the two sides of the TBP, a marked difference in the way not-incorporated technology was purchased and transferred in the post-WWII era emerges: 75% of total expenses for patents and licences in 1972-1988 *vis-à-vis* 48% of total receipts from technical assistance and designs on average in the same period. This contrast reflected, together with the weakness of domestic research activity and industry's peculiar specialization, the original post-WWII emergent Italian innovation system: the relevance of technical assistance and know-how as a form of transfer of technology signalled the country's strength in intermediate technologies (mechanics in particular), in rejuvenated traditional technologies ("made in Italy"), and the importance of specific and localised learning in industrial innovation processes. The weakness of Italian industry in exporting codified not-incorporated knowledge was evident, and ancillary to the limited multinational growth of Italian firms, the relatively small amount of resources devoted by Italian firms to direct investment abroad, notwithstanding the huge internationalization efforts and remarkable accomplishments reflected in export flows.[51]

Also the TBP geographical pattern prevailing until early 1990s – together with the technical pattern – revealed Italy's positioning as an economy which made a heavy and systematic use of recombination as the main process to generate new technological knowledge. Italy bought (codified) technology from the more industrialized countries (63% of total payments in 1972-1988) in the form of greater relative value (patents and licenses) and sold

[51] See Barbiellini Amidei and Goldstein 2010; Berta and Onida 2011.

specific and tacit relationship-based technological knowledge (technical assistance, know-how, and designs) to less developed countries (45% of receipts). In the 50 years after WWII Italian firms made, in fact, a considerable effort of creative adoption: they acquired codified/scientific foreign technological knowledge and used it in processes of technology recombination, which allowed adaptation and adoption of imported technology and valorization of specific knowledge result of localised learning (Antonelli and Barbiellini Amidei 2011).

Since mid-1990s a different – and still shaping – phase opened: both the geographical and technical pattern of the two sides of the TBP converged. In 2009 Italian international technological exchanges appear much more concentrated on EU partners and industrialized countries than in the previous decades both for payments and for receipts (62 and 65% with European Union countries, 84 and 76% respectively also considering the other more advanced countries). Even the differences of the technical pattern of the two sides of the TBP lessened (with a lower 18% of expenses for patents in 1996-2009 *vis-à-vis* an increased 12% of receipts; a lower 54% of receipts from technological services in 1996-2009 vis-à-vis 35% of expenses on average in the same period).

Looking at TBP sectoral distribution after the Golden Age a marked concentration of technology purchases emerges in the field of electronics (29% in the 1972-1988 period) and of sales in the field of chemicals (25%) and mechanics (13%). Since the end of the 1980s the traditional sectors of "made in Italy" and since mid-1990s transportation equipments gained ground too as sellers of technology. During the first decade of the new millennium mechanics became – alongside the transportation equipment industry – the main contributor of the receipts side of the TBP (around 15%), exhibiting a steady positive balance, machinery performance being particularly relevant. Chemicals, instead, since mid-1990s dropped markedly as exporter of technology (below 10%), joining ICT as main net buyer of foreign technology. As a result, while mechanics in its many forms has become the keystone of Italian technological system, and the chemical industry represents the challenge partly won but partly abandoned, electronics is confirmed the Italian technology Achilles' heel.

Finally, to gauge the evolving degree of Italian reliance on foreign technological sources in the last fifty years, we build a ratio of TBP payments on R&D expenditures (Figure 6.12). The relatively high values of the index TBP payments/R&D for the Italian economy until the end of the 1990s, more than 30%, recall that the import of foreign disembodied technologies was in post-WWII era and until recent years, an integral and crucial part of the national innovative effort, a complementary factor to R&D, an important input of Italian industry localised innovation processes. At the same time, they point to a hard-won tendency to balance domestic and foreign sources of technological knowledge, suggesting that the Italian process of "technological emancipation" and the formation of solid autonomous innovative capacity were incomplete. Even the drastic decrease showed by the ratio in the past decade, as it is mostly explained by the retrenchment of Italian expenses for foreign technologies and marginally by the modest increase in domestic R&D investment, signals a not so encouraging tendency towards a weaker investment both in the production at home and acquisition from abroad of codified technological knowledge.

7. Impact of foreign technology on innovation and productivity: an empirical analysis

In this section we test the relationship between the three sets of variables composing our original dataset – innovation activity output, technology import and domestic absorptive/innovative capability – so as to understand the contribution of foreign technological knowledge to Italian technological innovative activity and productivity growth (inspired by the approach of Athreye and Cantwell 2007). We also identify some structural breaks between different historical phases (i.e. the first Giolittian era, the Fascist – increasingly closed – interwar period, the Golden Age and its aftermath, and the second globalisation phase). Although we are aware of the connections and progressive interaction between the two over time, we examine separately the determinants of domestic innovative activity performance and the determinants of productivity growth in the country. We use a recursive model structure, in that we incorporate the output of innovation activity among productivity growth determinants, but we recognise that there may be other elements of reverse causation or interdependence that it is difficult for us to capture given the complexity of interactions and constraints of the data over such a long period. However, we believe that we have captured some of the key empirical relationships entailed in the change and evolution over time of the drivers of longer term innovation and productivity growth in the Italian case. The main findings we report are quite robust with respect to changes in model structure and variable operationalisation, and so paint a coherent overall picture, yet our empirical exercise falls more in the multivariate correlation analysis category than in a truly causal analysis.

We begin by examining the determinants of Italian technological innovation in our first regression equation:[52]

$$(7.1)\ \text{Innovation activity performance}_t = a + b_1\text{Machinery imports}_{t-1} + b_2\text{Inward FDI}_{t-5} + b_3\text{Engineers}_{t-1} + b_4\text{Technical students}_{t-1} + b_5\text{R \& D}_{t-1} + b_6\text{Technological Gap}_{t-5} + b_7\text{ Industry share}_{t-1} + \varepsilon_t$$

All explicative variables are lagged and log-transformed. The dependent variable is a simple (unweighted) average of the share of Italian resident inventors in total foreign patenting in various host countries (the US, Germany, France and Switzerland historically, and the USPTO and the European Patent Office since 1996). We appreciate that this measure better reflects

[52] It may be interpreted as an innovation equation drawn from a knowledge generation function – following Nelson (1982) and Weitzman (1996 and 1998) – in which the external knowledge, foreign external knowledge in particular, is a qualifying input together with internal knowledge obtained by means of research and development activities and learning processes. External technological knowledge does not spill freely in the air; if dedicated activities are necessary in order to identify, acquire and use it, additional resources and augmented skills are necessary in order to fully exploit it and find new uses for it, capitalizing on internal knowledge and the domestic factor endowment (Antonelli and Barbiellini Amidei 2011). In this knowledge generation function then enters the country absorptive capability, which enhances the matching of internal and external knowledge, which enables technological recombination and adaptation of the acquired external/foreign technological knowledge, allowing the valorization of internal knowledge and localized learning processes: (i) T = Ab (DK^a IK^g) with a+g =1; where T represents new technological knowledge generated with constant returns to scale by means of domestic/internal knowledge (DK) and imported/external knowledge (IK); a and g are their respective output elasticity; Ab is the absorptive capability.

and the European Patent Office since 1996). We appreciate that this measure better reflects innovative activities associated with large industrial firms than with other types of enterprise, but with this understanding in mind the patterns revealed are interesting.

Table 7.1 displays the results of our estimates. In the first equation, we have all the relevant variables available for the whole period as determinants. For the sub-periods estimates, the least significant variables have been dropped, and the estimates have been replicated without such variables. In the estimation over the 1889-2008 period (Table 7.1, Equation 1), we find positive and statistically significant coefficients on the variables that express the relevance of machinery imports (relative to industry value added), and of engineering human capital (share of university students studying engineering). These effects can be readily interpreted as the import of technology embodied in machinery and equipment supporting and complementing the internal Italian development of innovation processes thanks to the development of indigenous technical skills. These combined processes have consistently raised the innovativeness of Italian industry over time.

Inward FDI (ratio on GDP with a five year lag) has a negative effect on Italian innovation, where a positive effect might have been expected if FDI is thought of as an alternative means of importing technology from abroad. Indeed, it is known that FDI did contribute to the establishment of some of the most innovative industries in Italy that were most dependent upon large firm R&D, most notably in electrical equipment, chemicals and pharmaceuticals (Colli 2010). However, taking the period as a whole, and bearing in mind that patenting abroad reflects best the innovative efforts of large firms, three observations about these large firms in the Italian case help provide an explanation for our finding. First, the largest Italian firms were the ones most likely to have been in competition with the inward investments of large foreign-owned enterprises. Second, in Italy for a significant part of the period, the largest firms have been quite strongly oriented to the domestic market rather than international markets, and in this context they have operated in a relatively closed or protected environment, in which they have come to depend on various kinds of government support (but R&D public support). Third, and crucially, in the research-intensive sectors in which inward FDI in Italy grew most rapidly, the inherited technological capability base of large indigenous firms was on average quite weak by international standards.

In examining the varying effects of US FDI in Europe across different host countries and industries in the post-war period, Cantwell (1989) showed how the local technological impact depended upon the extent of absorptive capacity in indigenous firms. It was when the local industry in a host European country had inherited a strong technological tradition from the past (such as in the case of the German chemical industry) that inward FDI precipitated an indigenous revival and a closing of the post-WWII technology gap with the US. This was due to a virtuous cycle of cumulative causation, in which the incoming FDI provided a competitive stimulus that reawakened indigenous firms from their relative slumber in what had been a cartelised environment, and their research revival helped to engender further foreign-owned subsidiary research in the relevant host industry. Instead, vicious cycles may result where local companies have a certain technological standing but are significantly behind the leading foreign multinationals in their sector (Cantwell 1987). Local large firm innovative activity is eroded by the more direct competitive presence of foreign-owned subsidiaries that rely on best practice technologies derived from the innovation of their parent companies in their respective home countries.

This scope for vicious cycles, and the domestic policy reaction of further closing and protecting the domestic large firm segment of the economy, appears to be a reasonable description of the average Italian case when looking at the 120 year period as a whole. The relationship of inward FDI with innovative activities in smaller more entrepreneurial export-oriented Italian firms has been relatively weak as these firms have by and large built their own international networks, and as we have remarked their innovation is probably not well reflected in our measure.

Meanwhile, the share of manufacturing industry in total Italian output has had a positive (and statistically significant) influence on indigenous technological activities, which is consistent with a reading of this variable as an indicator of modernisation and a key driver of economic growth over the period as a whole (Kaldor 1957; 1958; 1966), as well as the fact that our innovation measure especially captures the activities associated with large industrial firms.

Turning now to the equivalent estimates for each of our sub-periods, we find that in the first Giolittian phase (Table 7.1, Equation 2) we obtain positive and statistically significant coefficients on the variables that represent the role of imports of machinery (relative to industry value added), and the share of university students studying engineering. This is equivalent to the story for the 120 year period as a whole, as we have just recounted, and is in line with our expectations. However, in this early phase of Italian development, inward FDI had a positive and significant effect on indigenous innovation. This was the period in which German firms helped to develop the Italian electro-technical equipment industry, and French and Belgian firms contributed to the utilities and transport infrastructure (Colli 2010); while as for Italian industries patenting at the USPTO, we have recorded for this period a relative technological specialization in electrical and in transportation equipment (Table 4.2). This phase thus has some analogies with the experience of interwar Japan, in which local actors learned from the direct presence of foreign-owned subsidiaries through inward FDI in the earliest stages of industrial development, in some key sectors in which there was indigenous potential for development (Cantwell and Zhang 2009). In the Japanese case this occurred especially in electrical equipment and motor vehicles – and through a joint venture in the former case and local supplier linkages in the latter case – helped to lay the foundation for the post-WWII technological success of Toshiba and Toyota. A parallel might also be found in the contribution of British textile machinery and synthetic fibre firms, and German dyestuffs firms to the development of these industries in the US before 1914.

Instead, in the Fascist period (Table 7.1, Equation 3) we find positive and statistically significant coefficients on the variables that depict the share of university students studying engineering, and the share of manufacturing industry in total Italian output. This was a phase of increasingly inward-looking development, in which the continued building of local technical skills and the commitment to industrialisation were what mattered for innovation. In contrast, the imports of machinery and FDI did not play a significant role, although some other international connections may have come through the movement of people and individual technical and commercial contacts abroad, joint ventures, licence agreements. Nonetheless, the relatively limited diffusion of international knowledge-based connections within the domestic productive fabric is likely to have slowed down the rate of Italian innovation during these years.

In the period of the Golden Age and its immediate aftermath (Table 1, Equation 4), we find a positive and significant effect of the share of high school students that obtained a specialised technical training in the Italian educational system, but a negative effect from inward FDI. So, local technical skills – of a different character – continued to matter, but with respect to the impact of FDI this is the one phase that matches our finding for the 120 year period as a whole, thereby demonstrating a vicious cycle relationship between foreign-owned multinational presence and local large firm innovation, as we have argued earlier. During these years the innovativeness of the Italian economy depended far more than previously on some smaller new entrepreneurial ventures which created their own export networks. Within Italy they were often associated with medium-sized internationalized and small firm clusters, as in the archetypal case of the industrial districts, which areas tended to be characterised by the limited presence of foreign-owned multinationals. Yet in the mainstream large scale domestic industry, in which large indigenous firms carried forward some technological capabilities inherited from the interwar years, once exposed to a more internationally competitive environment through inward FDI – in this phase particularly relevant in the petroleum, electrical equipment and chemicals industries (see Section 3) – these capabilities were adversely affected and further investment in them was discouraged.

In an earlier cross-country model depicting how the innovation outputs of countries depend upon their international relationships (Athreye and Cantwell 2007), we have distinguished between simpler forms of development associated with basic technological capabilities and intellectual property creation that rely upon arms-length trade relationships (as might be illustrated by machinery imports), and more sophisticated forms of development associated with advanced technological capabilities and R&D, relying on the more complex kinds of international connections for knowledge development that are provided by FDI. This distinction between two types of innovation or technological learning offers a good representation of the characteristics of two different phases of development that have been commonly observed and which especially reflect the recent East Asian pattern of economic and technological development.

However, as we have discussed elsewhere, the association of these two types of development path with an apparent sequence that runs first from an early stage of less R&D-intensive development, and then to a later more mature stage of more R&D-intensive development does not correspond with the Italian experience (Antonelli and Barbiellini Amidei 2011). Italian technological development has progressed successfully over the course of these decades, but it did not follow a path through to more R&D-driven forms of innovation in the early post-war period. In the long Golden Age Italy, innovation resulted relatively concentrated in intermediate technology, non-high-tech industries, and in terms of business functions it was much more incremental, process and design-based rather than R&D-based (as shown in Sections 4.1 and 4.2). Therefore, the Italian innovation system came to rely mainly on basic technological capabilities fostered through trade relationships, often by entrepreneurial exporting firms – many small, some large, increasingly medium-sized – rather than by big managerial corporations centred on sizeable R&D departments. Consequently, since the first simpler incremental type of innovative development just mentioned rather than the second complex type characterized Italy from 1950-1980, FDI was not the driver of that development. The international business connections on which Italian innovation has relied tended to be mainly trade-based, and not FDI-based.

With respect to the most recent period of renewed globalisation since 1980s (Table 7.1, Equations 5 and 6), we find positive and statistically significant coefficients on the share of high school students that obtained a specialised technical training in the Italian educational system, and the share of manufacturing industry in total Italian output. Somewhat surprisingly, this formulation is very similar to the results we reported for the increasingly closed interwar period. The principal difference is that while the university education of engineers was the most relevant indicator of the local development of technical skills in the earlier stages of economic development to the WWII, the high school training of technicians became the more important expression of local skill development after the WWII – as this educated intermediate human capital was pivotal to the development of technological innovations along vertical manufacturing filieres. Inward FDI was no longer significant after 1980, suggesting that any vicious cycle of competitive erosion of indigenous large corporations technical capabilities had mainly already occurred by that time.

