Was Italy a backward country? Evidence from the Steam Locomotive Industry, 1850-1913

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ABSTRACT

In this paper we examine the dynamics of technical change in the Italian locomotive industry in the period 1850-1913. From an historical point of view, the case of the Italian locomotive industry presents a major point of interest: it was one of the few relatively sophisticated “high-tech” industries in which Italy, a *latecomer* country, was able to set foot before 1913. Using technical data on the performance of different vintages of locomotives, we construct a new aggregate index of technical change for the industry. Overall the most successful phase for the Italian locomotive industry seems to be period 1895-1913 characterized by a very rapid technical progress and by the effective consolidation of the technological capabilities in this area of two major national firms: Breda and Ansaldo.

1. Introduction

This paper presents a new aggregate index of technical change for the locomotive industry. It focuses on the case of steam locomotives produced for the Italian market by national and foreign manufacturers during the 19th century. We have constructed a new dataset covering technical indicators of the performance of different vintages of steam locomotives. The dataset includes some five thousands steam locomotives in operation in Italy during the period from 1839, when the first trunk of the Italian railways network – the eight kilometers from Naples to Portici – was opened, to the eve of WWI. The paper casts doubts on the current and prevailing view in the literature, according to which the share of the Italian steam locomotive market covered by national producers was severely limited by their technical backwardness, at least in three decades following the Unification of the Country (1861). The new quantitative evidence on the technical change of Italy's steam locomotives suggests rather at the opposite that the technical capabilities of Italian producers were fully adequate when compared to that of more established foreign producers of the like of Cail, Koechlin, Parent-Schaken, Stephenson, and Wiener Neustädter.

Railways systems have featured prominently in the early cliometric literature, following the seminal contribution by Fogel (1964) dealing with the contribution of railways to the economic growth in the United States. The railways sector, in Italy as elsewhere, is very well documented. Government and company reports are rich of data and quantitative information. It is thus hardly surprising that the "founding fathers" of the debate on Italian industrialization during the 19th century also spilt a good deal of ink on the relation between railways extension and markets' unification (Romeo, 1959; Sereni 1966), and on the connection between the development of the railway network, the demand for industrial products, and the overall pace of economic growth (Gerschenkron, 1962). More recent contributions (Fenoaltea, 1972, 1983) reconsider the relation between railroads and industrial growth in post-unification Italy and highlight the major limitations of the then prevailing literature.[1] Subsequently, in the second half of the 1980s, Michèle Merger provided a set of contributions devoted to the emergence and consolidation of the Italian steam locomotive industry (Merger, 1986, 1989). Finally, more recently, Ciccarelli and Fenoaltea (2012) constructed annual time series of the value added at 1911 prices in the rail-guided vehicles industry in Italy's regions during the period 1861-1913.

The foregoing list is surely partial, and includes what seems to the present writers the most significant contributions to introduce the debates here considered. However, the aforementioned studies by Romeo, Gerschenkron, and Fenoaltea while representing fundamental milestones of the literature are not directly concerned with the issue of the technical capabilities of Italian producers of steam locomotives. In a similar way, the study by Ciccarelli and Fenoaltea, which is particularly important for our paper because it was one of the main source for the construction of our dataset, comprises no indicators of technical progress.[2]

The contributions by Merger published during the 1980s are instead very close in spirit to our study. The key-issue tackled by Merger is the development of the steam locomotive industry in Italy. The general framework adopted by Merger is that of a latecomer country that is borrowing advanced technologies from abroad, and it is subsequently trying to develop autonomous technological capabilities in what may be regarded as a "high tech" sector. It should be noted from the outset, that the main indicator used by Merger for assessing the "performance" of the national producers is the

[1] We refer the reader to Fenoaltea (2011) for a summary of the debate on the impact of the Italian railways.

[2] Ciccarelli and Fenoaltea (2012) were mainly interest in reconstructing the industrial value added in the manufacturing of rail-guided vehicles. In their framework indicators crucial to us (such as the weight and horse power of each steam locomotives) played only a minor role, if at all. The richness of the historical sources allowed us to integrated the above study with quantitative information on the technical characteristics of locomotives vintages in a relatively easily manner.

quantity of locomotives produced and sold. Following an original cue of Gerschenkron (1962), Merger focuses her attention on the connection between government policies in terms of protection and the development of the steam locomotive industry. This perspective connects Merger's analysis to a broader debate on the effects of tariff protection on the overall development of the mechanical engineering industry. Gerschenkron's assessment on the matter is well known and characteristically blunt. In his view, Italian industrialization would have benefited from a more "rationally conceived and executed tariff". In particular, Gerschenkron contended that the structure of the tariff (favouring iron and steel) was totally detrimental for the development of a domestic mechanical engineering sector which "was largely left to its own devices" (p. 370). In contrast, Toniolo (1977) provided a new reassessment of the evidence. While confirming that the rates of protection enjoyed by the engineering industry were negligible, he was reluctant to admit that the limited development of mechanical engineering before WWI was a result of the tariff. According to Toniolo, the main culprit, rather than mistaken policies, was the overall "technical and organizational backwardness of the sector". [3]

In our view, Merger's contribution should be read against the background of this debate on the early development of the mechanical engineering sector. According to Merger, the steam locomotive should be interpreted as a successful case of "import substitution" in the mechanical engineering sector. However, notwithstanding, the successful final outcome, Merger shares Gerschenkron's view that this process of technological emulation and catching up was substantially deflected towards a tortuous and difficult path by a set of ill-conceived policies.

Many other features of Merger's narrative have a strong Gerschenkronian flavor. Besides the negative role of the badly designed structure of import duties on the development of Italy's engineering industry, Merger emphasizes the role played by German style mixed-banks in support of some key-national manufacturers. She envisages the emergence of the Italian steam locomotive industry as a historical process characterized by three different phases.

The first phase of the Merger's periodization (1861-1884) is characterized by the predominance of foreign producers. Interestingly enough, within this period, it is possible to distinguish a rather clear sequence in terms of countries exporting locomotives to Italy: initially the Italian market is dominated by British manufacturers (1850-1860), in a second phase by French firms[4] (1860-1875) and finally by German firms (1875-1885). In this first phase, according to Merger, the two major Italian manufacturers – Pietrarsa (in southern Italy), and Ansaldo (in northern Italy) – were firms characterized by limited technological capabilities. However, the poor performance of Italian firms in the national market for locomotives reflected also some major structural weaknesses such as the limited endowment of engineering and mechanical skills of the country, the lack of specialization of the national producers and the structure of the tariff as pointed out by Gerschenkron. In this regard, it is important to point out once again that Merger's assessment of the inadequate competitiveness of Italian producers is essentially based on the limited number of locomotives produced, and on some qualitative evidence describing delays in the deliveries.

The second phase corresponds to the period 1885-1905. During these two decades there was the formation of a first industrial base in the locomotive sector by virtue of a number of favourable circumstances such as the expansion of the market (due also to the new railway conventions), but more importantly the intervention of "mixed banks" (from 1894) which provided a fundamental

[3] According to Toniolo, a more favourable tariff could have resulted in an increase 50% of the mechanical engineering sector, which in turn would have amounted to an increase of 7% for the whole industrial sector in 1908. Toniolo does not believe plausible that a revised tariff would have determined also a significant increase in exports.
[4] The success of French manufacturers in this period is also accounted for by the influence played by French capital (Rotschild bank) on railway operators, in particular on the *Società Strade Ferrate dell'Alta Italia* (Merger, 1989).

support to the creation of new "high tech" firms such as Breda, Costruzioni Meccaniche Saronno, and Officine Meccaniche Milano, all operating in Northen Italy.
Finally, in the third phase (1905-1914) there was the final consolidation of the sector, so that by 1914, national manufacturers were able to satisfy the entire demand of the country thereby completing the process of "import substitution".

