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Giacomo Domini[a]

Abstract. This work investigates the relationship between trade and technological specialisation in Italy, during the long time span ranging from Unification to the eve of the Second World War. To do this, new series of Italy's indices of specialisation in trade and technology are calculated on the base of official data. Empirical analysis, based on Spearman rank correlation coefficients and fixed-effects regression, shows the emergence of a positive relationship between specialisation in technology and specialisation in trade after the start of the country's modern economic growth, around the turn of the twentieth century. This, however, was uniquely driven by a negative relationship between technological specialisation and import shares, while no significant relationship between the former and export shares emerges. Furthermore, this finding excludes the most important sector, leading Italian industrialisation, i.e. textiles, the outstanding performance of which can be seen as largely determined by its being particularly suited to the country's factor endowment.

Keywords: innovation; trade; Italy; specialisation; comparative advantages

JEL classification codes: N73, N74, O14, O33

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1. Introduction

The existence of a bidirectional relationship, between technological change and international trade flows, is well established in international economics. On the one hand, international trade theories since the seminal work by Posner (1961) have acknowledged the central role of technology gaps as a major determinant of international trade flows (famously Krugman, 1979), in contrast with the previous Hecksher-Ohlin orthodoxy, only explaining trade on the base of factor endowments. This role is particularly stressed by neo-Schumpeterian or evolutionary accounts, which gained popularity in the 1980s (Dosi, Freeman, Nelson, Silberberg & Soete, 1988; Nelson & Winter, 1982), analysing the endogenous, microeconomic processes that govern technological change: a particularly important contribution along these lines is the trade model presented by Dosi, Pavitt and Soete (1990).

Technological progress affects trade performance under various forms: *process* innovations enhance productivity and reduce production costs, thus increasing a country's competitiveness on international markets; *minor product* innovations improve the quality of existing products, which become more appealing to buyers; *major product* innovations, widening the range of goods exchanged on international markets, provide innovators with a temporary monopolistic position in new products (Archibugi & Michie, 1998).

On the other hand, trade also has influences of various kinds on innovation (Onodera, 2008; Keller, 2010; Kiriyama, 2012). First, trade is an important channel of technology diffusion, as the technological content 'embedded' in traded goods flows from the seller to the buyer. Imports of capital goods are an important means, by which technology flows from advanced countries to less developed ones. Also exporters benefit from the diffusion of technological knowledge, as they come into contact with a broader set of technologies and have the possibility of acquiring elements of unmarketable 'tacit' knowledge by direct interaction with foreign traders. Finally, technology itself can be traded, in the presence of functioning and well-enforced Intellectual Property Rights.

In the empirical literature, the existence of a positive relationship between measures of innovative activity (mainly patents and R&D expenditure) and variously-defined measures of international trade performance has been observed since the first works addressing this issue and confirmed by subsequent analyses (*inter alia* Soete, 1987; Amendola, Guerrieri & Padoan, 1998; Wakelin, 1997; Laursen, 2000; Meliciani, 2001; Andersson and Ejermo, 2008).

This paper provides a contribution to this literature from an historical point of view, studying Italy from its Unification (1861) to the eve of the Second World War. While a number of analyses exist, providing evidence of a significant positive innovation-trade nexus for that country over recent decades (Amendola et al., 1998; Breschi and Helg, 1996; Malerba and Montobbio, 2000; Paci, 1991), to the best of my knowledge none has yet focused on the pre-war era. Although Italy's growth was fastest from the end of the Second World War to the early 2000s, the country experienced considerable growth and structural change also in the eight decades studied here (Felice & Vecchi, 2015; Toniolo, 2013): an overwhelmingly rural country in the aftermath of its unification, by the end of this long spell of time Italy had doubled its per capita GDP and had established itself as a producer and an exporter of manufactured goods. Trade played a fundamental role in these achievements, due to the structural openness of the Italian economy (the roots of which will be discussed below). Yet, over these eight decades, Italian trade was persistently characterised by specialisation in low-

technological content products, notably in textiles. The reason for this, as will be argued below, should be sought for in the latter being particularly suited to the country's factor endowment. This calls into question the significance of the innovation-trade nexus in Italian pre-Second World War development, rendering it an interesting case study.

The work is divided as follows. The next section will present the data and the variables employed, both on the side of international trade and on the side of innovation, and will deal with methodological issues. Section 3 will provide an historical account of Italy's economic growth in the period considered, of its international trade, and of its innovative activity. Section 4 will test empirically the presence of a relationship between patterns of specialisation in innovation and trade, in the case studied here. The main findings will then be summed up in Section 5.

2. Sources, data and methodological issues

This section discusses, on the side of both international trade and innovation, what type of data will be employed in the following analysis, what their sources are, and what variables will be constructed from them.

2.1. Trade data

The source employed for data on Italy's historical trade with foreign countries is the recent and authoritative Bankit-FTV database, produced by the Bank of Italy under the scientific direction of Giovanni Federico, Giuseppe Tattara and Michelangelo Vasta, that accurately reproduces all information about the country's import and export activity from 1862 to 1939, as it was recorded in the *Movimento commerciale del Regno d'Italia* (the country's official foreign trade publication, first published by the *Ministero delle Finanze*, and in later years by Istat). For each staple, available in the historical source for each year, the database provides information on quantity, unit value and total value of both imports and exports, as well as a classification code from the United Nations' Standard International Trade Classification, Revision 2, at the 5-digit level, which makes the data suitable for comparative and long-run analysis.[1]

Italy's trade specialisation will be gauged by means of the Michaely index (MI).[2] As a matter of fact, there exist a number of measures employed for this task. A fundamental one is the Revealed Comparative Advantage (RCA), introduced by Balassa (1965), comparing a country's export structure with that of the world (or of a selected group of countries): country i's RCA in product j is defined as the ratio between product j's share in country i's exports, and product j's share in world exports. Country i is said to be (under)specialised in product j if the pertinent RCA value is above (below) one. Though widely employed in empirical literature, the RCA presents some drawbacks: first, it requires world export data, which for the pre-Second World War period are very scarce, highly aggregated, and only available for few benchmark years; then, it only takes into account exports, while imports are neglected. This is a relevant omission, in

[1] Further information about the sources and the methods of elaboration of the database is provided by Federico, Natoli, Tattara and Vasta (2012, Ch. 2).

[2] This index was originally developed by Michaely (1967) as a measure of (dis)similarity between the countries' commodity composition, but can also be employed to gauge trade specialisation (Laursen, 2000, p. 43).

the presence of significant intra-industry trade flows – which, as will be shown below, was the case for Italy in the period observed.[3] By the contrary, the Michaely index takes into account imports as well as exports, and can be computed on the base of national trade data only. It is defined as

$$MI_{ij} = \frac{X_{ij}}{X_i} - \frac{M_{ij}}{M_i}$$

where X_{ij} (M_{ij}) are country i's exports (imports) of product j, and X_i (M_i) are total exports (imports) of the country. A country's trade specialisation in a sector is then gauged by the difference between the shares it accounts for in a country's exports and imports. The index varies between −1 and +1 and denotes (under)specialisation by positive (negative) values.[4]

The indices of trade specialisation employed in the following analysis will not be calculated on total trade, but on trade in those sectors that Lall (2000) has defined as *low-technology*, *medium-technology* and *high-technology*. The first of these labels identifies those sectors, characterised by mature technologies, where skill requirements are low and competitiveness is mainly driven by low wages; the other two refer to sectors characterised by 'difficult technologies', requiring advanced technical skills, where innovation plays an important role in building competitive advantages.[5] By the contrary, from the computation of the indices are excluded those sectors that Lall classifies as *primary* as well as, most importantly, *resource-based* manufactures, in which comparative advantages are largely given by factor endowments, e.g. the industries of simple foods and materials. This product selection is based on the assumption that the link between technological progress and trade is stricter, the larger is the technological content of traded commodities, and the more relevant is the role of innovation in determining comparative advantages.[6]

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[3] A third issue with RCA, which will be discussed below, is its asymmetry.