However, in order to understand the critical structural differences between the contemporary era of globalisation and interwar autarchy, we utilised two further variables in a second regression equation for our latest period. These are variables that were either not available for earlier years, namely R&D domestic effort (as expressed by intramural R&D expenditures on GDP), or less relevant in previous phases, namely a measure of a technological gap between Italy and the US in terms of the most sophisticated and complex kinds of technological knowledge. We measure the latter as the ratio of US invented patents granted in Europe (in France and Switzerland, at EPO since 1996) over US population divided by Italian invented patents granted abroad in Europe over Italian population with a five years lag. Both our R&D and technological gap variables have a positive and significant effect on Italian innovation since 1980. This shows that while inward FDI is still not the primary channel through which advanced technological knowledge is transferred to indigenous enterprise in Italy, the development of local formalised innovative capacity to capture and integrate with foreign sources of technological knowledge has become vital in the new era of globalisation. Unlike in the interwar increasingly closed period, the capacity to benefit from international knowledge flows, as represented here through the combination of our R&D and technological gap variables, is a critical part of the story of indigenous innovation.

In the second stage of our estimation strategy, we have related our import of technology and innovation variables to Italian productivity growth (TFP), in the equivalent historical phases.

$$(7.2)\ \text{TFP}_t = a + d_1\text{Machinery imports}_{t-1} + d_2\text{Inward FDI}_{t-1} + d_3\text{Engineers}_{t-1} + \\ + d_4\text{Technical students}_{t-1} + d_5\text{Italian Patents abroad}_{t-1} + d_6\text{Domestic production of machinery}_{t-1} + \\ + d_6\text{Productivity Gap}_{t-5} + d_7\ \text{TBP expences}_{t-1} + d_8\ \text{Openness}_{t-1} + z_t$$

where the dependent variable is the Italian economy total factor productivity growth, and all explanatory variables are lagged and either log-transformed or growth rates.[53]

Estimating a TFP equation, we evaluate in particular the relationship between Italian productivity growth and domestic innovative processes and various administrative modes for the import of foreign technology. Table 7.2 displays the results of our estimates. In the first equation, we have all the relevant variables available for the whole period as determinants. For the sub-period estimates, the least significant variables have been dropped, and the estimates have been re-run without such variables. The need to eliminate unnecessary variables, to increase degrees of freedom, is stronger for shorter sub-periods.

Our findings have some significant conceptual or theoretical implications and highlight some interesting historical differences. From a conceptual perspective it seems important to stress the positive and statistically significant association of domestic innovation activity (as expressed by the Italian share of foreign patenting in selected countries, as described above) with productivity growth over the whole 1892-2008 period under analysis (Table 7.2, Equation 1). Therefore, we capture a direct link between the output of our first innovation activity equation feeding into our second productivity equation. This innovation activity-TFP growth relationship has been widely acknowledged in theoretical and empirical work, as discussed in Section 2.

The growth of inward FDI (on GDP) consistently displays a positive and statistically significant correlation with TFP growth. This demonstrates that although inward FDI may have had a dampening effect on domestic technological innovation (at least on the innovative efforts of larger Italian firms, as revealed by patents) as emerged from the estimation of Equation 7.1, it did contribute positively to wider Italian economic growth. It is plausible to hypothesise that together with a direct productivity contribution of foreign controlled firms, the adoption and adaptation by indigenous Italian firms of FDI channelled foreign technologies (through spillovers) was productivity growth-enhancing. While formalised innovation by the largest indigenous firms might have been hindered by direct investments undertaken by more technologically advanced foreign firms, the FDI recipient business environment (including smaller suppliers and equipment users) would have been able to augment its technological and organisational capabilities, with positive implications for productivity growth potential.

We also find positive and statistically significant coefficients on the variables that express the productivity gap between Italy and a more mature industrialised economy (namely, the ratio of GDP per capita in the UK to that of Italy, with a five year lag) and the relevance of technical human capital (expressed by the ratio of engineering students to population). These effects – in

[53] We thank Stephen Broadberry, Claire Giordano and Francesco Zollino for providing us with the TFP time series (Broadberry, Giordano and Zollino 2011).

association with the positive impact of the innovation activity variable – are in line with a modern catch-up theory, wherein backwardness represents an opportunity for growth, but only when coupled with the existence of sufficient/appropriate human capital and absorptive capacity (Abramovitz 1986; 1993; Cohen and Levinthal 1990). The positive effect of our productivity gap (catch-up) variable also implies that there has been some mechanism for international flows of technological knowledge with a public good character to contribute to the productive methods in use in Italy over the period, although of course the precise nature of that mechanism may have changed over time. The positive impact of human capital on productivity growth, while it may have been expected, must be interpreted as supplementary to the positive indirect effect of the presence of trained engineers which passes through the innovative activity performance variable (patents abroad).

Some interesting differences emerge when considering individual sub-periods. In the Giolittian and in the Fascist periods (Table 7.2, Equations 2 and 3), productivity growth is directly associated with foreign inputs, rather than indigenous formalised innovation activity. Accordingly, in these sub-period equations, the statistically insignificant effect of domestic innovation activity has been dropped. Inward FDI growth directly affected productivity growth in the Giolittian and in the Fascist era, while the imports of embodied technology is directly (and significantly) associated with productivity growth only in the interwar decades when machinery imports show a decreasing trend (Figure 5.1). Similarly to the case of FDI for the full period, in the Fascist era imported machinery had a significant impact on productivity growth, but not on innovation activity within the same sub-period (Table 7.1, Equation 3).

Our results suggest also that the domestic ability to produce science-based innovation (mainly through formal experimentation, R&D) is significantly and positively associated with productivity growth since the post-WWII period (Table 7.2, Equations 4 and 5), which was not the case in earlier sub-periods. With respect to the impact of the innovative activity variable on productivity, these are the two phases that match our finding for the 120 year period as a whole, thereby signalling that formalised innovative activity is a crucial ingredient for productivity growth in any modern open economy.

In the results for the high productivity growth Golden Age sub-period (Table 7.2, Equation 4) particularly relevant is the joint significance, which emerges for the first and only time in this phase, of the two variables expressing the Italian ability to produce innovations – both formalised innovation (as revealed through patents abroad) and indigenous machinery-embodied innovation (as revealed by the ratio of domestic machinery production to internal investment in machinery) – together with the two variables expressing foreign technology transfers – in the form of inward FDI and the productivity gap.[54] These results are in line with an absorptive capacity enabled catch-up story together with a technological congruence and creative adoption story (Abramovitz 1993; 1994; Abramovitz and David 1996; 2001; Fagerberg

[54] Admittedly, the variable for "engineers" is not statistically significant. However, the role of indigenous human capital is captured to a considerable extent by other variables, notably "Italian patents abroad" (in this phase in particular, the variable "technicians" was positive and statistically significant in the estimation of the determinants of innovative activity equation, in Table 7.1 Equation 4) and "domestic production of machinery."

1987; Antonelli 2006): in this phase Italian industry was able to develop a productivity-enhancing match of imported technology and domestically generated technological innovation (and factor endowment), enjoining a virtuous cycle of imitation, adaptation and localised innovation. The Italian growth process demonstrated in the relationship between the upstream domestic machinery industry (and intermediary inputs) and the downstream users (medium and low-tech consumption good producers) its crucial engine of productivity growth, the specific keystone of the system; which increased the dynamic efficiency of the low levels of R&D activities and engendered fast rates of diffusion and creative adoption of innovation. It also gave life to a system of virtuous interaction between process innovations introduced by adopters and product innovations introduced by upstream producers.

Italian firms' ability to innovate and sustain productivity growth increased significantly in the Golden Age. Previous work has suggested that this occurred mainly through a process of imitation and adoption of foreign technology. However two new elements emerge from the analysis undertaken in this paper: the novel and extensive dataset used in this work has highlighted that in the Italian long Golden Age industry produced appreciable levels of formalised innovation and especially considerable levels of incremental, design-based and process innovation; the econometric analysis shown in Table 7.2 ascertains that the association of technology import with these domestic innovative dynamics had a positive and significant impact on the productivity growth of the period.

Domestic innovation and foreign technology also played an important role in the productivity growth in the last sub-period (Table 7.2, Equation 5). The import of disembodied technology – which was possible to include for the last sub-period only, due to the lack of continuous data for earlier times – emerges as the most relevant form of international technology transfer in recent decades. The significance of the technological balance of payments (licensing) expenses variable indicates in the first place an evolution towards relatively more sophisticated kinds of international connection for knowledge development, that imply as well the availability of sufficiently developed absorptive capacity in the country, so as to enable a profitable recombination and widespread use of foreign disembodied technology; and secondly Italian participation to the dramatically enlarging international market for technological knowledge. However, the positive and statistically significant relationship displayed by these two variables in this specific sub-period mostly signals that the declining trend in both domestically generated and imported innovation (Figures 4.1 and 5.9) contributed to the decline in TFP growth after the early 1990s. Also in this last sub-period the loss of significance of the effect of domestic machinery points out to a decreasing role of the machinery centred innovation system in a resilient but shrinking Italian industrial sector.

8. Conclusions

This paper has explored the long run evolution of Italy's performance in technological innovation as a function of international technology transfers, reconstructing the different phases and dimensions of Italian innovative activity, tracking the transfer of foreign technological knowledge through a number of channels. The study has assessed the impact of foreign technology on Italian innovation activity and productivity growth since the country's unification. This assessment relies on a newly constructed dataset, over the 1861-2009 period, composed of variables related to: innovation activity performance (patents, trademarks and designs); foreign technology transfer (machinery imports, inward FDI, imports of disembodied technological knowledge); domestic absorptive capability (technical human capital, R&D, domestic production of machinery).

For what concerns Italian innovation activity, the information referring to inventions patented abroad – index of more formalised, laboratory-based, structured technological innovation activities, which were developed mostly by the (few) Italian large corporations – reveal that Italian patenting performance progressed over the 20th century, in particular in the Giolittian and in the post-WWII catch-up phases, but resulted still modest in relative terms, at odds with the country's economic weight. Italian patent shares over the long run resulted higher in Europe, across the different foreign location surveyed, than in the US. Since early 1990s a relative stepping-back of Italian patents seems shared by the two sides of the Atlantic. Looking at the first catch-up phase, Italian patents abroad gained ground (*vis-à-vis* other foreigners) in particular in the more advanced sectors – in rubber, transportation equipments and electrical equipments and supplies. In the second crucial post-WWII catch-up phase, Italian USPTO patents gained significantly ground across all sectors but more towards traditional and technologically intermediate sectors, prefiguring the pattern that will finally prevail in recent decades. Over the long run specialization in the machinery sector progressed significantly; the chemical and rubber industry, while losing some patent shares, was able in the end to broaden its technological specialization over an higher number of product fields, sharpening its technological participation in product niches; the Italian food industry and the textile industry reached levels of relative technological specialization after WWII, but became areas of high specialization only in recent years. In the sphere of electric and electronic a long run trend of de-specialization prevailed with the index constantly well below one after WWII, particularly the free-fall of the increasingly crucial ICT area hurting in the past three decades. Looking at designs & models, utility models and trademarks registered abroad and at home – useful complementary indicators (underused in economic history as well as in economics of innovation) to the more traditional measures of formalised innovative activity such as patents – to track the output of the softer, lower grade, less formalised innovative processes typical of Italian firms, a much better Italian relative performance in these simpler innovative activities emerged. Since 1960s in particular, the Italian shares of design & models and utility models deposited abroad – proxy of the investment in industrial design activities and light product innovation, and of markedly incremental innovations respectively – appear much closer to its industrialized competitors ones, than what emerged for patenting activity. Also Italian industry's effort in trademarks revealed innovation activities – light design product innovation and differentiation, marketing innovations, innovation activities performed by smaller firms in low-tech and intermediate industries – increased along the post-WWII decades. In recent years, Italian trademarks performance resulted again, as for designs & models and utility models, much closer to its main competitors ones, than what emerged for patenting activity.

Turning to the import of foreign technology, our dataset showed that, for a relevant part of the past 150 years, investment in foreign produced machinery represented for Italy the main channels for the introduction of new technologies. The higher and increasing weight of machinery imports as a ratio on national investments in machinery highlights the relevance of this technology transfer channel for Italian firms during the Giolittian era in particular. Even in the second catch-up phase the ability to adopt external foreign knowledge depended initially on imports of foreign machinery, in the first two decades after WWII, however, a process of quantitative and qualitative growth of the rising Italian machinery industry was set in motion. For what pertains inward FDI as a form of international technology transfer, a relatively high weight of FDI on GDP resulted during the Giolittian phase in the first half of the 20th century, while after WWII the FDI contribution increased until mid-1970s. Since 1990 Italian inward FDI remains anchored at much lower levels than its main trading partners. In early 1950s the European Recovery Program (ERP) was very important as a channel for transferring American technology to European countries after WWII, to Italy in particular. In the Italian experience, metal working machinery and machine tools – machines to make machines – resulted the most relevant kind of ERP funded imports, also Italy used a significant share of its counterpart funds to promote domestic production of machinery and to sustain Technical Assistance programs. In the second half of the 20th century the purchases by Italian firms of disembodied foreign technological knowledge – as registered by the Technology Balance of Payments – appears to be particularly relevant; up to early 1990s, Italy's effort to purchase technology abroad stands out among OECD countries. Not-incorporated foreign technology was a crucial input of Italian innovative activity over the second half of the 20th century, during the Golden Age era and beyond. Since the beginning of the new millennium instead, the investment in disembodied foreign technology as a share of GDP dropped.

Looking at the building process of the national absorptive capacity and the development of a domestic innovative system, for what concerns human capital, our dataset showed, on the one hand, that only prior and during the first Italian catch-up, the Italian educational system did a significant selective investment in science-based educated technical human capital. Yet in the middle of the 20th century Italy had accumulated an adequate stock of high technical human capital as a result of its Giolittian era investments in engineering graduate studies. After the Golden Age mild growth instead, the 1970s and 1990s engineers' enrollment relative retrenching has probably been increasingly damaging in recent years. On the other hand, prior and during the second Italian catch-up a relevant investment was done in intermediate technical human capital. The increased investment in technical secondary education was important in this phase for the development of the national capability to adapt the technologies being adopted from abroad. The decline of the share of students enrolled in industrial technical high schools, evident since mid-1970s, combined with an increasingly hurting quality loss, brought in recent decades the industrial section of higher technical education to lose progressively its leading role. The statistical data on R&D expenditures since early 1960s confirm that in Italy both the public sector and above all the business sector historically invested few resources in research activities. After three decades of catch-up, since the 1990s the still considerable gap between Italy and the other main industrialized countries widened; the R&D/GDP ratio remains anchored at rather low levels, incompatible with Italy's economic position on the international scene. The particular dimensional structure of the Italian industrial system is, in fact, the main determinant of the low level of R&D activity; the original specialization model, biased towards traditional sectors, being the second major determinant of the low involvement of domestic firms in R&D activity. The extreme character of these figures, suggest that, in Italy in particular, R&D expenditures – reflecting in fact a kind of behaviour and operational criteria typical of large firms active in sectors with a strong scientific base, with laboratories and scientific staff quite rare in the Italian industrial landscape – cover only a limited part of the production of technological knowledge useful for industrial innovation. After 80 years in which Italian industry (and agriculture) depended decisively on machinery and equipments imported from abroad, innovation and structural change after WWII fulfilled the opportunity to develop a domestic machinery industry, crucial in the emerging Italian innovation system. If in the first phase of Italian post-WWII catch-up a significant part of investment passed through the purchase of capital goods produced abroad, imported machinery, while allowing the access to external foreign knowledge, provided an important impulse and was an important input in the process of imitation, creative adoption and technological innovation for investing Italian industries as well as for domestic producers of capital goods. Since 1965 domestic production of capital goods exceeded significantly internal absorption and the balance of specific commercial trade in capital goods turned structurally positive. Exports grew strongly in the long run and Italy gained in this sector a new significant and long-lasting competitive advantage. The emergence of a domestic machinery industry competitive in developing specialized machinery, tailored on the needs of the users, resulted a crucial competitive factor for Italian industry in the second half of the 20th century. Through creative adoption, increasingly reshaping foreign technologies so as to increase their technological congruence with respect to the needs and characteristics of the industrial domestic users, the development of the Italian capital goods industry resulted in fact in a reduction in the price of capital goods, feeding capital deepening, in a decisive boost to the diffusion of technological innovation and to productivity growth in important domestic manufacturing sectors. In recent years this machinery industry centred innovative dynamics may have been progressively restrained by at least two globalization related factors: as domestic and international demand for Italian consumer goods slowed down and was made more uncertain by new producer countries entering international markets, internal investment in fixed capital fell and the strength of derived demand for capital goods incorporating localized technological innovations fell with it; the relative small size of firms makes it difficult on the one hand to recreate at an international level, in a global production structure, those mechanisms of virtuous interaction between users and producers, on the other hand to make the needed higher investments in formal research and human capital. Again the also sectoral Technology Balance of Payments time series data showed that in the four decades after WWII Italian firms made, in fact, a considerable effort of creative adoption: they acquired codified/scientific foreign technological knowledge and used it in processes of technology recombination, which allowed adaptation and adoption of imported technology and valorization of specific knowledge result of localised learning. In the past decade instead, the retrenchment of Italian expenses for foreign technologies registered in the Technology Balance of Payments signals a not so encouraging tendency towards a weaker investment in the acquisition from abroad of codified technological knowledge, along with a still modest production at home as revealed by modest increases in domestic R&D investment.