The organization of the rest of paper is as follows. The second section provides a short summary of the historical evolution of the organization of the Italian railways system since the unification. The third section describes the methods underlying the proposed aggregate index of technical change for the locomotive industry and the historical sources used. In section 4 we discuss the patterns of technical progress in steam locomotives as represented by the trends in our aggregate index. In section 5 we try to link our findings on the rate of technical change in a broader account of the evolution of the industry. Section 6 concludes.

2. The evolution of the railway sector

A useful point of departure to approach the study of the steam locomotive industry in Italy is the outline of the institutional evolution of the railway system. In this respect, it is possible to distinguish five major phases (Cornolò, 1998): [5]

(a) The pre-unification phase (1839-1865)

In this phase, the extension of the railway network was very limited and the system has an eminently local character as a result of the uncoordinated installation of railways by pre-unitary states

(b) The railways conventions of 1865 (1865-1876)

The extension of the Italian network in 1864 amounted to some 3,850 kilometers. As a term of comparison, the situation elsewhere was the following: USA (56,000), UK (18,000) France (12,000 km), Germany (16,000), Austria (5,800), Spain (2,800), Russia (2,400), World (130,000).[6] A certain number of regions (including Basilicata, Calabria, and Umbria in mainland Italy, and the two big islands of Sicily and Sardinia) were in 1864 still without rails. After the unification, the law n. 2279 (1865) established that four major private "franchise" firms should be appointed for the operation of the existing railway systems and for the construction of new ones. The companies to whom the railway convention of 1865 entrusted the management of the network were

- *Società delle Strade Ferrate dell'Alta Italia (SFAI):* This company was under the control of the Rotschild bank until 1878 and was managing mostly the network in Northern Italy, as the name suggests.
- *Società delle Strade Ferrate Romane (SFR):* This company was managing mostly the lines operating in the previously Papal States.
- *Società Italiana delle Strade Ferrate Meridionali:* This company was managing the lines along the Adriatic coast from Bologna to Otranto plus an additional trunk connecting Foggia to Naples.

[5] Fenoaltea (2011) suggests a somewhat different periodization which is essentially based on the different waves of construction of the railway network, rather than on the institutional arrangements. A detailed account of the evolution of the Italian railways system can also be found in Crispo (1940). See also the more recent Guadagno (1996).
[6] Giordano (1864), p. 93. The numbers referring to Italy also include Venetia and Latium only annexed to the country respectively in 1866 and 1870. According to Istat (1956, p. 137) the extension of the Italian network was of 8 km in 1839 (from Naples to Portici), about 1,200 in 1855, about 2,400 in 1860, about 6,400 in 1870, about 9,100 in 1880, about 12,200 km in 1890, about 14,400 in 1900, about 15,300 in 1910, and, finally, about 16,700 in 1955.

- *Società Strade Ferrate Vittorio Emanuele*, operating mainly in Sicily.

(c) "Indirect" state control (1876-1885)

This is a rather obscure phase in which, due to the financial difficulties of the "franchisee" companies , the State was forced to take gradually back their control.

(d) The railways conventions of 1885 (1885-1905)

After a decade of "indirect" State management (1876-1885) the system underwent a major reform in 1885, when the vast majority of the railway network was assigned to three operating companies. Two major ones covering the peninsula along a west-east divide (*Società italiana per le strade ferrate meridionali*, *Società italiana per le strade ferrate del Mediterraneo*), and a third one operating in Calabria and Sicily (*Società italiana per le strade ferrate della Sicilia*).[7]

(e) The creation of *Ferrovie dello Stato* (1905-1914)

Finally from 1905, at the end of the twenty-year contract with the three operating companies previously mentioned, the railways system was directly managed by the State through the newborn *Ferrovie dello Stato* a fully public company.[8]

3. An aggregate index of technical change: sources and methods

The traditional economic approach to the measurement of technical change involves the adoption of the conceptual framework of the production function relating the inputs used in the production process to the outputs. In this framework, technical change (total factor productivity) can be measured in terms of the shift of the production function over time. This approach is typically applied at rather aggregate levels (countries or industries) considering chiefly as inputs capital and labour (in some more sophisticated examples land and other natural resources are also included). Although appealing because it is fully consistent with the mainstream economic theory of production, the application of this framework of inquiry at the "micro" level of a specific technology is not straightforward. Let us consider the case in question: the steam locomotive. In principle, one could attempt the construction of one or more indicators of output (eg. freight/total weight carried per kilometer per unit of time) or perhaps a combination of indicators such as speed, durability, etc. In terms of inputs, one could consider capital (for example the real cost of each locomotive by horsepower, or by ton) and coal consumed. This data ought to be collected at the manufacturer or country level so that it would be possible to fit some kind of production function. Unfortunately, the amount of data available, in most cases, prevents the application of this type of approach at the "micro" level of specific technologies.

[7] According to Ministero dei Lavori pubblici. R. ispettorato generale delle strade ferrate (1901), p. 124, the existing stock of 1789 locomotive were assigned in June 1885 to the three newborn companies as follows: 760 were given to the *Società italiana per le strade ferrate meridionali* operating on the *Rete Adriatica*; 920 to the *Società italiana per le strade ferrate del Mediterraneo,* operating on the *Rete Mediterranea*; 109 were finally assigned to the *Società italiana per le strade ferrate della Sicilia* operating on the *Rete Sicula*.

[8] According to Ministero dei Lavori pubblici. Direzione generale delle ferrovie dello Stato (1906), p. 95, in July 1905 the newborn Ferrovie dello Stato inherited from the existing major companies a total of 2664 locomotives. The company-by-company breakdown is as follows: 1617 from the *Società italiana per le strade ferrate del Mediterraneo,* 877 from the *Società italiana per le strade ferrate meridionali*, and 170 from the *Società italiana per le strade ferrate della Sicilia*.

There is however, a suitable alternative, which consists in the adoption of a more "phenomenological", direct method. In a nutshell, this approach consists in measuring directly the rate of technical progress on the basis of the relevant engineering indicators. It is worth noting that this type of approach is also consistent with the paradigm/trajectory conceptualization of technical change proposed by Dosi (1982). Dosi defines a technological paradigm as a ' "model" and a "pattern" of solution of *selected* technological problems, based on *selected* principles derived from natural sciences and on *selected* material technologies' (Dosi, 1982, p. 152). The term 'paradigm' is borrowed from Thomas Kuhn's philosophy of science and indicates a cognitive framework, jointly adhered to by a significant group of innovators, guiding the search for technical advances in a particular historical context. In this way, a technological paradigm defines the boundaries of the domain in which future technological developments will take place. Dosi suggests that it should be possible to 'deconstruct' each technological paradigm into a set of particular engineering 'heuristics'. These represent the accepted rules prescribing the procedures adopted in the search for innovations. For example, in the field of computer micro-processors the general heuristic guiding the search for improvements can be characterized as "miniaturization". This heuristic was famously encapsulated in a stark form in the so-called Moore's Law (Moore, 1965; the title of Moore's paper – "cramming more components onto integrated circuits" – is also particularly evocative of this specific "miniaturization" heuristic).

In Dosi's view, technological heuristics are the product of the combination of what might be termed the 'autonomous drift' of a technology (that is, the 'compulsive sequences' of technical challenges and solutions individuated by Rosenberg (1982), which are typically insensitive to market signals) with 'inducement factors' of a genuinely economic type (such as current and expected factor prices).