[4] Another index of trade specialisation, only based on national trade data, is the Contribution to Trade Balance (first presented in CEPII, 1983; also known as Lafay index), defined as

$$CTB_{ij} = \frac{X_{ij} - M_{ij}}{X_i + M_i} - \frac{X_i - M_i}{X_i + M_i} * \frac{X_{ij} + M_{ij}}{X_i + M_i}$$

(N.b. the index is typically rescaled, by multiplying it by an arbitrary constant.) Positive (negative) values denote (under)specialisation. This index presents the advantages, over the MI, of controlling for overall trade unbalances, and of weighing each sector by its share in a country's total trade. However, as Laursen (2000, p. 42) points out, 'the CTB measure correlates strongly with the Michaely index by definition, leaving the pros and cons of the Michaely index and the CTB alike. The two measures differ only if very large trade imbalances are present for a given country. Hence, in the real world the two measures are close to being identical'. Although Italian international trade was characterised by persistent trade deficits, using either index leads to identical conclusions (the results obtained by using CTB are available upon request from the author). This given, the Michaely index has been preferred because of its easier and more intuitive definition.

[5] As noticed by Vasta (2010, fn. 6), the adoption of Lall's classification for a very long time span raises the problem that one product might be high-tech at the moment it is introduced, and become low-tech as time goes by. However, the decades encompassed by the present work are rather homogeneous, from a technological point of view, as they are dominated by the technological paradigms and trajectories associated to the Second Industrial Revolution (1870s-1970s).

[6] Consistently with the criterion just illustrated, raw and thrown silk (SITC subgroup 6511) is not included among low-technology manufactures, unlike the rest of group 651, but is treated as primary, and therefore not used to calculate the trade specialisation indices, since a large part (around 80%) of its value was coming from the agricultural raw material, i.e. silk cocoons (Federico, 1997). This product had a huge importance in Italian trade, as it accounted for as much

Finally, in order to limit the influence of temporary factors on trade, the values of the MI are calculated over periods of three years, centred on the benchmark years which will be henceforth referred to (e.g. the MI for 1901 is based on trade from 1900 to 1902).

2.2. Innovation data

Technological innovation will be proxied by patents granted in Italy. The use of patents *per se* is standard practice, as they are one of the most important and widely employed measures of innovation, though having some well-known drawbacks (Griliches, 1990; Nagaoka, Motohashi & Goto, 2010). Furthermore, for historical analyses they often represent Hobson's choice, given the lack of data about other common proxies, e.g. R&D expenditure, previous to the Second World War.

The choice of using Italian patent data, however, requires some words of motivation: in fact, many works in the empirical literature make use of patents granted by countries other than that under analysis. While data on foreign-granted patents would be good to capture the performance of the most competitive and internationalised fringe of Italian innovators, it would not be suitable for providing a broader picture of Italian innovative activity (cf. Paci, Sassu, and Usai, 1997), a large share of which consisted of incremental innovations and local adaptations of foreign ones, or pertained to low-technological content sectors (Barbiellini Amidei, Cantwell and Spadavecchia, 2013; Giannetti, 1998). As a consequence, while patents were taken out at home to protect such innovations, not only because of the proximity of the domestic patent system, but also due to its being cheap and little demanding (the Italian patent system was based on registration and its fees were considerably low, by international standards; cf. Nuvolari & Vasta, 2015a), protection was in most cases not sought for beyond national borders. A further reason for using domestically-granted patents in this analysis is that the number of patents granted to Italians in foreign countries might be too small to establish a sensible classification and to perform any empirical exercise, especially for earlier years.[7]

Patent data from eight benchmark years (1865,[8] 1881, 1891, 1901, 1911, 1925, 1930 and 1935) will be employed, the source of which are the official publications of the *Ministero d'Agricoltura, Industria e Commercio*, containing the lists of patents granted by the Kingdom of Italy.[9] In these publications, patents were classified into several categories, the number and type of which gradually evolved, until a final structure was reached in the mid-1890s, made of 25 categories: this classification framework will be adopted in this work.[10] In order to make data of different nature

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as 30% of total Italian exports until the 1900s; then it settled down at 15-20% until the mid-1920s, and eventually collapsed during the Great Depression.

[7] To make an example, the number of patents granted in the United States to Italians increased from less than 10 per annum in the 1880s and before, to a peak of 148 in 1931, before setting back to around 90 p.a. in the late 1930s (USPTO, 1977).

[8] Since the number of granted patents was relatively low at that time, an average for the period 1864-1866 will be employed for this benchmark year.

[9] Ministero di Agricoltura, Industria e Commercio (MAIC), *Bollettino industriale del Regno d'Italia* (for years until 1876); MAIC, *Bollettino delle privative industriali del Regno d'Italia* (from 1877 to 1901); MAIC, *Bollettino della proprietà intellettuale* (from 1902 onwards).

[10] This taxonomy was not based on a purely technical criterion, unlike e.g. that of the United States: in fact, it is more of a product classification, mainly based on the sector of use. For example, special-purpose machinery is typically classified in the category of the final products it is used for, e.g. food-processing machines into the category of food.

comparable, trade data has been re-classified according to the Italian patent classification system, on the base of a concordance between that and SITC, elaborated *ad hoc* for the present work. The classification and the concordance are presented in Appendix A; complete data, classified according to this system, are displayed in Appendix B.

As a measure of technological specialisation, Soete (1987) has introduced the *Revealed Technological Advantage* (RTA), defined in the vein of Balassa's RCA as the ratio between the share of a sector in a country's patents granted in a certain country, and the corresponding share in total patents granted there (typically excluding patents granted to domestic residents).[11] RTA is asymmetric (as RCA is), as it varies between zero and infinity, with an average of 1: this not only causes it not to be comparable on both sides of unity, but hinders the reliability of the statistics in regression analysis, as a skewed distribution violates the assumption of normality of the error term. To overcome this issue, Dalum, Laursen and Villumsen (1998) have suggested taking the following transformation:

$$RSTA = \frac{RTA-1}{RTA+1}$$

The resulting measure, known as *Revealed Symmetrical Technological Advantage* (RSTA) is symmetrical, as it takes values between −1 and +1, with an average of zero. Again, (under)specialisation is denoted by positive (negative) values. This normalised index will be adopted in the rest of this work to measure Italy's technological specialisation.

3. Italy from Unification to the Second World War

Simon Kuznets (1966) defined *modern economic growth* as 'a sustained increase in per capita or per worker product, most often accompanied by an increase in population and usually by sweeping structural changes', among which is the process of industrialisation. Italy started its modern economic growth in the long period covered by this work. Table 1 illustrates the rate of growth of the country's per capita GDP, over the whole period and some sub-periods. The long-run rate was 0.75% p.a., but growth was not homogeneous over the period: the table clearly reveals that, in the first four decades following Unification, it was below the long-term average; then a dramatic change of pace occurred at the turn of the century. During the period preceding the outbreak of the First World War, known as the Giolittian era,[12] the rate of growth more than doubled, with respect to the earlier decades. In the subsequent quarter of century, after an initial setback during wartime, growth rates were again higher than long-period average, though lower than during the Giolittian boom.

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[11] In formula:

$$RTA_{ij} = \frac{P_{ij}/P_i}{P_{tj}/P_t}$$

where P_{ij} are country i's patents in sector j, P_i are total country i's patents, P_{tj} are all patents in sector j 's exports, and P_t are total patents.

[12] The two decades preceding the First World War are usually named *età giolittiana*, after Giovanni Giolitti (1842-1928), the most influential statesman of the time, serving five times as Prime Minister between 1892 and 1921, as well as Minister of the Interior and Minister of the Treasury.

In accordance with Kuznets's definition, this quantitative change came along with qualitative transformations of Italian economy, which experienced a relevant process of industrialisation: the primary sector, whence almost half of value added originated at the time of Unification, underwent a slow but steady decline; conversely, the share of value added coming from industry (initially below one-fifth) grew ever larger. By the end-1930s, the primary and secondary sectors accounted for an equal share of Italian GDP.

Despite economic growth, the real wages of Italian workers remained quite stable during this very long period. Malanima (2007) has shown that they underwent a sharp fall in the period 1750-1820; then they remained steady during the central decades of the 19th century and rose in the last decades of the century. Yet, Williamson's (1995) series of relative real wages significantly downsize the latter increase: compared to those of industrialised economies, Italian real wages increased very slightly, if at all, until the turn of the century. Only since the late Giolittian years they enjoyed a significant increase, which however was compensated by a decline during the inter-war period: by the eve of the Second World War, they had retrenched to their late-19th century levels. Based on these data, Nuvolari and Vasta (2015b, pp. 285-287) claim that the stagnation of Italian comparative real wages represented, over the long run, an important compensating factor for the country's low technological competitiveness, which may have pushed it 'to adopt a peculiar road toward "modern economic growth" based on the combination of low real wages and the intensive use of unskilled labor'. This is a crucial point that must be kept well in mind while reading the rest of this work.