The analysis highlights, also by econometric assessment, the significant contribution of foreign technology both to innovation activity results and to productivity growth. Differences across channels of technology transfer and historical phases emerge, also in connection with the evolution of human capital endowment and domestic autonomous innovative capacity. Machinery imports contributed positively both to innovation activity and to productivity growth (in particular in the first catch-up Giolittian phase); inward FDI contributed positively to productivity growth, but not to indigenous innovation activity; the accumulation of technical human capital fuelled both.

The econometric analysis shows that FDI was positively associated with formalised innovation only in the Giolittian period, whereas the association is negative and significant for the overall period (1889-2008). The indicator of innovation used in this paper, foreign patenting, reflects more accurately innovation taking place within large firms. Therefore, our results suggest that FDI in technologically advanced sectors hindered new formalised innovation within large Italian corporations. Although inward FDI may have had a dampening effect on domestic technological innovation (at least on the innovative efforts of larger Italian firms, as revealed by patents), it did contribute positively to wider Italian economic growth: imports of foreign technology through FDI displayed a consistently positive association with Italian productivity growth. The presence of sufficient and appropriate domestic absorptive capacity, human capital in particular, was critical, as suggested by an Abramovitz catching-up story.

To sum up, our results concerning the impact of foreign technology on Italian innovation activity, indicate that this took place through a process of adoption and adaptation of foreign technology. The import of machinery has a positive impact on Italian innovation as this type of imported technology enabled Italian firms to improve on the equipment and, where appropriate, to patent such innovation. Similarly, the negative impact of FDI on formalised innovation and its positive impact of productivity growth suggests that Italian firms did adapt to their needs and markets new technologies and organisational structures. Moreover, this process of adaptation was most likely not confined to large firms, but the dynamic Italian SME sector might have taken an active role in it; this would also help explain the opposite impact of FDI on Italian patenting abroad and on productivity growth.

In the long Italian Golden Age in particular, for the first time the association of foreign technological knowledge (through both inward FDI and the interception/absorption of international technological spillovers) with indigenous innovation processes (through both formalised innovation activity and the domestically embodied technological progress), strengthened productivity significantly. These results are in line with an absorptive capacity enabled catch-up story together with a technological congruence and creative adoption story: in this phase Italian industry was able to develop a productivity enhancing match of imported technology and domestically generated technological innovation (and factor endowment), enjoining a virtuous cycle of imitation, adaptation and localised innovation. The Italian growth process demonstrated in the relationship between the upstream domestic machinery industry (and intermediary inputs) and the downstream users (medium and low-tech consumption good producers) a crucial engine of productivity growth, perhaps the specific keystone of the system.

More recently instead (within the last two decades) the dismal productivity growth seems directly associated with innovation activity under-performance (especially in ICT) – more dependent than in the previous phases on the quantitatively and qualitatively evolution of technical human capital and on the poor level of R&D efforts – and with the reduced imports of disembodied foreign technology. Also a less effective role of the domestic embodied technological change in sustaining productivity growth emerged. The direction of technological change, based on digital technology favoring the intensive use of labour with high levels of human capital – while the supply of highly educated human capital in Italy was rather limited – may have had a part in this underperformance, firstly slowing down the process of creative adoption.

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Tables and figures

Table 4.1

Share (%) of Italian patents on total patents granted to foreigners, 1890-2008 - USPTO.

USPTO PRODUCT FIELD	1890-1919	1920-1949	1950-1973	1974-1988	1989-2000	2001-2008
FOOD	1.0	1.3	2.7	2.6	2.8	3.5
TEXTILE	0.2	1.2	3.9	2.2	2.6	4.2
CHEMICALS	1.0	0.9	4.2	4.0	4.0	3.0
PETROLEUM EXTRACTION AND REFINING	0.8	0.7	1.8	1.0	2.3	2.5
RUBBER AND PLASTICS	1.0	2.8	5.0	3.2	3.0	3.2
STONE, GLASS AND CONCRETE	1.1	1.3	2.6	2.3	2.0	1.9
PRIMARY METALS	1.5	1.3	2.3	2.3	1.6	1.8
FABRICATED METAL PRODUCTS	0.9	1.6	3.0	2.7	2.8	2.8
MACHINERY, EXCEPT ELECTRICAL	1.0	1.6	3.4	3.7	3.3	3.0
ELECTRICAL AND ELECTRONIC EQUIPMENT	1.8	1.5	2.3	2.2	1.6	1.1
TRANSPORTATION EQUIPMENT	2.7	3.5	3.1	2.4	1.9	1.9
PROFESSIONAL AND SCIENTIFIC INSTRUMENTS	1.3	1.9	2.3	1.9	1.5	1.8
ALL OTHER SIC'S	1.4	2.5	3.7	3.6	3.3	2.4
TOTAL	1.2	1.7	3.2	3.0	2.5	1.9

Source: our calculations on USPTO 2001; 2011; Cantwell 2002.

Table 4.2

Index of Italian revealed technological advantage, 1890-2008 (USPTO patents).

USPTO PRODUCT FIELD	1890-1919	1920-1949	1950-1963	1964-1973	1974-1988	1989-2000	2001-2008
FOOD	0.79	0.78	1.13	0.65	0.88	1.09	1.80
TEXTILE	0.19	0.73	1.69	1.03	0.72	1.03	2.17
CHEMICALS	0.79	0.54	1.03	1.43	1.33	1.57	1.56
PETROLEUM EXTRACTION AND REFINING	0.63	0.40	0.33	0.79	0.34	0.89	1.29
RUBBER AND PLASTICS	0.83	1.69	2.56	1.35	1.07	1.19	1.64
STONE, GLASS AND CONCRETE	0.89	0.79	0.87	0.79	0.78	0.79	0.97
PRIMARY METALS	1.22	0.76	0.69	0.76	0.77	0.62	0.92
FABRICATED METAL PRODUCTS	0.69	0.97	1.22	0.80	0.91	1.10	1.46
MACHINERY, EXCEPT ELECTRICAL	0.79	0.98	1.10	1.07	1.22	1.28	1.53
ELECTRICAL AND ELECTRONIC EQUIPMENT	1.44	0.89	0.60	0.77	0.74	0.63	0.59
TRANSPORTATION EQUIPMENT	2.15	2.09	1.32	0.82	0.81	0.76	0.97
PROFESSIONAL AND SCIENTIFIC INSTRUMENTS	1.04	1.12	0.90	0.63	0.62	0.61	0.93
ALL OTHER SIC'S	1.13	1.48	1.23	1.11	1.19	1.29	1.26

Source: our calculations on USPTO 2001; 2011; Cantwell 2002.

Table 5.1

Composition of shipments to Italy under the European Recovery Programme (percentage)

	1948	1949	1950	1951	1952
Food, feed and fertilizer	45.1	36.6	11.0	3.3	0.8
Fuel	34.9	18.6	10.1	16.2	41.0
Raw materials and semi-finished products	19.8	37.1	45.0	48.5	35.8
Machinery and vehicles	0.1	6.9	31.9	31.0	22.4
Miscellaneous and unclassified	0.0	0.8	2.0	1.0	0.0
Total (current $ mill.)	163.1	338.7	261.1	281.1	179.4

Source: Own calculations on US Department of Commerce 1948-1953.

Table 5.2

Machinery imported in Italy through the ERP (percentage)

	April 1948-June 1949	July 1949-June 1950	July 1950-June 1951	July 1951-June 1952	Total
Metal working machinery	0.42	7.17	16.92	17.06	14.89
Machine tools	1.66	21.42	18.74	7.98	14.70
Turbines	0.00	0.43	5.21	18.21	9.33
Mining equipment	5.05	10.24	8.07	6.12	7.64
Electrical machinery and apparatus	9.96	7.07	6.08	5.89	6.26
Engines and energy generators	0.00	0.00	0.03	13.51	5.30
Aircrafts, parts and accessories	1.62	0.37	4.93	0.46	2.29
Tractors	0.00	2.00	2.12	1.89	1.97
Precision tools	8.55	1.14	1.23	1.22	1.34
Technicians, designers and patents	0.00	0.00	0.39	1.74	0.84
Agricultural Machinery	1.25	0.48	0.76	0.32	0.55
Railway equipment	0.71	0.44	0.01	0.20	0.18
Motor vehicles, parts and accessories	2.08	0.30	0.01	0.03	0.11
Other industrial machinery	68.70	48.94	35.52	25.37	34.61
Total (mill. current lire)	3,636	35,598	79,632	76,512	195,378

Source: Own calculation on Fauri 2010, p.233.

Table 5.3

Use of Counterpart Funds to Promote Production (US$ mln)

	France	**Germany**	**Italy**
Electric, Gas and Power Facilities	724.5	166.6	
Transportation, Shipping, and Communications	281.3	56.1	269.9
Agriculture	203.9	70.5	99.5
Coal Mining and Other Mining and Quarrying	340.2	82.4	
Primary Metals, Chemicals and Strategic Materials	195.1	52.6	20.6
Machinery	10.4	61	83.2
Light Industry	10.8	24	
Petroleum and Coal Products	11.7	10.3	
Technical Assistance		4.6	5.6
Other and Undistributed	157.4	101.3	113.1
Total (mill. Current $)	1935.3	629.4	591.9

Source: Brown and Opie 1953, p. 237.

Table 7.1

Innovation activity and foreign technology, Italy 1889-2008: regression analysis; eq. (7.1).

(Dependent variable: Share of Italian patents abroad)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	**1889-2008**	**1889-1919**	**1920-1948**	**1949-1980**	**1981-2008**	**1981-2008**
Machinery imports	0.138***	0.445***	-0.0300			
	(0.0444)	(0.0743)	(0.0312)			
Inward FDI	-0.202***	0.752**	0.0303	-0.157***	0.105	-0.0342
	(0.0534)	(0.356)	(0.0695)	(0.0432)	(0.108)	(0.0903)
Technological gap						0.0869*
						(0.0442)
Engineers	0.182**	0.815***	0.288***			
	(0.0803)	(0.166)	(0.0546)			
Technicians				0.497***	1.021***	0.796*
				(0.174)	(0.327)	(0.431)
R&D						1.052***
						(0.236)
Industry share	0.865***	-0.832	0.304**	-0.148	1.528***	1.666***
	(0.157)	(0.844)	(0.131)	(0.277)	(0.490)	(0.343)
Constant	-1.989**	-0.534	-0.467	0.464	-6.944***	-6.484***
	(0.601)	(2.264)	(0.448)	(0.800)	(1.873)	(1.806)
Observations	118	29	27	32	29	29
Adjusted R-squared	0.526	0.805	0.520	0.159	0.606	0.854
F test	0	5.75e-09	2.82e-05	0.0101	2.44e-08	0

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7.2

Productivity, innovation and foreign technology, Italy 1892-2008: regression analysis; eq. (7.2).

(Dependent variable: Total Factor Productivity)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	**1892-2008**	**1892-1913**	**1920-1948**	**1949-1980**	**1981-2008**
Italian patents abroad	0.0369*			0.0494*	0.0349***
	(0.0217)			(0.0287)	(0.0109)
Machinery imports	0.00149		0.0877**		
	(0.0187)		(0.0379)		
Inward FDI	0.131***	0.122***	0.370***	0.0469**	
	(0.0418)	(0.0333)	(0.0942)	(0.0207)	
TBP expences					0.0356**
					(0.0159)
Engineers	0.0175*	0.0126			
	(0.00943)	(0.0148)			
Domestic production of machinery				0.186***	0.0558
				(0.0503)	(0.0441)
Productivity gap	0.0892**		0.241	0.0547***	
	(0.0416)		(0.269)	(0.0146)	
Openness	-0.00101				
	(0.0327)				
Constant	-0.132	-0.0194	-0.130	-0.922***	-0.305
	(0.133)	(0.0323)	(0.155)	(0.256)	(0.218)
Observations	117	22	29	32	28
Adjusted R-squared	0.193	0.252	0.462	0.422	0.283
F test	0.00245	0.00575	0.00215	0.00389	0.000923

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 4.1

Italian residents patents granted in the US and in the main European countries as a share of total foreign (patents applications in Spain, UK and at EPO)