The heuristic search process practised by the inventors' community, by channelling inventive activities in specific and finalized directions, generates relatively ordered paths of improvement, called 'technological trajectories'. Improvements along a trajectory are strongly cumulative, in the sense that they are tightly related with previous attainments. In this way, technical progress ought to be conceived as an inherently path-dependent process in which specific innovations are to be understood in terms of the state of the art that preceded them. Again, in the field of microprocessor, the regular increase in the computational power of micro-processors (another dimension of Moore's law) can be regarded as mapping the unfolding of a specific technological trajectory.

In this conceptual framework, the most natural way to measure the rate of technical progress is by looking at the rate of improvement along the relevant technological trajectory. In an engineering perspective, a natural indicator for the performance of a locomotive (and of other vehicles as well) is the power-to-weight ratio. The power-to-weight ratio provides a measurement of the performance of the locomotive in a metric which is independent of its size. In the celebratory centenary volume of Italian railways (Ferrovie dello Stato, 1939), the inverse of the power-to-weight ratio was used a general indicator for charting the progress of the most representative exemplars of steam locomotives constructed in Italy. In the same vein, in a celebratory publication of 1961, the engineer Manlio Diegoli identify in the evolution of the weight/power ratio a performance indicator that was "chiaramente espressivo del progresso [realizzato]" in steam locomotives (Diegoli, 1961, p. 114). This performance indicator seemed particularly relevant in the Italian context also because "[le] linee italiane presentavano numerosissime travate metalliche di modesta resistenza, per cui le locomotive dovevano avere peso limitato per asse e per metro lineare e quindi notevoli valori specifici della potenza" (Diegoli, 1961, p. 108).

These shreds of evidence (to be further corroborated) suggests that the technological trajectory of the steam locomotive may be characterized by a process of incremental changes of the power-to-weight ratio. Accordingly we shall use this metric to construct the aggregate index of technical change. Another performance indicator of potential interest is clearly the fuel efficiency of the locomotive. Unfortunately, for this indicator, data are not systematically available. However, it is also worth noting that estimates referring to 1898 by Fenoaltea (2011, p. 180) suggests, that, notwithstanding the high price of coal, fuel costs had a relatively small share in the overall operating costs of railway costs (about 12% -14% of total operating costs).

3.1 The data

Our locomotives data-set is based on two major components. The first one is largely based on the data compiled by Ciccarelli and Fenoaltea (2012) for their statistical reconstruction of the engineering industry in Italy during the Liberal Age. The second component is entirely new and it covers indicators of technical characteristics and performances of locomotives.

We do not consider in our sample tank locomotives (i.e., locomotives carrying water and coal on-board instead of pulling them behind in a separated tender) because they are of different nature, typically of reduced size and weight, and often operating in narrow gauge railways (cfr., Ministero dei lavori pubblici (1901), pp. 200-201, where the tank locomotives are classified as a category apart, with an average price well below that of standard locomotives).

The main source of data for the first component of the data-set is a series of catalogues portraying the locomotive "park" of the companies operating the railways system at different moments in time. As we have mentioned, in 1885, the vast majority of the railway network was assigned to three operating companies. In the late 1880s the three companies *Società italiana per le strade ferrate meridionali*, *Società italiana per le strade ferrate del Mediterraneo,* and *Società italiana per le strade ferrate della Sicilia* start publishing a series of a catalogues with engineering drawings and lists of the technical characteristics for each type of locomotive in service together with a numerical identifier allowing the precise identification of each vehicle in service, the year of construction, and the name of the building-company.[9] More specifically for this paper we use:

1) *Locomotive Mediterranea 1888* (*Album delle Locomotive 1888,* Società italiana per le strade ferrate del Mediterraneo, Torino, 1888)
2) *Locomotive Adriatica 1887* (*Tipi delle Locomotive e dei Tenders. Anno 1887,* Società italiana per le strade ferrate meridionali. Esercizio della Rete Adriatica, s.p., 1887).
3) *Locomotive Sicula, c. 1902* (*Materiale Rotabile. Tipi delle Locomotive e delle Carrozze.* Palermo, s.d.)

These data are integrated with information from a further similar catalogue published in 1914 which provided a similar exhaustive list of locomotives for all the vehicles in operating service in 1914:

4) *Locomotive F.S. 1914* (*Locomotive ed Automotrici in servizio e in costruzione al 30 giugno 1914*, Ministero dei Lavori Pubblici. Direzione generale delle Ferrovie dello Stato, Firenze, 1914)

To construct our data-set we have merged the relevant quantitative information stored in the four publications. Luckily enough, as noticed, the historical sources include a numerical identifier assigned to each single locomotive produced, what allowed us to avoid double counting. In this way, we have been able to construct a data-set which contains each individual locomotive used by the major operating companies from about 1850 to 1913. Overall, the number of locomotives

[9] Our data-set does not cover the locomotives in operation in the minor networks (eg, Ferrovie Nord Milano, or Compagnia Reale Strade Ferrate Sarde). The evolution of the Ferrovie Nord Milano is described in Cornolò (1979).

included in the data-set covers probably some 90% of the population of locomotives used in Italy during the same period.

The data described so far while providing an important and statistically accurate representation of the population of the locomotives in operation, do not contain any information on technical characteristics and performances. Therefore, for each locomotive model in our data-set we have retrieved a detailed summary of its major technical features and of its performance from the authoritative volume by Cornolò (1998). This volume is probably the ultimate historical account of the development of steam locomotives in Italy from an engineering history point of view. It is worth noting that the historical catalogues contained also similar technical information on locomotives, but we have preferred to use Cornolò as a chief source in order to avoid the problem of possible inconsistencies arising from collating technical information from different historical sources. In other words, we have chosen to rely on a homogenous secondary source since this was compiled by a truly leading authority in this field

3.2 The Index of Technical Change

Our approach to the construction of the index of technical change is relatively straightforward. For each locomotive we have computed the weight to power ratio using the data from Cornolò (providing the power in HP and the weight in kg). This indicator which we label whp represents the proposed proxy of technical performance of the individual locomotive. At each moment in time, locomotives characterized by different whp are introduced in the locomotive park. We construct an aggregate industry-level index (WHP) of technical change as the weighted average of the technical performance of the different locomotives entering in service in that year:[10]

$$WHP_t = \sum_{i=1}^{K_t} s_{it} whp_i$$

In the above formula t represents time (year), s_{it} is the share of locomotive of type i introduced in year t $s_{it} = n_{it} / N_t$ (with n_{it} and N_t indicating respectively the number of locomotives of type i, and the total number of locomotives introduced in the year t; K_t denotes the number of the different types of locomotives introduced in year t and whp_i is the weight to power ratio of locomotive of type i. [11]

It is important to point out that the aggregate index portraits only the locomotives introduced in that year. While the sources indicate systematically the year in which locomotive entered in operation, the information about the year in which it was scrapped is not systematic. The aggregate index of technical change, therefore, should be regarded as an index representing the level of technological performance of the investment in locomotives in a specific year.

4. Patterns of technical progress in steam locomotives

Figure 1 illustrates the temporal evolution of the number of locomotives included in our data-set. As a term of comparison it also includes evidence from two alternative sources: the recent contribution of Ciccarelli and Fenoaltea (2012), and the report to the Italian Parliament by Pietro Carmine, the

[10] Van Dijk and Szirmai (2006) have constructed a similar index of aggregate technical progress for the case of the paper making machines in operation in the Indonesian pulp and paper industry.