3.1. International trade

In line with the country's economic expansion, Italian trade with foreign countries grew almost constantly over the whole period considered, apart from two downturns corresponding to the First World War and the Great Depression, due to the general contraction of international exchanges. As a result, at 1929's peak, constant-price exports were 6.1 times higher than they were in the mid-1860s, while imports had grown by a factor of 7.3. The subsequent crisis brought about a sharp fall in traded volumes; still, at 1936's minimum, exports and imports were 3.6 and 3.2 times higher than in the post-Unification years, respectively. Italian trade not only increased in absolute terms, but also relative to GDP: the *openness* of Italian economy – defined as the ratio of the sum of imports and exports to GDP – which was 10% in 1862, reached 27% at the end of the Giolittian era and, after a fall during the war, peaked at 30% in 1929; then it dropped by half in the following decade (Federico and Vasta, 2010; Federico et al., 2012; Vasta, 2010).

The main reason behind the importance of trade to Italian economy was the country's scarcity in natural resources, forcing it to import large supplies of raw materials and fuels. Moreover, the domestic market was large (counting more than 25 million residents in 1861, and more than 40 million in the late 1930s) but weak, as demand was restricted by the predominantly agricultural structure of Italian economy and by compressed wages. Therefore, like smaller open economies, Italy had to allocate a large share of its product abroad. The process of industrialisation accentuated this 'structural openness': on the one hand the domestic market became richer and more absorptive, and the developing industrial sector demanded ever larger supplies from abroad; on the other hand, increasing imports had to be financed by expanding exports.

The technological content of products traded by Italy underwent big changes over the decades considered. Figure 1 shows the shares in Italian exports (top) and

imports (bottom), accounted for by Lall's low-tech and 'difficult-technology' (i.e. mid-tech plus high-tech) products,[13] as well as the share of *low-tech textiles*.[14] The starting point of the country is particularly important, in order to better interpret the subsequent achievements: in 1862, in the aftermath of Unification, products characterised by at least low technological content overall represented a very small part (7.4%) of Italian exports, meaning that over 90% were accounted for by primary commodities (64.5%) and resource-based manufactures (27.7%); also on the import side did low-to-high-tech products represent a minority (34.9%), while 46.2% of Italian imports were primary and 18.2% were resource-based. The most striking feature of the chart are the dynamics of low-tech manufactures, which experienced a spectacular increase on the export side and a comparable decrease on the import side. After a substantial stagnation at 5% during the 1860s, the low-tech export share made a first, relevant jump in the early 1870s, and oscillated within the 10%-15% band until the 1890s, when it started a four-decade-long rise. If wartime is excluded, a peak was reached in 1929, at 32.8%. A major drop ensued, down to less than 20%, during the depression years. Finally, a recovery took place in the late 1930s, to be associated with trade with colonies. On the side of imports, apart from an initial rise in the 1860s, the share of low-tech products experienced a 30-year-long decrease, from more than 30% in the early 1870s to slightly more than 10% in the early 1900s; then it remained steady throughout the 1920s, and slightly decreased in the last decade observed.

It is important to observe that, over the whole period in the case of imports, and from the 1890s onwards in the case of exports, the dynamics of low-tech manufactures are largely explained by those of low-tech textiles. It thus appears that the development of this industry allowed Italy, in a first phase (from the 1870s to the 1890s) to substitute textile imports for domestic ones, and in a second phase (from the 1890s to the 1920s) to even direct this production abroad, thus establishing itself as an exporter of manufactured products.[15] As it will be seen below, the roots of Italy's strength in textiles are by no means to be sought for in technological advantage. A more plausible explanation is this sector's suitability to the country's factor endowment, as it was intensive in unskilled labour and little dependent on scarce resources, such as coal. Textiles represented for Italy a formidable opportunity to establish itself in manufacturing, overcoming its resource-poverty.

Let us now turn our attention to the series of 'difficult-technology' traded products, i.e. those characterised by medium and high technological content. Italy exported a negligible amount of such manufactures, until the mid-1890s. After the start of modern economic growth, however, their share in exports began to trend upwards, exceeding 10% in the late 1920s, and it even accelerated in the following decade,

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[13] Mid-tech and high-tech sectors are considered together in the following because, while the distinction between these two categories, on the one hand, and low-tech manufactures, on the other, is relevant due to the main driver of competitiveness being different (namely, innovation for the former and cost for the latter), a finer distinction between high- and medium-technological content products is of no real interest for the purpose of this work, as in both cases innovation represents an important determinant of comparative advantages. Furthermore, most of the technologies classified under label 'high-tech' were still at an early stage in the period considered, and therefore represented a very limited share in both exports and imports (Federico & Wolf, 2013, pp. 336-7).

[14] *Low-tech textiles* are products, belonging to category 19 of Italian patent classification, that are labelled as *low-tech* by Lall, minus raw and thrown silk (SITC 6511), cf. fn. 6.

[15] In the words of Vera Zamagni (1993, p. 85), the textile sector, 'although not the most technologically advanced of the modern industries, certainly predated the others (especially in the case of silk industry), boasted a long tradition, and played a very important role in the rise of an industrial milieu in Italy'.

doubling by the end of the 1930s. Although this last boost in complex exports was largely due to the 'colonies effect', i.e. to the export of sophisticated goods towards the members of the ephemeral Italian colonial empire (Federico & Wolf, 2013; Vasta, 2010), a significant shift of Italian export composition towards more sophisticated goods seems unquestionable.[16]

The share of complex products in imports started to rise much earlier than that in exports: an increasing trend can be observed from the early 1880s to the late 1900s, peaking at more than 16% in 1908; then this series oscillates around 10% until the 1930s, when a new steady growth can be observed. The long pre-war positive trend of sophisticated products' imports was an important part of the process of capital accumulation undergoing in those decades (Baffigi, 2013; Broadberry, Giordano & Zollino, 2013), which was particularly intense in the 1900s and can be seen as an important precondition for the structural shift of Italian export structure towards more sophisticated goods that mainly took place during the inter-war period. As will be pointed out below, the import of sophisticated manufactures from abroad was not only aimed at capacity-building, but it was also a very important means, for little-innovative Italy, to absorb the most advanced technologies, as well as to develop its own technical capabilities, by imitating and adapting foreign technologies. By the contrary, the earlier shift from primary and resource-based products to low-tech ones, occurring during the Giolittian era, does not seem to be so related to innovation, as it was led by the textile sector.

After this aggregate picture, Figure 2 will now provide a more accurate insight of the structure of Italian exports (X) and imports (M). The chart shows the share of eight broad groups, gathering the twenty-five categories of Italian patent classification, for four benchmark years, respectively representing the earliest post-Unitarian phase, the years just before the start of modern economic growth, the end of the Giolittian industrial boom, and the interwar period. A first glance reveals that exports became more concentrated over time, while the converse is true for imports. This is primarily explained by the share of the group 'textiles and apparel', rising from one-half of exports before the industrial take-off to two-thirds afterwards, while decreasing from as much as two-thirds of imports in the early 1870s to approximately 30% during and after the late Giolittian era – a not much larger share than those of groups 'Mining, metalworking and machinery' and 'Electricity, instruments and chemicals'. Furthermore, a relevant steady decrease can be clearly noted in the exports share of the residual group 'Other': a closer inspection of the Bankit-FTV database reveals that this reflects the dynamics of worked coral, representing around 60% of the group exports in the 1870s and still around 50% until the early 1900s, before halving in the second part of that decade, and fading out over the following twenty years.