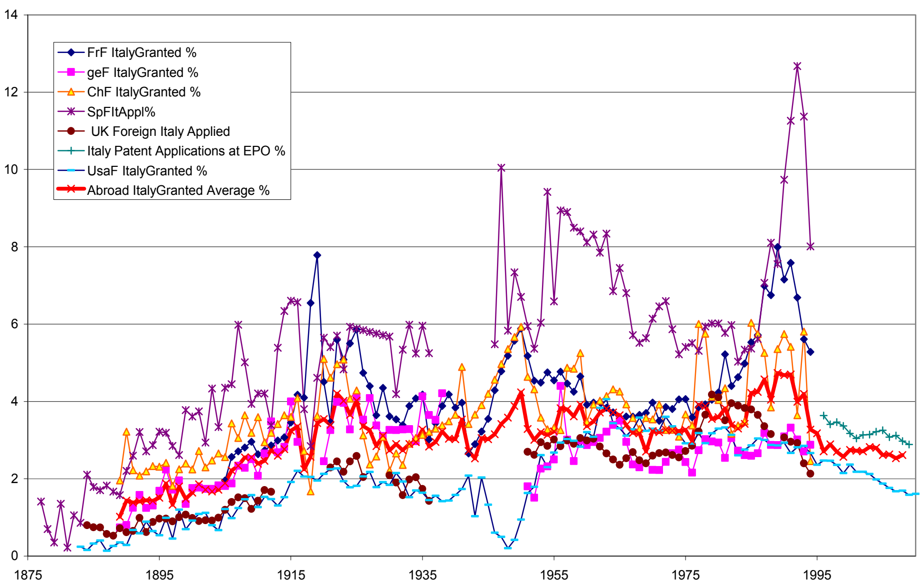


Figure 4.2

Foreign patents granted in France as a share of total foreign

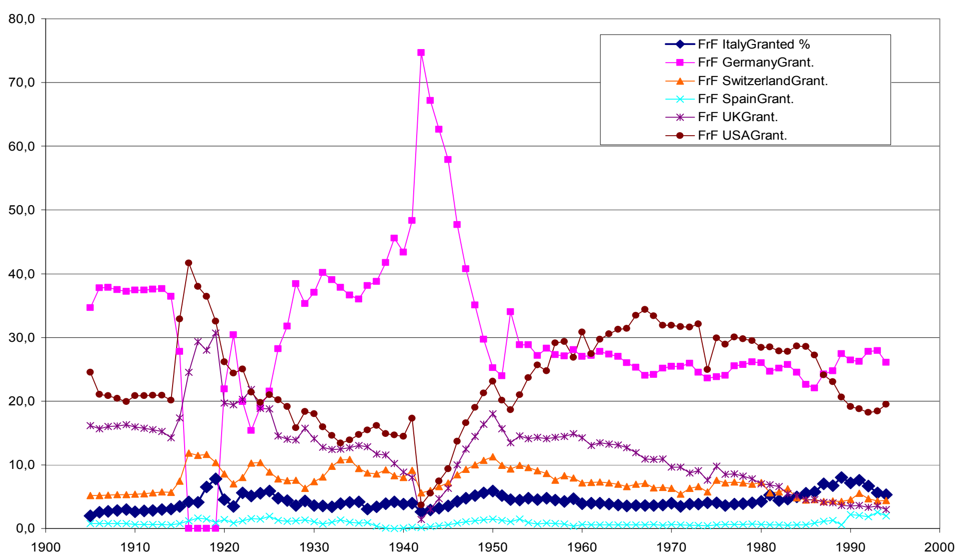


Figure 4.3

Foreign patents granted in Germany as a share of total foreign

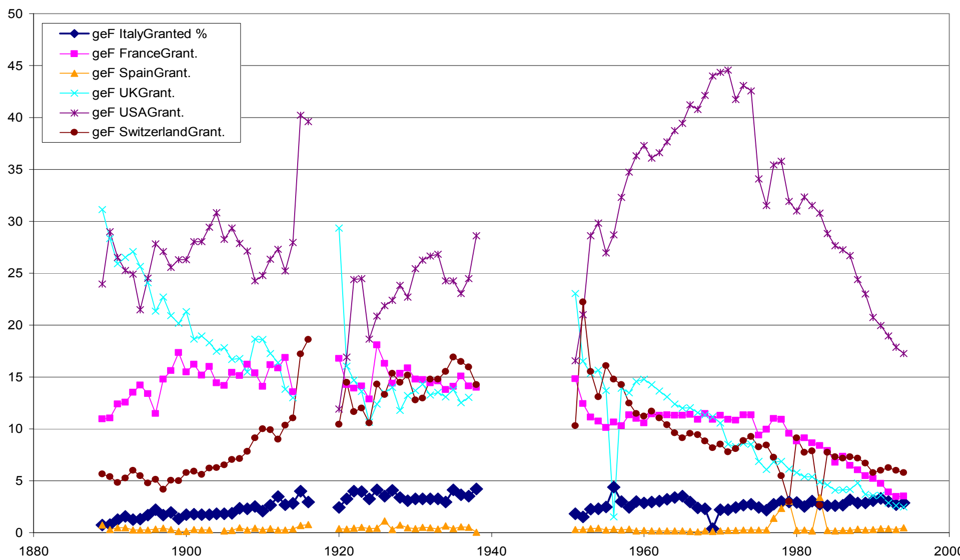


Figure 4.4

Italian and other main countries patents granted in US as a share of total foreign

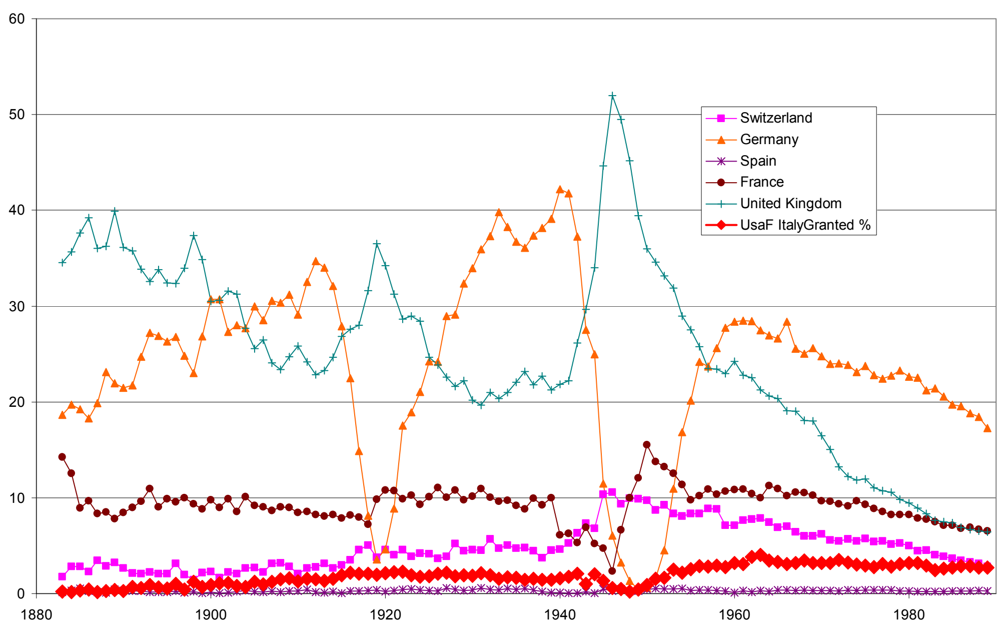


Figure 4.5

Foreign patents applications in UK as a share of total foreign

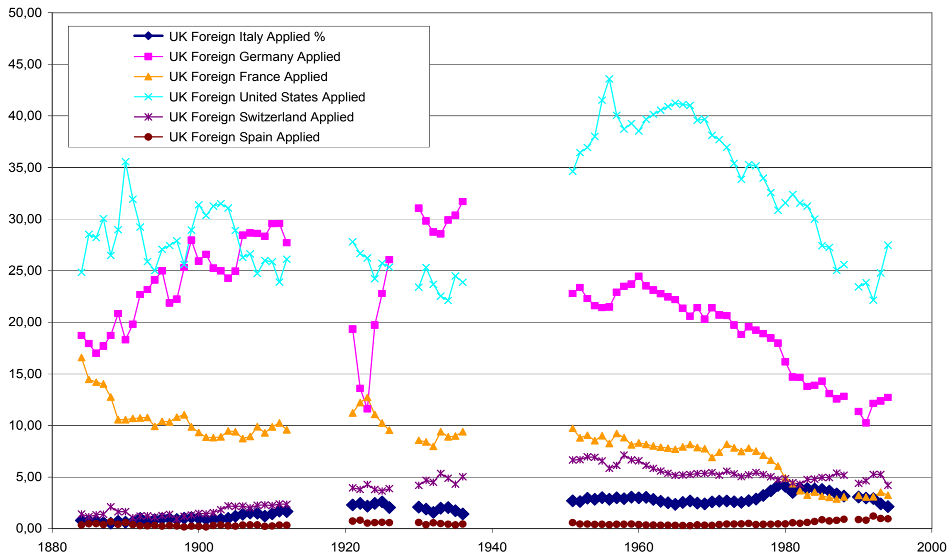


Figure 4.6

Patents granted in Italy to residents on Italian GDP and in selected countries to residents on GDP

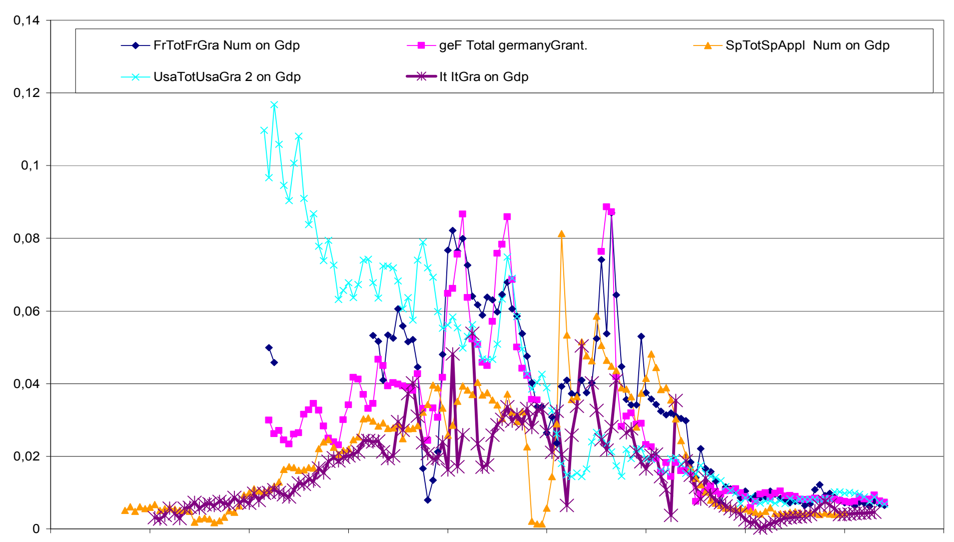


Figure 4.7a

Foreign patents granted in US as a share of total foreign in the post WWII period

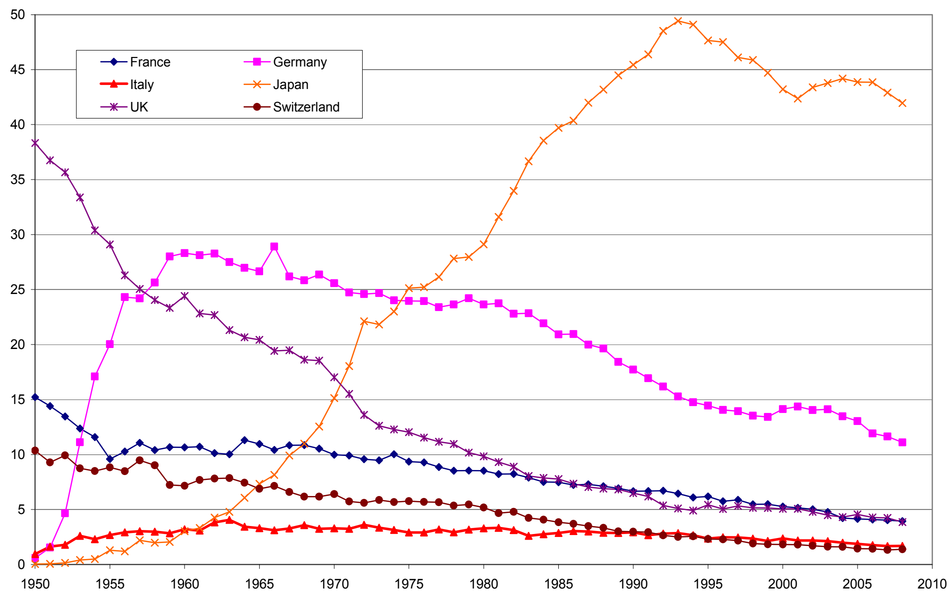


Figure 4.7b

Foreign patents granted in US as a share of total foreign in the post WWII period

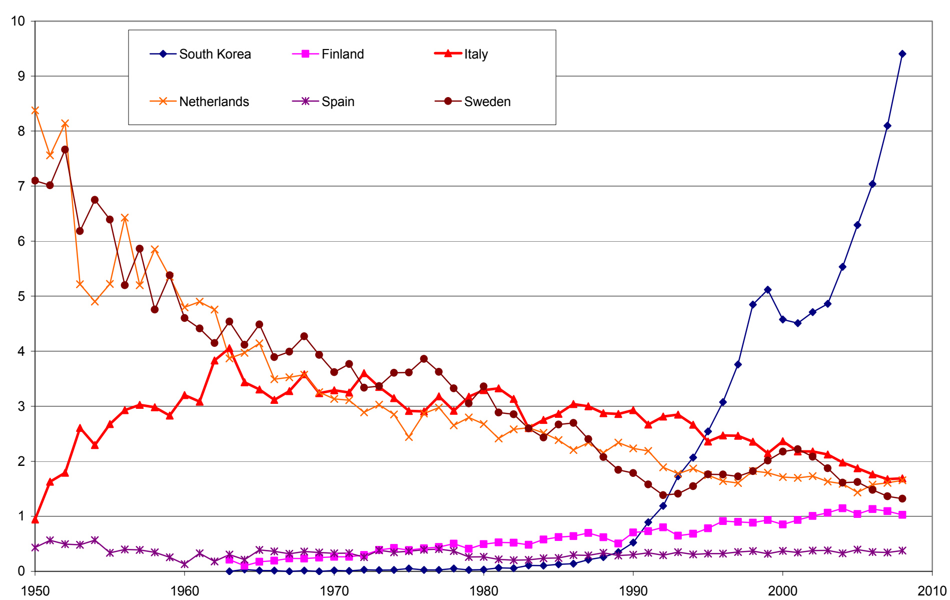


Figure 4.8

Italian patents granted in the US as a share of total foreign and Italian patents granted and patent applications submitted at the EPO as a share of total patents/applications

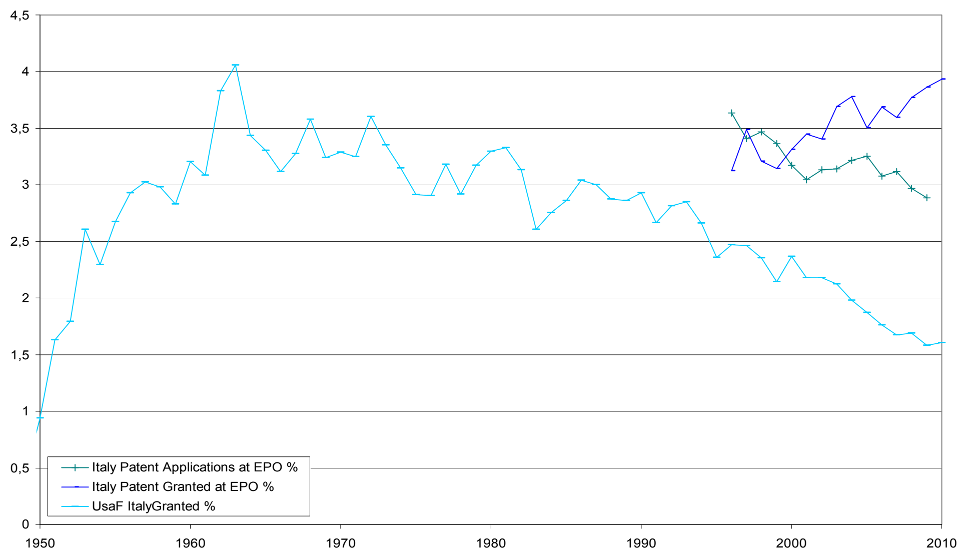


Figure 4.9

Number of Patent applications at the EPO per mln inhabitants in selected countries