[11] The different types of locomotives (*Gruppi FS*) were defined by the engineers of the newborn *Ferrovie dello Stato* in 1905. The detailed technical description of each category is provided by Cornolò (1998), whereas the technical characteristics of each type are summarized in Cornolò (1998, pp. 584-599)

then Minister of the public works (Camera dei deputati, 1906). The Carmine-report dates 1906 and the relative time series depicted in Figure 1 ends necessarily in 1905. Apart from that, it is clear that the three series differ only marginally.[12]

Figure 1 around here

Figure 2 shows the series of the total number of locomotives in each year and of the number of locomotives produced by national producers. The difference between the two series is the number of locomotives introduced by foreign manufacturers. Figure 2 clearly shows that until 1885, the Italian market is, by and large, dominated by foreign manufacturers. During the 1890s there is major slowdown during which, Italian producers seem to be able to gain the entire market. Finally there is a new "growth spurt" during the 1900s. In this phase, Italian producers still maintain the largest share of the market (although it is interesting that in the peak of investment after 1905 there is a significant resurgence of foreign manufacturers).

The interpretation put forward by Merger (1986, 1989) relies, in a major way, on the type of evidence presented in Figure 2. In her account, the limited number of locomotives produced in the period 1861-1885 is due to three concomitant factors: the limited depth of the technological capabilities of the national firms, the lack of specialization (increasing their costs), and the penalties induced by the tariff. After 1885, by virtue of the new railway convention, a new wave of investment took place. In this phase there is an increase of the share of national producers (according to Merger, this may also be due to the role played by the 5% clause in favour of national manufacturers). The ultimate consolidation of the national industry of steam locomotives, according to Merger, takes place after 1905 when the production of national producers is elicited by the wave of investment following the creation of *Ferrovie dello Stato*.

Figure 2 around here

Figure 3 shows the series of the locomotives with and without tender. As we have mentioned, in this paper, we focus on the locomotive without tender which comprise the bulk of the locomotive park installed in the period in question. The locomotives with incorporated tender were of smaller sizes and typically used in specific circumstances.

Figure 3 around here

Figure 4 shows the series of locomotives produced for the Italian market by three major countries (England, France, and Germany). The historical sequence pointed out in Merger's account is also visible in this figure. In an initial phase, the Italian market is dominated by English producers, in a second phase by French producers, and finally by German manufacturers (for whom, the Italian market was clearly significant)

Figure 4 around here

Figure 5 presents the evolution of our aggregate indicator of technical change WHP. The red line is the "aggregate" WHP for Italian manufacturers, whereas the green line is the "aggregate" indicator for foreign producers. The area shaded in grey are the maximum and minimum value of whp in each period. Two points merits attention in figure 5. First, the overall technological trajectory can be characterized in terms of three major phases. There is an initial phase with some relatively wide fluctuations (which may perhaps be interpreted as a phase of "exploration" of the boundaries of the

[12] It is worth noting that the series constructed by Ciccarelli and Fenoaltea (2012) also include tank locomotives, electric locomotives, and rail-cars, which accounts at least partially for the small differences reported in Figure 1.

paradigm). This is followed by a phase of substantial stability with no drastic improvements (1870-1900). Finally, there is a phase of rapid acceleration (1900-1914). This acceleration is concomitant with the introduction of two major innovations such as compounding and super-heating (Tey, 1910, pp. 28-36; Diegoli, 1961, pp. 108-109).

Second, perhaps surprisingly, the performance of Italian manufacturers is absolutely comparable with that of foreign manufacturers, throughout the entire period considered (including the initial phase)

Figure 5 around here

Figure 6 depicts a kernel density plots of whp. In the figure the density of the distribution of whp in each individual year has been estimated using an Epanechnikov kernel. The figure suggests that there is a relative wide dispersion of whp in the initial period (1860). From the early 1870s, the distribution becomes more concentrated around a value of whp of about 80. Finally, in the last phase, there is another phase of increasing dispersion coupled with an improvement of performance.

Figure 6 around here

Figure 7 compares the WHP index of the three major national producers of locomotives: Ansaldo, Breda, and Pietrarsa.[13] It is interesting to notice that all three producers seems to be able to manufacture locomotives whose performance is fully in line with that of foreign producers (and this seems to occur from a very early stage). The well known difficulties of Pietrarsa during the 1870s and early 1880s are perhaps captured by the slightly increasing trend that seems to characterize the series in this phase.

Figure 7 around here

The evidence presented in Figure 5 is not consistent with Merger's account, who emphasizes the limited depth of engineering capabilities in Italy in the period before 1884. However, the evidence she points to concerns the restricted base of mechanical and engineering skills of the country and does not pertain specifically to the locomotive industry (Merger, 1986, pp. 76-77).

In fact, it is possible to point to shreds of contemporary evidence suggesting that already by the 1880, Italian manufacturers were indeed capable of designing and producing steam locomotives of quality fully comparable to that of foreign competitors.

As already noticed by Ciccarelli and Fenoaltea (2012), Felice Giordano – in his 1864 detailed appraisal of the iron and metal working industry in Italy – argued convincingly that the engineering establishments of Naples and Genoa could produce locomotives at prices that were similar to that of foreign ones (Giordano, 1864, pp. 102, 359). In 1879, Pietro Peirano, a manager of Ansaldo, argued that the key factor that had forced his company to give up the production of locomotives was the

[13] In present days Pietrarsa (near Naples) hosts the National Railway Museum inaugurated in 1989 to mark the 150th anniversary of Italian railways. In 2001, Ansaldo and Breda merged into AnsaldoBreda a new company specialized in the manufacturing of rolling stock (including the celebrated Frecciarossa1000 capable of reaching 400 km/h possibly the fastest train circulating in Europe). Brands such as Ansaldo, Breda, Fiat, Terni steelworks, and the like represent Italy's first industrial nucleus dear to business historians. The related literature is correspondingly sizeable. On the origin of Breda see Società Italiana Ernesto Breda (1908), and Società Italiana Ernesto Breda (1936). On Pietrarsa see, among others, Chiuriello (1940). On Ansaldo see Gazzo (1953), and especially the more recent *Storia dell'Ansaldo* comprising nine volumes (Castronovo 2003). Interestingly enough, the present authors weren't able to find in the above literature a quantitative account of the annual production of steam locomotives by either Ansaldo, or Breda, or Pietrarsa, although, for the sake of completeness, it has to be said that the figures at the very end of Società Italiana Ernesto Breda (1908) are surely informative on the matter.

penalty of the tariff, rather than the a backwardness of technological competences (Commissione d'inchiesta sull'esercizio delle ferrovie italiane, 1879, pp. 371-372). [14]

In a conference for the Exposition of Milan of 1881, prof. Leonardo Loria delivered this stark assessment:

> Le locomotive nazionali stanno perfettamente a paro per finitezza di lavoro e buona disposizione di parti delle migliori locomotive straniere… Le nostre locomotive non sono più semplice copie di locomotive forestiere, fabbricate direi quasi riunendo una serie di pezzi provenienti dall' estero; sono locomotive appropriate alle condizioni speciali delle nostre linee, costrutte pressocchè completamente da noi e nelle quali i nostri ingegneri introducono perfezionamenti importanti…. E anche per ciò che riguarda il costo delle locomotive non siamo ormai molto discosti dalle fabbriche estere. (Loria, 1881, pp. 76-77)

Another major technical achievement attained in this pioneering phase was the design of the "Mastodonte dei Giovi" a locomotive which was constructed as a compound version of two basic Stephenson locomotives and which was able to deliver enough power to overtake the steep inclination of the Giovi tunnel on the Turin-Alessandria-Genoa line (this locomotive was designed by Germain Sommellier). In his detailed historical account, Cornolò mentions other model of locomotives (such as the "Ariosto" or the "Frescot") designed during the 1870s and early 1880s that were crowned with critical acclaim at international exhibitions and in the engineering literature (Cornolò, 1998, p. 31).