The groups 'Mining, metalworking and machinery' and 'Electricity, instruments and chemicals' represented a much larger share in imports than in exports, especially after the start of modern economic growth. While, for the former group, this fact can be explained by a 'natural' disadvantage, encountered by resource-poor Italy in 'heavy' industries, the case of the latter group should rather be seen as a failure to specialise in the sectors linked to the technologies of the Second Industrial Revolution, despite their being much more favourable to Italy's resource endowment, probably due to lack of

[16] Blattman, Hwang and Williamson (2007) claim that Italy converged towards the 'normal' export composition for advanced countries: its share of primary products in exports was twice the average of Core countries in 1870, but it was only one-third higher than that, at the eve of the Second World War.

adequate capabilities. The same applies to the group 'Agriculture and food', as its larger share in imports than in exports is caused by highly unbalanced flows of agricultural machinery and fertilisers. [17] The appearance of group 'Transport' on the export side, since the Giolittian era, is a consequence of the establishment of automotive industry in the country,[18] the share of which steadily increased from practically zero after the turn of the century to 12% of Italian exports in low-, mid- and high-tech manufactures (3.8% of *total* exports) in the mid-1920s, before entering a decade of decline, and then again booming in the late-1930s, doubling the mid-1920s peak, because of the 'colonies effect'. Likewise, in the 1930s the arms race of the fascist regime caused the navigation and aircraft industries to expand.

The considerations just made allow us to easily interpret the pattern of Italian trade specialisation, as suggested by the Michaely index, shown in the top part of Figure 4 for all the 25 categories of Italian patent classification. Since it has been shown that the most important changes in the structure of Italian trade occurred during the start of modern economic growth, around the turn of the century, only the last three benchmark years of Figure 2 are displayed, in order for the figure to be more easily readable. Consistent with what has been stated above, an impressive shift can be observed in the textile sector (category 19), from a quite severe under-specialisation before the start of modern economic growth, to an extraordinarily high level of specialisation afterwards. Conversely, the high specialisation level of the residual category (number 25) before the industrial take-off cancelled out afterwards, as a consequence of the fall of worked coral's exports. The only sector, characterised by a marked positive specialisation in all three benchmark years shown in the figure, is apparel (20). A light specialisation can be observed since the 1910s in the category of vehicles (7) and in the 1930s in navigation and aircraft (8). Many categories, by the contrary, feature permanently negative values of the trade specialisation index: agriculture (1), 'heavy' industries (3 to 5), instruments (10), leather (21) and, since the start of modern economic growth, the sectors most directly linked to the Second Industrial Revolution, i.e. electricity (9) and chemicals (24). The other sectors present practically nil values of the Michaely index.

To draw some general conclusions, Italian trade was generally specialised in traditional, unsophisticated manufactures, with the only exception of vehicles, in which a moderate specialisation was acquired since the late Giolittian era. In the terms of the taxonomy introduced by Pavitt (1984), Italy presented an advantage in less technology-intense *supplier-dominated* and *scale-intensive* industries; while it had a general disadvantage in the more technology-intense *specialised-suppliers* sectors of metals, mechanics and instruments, as well as in *science-based* electricity and chemicals. This pattern is largely consistent with the country's factor endowment: abundance in cheap unskilled labour favoured Italy's specialisation in unsophisticated manufactures;[19] conversely, scarcity in resources prevented heavy industrial sectors from developing.

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[17] Notice that the presence of relevant intra-industry trade flows, i.e. of significant inflows and outflows within the same group, and at the same time the imbalances between these opposite flows, provide strong legitimation to the choice, made in the present work, of using a measure of trade specialisation, based on both exports and imports.

[18] FIAT, the largest Italian carmaker, as well as one of the largest companies in the country since its foundation, was established in 1899. Before FIAT, only few carmakers had existed in the country: Miari & Giusti, which can be regarded as the first proper car producer in Italy, had been established in 1894, a decade after the birth of Germany's Benz (1883).

[19] This is in line with the claim by Caselli and Coleman (2006) that firms in poorer countries select technologies that are complementary with unskilled labour, which they are abundant in; while rich

3.2. Innovative activity

Long-term works on Italian innovative activity have underlined, on the one hand the structural weakness of the country's National Innovation System[20] (Nuvolari & Vasta, 2015b), and on the other hand the crucial importance of foreign technology to Italy's development (Barbiellini Amidei et al., 2013). Some relevant transformations did however occur during the period considered in this study, which will now be reviewed.

The start of modern economic growth, which as we have seen had profound implications on Italy's international trade, also produced structural change in Italian innovative activity, as measured by patents. Figure 3 shows that patents granted in Italy started to increase at a much faster pace than in the past, since the last years of the 19th century. Interestingly, the steep rise that took place in the early 1910s was largely contributed to by patents granted to Italian residents – a symptom of increased domestic innovative activity. After a fall of patenting activity during the war, which unsurprisingly hit foreigners more than residents, an effervescent and volatile recovery took place in the 1920s – probably due to the restart of a fully functional patent system after the war shock[21] and to legislative changes –,[22] which was led by residents' patenting in the first half of the decade, and by foreigners' afterwards. In the 1930s, residents' patenting increased, but foreigners' correspondingly declined, so that the level of total patenting remained steady: this reflects the increasing closure caused by the Great Depression, at an international level, and by the autarkic policies of the fascist regime, at a national one.[23]

Similar trends characterised patents granted abroad to Italians: the shares of patents granted to Italian residents in total patents granted in the major foreign countries steadily increased (if war years are not considered) until the mid-1920s, when they reached a peak; they then declined for some years and, in some cases, recovered during the 1930s (notably not in Britain and America; while in Germany a recovery did occur, but it might be related to the political proximity of the Italian and German regimes in that decade; see Barbiellini Amidei et al. 2013, Figures 14.1-14.3). Italian inventors represented a larger share in the French, Spanish and Swiss patent systems, both culturally closer and less demanding, than in the more distant and challenging German and Anglo-Saxon systems.

The overall picture suggests that Italian innovative activity improved in a marked way during the Giolittian era and in the first post-war years; while the picture is not clear-cut afterwards: on the one hand, a moderate increase in patent volumes can be

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countries, having a large availability of skilled labour, choose technologies more suited to skilled workers.

[20] For a thorough review of this concept, see Soete, Verspagen and Ter Weel (2010).

[21] A confirmation of this view comes from a question made in 1922 by MP Alice to the Minister of Agriculture, Industry and Trade about (my translation) 'the measures he intends to adopt to reorganise the important Intellectual Property service, where more than 35,000 patent, design and trademark applications lie unprocessed' (*Atti Parlamentari Camera dei Deputati. Tornata di Sabato 18 Marzo 1922*, p. 3285).

[22] Patent legislation was reformed in 1923 by royal decrees n. 1970 (*Disposizioni sul servizio delle privative industriali*) and n. 2878 (*Modificazioni alle norme per rilascio degli attestati di privativa industriale*). Notably, patent renewals were abolished.

[23] Barbiellini Amidei et al. (2013, pp. 391-3) also analyse the trend of less formalised innovative activities, such as design and models, and trademarks. However, they find that the Italian performance in this respect was modest until the 1930s, and only started to catch-up with the main foreign competitors during the 1960s.

observed; on the other hand, the Italian patent system became less internationalised, and Italy lost ground in the most competitive markets, in terms of patent shares.

Foreign technology played a particularly important role, in the building of Italian own innovative capabilities, especially during the Giolittian era. Investigating the drivers of Italian innovative activity by econometric analysis, Barbiellini Amidei et al. (2013, Table 14.2) find that the improvement in Italian innovativeness during the 1889-1919 period was significantly and positively associated to machinery imports and inward Foreign Direct Investment, as well as to the share of university students enrolled in Engineering; whereas in 1920-1948, the only significant effects were those of the share of manufacturing in Italian GDP and, again, the share of Engineering students (though with a much reduced coefficient, with respect to the previous period) – a symptom of the increasingly closed nature of Italian development. In a comparative perspective Giannetti (1998, Ch. 2), analysing the ratio between investment in capital goods and patents, has pointed out that Italy relied on imitation of foreign technologies much more than Spain, France, Germany, and the United Kingdom did, both in the 1890s and in the late 1930s, even though an improvement occurred over the period.

Patents taken out by foreigners were also an important channel of technological transfer to Italy. Indeed the Italian patent system was characterised by large openness: if the war and first post-war years are excluded, the share of foreign patents on total patents granted in Italy oscillated between 55% and 70% from the 1880s onwards (Figure 3, right scale), similar to that of smaller open economies such as Belgium and Switzerland, and far above that of large advanced countries (Nuvolari & Vasta, 2015b, Table 3). This high degree of openness may be explained by Italy's patent system being based on registration, and not discriminating foreign inventors, as well as by the size of Italian economy, rendering it an appealing market (Nuvolari & Vasta, 2015a, pp. 855-866; Nuvolari &Vasta, 2015b, pp. 279-280).