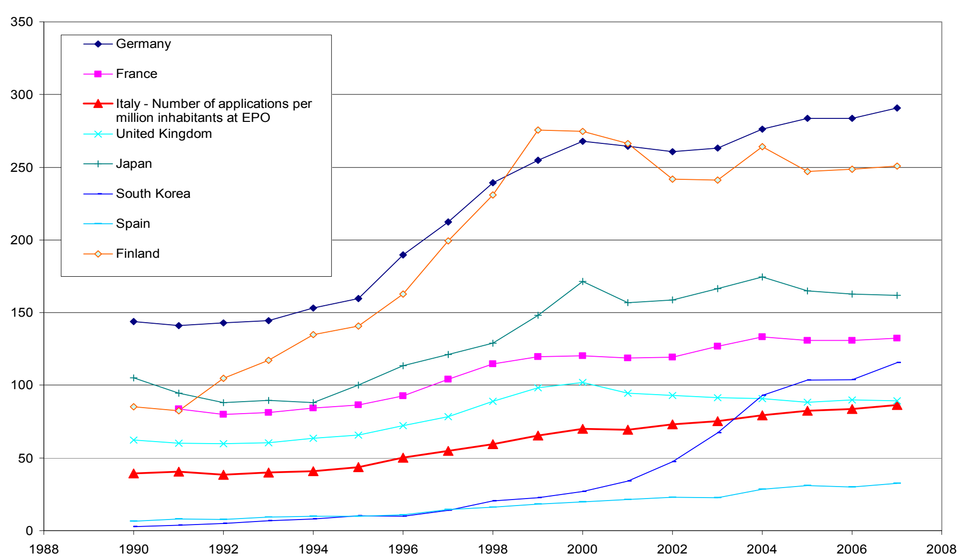


Figure 4.10a

Patents granted at the EPO as a share of total patents – selected countries

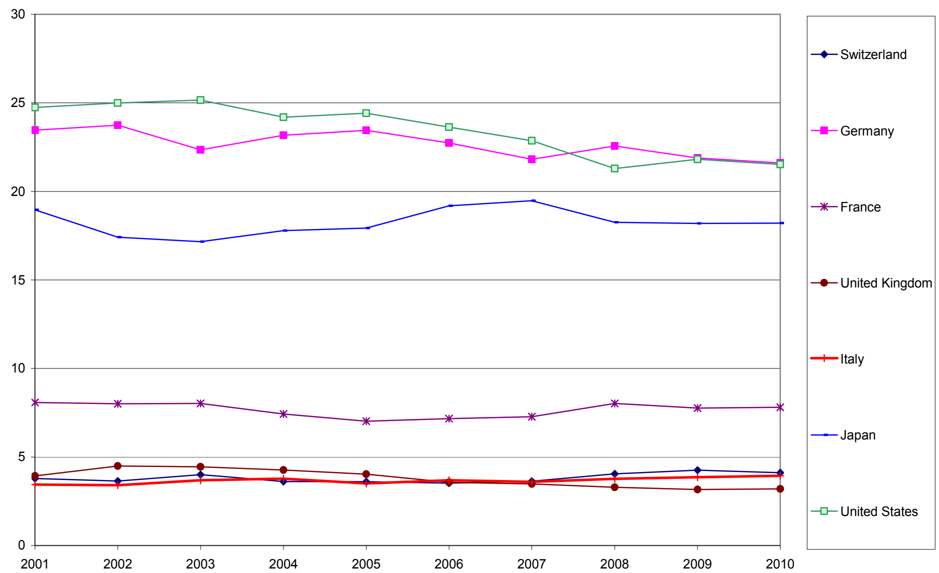


Figure 4.10b

Patents granted at the EPO as a share of total patents – selected countries

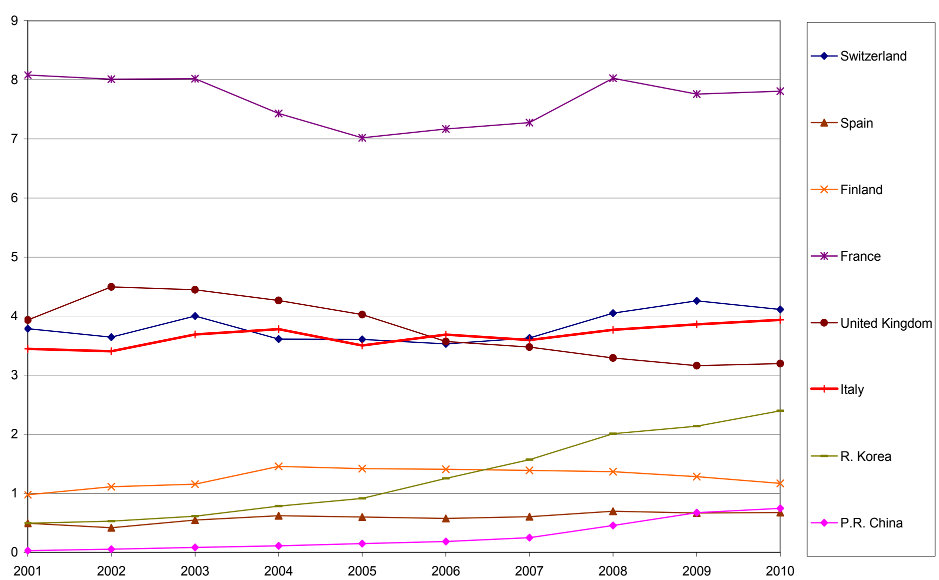


Figure 4.11

Index of Italian revealed technological advantage, 1890-2008 (USPTO patents)

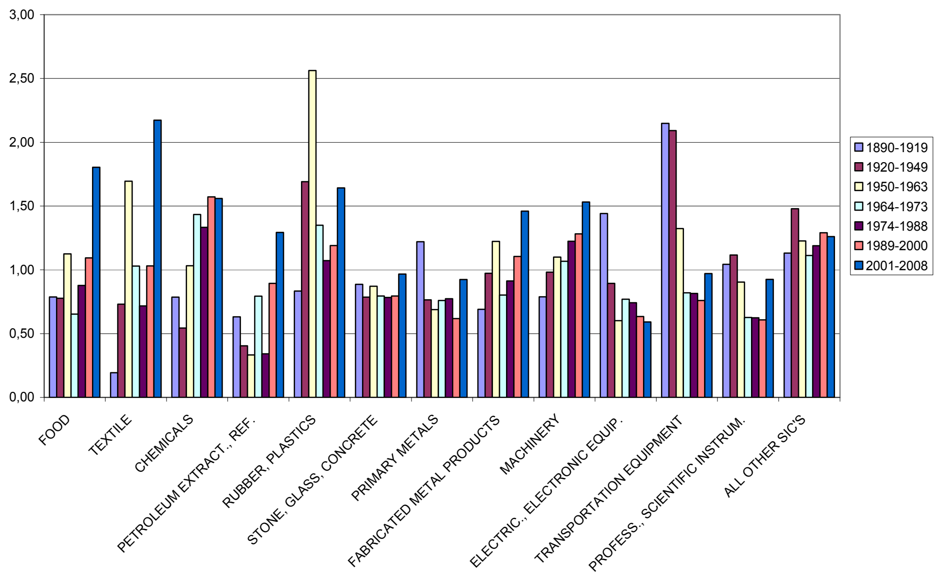


Figure 4.12

Industrial designs and models deposited in France by Italian residents as share of total foreigners

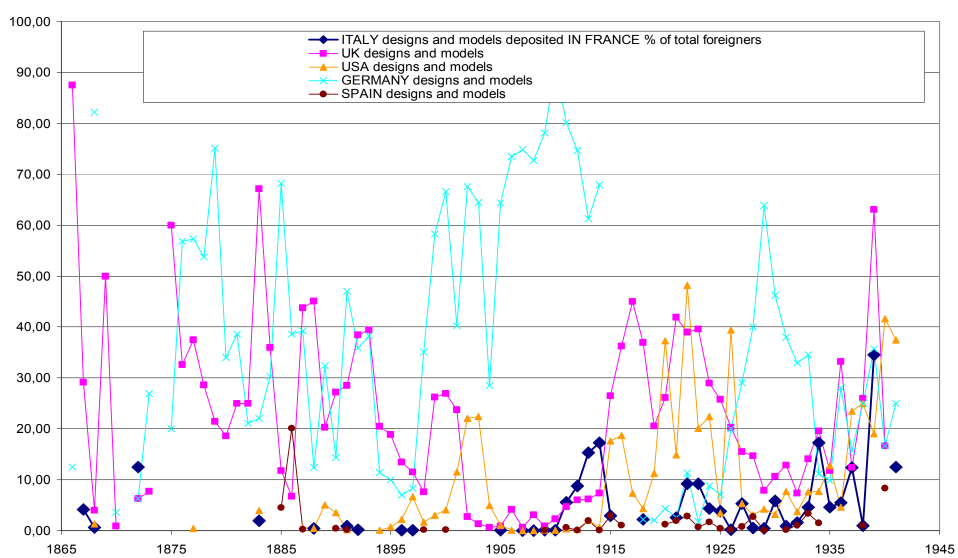


Figure 4.13

Utility models registered in Germany by Italian residents as share of total foreigners

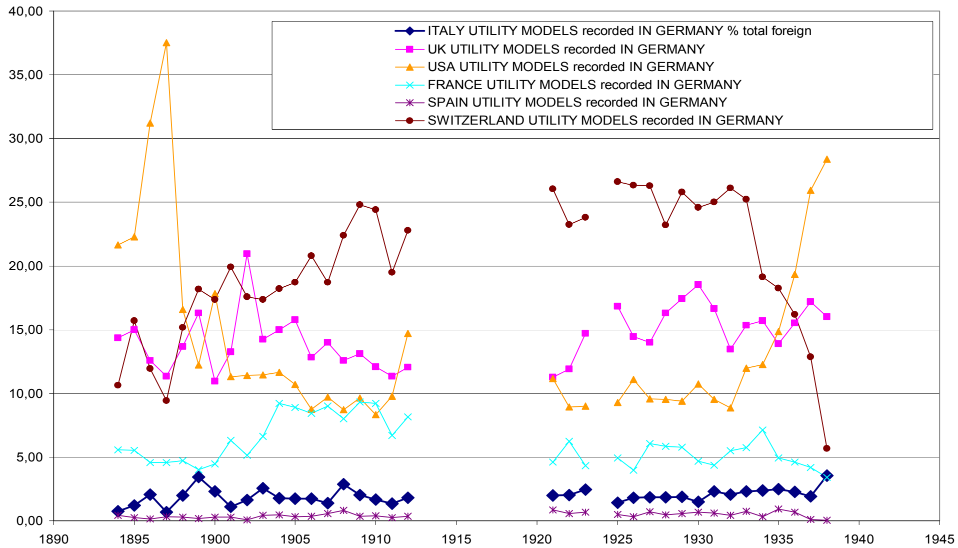


Figure 4.14

Industrial designs & models deposited in France by Italian residents as share of total foreigners

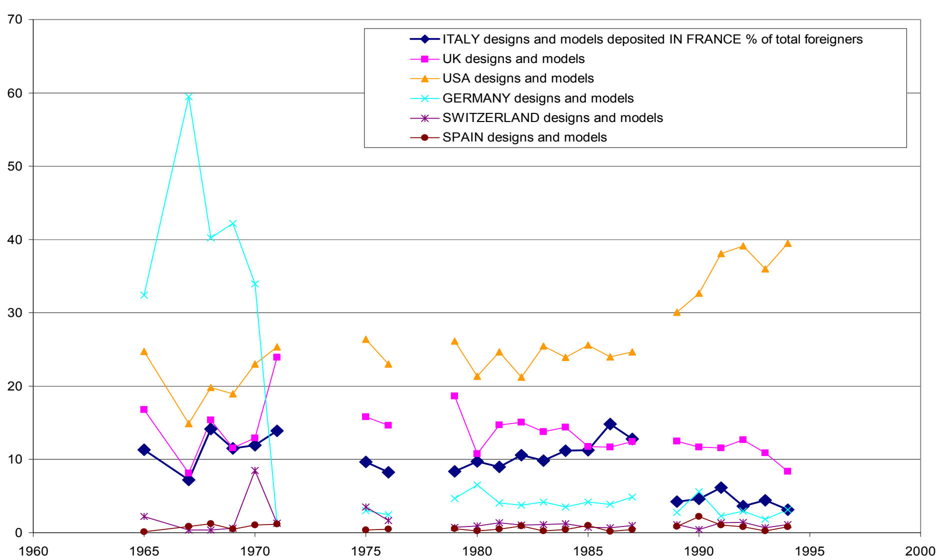


Figure 4.15

Industrial designs recorded in Germany by Italian residents as share of total foreigners

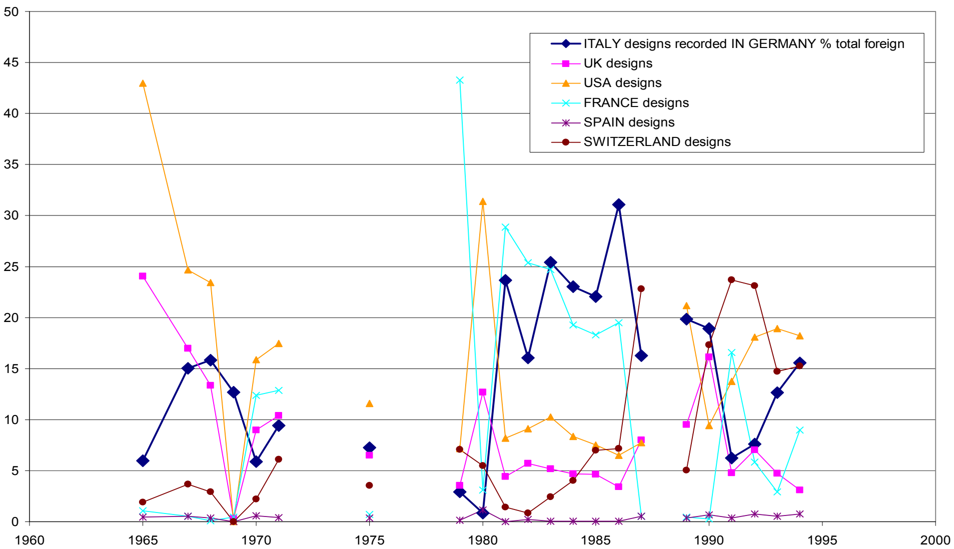


Figure 4.16

International trade marks recorded in Geneva by Italian residents as share of total TMs

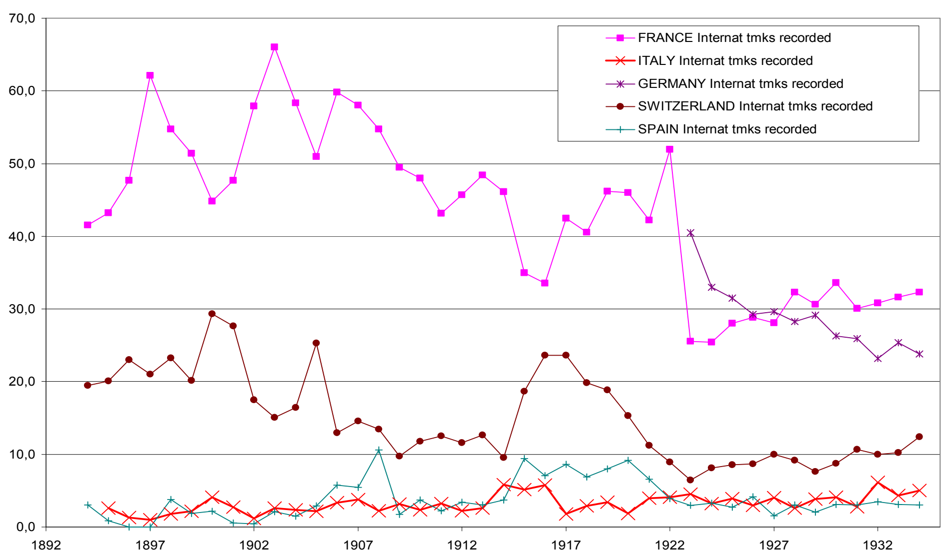


Figure 4.17

Trademarks recorded by residents in the reporting countries, total numbers on GDP