5. The steam locomotive industry in Italy: conjectures and refutations.

The evidence discussed in the previous section suggests a reappraisal of the history of the locomotive industry in Italy, while, at the same time, questioning some elements of the account put forward by Merger. In our interpretation, the technical attainments of Italian firms and engineers in the field of locomotive design and production suggests that the structure of the tariff represented probably the main bottleneck stifling the expansion of the industry during the 1870s and in the first half of 1880s. On this matter, we are convinced that the early assessment by Gerschenkron (1962) has been fully vindicated. If this is the case, what accounts for the first wave of growth in locomotive investment that our data suggests that is taking place from 1885 ? The Act of 1885 specified that railway companies were obliged to afford a preference to national producers equal to the five per cent of the price. (Gerschenkron, 1962, p. 371). As Gerschenkron himself commented, this provision was probably too weak to exert a major impact.

There are however two features of the Act of 1885 that so far have received only limited attention, but can probably go a long way in accounting for this first growth spurt in the production of locomotives. The first point is that the with the restructuring of the system in 1885 the three major

[14] "La causa dell'impossibilità in cui si trovano le nostre fabbriche di fare concorrenza con le estere si deve ricercare nella sproporzione dei dazi di dogana, fra le materie prime componenti una macchina, e la macchina stessa. Per una locomotiva compiuta si pagano 700 lire di dazio, per materiale greggio che fa d'uopo acquistare per costruirla in Italia, si pagano 4000 lire; per questo fatto le case estere vinsero sempre in tutte le gare, che le nostre società fecero per forniture di locomotive…Riguardo poi al mezzo per vincere la concorre estera io non vedo che un solo espediente, già adottato dalla marina, e che consiste nel permettere l' importazione temporanea dei material greggi, destinati alla produzione delle macchine, esentandole dalle tasse doganali…Si potrebbero vincere gli stabilimenti esteri quando venissero esonerati dal dazio i materiali greggi" (Peirano, 1879, pp, 371-372). Even if self-interested, in our view the statement probably reflects a sincere assessment. In fact in the same interview it is also discussed the procurement policy practiced by *Ferrovie Meridionali* in favour of Pietrarsa. Clearly, if Peirano had not been intimately convinced of the critical role of the tariff, the best course of action would have been to advocate for the extension of a similar procurement policy rather than the revision of the tariff. According to Gerschenkron (1962, p. 369), in 1878 the tariff was 10 lire per quintal both for steel and for locomotives, which effectively provided only a partial compensation.

operating companies received a special endowment of 15 million lire for the purchase of railway equipment and material also to be spent in the renovation of the locomotive park (Merger, 1986, p. 81). The second point is that, after 1885 there was a sort of "silent" procurement policy that amounted to a favour of "national champions", well beyond the clause of the 5 per cent preference.[15] In fact, the clause of the five per cent was to be applied for contracts assigned by means of formal competitive calls ("licitazione"), but the franchisee companies could purchase locomotives also directly by means of direct deals. Ministero dei Lavori pubblici. R. ispettorato generale delle strade ferrate (1901) contains some aggregate data on the purchase of locomotives for the period 1885-1899 subdivided according to the type of purchase. These data are set out in table 1. Two points merits attention. First, as also noted, by Gerschenkron, the five per cent clause is by no means sufficient to tilt the price advantage in favour of national manufacturers. The second is that a significant stimulus to the national industry was actually exerted by means of special deals.

Table 1 around here

Table 2 sets out price data for the year 1905 as reported in the 1906 Carmine-report. Interestingly enough, the price gap between national and foreign manufacturers is significantly lower than in the previous period. In the Carmine-report (Camera dei deputati (1906), p. 5) it is noted that for the year 1905 the gap was exactly equal to the tariff (0.14 lire per kilogram) plus an amount corresponding to the five per cent clause (0.775 lire). Hence the favour accorded to the national manufacturer in that year was completely in line with the guidelines implicit in the tariff and in the five per cent clause, even if the purchase of locomotives was managed by means of private deals.

Table 2 around here

The picture we have drawn so far may be further completed by noticing that several informed contemporaries identify in the small and irregular number of orders the main problem affecting the cost competitiveness of national manufacturers (again also in this respect the technological competences of Italian firms were instead deemed as fully comparable to those of foreign producers). Giuseppe Colombo in 1881 wrote:

> Per fabbricare delle locomotive in condizioni economicamente possibili, bisogna farne almeno una cinquantina all'anno, e avere un' officina montata e corredata di macchine nel modo più perfetto, esclusivamente per questo lavoro. Due di queste sarebbero più che sufficienti a servire tutte le ferrovie italiane. Nel modo in cui è organizzata oggigiorno la fabbricazione delle locomotive anche presso le grandi officine forestiere, nelle quali molti pezzi si prendono belli e fatti dalle ferriere o da officine speciali, e coll'attitudine già dimostrata in parecchie officine italiane nella costruzione e nella riparazione di queste macchine, il successo di una simile fabbricazione in Italia non sarebbe dubbio (Colombo, 1881, p. 67)

A similar point is also stressed in the 1908 celebratory volume for the 1000th locomotive constructed by Breda:

[15] Ministero dei Lavori pubblici. R. ispettorato generale delle strade ferrate (1889, pp. 501-502), explicitly acknowledged that a segment of the Italian market for locomotives was to be guaranteed for national manufacturers: "Per le locomotive non solo non bastò la protezione accordata dal citato articolo dei capitolati [ie, the five per cent clause], perchè le officine nazionali restassero aggiudicatarie, ma non avrebbe bastato neppure una protezione notevolmente maggiore. Tuttavia allo scopo di favorire l' industria delle locomotive in Italia, che è solo incipiente, e viene esercitata da poche Ditte, le quali vanno ora dotando i propri stabilimenti degli impianti necessari, in modo da poter pure esse vincere la concorrenza degli stabilimenti esteri, si è loro dato sempre lavoro a trattativa privata, combinando i prezzi in modo tale da rendere possibile a quelle Ditte il lavorare senza perdita ed al tempo stesso non gravare troppo lo Stato". As mentioned, this policy has not been widely discussed in the literature.

> Le difficoltà di ordine tecnico che, nello svolgimento della sua vita industriale la ditta Breda dovette superare, furono aggravate da due ordini di fatti: dalla sfrenata concorrenza dell'estero, e dalla irregolarità e discontinuità delle commesse(Società Italiana Ernesto Breda, 1908, p. 22).

6. *Concluding Remarks*

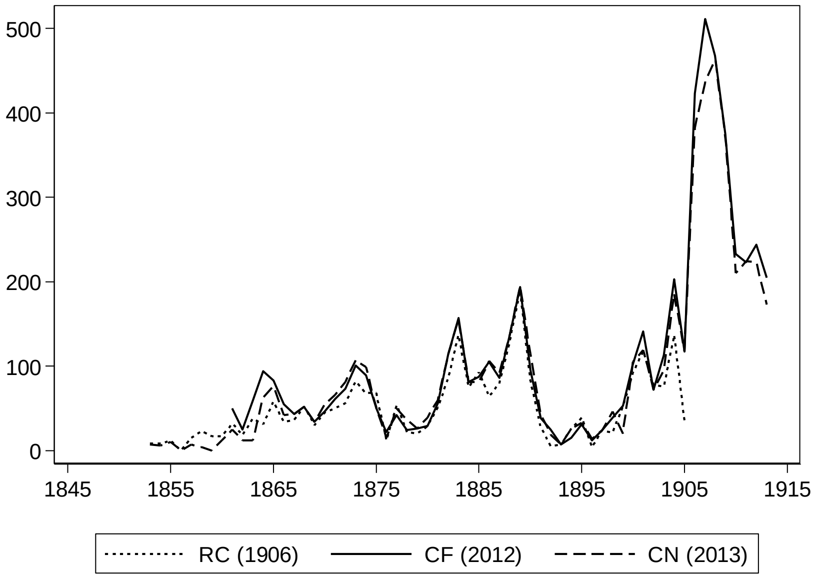
Our interpretation may be easily summarized. Notwithstanding the limited endowment of the country in terms engineering skills and competences, the Italian steam locomotive industry has in general demonstrated a good performance throughout the entire period in consideration (1850-1913). Italian locomotives were, by and large, of a level of technological sophistication similar to that of foreign exemplars. This was true both in an early phase and also with the acceleration of technical progress brought about by the innovations of compounding and super-heating at the end of the 19th century. Probably to a certain degree, this process of development was disturbed first by the vagaries of the demand which prevent the major national players to plan an ordered expansion of productive capacity and, secondly, by the tariff protecting iron products, which may sounds as a vindicated a point already made by Gerschenkron a long time ago. On the other hand, from 1885 onwards national manufacturers received a considerable help through a discretionary procurement policy. In this sense Gerschenkron was wrong, since it cannot be said that Italian locomotive manufacturers "were left to [their] own devices".