The importance of foreign inputs during the Giolittian era should not eclipse the significance of Italian absorptive capabilities, given by skilled human capital. While Italy was lagging severely behind major countries in terms of basic education, the situation was better concerning technical education: the share of university students enrolled in Engineering more than doubled in the 1900s and 1910s, from 10% to 25%; the same applies to the share of secondary-school students, enrolled in technical high schools (which, however, also include commercial ones): in this latter case, growth continued well into the 1920s. Both shares then fell during fascism, after the Gentile reform of the educational system. Despite this, Italy's stock of engineers can be considered adequate to its industrial needs, during the first important phase of Italy's modern economic growth (Barbiellini Amidei et al., 2013; Nuvolari & Vasta, 2015b; Vasta, 1999). This was a crucial element, establishing the above-mentioned link between foreign technology and indigenous innovativeness, and fostering the ability of Italian firms to successfully employ foreign machinery and to adapt it to local needs.[24]

A final element to consider, in order to understand the development of Italian innovative activity, is the structure of Italian industry, which was specialised in traditional sectors, where innovation relies on formal research activities very little if at all, while it was weak in sectors characterised by high technological opportunity and

[24] By the contrary, Nuvolari and Vasta (2015b, pp. 280-282) show that another domestic input, namely scientific activity, does not seem as important for Italian innovative activity. Despite an increase in academic publications, 'major difficulties in the technology transfer of scientific results from universities to firms' existed, due to lack of adequate bridging institutions between universities and industry.

patenting intensity. Italian big manufacturing firms – mainly family-controlled businesses – were 'strongly rooted into the light sectors of the First Industrial Revolution up to the 1930s' (Giannetti & Vasta, 2010, p. 46)[25] and tended to focus on incremental innovations and local adaptations of technologies acquired from abroad (Giannetti, 1998). Finally, the country's large availability of unskilled labour and the low levels and sluggish dynamics of real wages represented a competitiveness-compensating factor for little-innovative Italian firms, and may have discouraged, over the long run, the search for innovations that would increase the productivity of labour and favour the mechanisation of production (Nuvolari & Vasta, 2015b).

After this account of the levels and trends of Italian innovative activity, let us eventually see what the sectors of Italy's relative strength in patenting were. Figure 4 (bottom) displays Italy's Revealed Symmetrical Technological Advantage indices, calculated on the base of Italian patent data, for 1891, 1911 and 1930. All over the period, Italy featured a marked technological specialisation in the *supplier-dominated* and scale-*intensive* sectors of agriculture (1), food and beverages (2), hygiene and safety (12), construction and building materials (13 and 14), and furniture (18; much increasing in the inter-war period). A remarkable advantage in apparel (20) also emerged during the inter-war period. However, specialisation was also developed, since the start of modern economic growth, in more complex categories related to transport, namely vehicles (7) and navigation and aircraft (8; to which can be associated the sharp reversal from negative to highly positive of the warfare category, 11, during fascism).

Persistent disadvantages, on the contrary, characterised 'heavy' industries (3 to 5), electricity (9; with the exception of the late Giolittian era), instruments (10), glass and ceramics (15; since the turn of the century), graphics (23), chemicals (24). Moreover, and most importantly, a permanent negative technological specialisation characterised textiles (19). This fact, only apparently surprising, shows that Italy's strength in this sector did not rely on technological advantage: it was rather driven by the sector's suitability to Italy's factor endowment, as it was intensive in unskilled labour and little dependent on scarce resources.

4. A link between trade and technological specialisation

The review carried out in the previous section has revealed the presence of relevant similarities between Italy's patterns of specialisation in technology and trade. Indeed in both cases Italy featured persistent advantages in traditional, low-technological content sectors, and disadvantages in more advanced ones. A very important exception to this rule is represented by the textile sector, the excellent trade performance of which seems to be totally unrelated to Italian innovative activity in the sector, as it couples strong trade specialisation with serious technological under-specialisation.

A graphical confirmation of these insights is provided by Table 2, cross-tabulating the two patterns of specialisation. It is only based on the years after the turn

[25] Carrying out an analysis *à la Chandler* of Italian big businesses over the 20th century, the same authors show the dominance of traditional sectors, among top 200 manufacturing enterprises, before the Second World War. The textile sector accounted for around one-fourth of them (though decreasing from 64 in 1913 to 41 in 1936), followed by the industries of food, transport, metals, and chemicals, each representing 10%-20% of total. It is important to notice that chemicals were dominated by less technology-intensive 'new' products, like nitrogenous fertilisers, and by 'old' products, derived from the processing of animal fats (Vasta, 1999).

of the century, as it has been noticed that some major changes (even reversals in the sign of specialisation indices) occurred around that period, while patterns were relatively stable afterwards. The two specialisation profiles display considerable consistency, as most sectors lie on the bottom-left-to-top-right diagonal, and only two sectors are on the top-left and bottom-right cases, meaning severe inconsistency, respectively Textiles and Agriculture (including agricultural machines, manufactured fertilisers, insecticides and the like).

The same argument can be formally verified by means of a correlation test. The non-parametric Spearman rank correlation coefficient has been preferred over the more common Pearson coefficient, since the former, unlike the latter, does not rely on restrictive assumptions such as linear relationship, absence of significant outliers and approximately normal distribution of variables. This makes it particularly suitable for the present analysis, where the number of observations per year is limited (maximum 25). No lag has been introduced between the indexes of specialisation in technology and trade, as causality may run both ways in the innovation-trade nexus; hence any assumption about its direction and dynamics would imply a high degree of arbitrariness.

Table 3 displays the correlation coefficients between technological specialisation (RSTA), on the one hand, and trade specialisation (as given by the Michaely Index, MI), export shares (XSHA) and import shares (MSHA), on the other, in the observed benchmark years. For each relationship, coefficients both including and excluding the textile sector are displayed. In either case, a significant positive relationship emerges, between RSTA and MI, during the inter-war period. If textiles are not included, the relationship becomes stricter (as signified by larger and more significant coefficients) and it extends back in time to the late Giolittian era. The table reveals that the relationship between the two types of specialisation is totally driven by imports. Indeed no clear pattern of correlation between RSTA and XSHA emerges. The correlation coefficients are only mildly significant for the first and the last of the benchmark years considered. What is more, they have negative sign, whereas a positive relationship would be expected. This paradoxical finding is largely due to the presence of the textile sector, featuring the largest export shares despite a very serious technological under-specialisation: in fact, if textiles are not considered, both the magnitude and the significance of the coefficients decrease (the p-value of the coefficients, not displayed, is 9% for 1865, and 8% for 1935, very close to the 10% critical threshold). In any case, no evidence is provided by the table of a positive correlation between innovation and exports. By the contrary, between RSTA and MSHA a significant negative relationship clearly emerges during the Giolittian years, consistent with theoretical expectations.

The final means by which the thesis of this paper is tested is a formal econometric model. The panel structure of the data allows to account for those variables, not explicitly included in the model specification, that vary across categories but not over time. The following *dummy-variable fixed-effects* regression is estimated:

$$MI_{it}^{*} = \beta_0 + \beta_1 RSTA_{it}^{*} + \beta_2 Text_t + \sum_{i=1}^{n-1} \gamma_i E_i + u_{it}$$

where i = 1, …, 25 are the categories of Italian patent classification, and t = 1865, …, 1935 are the benchmark years employed in this analysis. The same equations are estimated, having XSHA and MSHA as dependent variable, in the place of MI. E_i are category dummies (entity fixed effects); *Text* denotes a linear time trend for the category of textiles, which was introduced to account for those factors, other than innovation, lying at the roots of the impressive improvement in this sector's MI, which cannot be accounted for by the sole categorical fixed-effects dummy. Asterisks attached to the dependent variable and to regressor RSTA indicate that these variables have been

transformed, by adding one (to rescale non-positive values) and then taking the natural logarithm; therefore, coefficients can be interpreted in percent terms. For each of the dependent variables considered, regressions have been run, both over the whole period, i.e. employing data from all the benchmark years, and over two sub-periods, splitting the benchmark years into two sets (1865 to 1901, and 1911 to 1935), respectively representing the periods before and after the industrial take-off. Standard errors that are robust to both heteroskedasticity and autocorrelation have been employed.