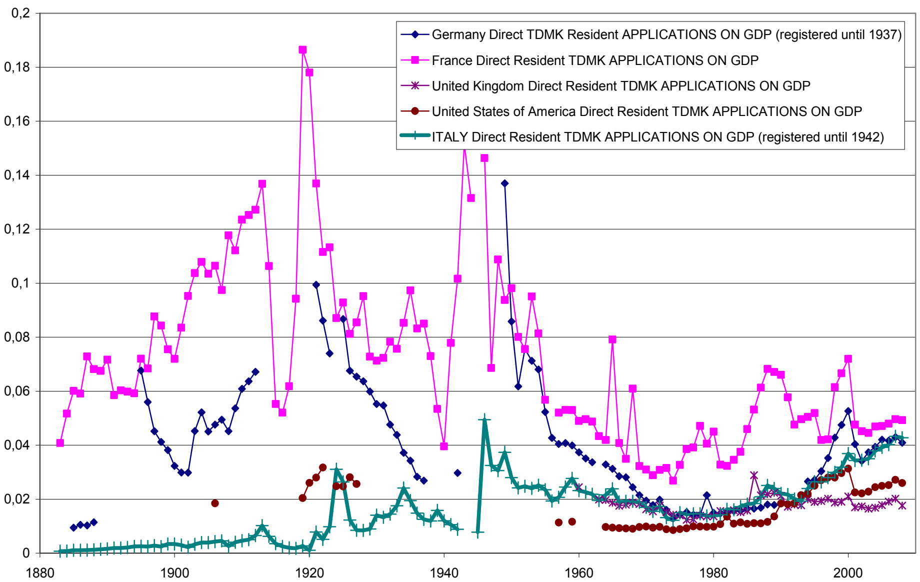


Figure 4.18

Trade marks recorded in France by Italian residents as share of total foreigners' TMs

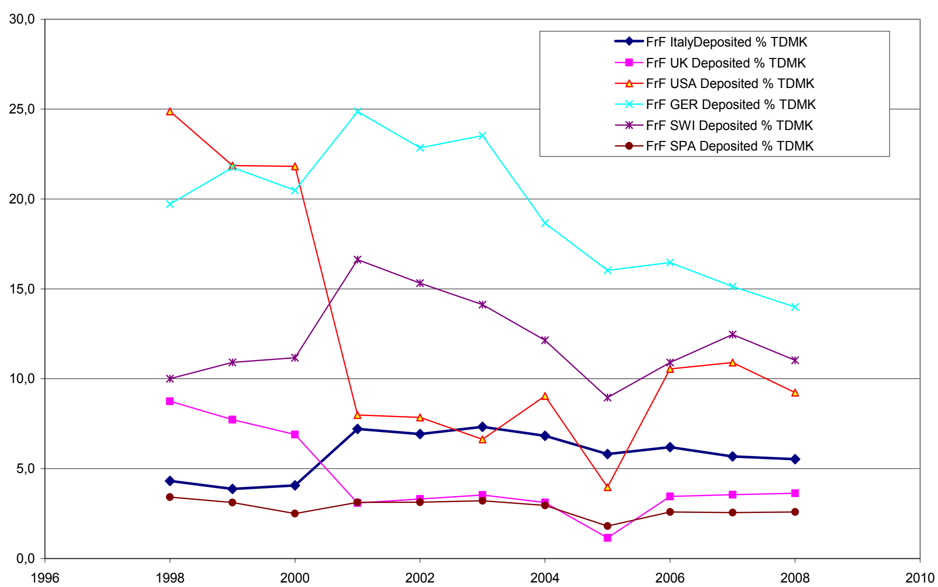


Figure 4.19

Community trade marks recorded by Italian residents as share of total CTM

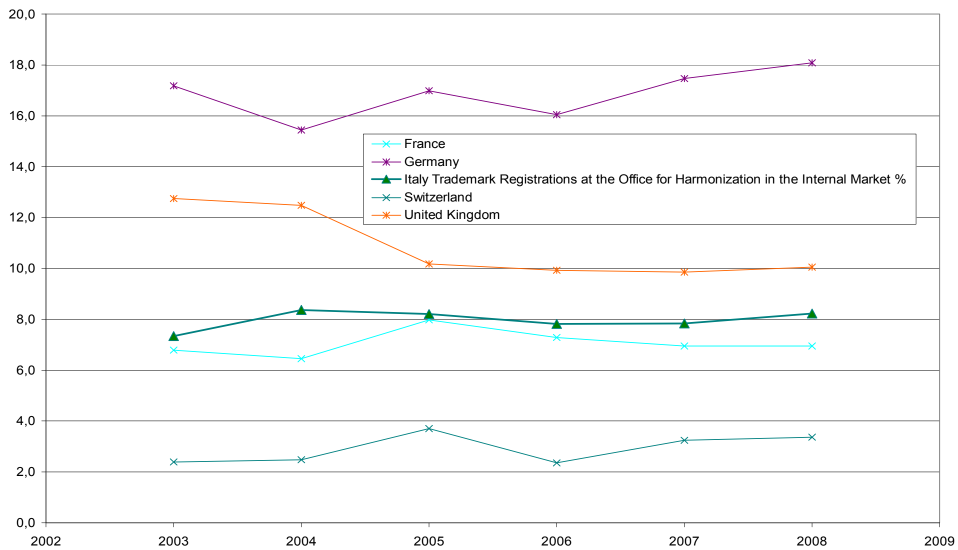


Figure 4.20

Trade marks recorded in the US by Italian residents as share of total foreigners' TMs

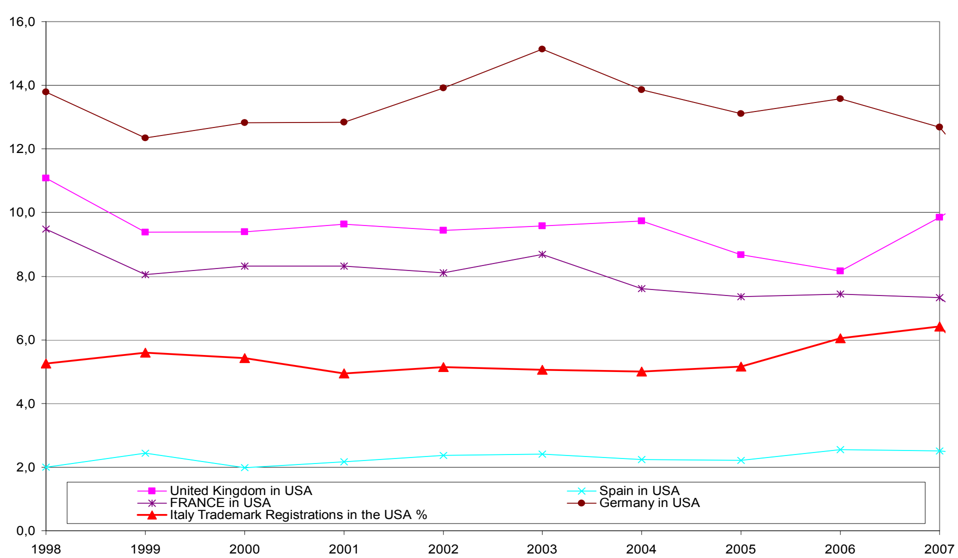


Figure 5.1

Italian machinery imports on GDP, industry value added and investment

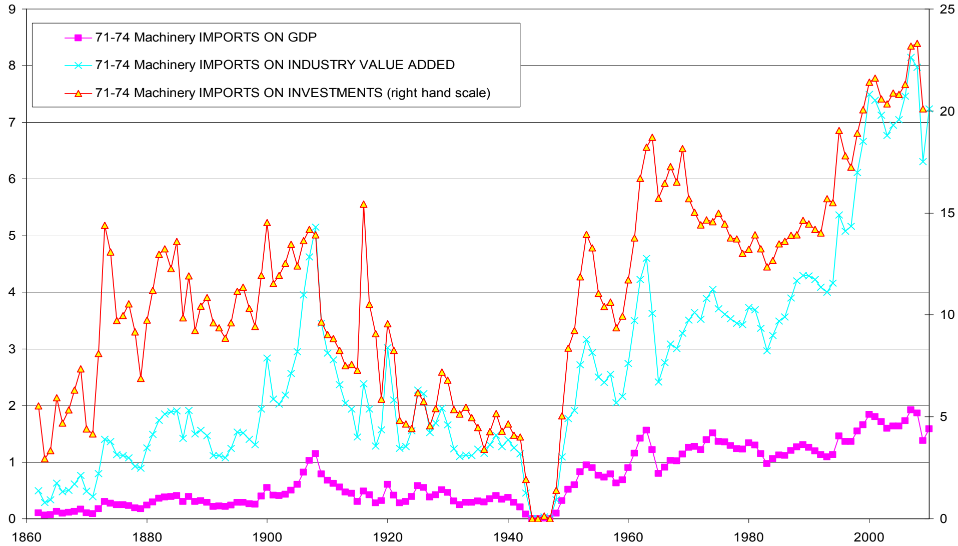


Figure 5.2

Italian machinery imports on Total imports and on Manufactured goods imports

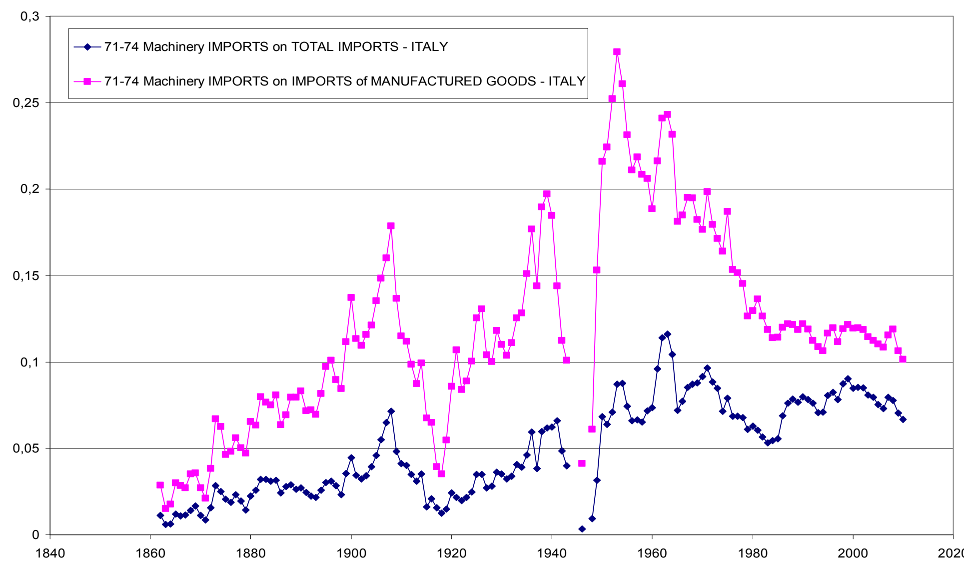


Figure 5.3

Italian machinery imports – selected two digit 7 SITC classes (current values)

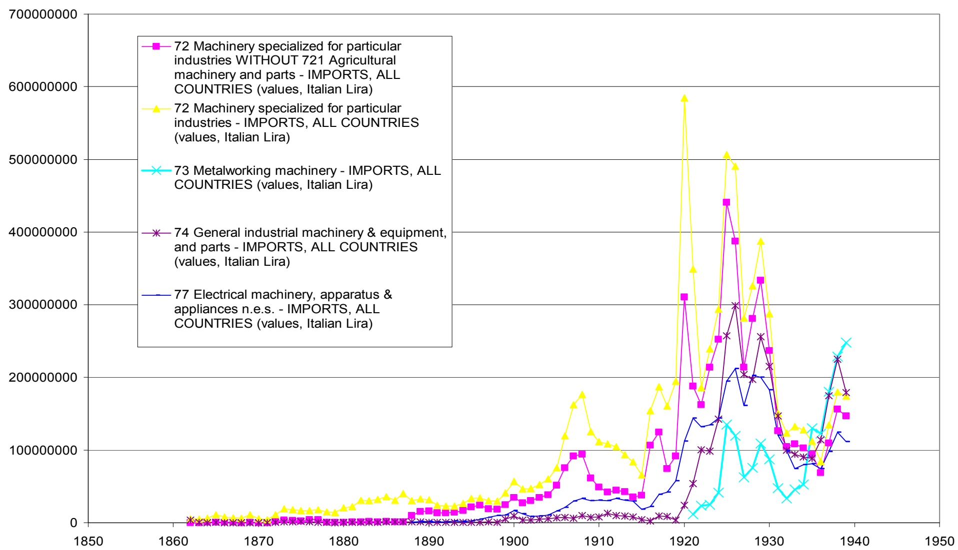


Figure 5.4

Italian machinery imports, selected two digit 7 SITC classes - percentage composition