In a broader perspective, it is interesting to point out that, in the nineteenth century, the design and construction of locomotives was probably one of the most sophisticated segments of the mechanical engineering industry. Hence, the fact that Italy was capable to set foot in this sector may appear somewhat paradoxical if one takes into account the bleak performance of other less sophisticated branches. For example, the country was not able to develop an indigenous production in the comparably less sophisticated field of cotton textile machinery (Besso, 1910, pp. 142-143; A'Hearn, 1998). In other branches, the emerging pattern was that of Italian producers focusing on the less sophisticated product niches, leaving to foreign the most technologically sophisticated segments of the markets. This is the case described of steam boilers described by Bardini (1997). From this point of view, the successful entry of Italian manufacturers in the production of steam locomotive may be even understood as a case of "technological leapfrogging", in which the backward country is capable to jump directly to the most sophisticated types of technologies (Soete, 1981). Interestingly enough, it is possible also to mention other complex engineering products in which Italy was also able to deliver a very good performance such as the production of war-ships (Fenoaltea, 2011, p. 150), some of which were also exported.

If this is the case, the paradox outlined above may be perhaps solved by noting that some of the most sophisticated branches of the mechanical engineering could, at least to a degree, endure the negative effects of the tariff, by virtue of public procurement, subsidies and other similar policies, whereas the less sophisticated branches had to bear its full burden.[16]

[16] See Fenoaltea (2011, p. 151, citing also Cottrau (1891)).

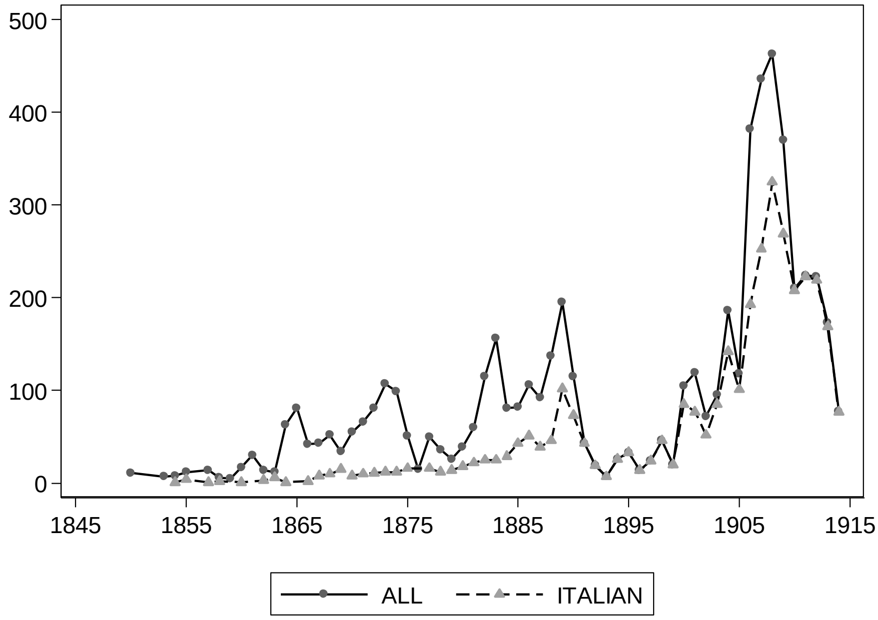
Figure 1: Estimated acquisition of locomotives: alternative sources, 1853-1913[a] (units)



[a] RC (1906): Relazione Carmine (1906); CF (2012): Ciccarelli and Fenoaltea (2012), CN (2013): Ciccarelli and Nuvolari (2013).

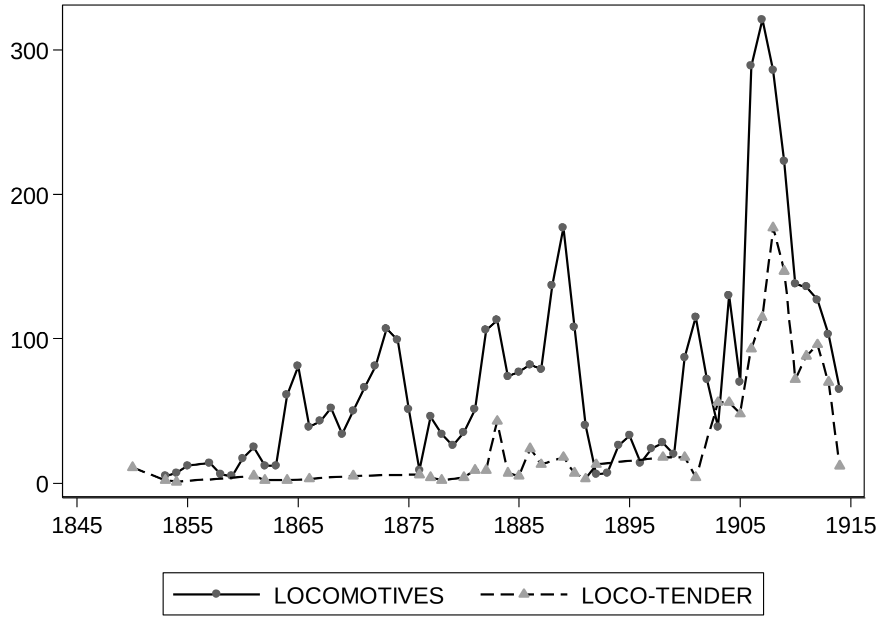
Source: see text.

Figure 2: Estimated acquisition of locomotives: total and national producers, 1853-1913 (units)



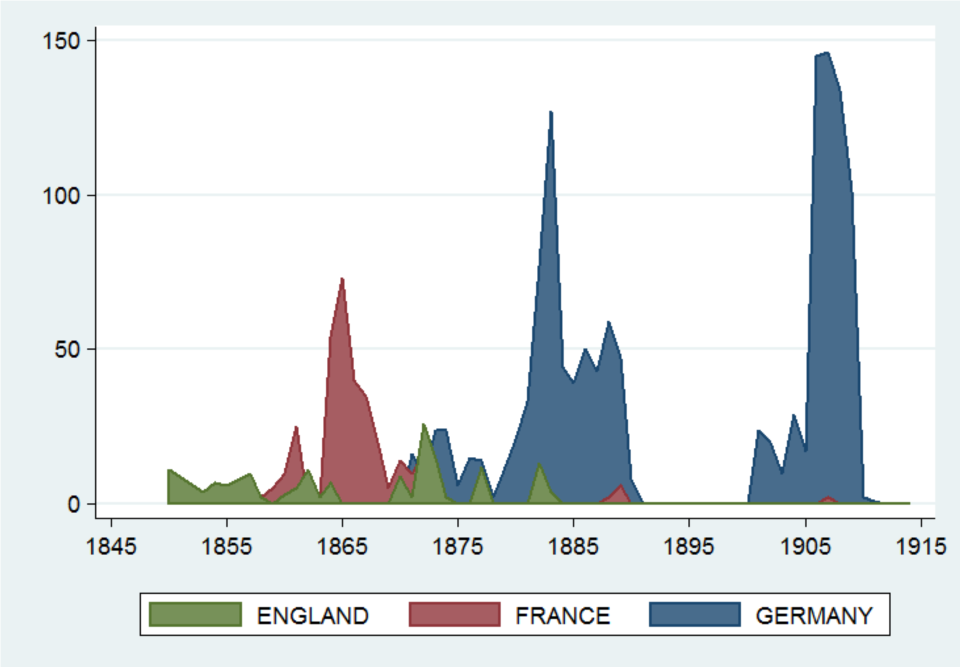
Source: see text.