Consistent with the results from Spearman correlation analysis, in none of the regressions over the whole period and the first sub-period the dependent variable emerges to be significantly related with RSTA; however, in the second sub-period, a significant positive relationship between RSTA and MI, and a significant negative one between RSTA and MSHA can be observed. Textiles' trend turns out to be highly significant in all regressions, with a positive sign on those having MI and XSHA as dependent variable, and a negative one on those having MSHA as dependent variable. However, the magnitude of the coefficients attached to the trend decreases from the first to the second sub-period, which reflects the fact that this development mainly took place during the Giolittian era, as was pointed out in Section 2.[26] The adjusted R^2 is very high in all regressions, ranging between 0.74 and 0.98.

To sum up, a significant positive relationship between Italy's patterns of specialisation in technology and trade emerged after the country started its modern economic growth, around the turn of the 20th century. However, this link was uniquely driven by a negative relationship between technological specialisation and import shares, while no statistically significant relationship can be observed, between the former and export shares. Furthermore, this innovation-trade nexus does not appear to work for the sector leading Italian industrialisation, i.e. textiles, the outstanding performance of which was driven by factors other than technological advantage. As it was argued above, especially important seems to be its being suited to Italy's factor endowment.[27]

5. Conclusions

This paper has investigated whether a relationship between Italy's patterns of specialisation in technology and trade existed in the pre-Second World War era, which has been neglected by the empirical literature on this issue, despite its importance in Italian economic history. Indeed those were the decades when Italy started its modern economic growth, and its international trade and innovative activity experienced quantitative and qualitative changes.

To settle this issue, new series of Italy's indices of specialisation in trade (Michaely index) and technology (RSTA) have been constructed, based on official data about Italy's trade in manufactures and patenting activity. An inspection of the patterns

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[26] Results concerning RSTA are robust to removal of variable *Text*.

[27] Let us stress once more that the indices of trade specialisation, employed in this analysis, are only based on trade in products characterised by at least low technological content, thus excluding both *primary* products and *resource-based* manufactures. If Michaely indices are also calculated on resource-based products instead, then the coefficient attached to RSTA becomes non-significant in all specifications (regression outputs are available upon request to the author). This comes as no surprise, since the very definition of 'resource-based' sectors implies that comparative advantages are largely determined by factor endowment.

resulting from these measures has been carried out, the insights from which have been formally tested by means of Spearman rank correlation analysis and fixed-effects regression. The central result is the emergence of a positive relationship between Italy's patterns of specialisation in technology and trade since the late Giolittian era, that is after the country entered its modern economic growth and experienced its first important phase of industrialisation. In this nexus, causality might run both directions: on the one hand, increasing technological specialisation in products characterised by a higher technological content enhanced the competitiveness of domestic 'sophisticated' products *vis-à-vis* foreign ones, thus fostering demand for the former; on the other hand, as such industries expanded, domestic innovative efforts and investment in the acquisition of adequate technical capabilities were stimulated, resulting in increasing technological specialisation.

However, two important qualifications must be added to this core finding. First, this relationship was uniquely driven by imports: in fact, no significant positive correlation is found between RSTA and export shares, while a significant negative relationship can be observed between RSTA and import shares. This may indicate that expanding Italian 'sophisticated' productions could successfully compete on the domestic market – which resulted in an import substitution process – but were not yet able to challenge competitors on international markets.

Second, and even more important, this innovation-trade nexus does not appear to work for the textile sector, which couples (after the start of modern economic growth) Italy's highest trade specialisation with a marked, persistent technological under-specialisation. This is a relevant exception, given the leading role of this sector in the Italian process of industrialisation. Textile industry allowed Italy to establish itself first as a producer then as an exporter of manufactured goods, in spite of resource-poverty, thanks to its being intensive in abundant and cheap unskilled labour, and little dependent on scarce resources, like coal. It appears that it was this suitability for Italy's factor endowment, rather than technological advantage, that drove the outstanding trade performance of this sector.

Overall, the results of the present paper reveal a duality in Italian early industrial development: on the one hand, the claim by Nuvolari and Vasta (2015b), that Italian comparative low real wages represented a compensating factor for the country's low technological competitiveness, is confirmed for the leading sector of textiles. On the other hand, a more 'optimistic' nuance is added to that claim, as it is observed that, though with the notable exception of textiles, advantages in trade and innovation started to be related, after the beginning of the country's modern economic growth.

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Table 1. Average rates of growth of Italian per capita GDP, 1861-1936.

	%
1861-1936	0.75
1861-1900	0.63
1900-1913	1.69
1913-1919	-1.52
1919-1936	1.12

Source: own calculations on the series from Baffigi (2013).

Table 2. Cross-tabulation of Italy's specialisation patterns in technology and trade, 1900-1939.

	Persistent technological under-specialisation	Unstable/limited technological specialisation	Persistent technological specialisation
Persistent trade specialisation	Textiles	Apparel	Vehicles
Unstable/limited trade specialisation		Railways; Lighting; Other industries	Food and beverages; Navigation and aerospace; Weapons; Hygiene and safety; Construction; Building materials; Furniture
Persistent trade under-specialisation	Mining and metal production; Metal, wood and stone working; Motors and machines; Electricity; Minute mechanics and instruments; Glass and ceramics; Heating, ventilation and cooling; Paper; Graphics; Chemicals	Leather	Agriculture

Table 3. Spearman correlation coefficients between RSTA and various trade variables.

	MI		XSHA		MSHA	
1865	0.087	-0.096	-0.529**	-0.443*	-0.340	-0.208
1881	0.020	-0.024	-0.089	-0.030	-0.216	-0.177
1891	0.068	0.066	-0.079	-0.085	-0.190	-0.198
1901	0.160	0.248	-0.336	-0.292	-0.412**	-0.379*
1911	0.218	0.362*	-0.309	-0.222	-0.517***	-0.460**
1925	0.386*	0.497**	-0.232	-0.164	-0.455**	-0.401*
1930	0.432**	0.557***	-0.252	-0.196	-0.540***	-0.509**
1935	0.525***	0.609***	-0.394*	-0.364*	-0.572***	-0.554***