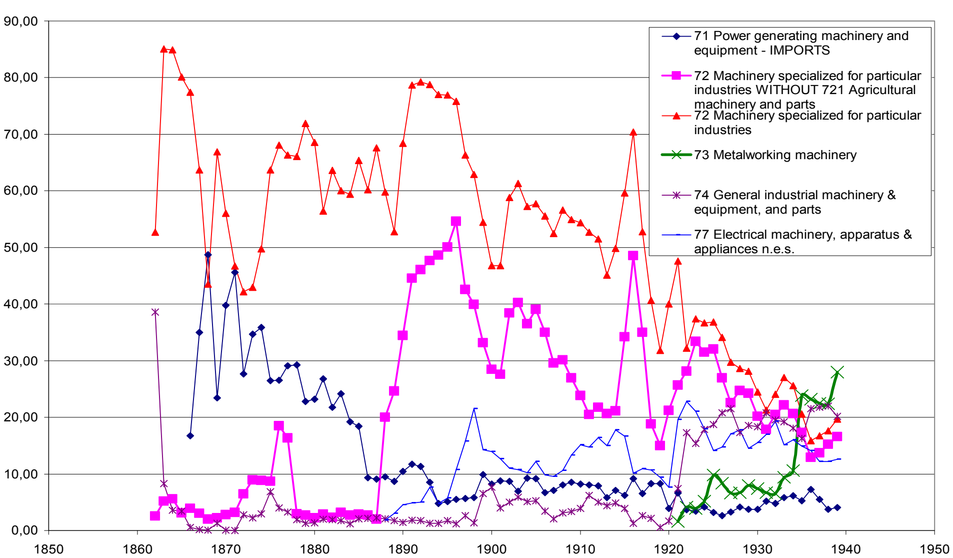


Figure 5.5

Italian FDI inward (stock) on GDP

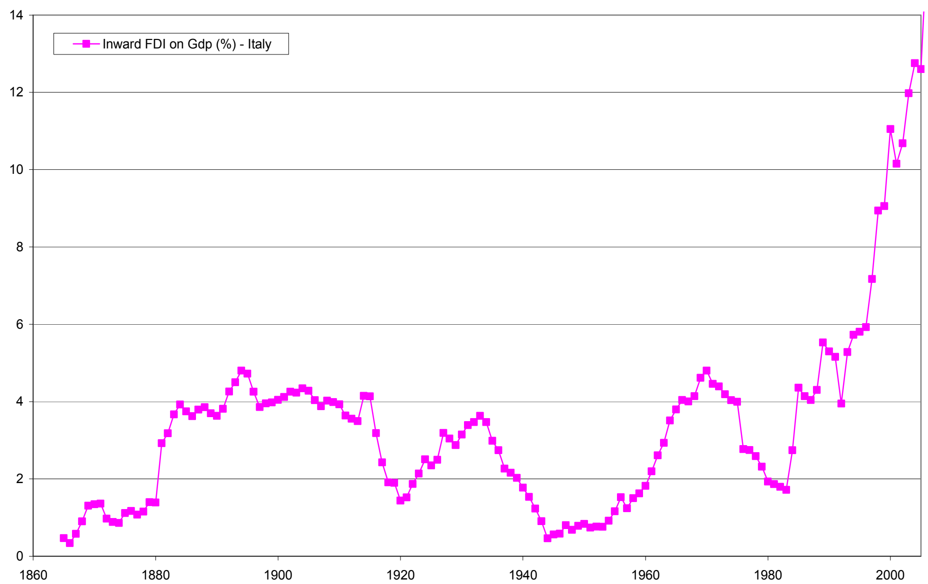


Figure 5.6

Italian and French FDI inward (stock) on GDP

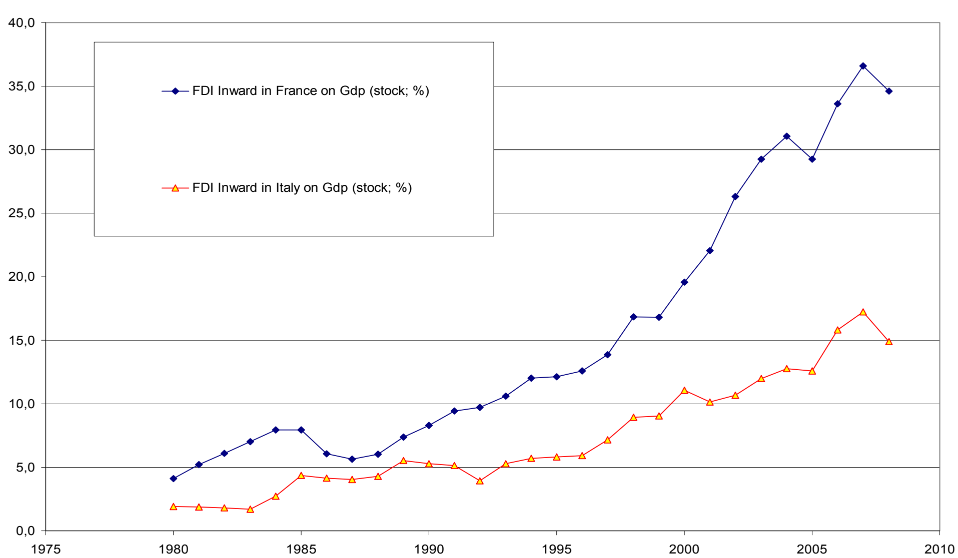


Figure 5.7

Patents granted to foreigners on Industry Value Added - ITALY

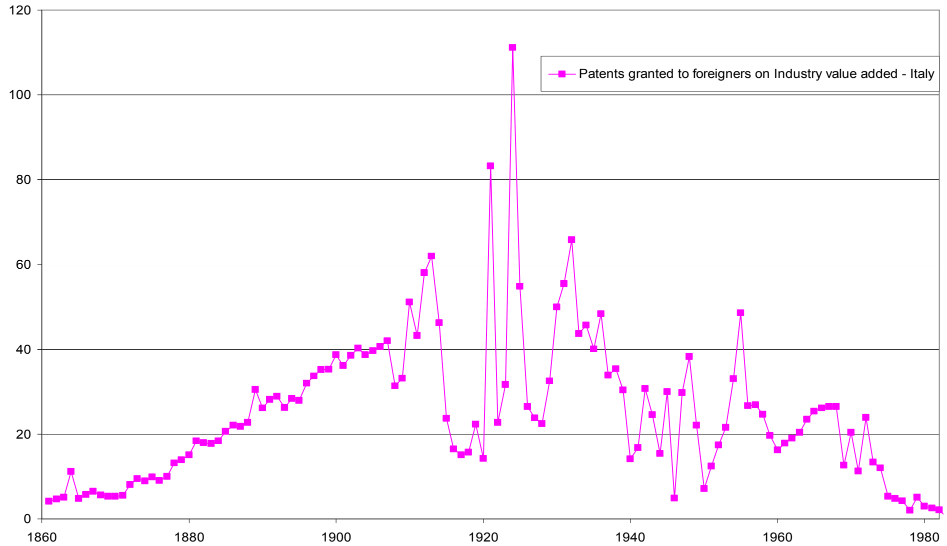


Figure 5.8

Patents granted to foreigners on GDP – Selected countries

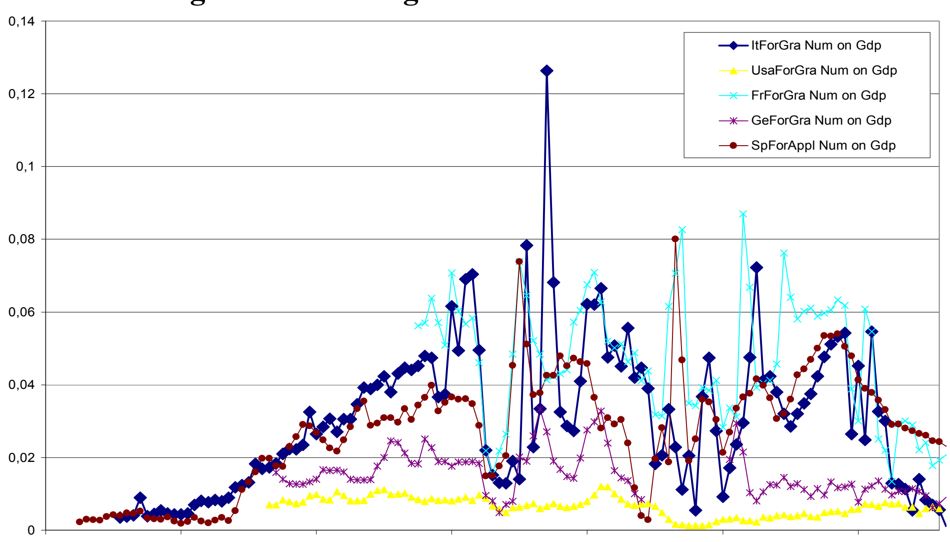


Figure 5.9

Technology Balance of Payments - Italy

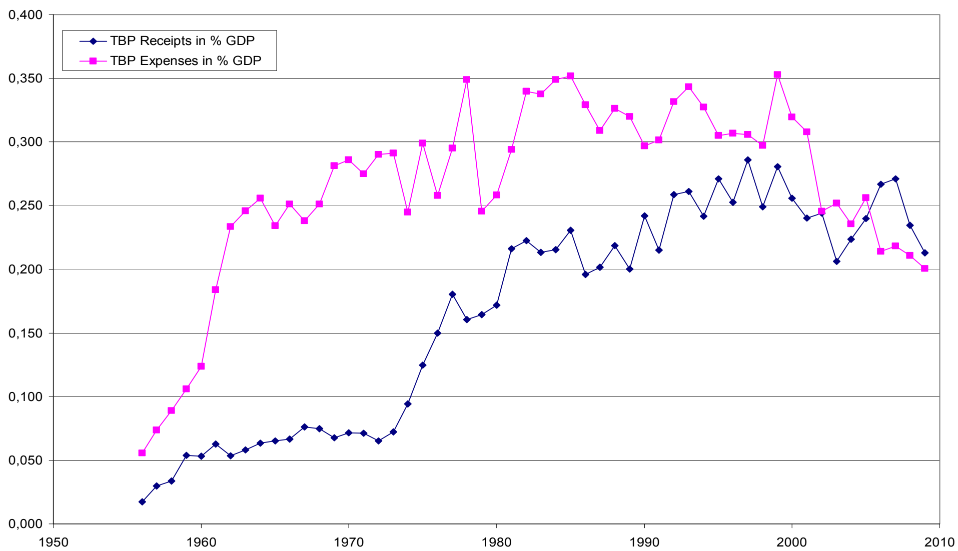


Figure 5.10

Share of TBP Expenses (%) - Selected OECD Countries

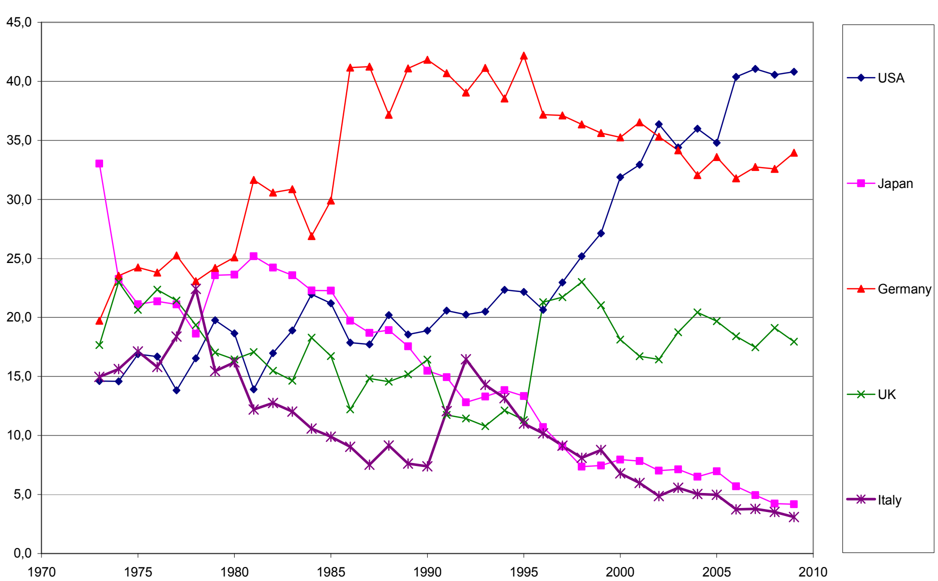


Figure 6.1

Students enrolled in engineering courses as a percentage of University students - Italy

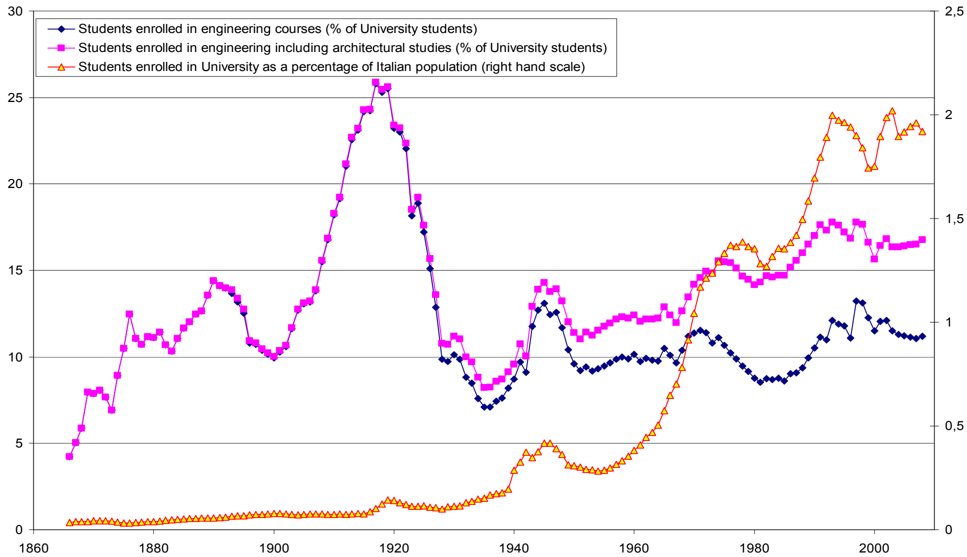


Figure 6.2

Students enrolled in technical schools as a percentage of secondary school students - Italy

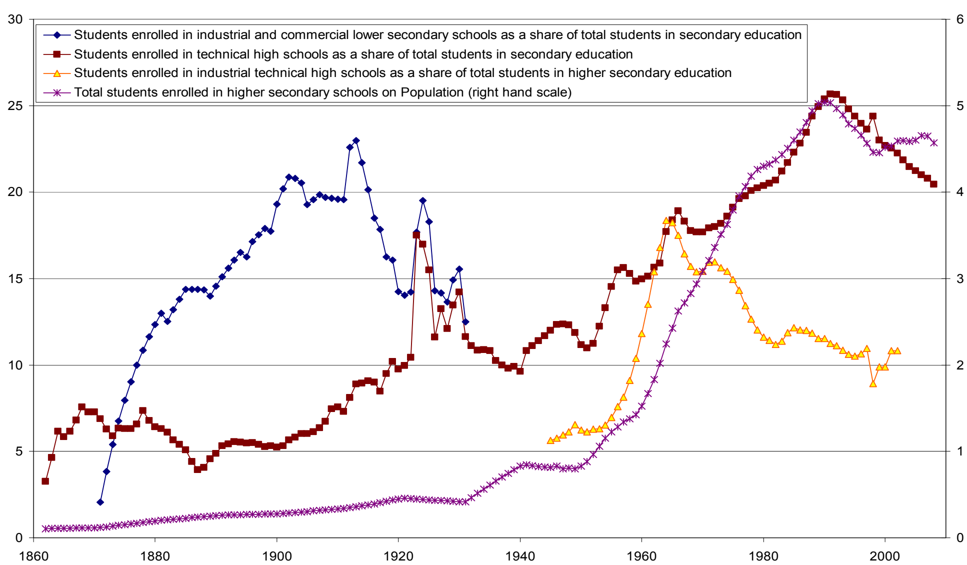


Figure 6.3

Students enrolled in technical industrial high schools on industry's employees (%) - Italy