Figure 3: Estimated acquisition of locomotives, with incorporated and separated tender (units)



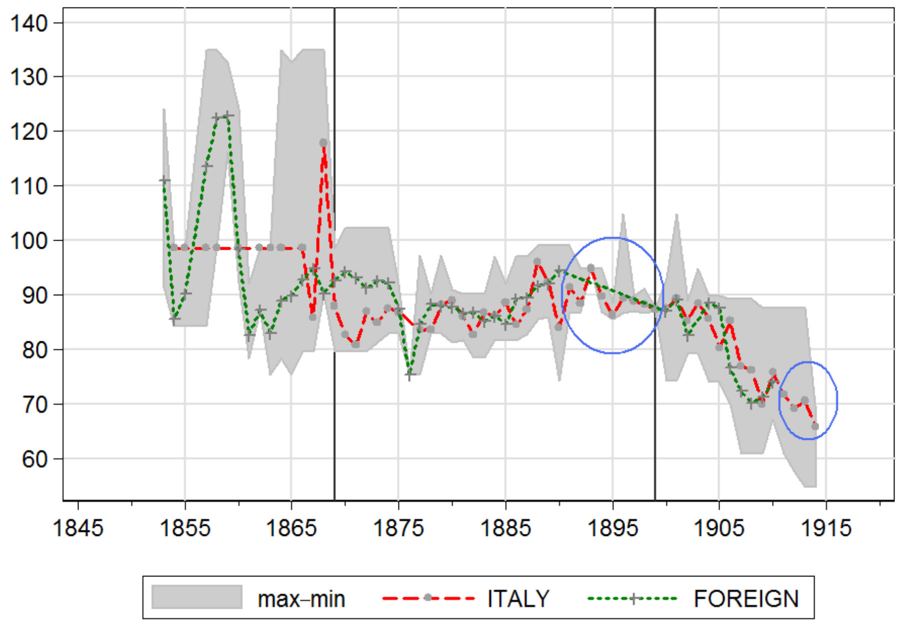
Source: see text.

Figure 4: Locomotives produced for the Italian market, selected country (units)



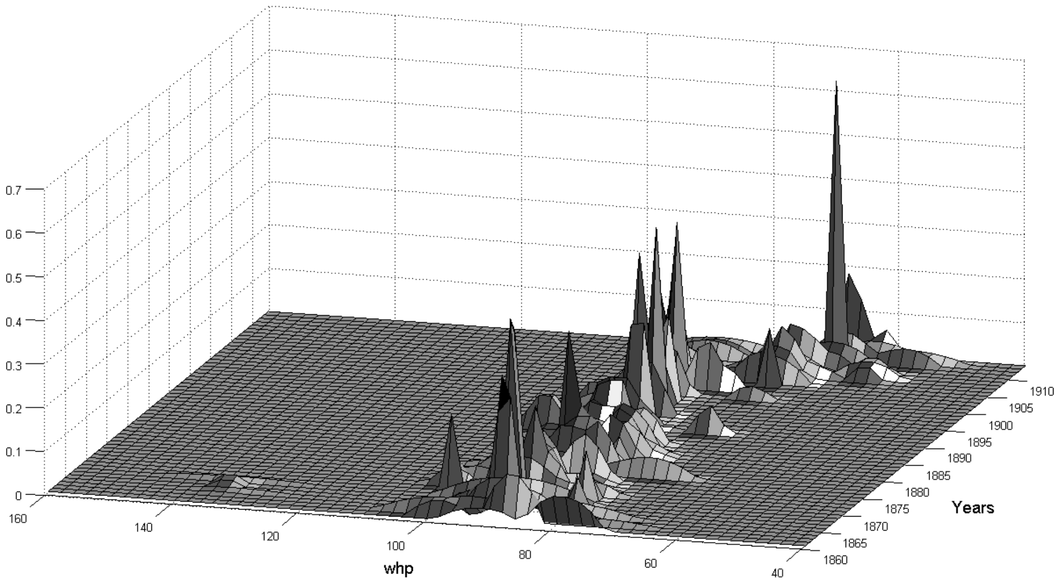
Source: see text.

Figure 5: The weight-to-power index (WHP), 1850-1913



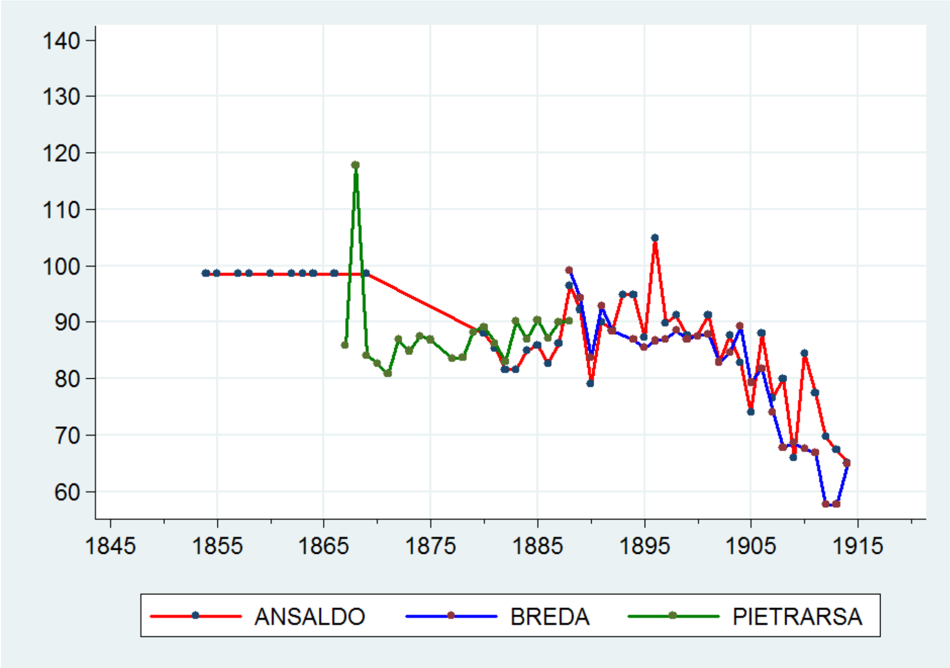
Source: see text.

Figure 6: Kernel density plot of the WHP index, 1861-1913



Source: see text.

Figure 7: Aggregate WHP index, selected Italian manufacturers



Source: see text.

Table 1: Expenditures in locomotives and types of procurement deals (1885-1899)

(1) Type of procurement contract	(2) Number	(3) Total expendture (lire)	(4) Average price per locomotive[a]	(5) National / foreign price[b]
Licitazioni internazionali stranieri	291	17,299,848	59,449.65	
Licitazioni nazionali	311	24,892,467	80,040.09	1.346
Trattative private estero	46	2,217,898	48,215.17	
Trattative private nazionali	284	21,112,045	74,338.19	1.541
Totale	932	65,522,258		
Totale nazionali	563	43,392,879	77,074.39	
Totale estero	337	19,517,745	57,916.16	1.331

[a]col. 4 = (col. 3 / col. 2); [b]the national to foreign price ratio was obtained (rounding errors apart) as follows: (80,040.09/59,449.65) = 1.346; (74,338.19/48,215.17)=1.541; (77,074.39/57,916.16)=1.331.