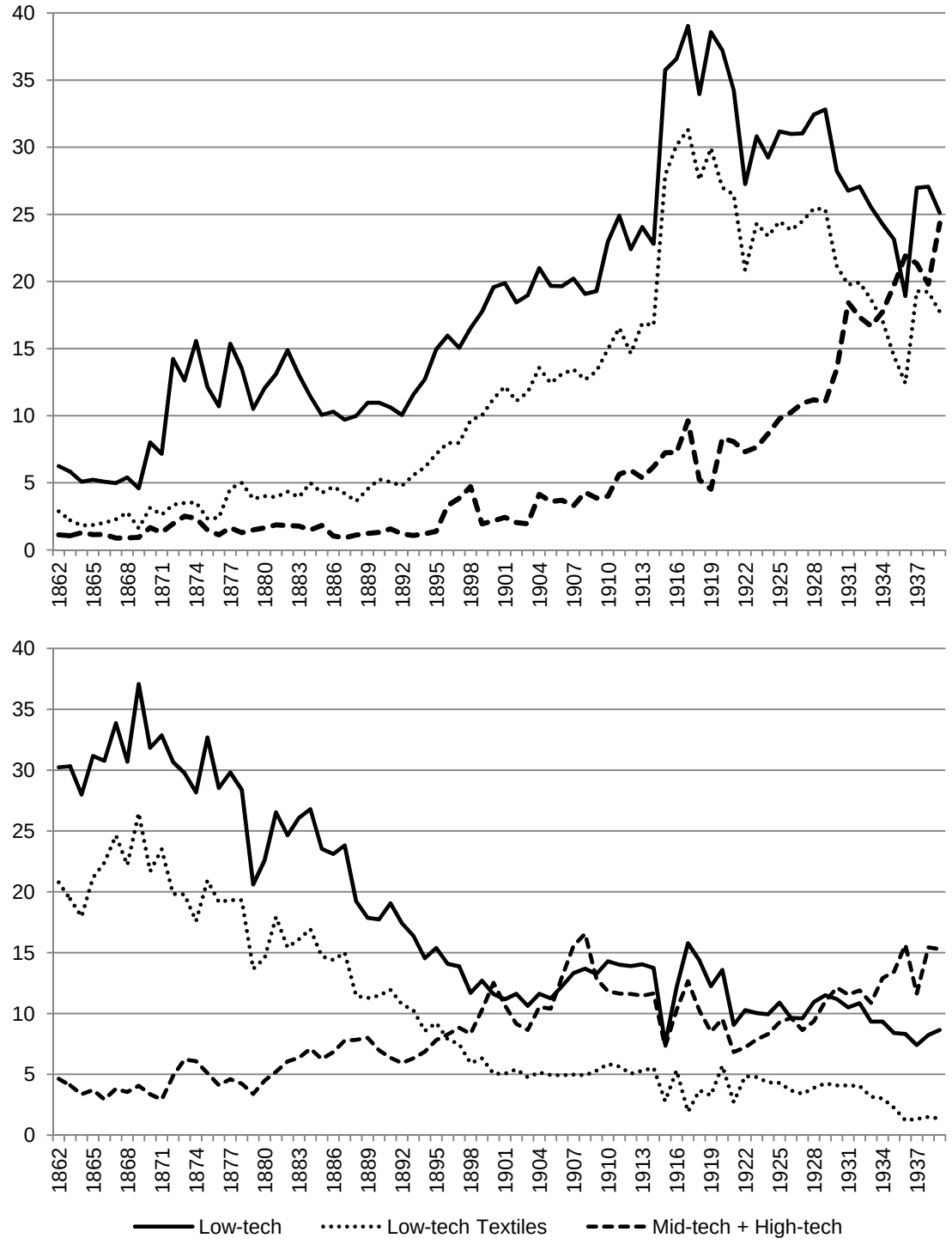
*Note: *, ** and *** denote p < 0:1, p < 0:05 and p < 0:01, respectively.*

Table 4. Fixed-effects regressions results.

	MI			XSHA			MSHA		
	(i)	(ii)	(iii)	(i)	(ii)	(iii)	(i)	(ii)	(iii)
RSTA	0.023	-0.006	0.038***	0.016	0.001	-0.005	-0.005	0.007	-0.039**
	(0.04)	(0.06)	(0.01)	(0.04)	(0.06)	(0.01)	(0.01)	(0.01)	(0.02)
Text.	0.011***	0.016***	0.003***	0.004***	0.005***	0.001***	-0.005***	-0.006***	-0.002***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Const.	-0.023***	-0.020***	-0.009***	0.031***	0.035***	0.032***	0.048***	0.047***	0.043***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Cat. FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
N. obs.	188	88	100	188	88	100	188	88	100
Adj. R2	0.733	0.718	0.967	0.846	0.791	0.976	0.931	0.965	0.892

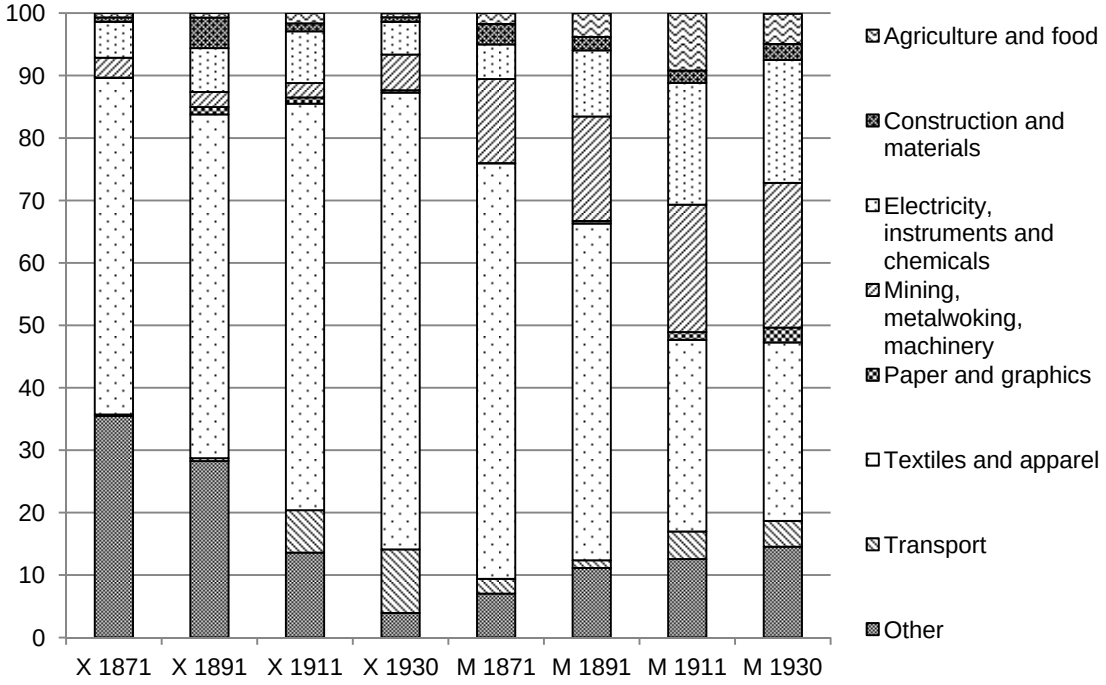
*Notes: (1) Regressions indicated by (i), (ii) and (iii) refer to the whole period (1865-1935), the first sub-period (1865-1901) and the second sub-period (1911-1935), respectively. (2) Heteroskedasticity- and autocorrelation-robust standard errors in parentheses. (3) *, ** and *** denote $p < 0:1$, $p < 0:05$ and $p < 0:01$, respectively.*

Figure 1. Share of *low-tech*, *mid-tech*, *high-tech*, and *low-tech textile* manufactures in total Italian exports (top) and imports (bottom), 1865-1938.



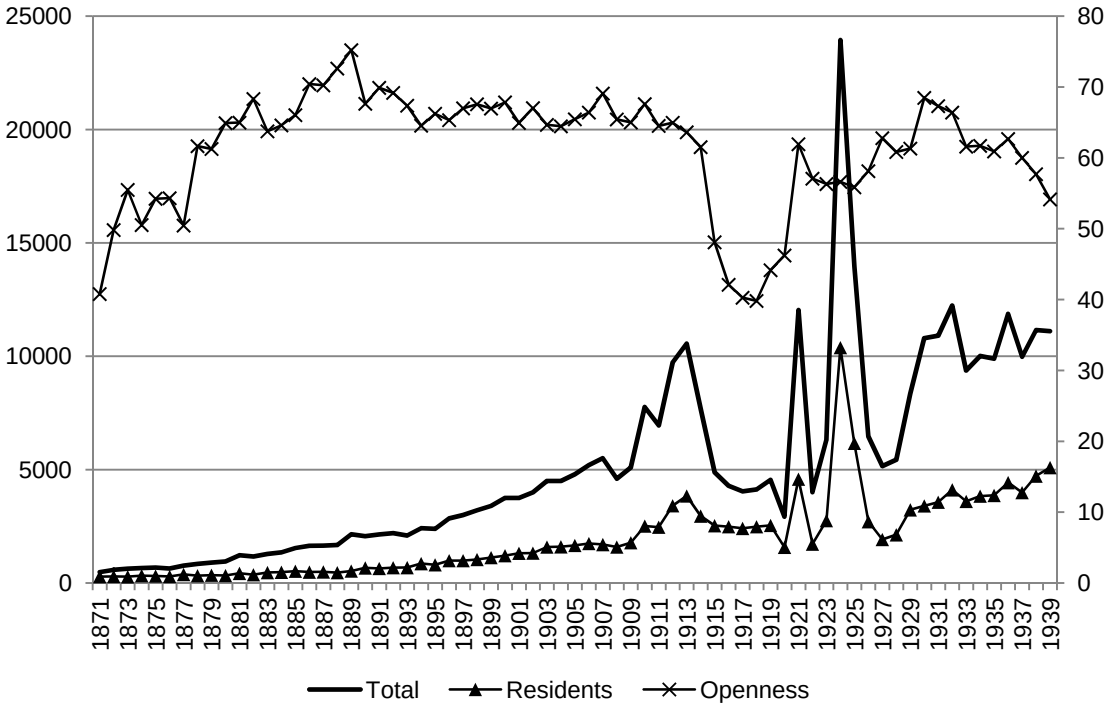
Source: own elaboration on Bankit-FTV data. Note: series do not sum up to 100%.