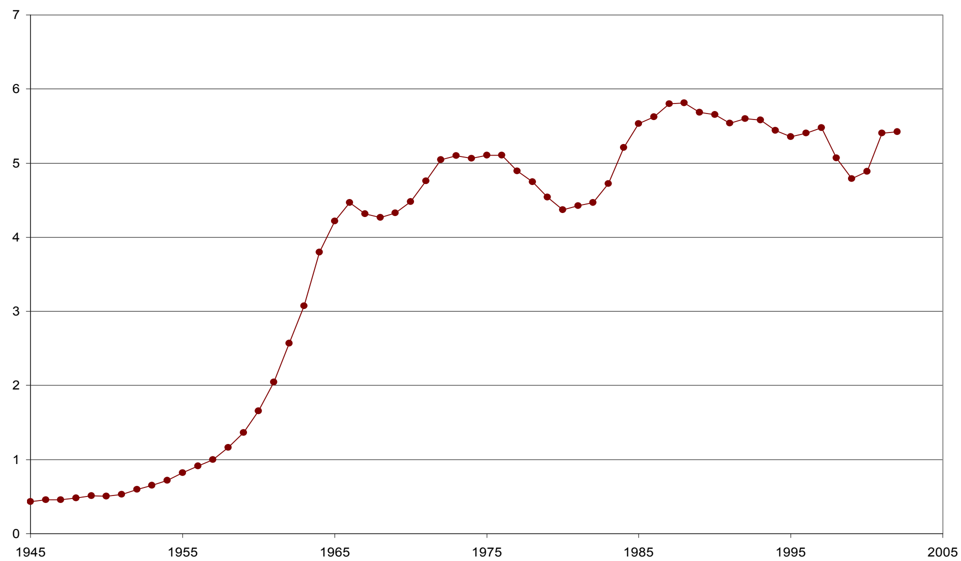


Figure 6.4

Domestic expenditures on Research and Development - Italy

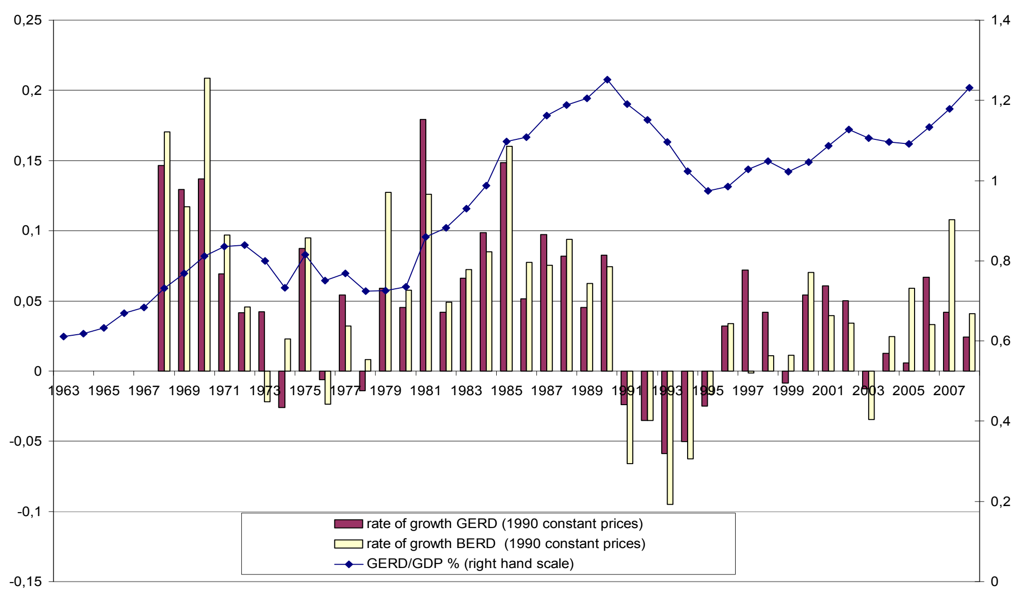


Figure 6.5

Gross domestic expenditure on R&D as a percentage of GDP in selected countries

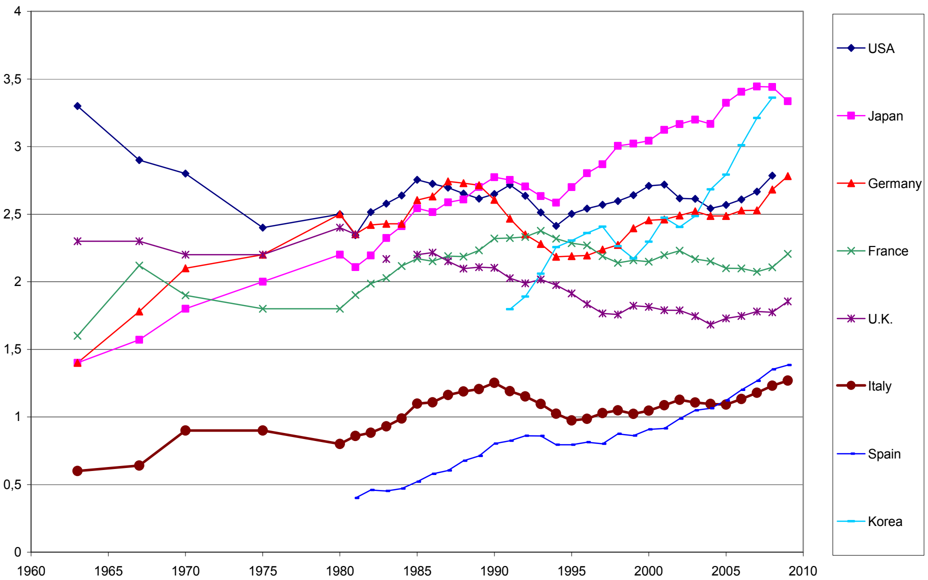


Figure 6.6

Business enterprise sector expenditure on R&D as a percentage of GERD in selected countries

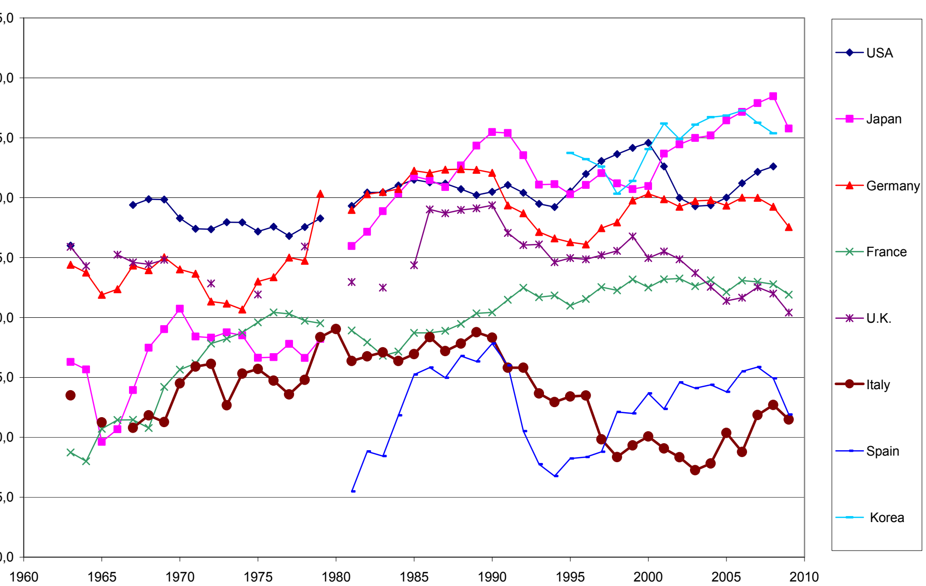


Figure 6.7

Ratio of domestic production of machinery and internal gross investment in machinery Italy

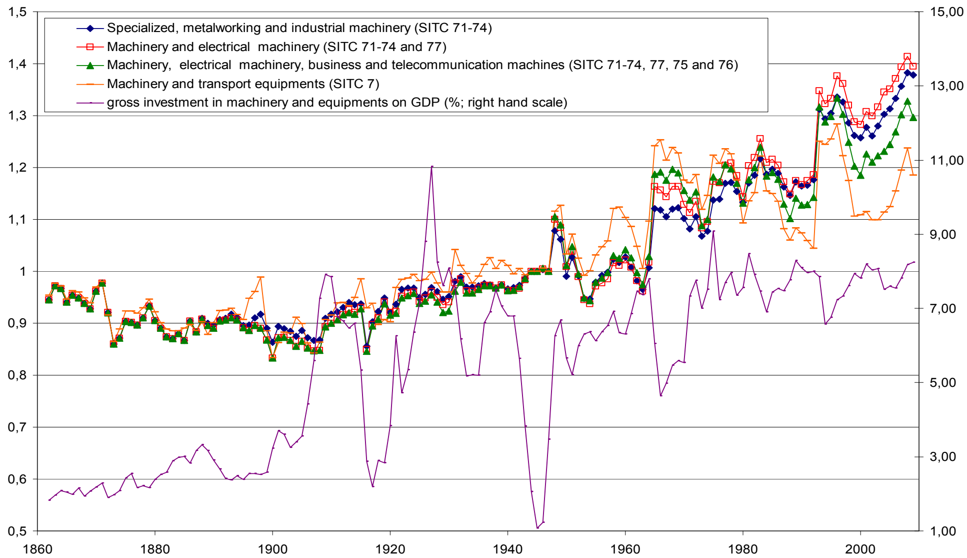


Figure 6.8

Ratio machinery imports on machinery exports, 1890-2010 - Italy

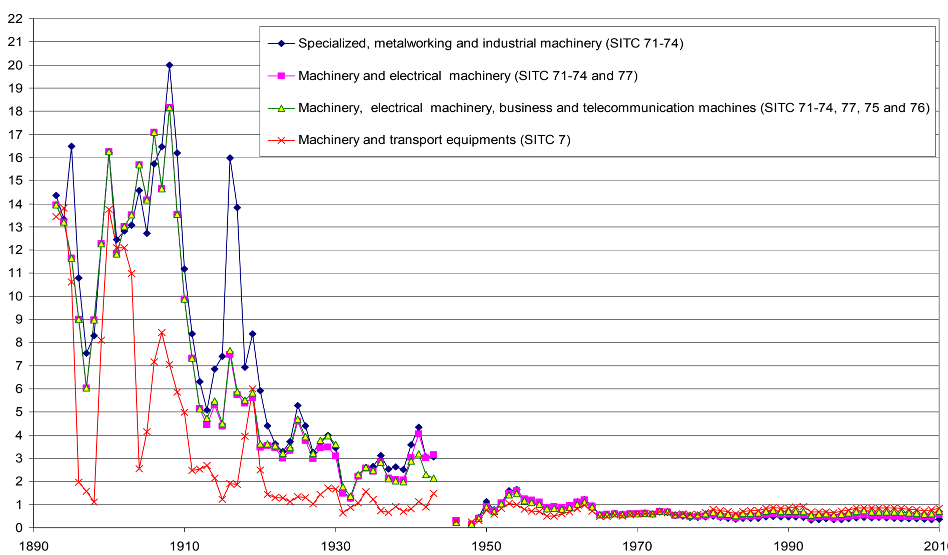


Figure 6.9

Ratio machinery imports on machinery exports, 1948-2010 – Italy

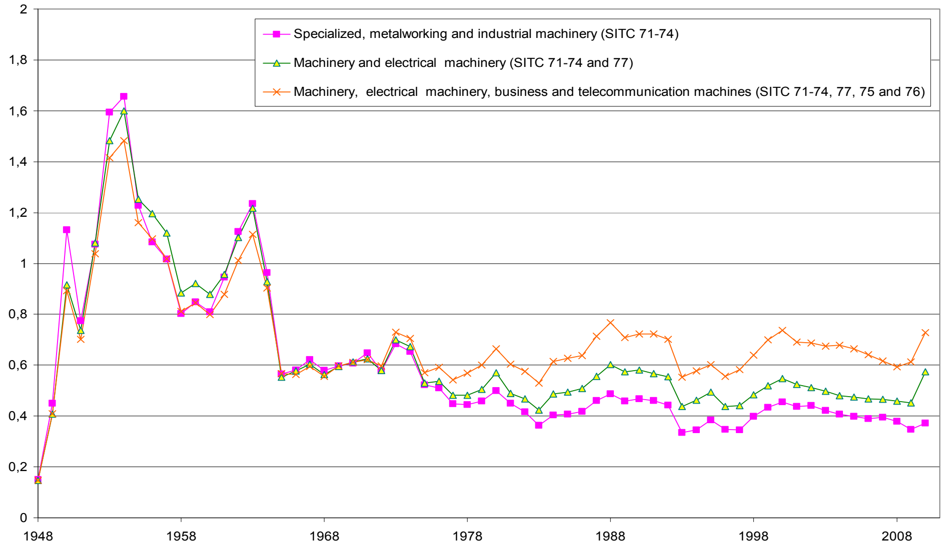


Figure 6.10

Ratios of machinery imports and exports on manufactured goods imports and exports Italy

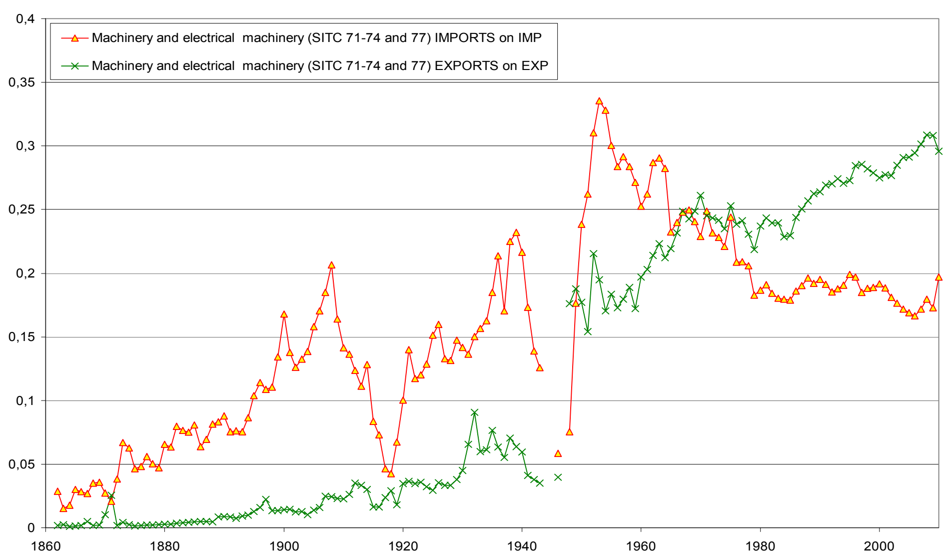


Figure 6.11

Share of TBP Receipts (%) - Selected OECD Countries

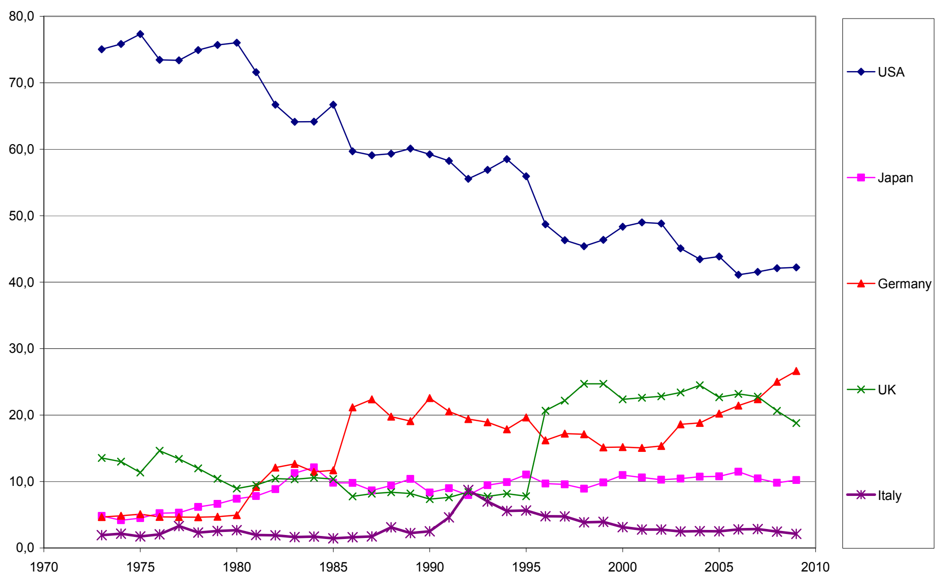
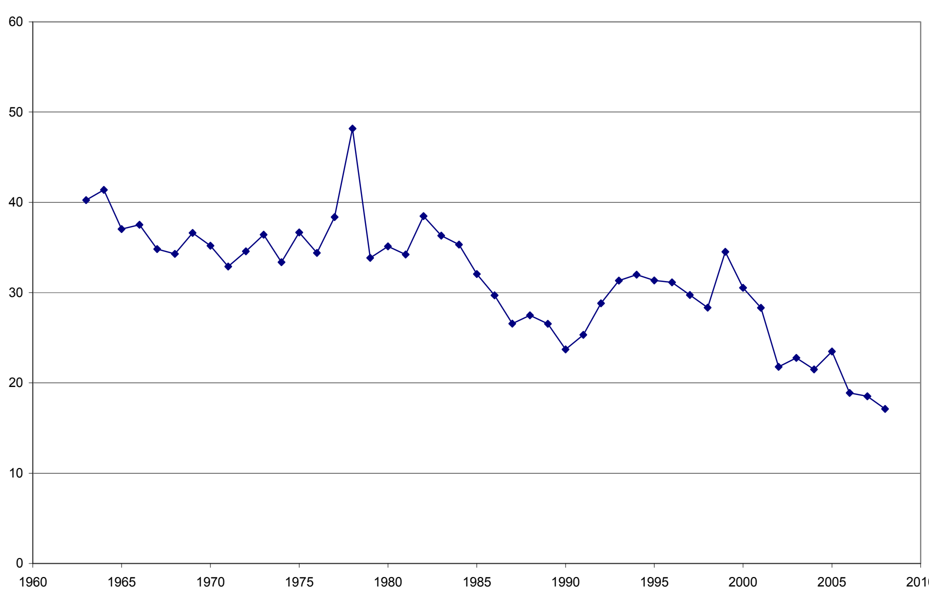


Figure 6.12

TBP Payments on R&D Gross domestic expenditure (%) - Italy



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