Source: Ministero dei Lavori pubblici. R. ispettorato generale delle strade ferrate (1901), pp. 202-209.

Table2: Price of locomotives in 1905

	price (lire per kg.)	National /foreign price
Italian locomotives	1.77	
Foreign locomotives	1.56	1.135

Source: Camera dei deputati (1906), p. 5.

References

A'Hearn, B. (1998), 'Institutions, externalities and economic growth in Southern Italy: evidence from the cotton textile industy, 1861-1914', *Economic History Review*, 51, pp. 734-762.

Bardini, C. (1997), 'I fattori cumulativi nella diffusione di una tecnologia. Le caldaie a vapore in Italia tra la fine del XIX secolo e il 1911', *Rivista di Storia Economica*, 13, pp. 41-74.

Besso, S. (1910), *The Cotton Industry in Switzerland, Vorarlberg and Italy. A Report*, Manchester.

Camera dei deputati (1906), *Relazione sulle condizioni del materiale rotabile delle ferrovie dello Stato presentata ministro dei lavori pubblici (Carmine) nella tornata del 16 marzo 1906*, Atti parlamentari, Camera, Legislatura XXII, Sessione 1904-06, Documenti, Doc. 29, Allegato A, Rome.

Castronovo V. (1994-2003), *Storia dell'Ansaldo* (9 vols.), Rome-Bari.

Ciccarelli, C., and Fenoaltea, S. (2012), " The rail-guided vehicles industry in italy, 1861-1913: the burden of the evidence," *Research in Economic History*, 28, pp. 43-116.

Chiuriello, S. (1940), *L'officina locomotive ferroviaria di Pietrarsa nel suo centenario, 1840-1940*, Naples.

Colombo, G. (1881), 'Sui progressi compiuti nell' industria delle macchine dall' epoca dell' Esposizione di Firenze ad oggi' in Brioschi, F. (ed.), *L' Italia Industriale nel 1881. Conferenze sulla Esposizione Nazionale di Milano,* Milano, 1881.

Commissione d'inchiesta sull'esercizio delle ferrovie italiane (1879). *Atti della commissione d'inchiesta sull'esercizio delle ferrovie italiane*, *Parte I, Vol. I*, Rome.

Cornolò, G. (1979), *Cento anni di storia .... delle Ferrovie Nord Milano*, Trento.

Cornolò, G. (1998), *Locomotive a vapore FS*, 2a ed. Parma.

Cottrau, A. (1891), *Le industrie meccaniche e il regime doganale,* Rome.

Crispo, A. (1940), *Le ferrovie italiane. Storia politica ed economica*, Milan.

Diegoli, M. (1961), "La trazione a vapore," Collegio ingegneri ferroviari italiani (*eds*.), *Evoluzione tecnica ed economica delle ferrovie nei cento anni dall'Unità d'Italia, 1861-1961*, Rome

Direzione generale delle ferrovie dello Stato (1940), *Il centenario delle ferrovie italiane,* Rome.

Direzione generale delle ferrovie dello Stato (1914), *Locomotive ed Automotrici in servizio e in costruzione al 30 giugno 1914*, Florence.

Dosi, G. (1982), "Technological paradigms and technological trajectories. A suggested interpretation of the determinants and directions of technical change," *Research Policy*, 11, pp. 147-162.

Fenoaltea, S. (1972), “Railroads and Italian Industrial Growth, 1861–1913,” *Explorations in Economic History*, 9, pp. 325–351.

Fenoaltea, S. (1983), “Italy,” in P. K. O’Brien (ed.), *Railways and the Economic Development of Western Europe*, pp. 49–120, London .

Fenoaltea, S. (2011), *The Reinterpretation of Italian Economic History*, Cambridge MA.

Fogel, R. W. (1964), *Railroads and American Economic Growth: Essays in Econometric History*, Baltimore.

Gazzo, E. (1953), *I cento anni dell’Ansaldo: 1853-1963*, Genoa.

Giordano, F. (1864), *L'industria del ferro in Italia; relazione dell'ingegnere Felice Giordano per la Commissione delle ferriere istituita dal Ministero di marina*, Turin.

Gerschenkron, A. (1962), *Economic Backwardness in Historical Perspective*, Cambridge MA.

Guadagno, W. (1996), *Ferrovie ed economie nell’ottocento post-unitario*, Rome.

Loria L. (1881), ‘Il materiale ferroviario’ in Brioschi, F. (ed.), *L’ Italia Industriale nel 1881. Conferenze sulla Esposizione Nazionale di Milano*, Milano, 1881.

Merger, M. (1986), “Un modello di sostituzione: la locomotiva italiana dal 1850 al 1914”, *Rivista di storia economica*, 3, 1, pp. 66–108

Merger, M. (1989), “L'Industrie italienne de locomotives, reflet d'une industrialisation tardive et difficile (1850-1914),” *Histoire, économie et société*, 8, 3, pp. 335–370.

Ministero dei Lavori pubblici. R. ispettorato generale delle strade ferrate (1889), *Relazione sulle costruzioni e sull’’esercizio delle strade ferrate italiane per gli anni 1885-1886-1887*, vol II, Rome.

Ministero dei Lavori pubblici. R. ispettorato generale delle strade ferrate (1901), *Relazione intorno all’esercizio delle strade ferrate delle reti mediterranea, adriatica e sicula dal 1885 al 1900*, parte IV, vol. II, Rome.

Ministero dei Lavori pubblici. Direzione generale delle ferrovie dello Stato (1906), *Relazione a S.E. il Ministro dei lavori pubblici sull'andamento dell'amministrazione delle ferrovie dello Stato nell'esercizio 1905-06*, Rome.

Ministero dei Lavori pubblici. Direzione generale delle ferrovie dello Stato (1914), *Locomotive ed automotrici in servizio e in costruzione al 30 giugno 1914*, Florence.

Moore, G. E. (1965), “Cramming More Components onto Integrated Circuits,” *Electronics*, pp. 114–117.

Romeo, R. (1959), *Risorgimento e capitalismo*, Bari.

Rosenberg (1982), *Inside the Black Box. Technology and Economics*, Cambridge.

Sereni, E. (1966), *Capitalismo e mercato nazionale in Italia*, Rome.

Società Italiana Ernesto Breda (1908), *Per la millesima locomotiva*, Milan.

Società Italiana Ernesto Breda (1936), *La Società italiana Ernesto Breda per costruzioni meccaniche: dalle sue origini ad oggi, 1886-1936*, Verona.

Società italiana per le strade ferrate meridionali. Esercizio della rete adriatica (1887 ca), *Tipi delle locomotive e dei tenders. Anno 1887*.

Società italiana per le strade ferrate del Mediterraneo (1888), *Album delle locomotive 1888*, Turin.

Società italiana per le strade ferrate della Sicilia (1902 ca). *Materiale rotabile. Tipi delle locomotive e delle carrozze*, Palermo.

Soete, L. (1981), 'International diffusion of technology, industrial development and technological leapfrogging', *World Development*, 13, pp. 409-422.

Tey, G. (1910), *La locomotive a vapore. Storia, sviluppo e perfezionamento al 1910*, Milan.

Toniolo, G. (1977), "Effective Protection and Industrial Growth: The Case of Italian Engineering," *Journal of European Economic History,* 6, pp. 659–673.

Van Dijk M, and Szirmai, A. (2006) "Industrial Policy and Technology Diffusion: Evidence from Paper Making Machinery in Indonesia," *World Development*, 34, 12, pp. 2137–2152.