Figure 2. Italian exports (X) and imports (M), by patent category, selected benchmark years.



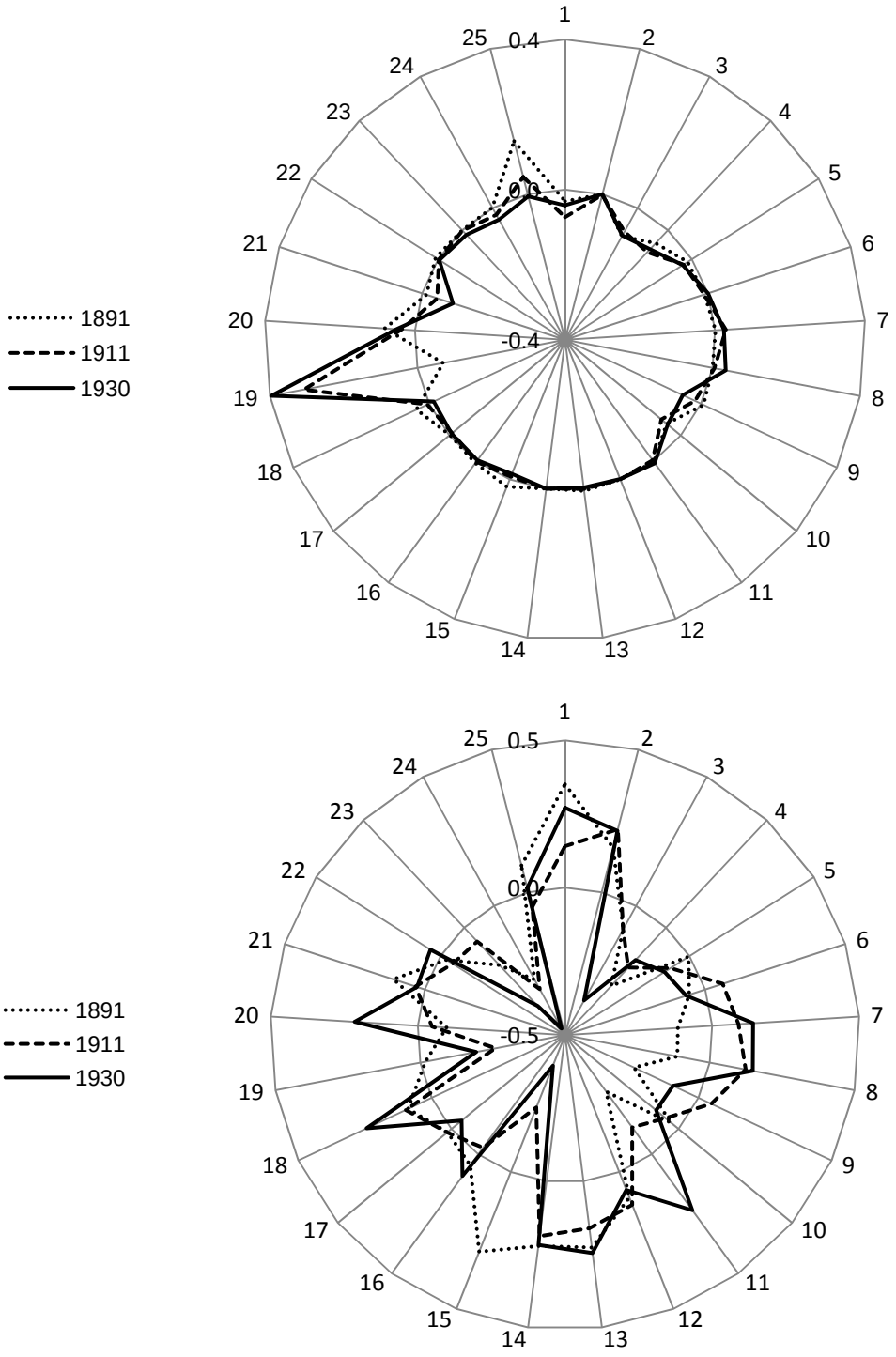
Source: own elaboration on Bankit-FTV data.

Figure 3. Patents granted in Italy (left scale) and degree of openness of the Italian patent system (right scale), 1883-1938.



Source: own elaboration on data from MAIC, Bollettino della Proprietà Intellettuale (for years until 1911) and WIPO (1983) (for years since 1912).

Figure 4. Michaely index (top) and RSTA (bottom), by patent category, selected benchmark years.



Sources: see Section 2.

Appendix A. Correspondence between Italian patent classification and SITC, Rev. 2

Notes: (1) For details about the SITC sectors, see the *UN Department of Economic and Social Affairs Statistical Office Statistical Paper Series M No. 34/Rev2*. (2) The following is a full correspondence between Italian patent classification and SITC, Rev. 2. As such, it also includes products labelled as *primary* and *resource-based* by Lall (2000) and raw silk (SITC subgroup 6511; cf. fn. 6), which have been excluded from the analysis carried out in the present work (see 2.1). For a list of the excluded SITC groups, see Table A1 of that work.

Cat.	Italian patent classification	SITC, Rev. 2
1	Agriculture, agricultural industries and alike	00; 08; 22; 271; 41; 42; 4314; 56; 591, excl. 5914; 721; 722
2	Food and beverages	0, excl. 00 and 08; 11; 727
3	Mining and metal production	274; 277; 278; 28; 333; 67, excl. 676, 678 and 679; 68; 7283
4	Metal working, wood and stones manufacture	24, excl. 2481; 63; 678; 679; 69, excl. 691, 696, 697; 73
5	Steam generators, motors, machines and their parts	3345; 71, excl. 716; 728, excl. 7283; 74, excl. 741; and 7434
6	Railways and tramways	2481; 676; 791
7	Vehicles	625; 7783; 78; 8941
8	Navigation and aerospace	792; 793
9	Electrical engineering	35; 716; 76, excl. 763; 77, excl. 774, 775, 7782 and 7783
10	Minute and precision mechanics, scientific instruments and musical instruments	763; 87, excl. 872; 884; 885; 898
11	Weapons and war, hunting and fishing materials	8946; 8947; 951
12	Surgery, therapy, hygiene and fire and injury prevention	5914; 6281; 774; 872; 8996
13	Civil construction, roads and hydraulic works	691; 723; 8122
14	Bricks, limes, cements and other building materials	273; 335; 661; 662; 663, excl. 6639
15	Glass and ceramics	6639; 664; 665; 666
16	Lighting	7782; 8124; 8993
17	Heating, ventilation and cooling	32; 334, excl. 3345; 34; 741; 7434; 7752; 7758; 8121

18	Furniture and materials for houses, shops, offices and public places	6422; 6423; 696; 697; 75, excl. 7511; 775, excl. 7752 and 7758; 82; 895
19	Spinning, weaving and complementary industries	26; 65; 724, excl. 7243 and 7248
20	Apparel and accessories	553; 7243; 83; 84; 85; 8942; 897; 8994
21	Hides and skins	21; 61; 7248
22	Paper	25; 64, excl. 6422 and 6423; 725
23	Graphics	726; 7511; 881; 882; 883; 892
24	Chemicals	233; 43, excl. 4314; 5, excl. 54, 56, 553 and 591
25	Other industries and miscellanea	12; 232; 29; 54; 62, excl. 625 and 6281; 667; 893; 896; 8990; 8991; 8997; 8998; 8999; 9, excl. 951, 96 and 9710a

Appendix B. Italy's specialisation indices in benchmark years

year	cat	XSHA	MSHA	MI	RSTA
1865	1	0.003	0.025	-0.022	0.119
1865	2	0.000	0.000	0.000	0.142
1865	3	0.015	0.083	-0.068	0.123
1865	4	0.024	0.034	-0.010	-0.038
1865	5	0.000	0.003	-0.003	0.016
1865	6	0.002	0.022	-0.020	-0.047
1865	7				
1865	8	0.002	0.009	-0.007	-0.117
1865	9				
1865	10	0.003	0.019	-0.015	-0.005
1865	11				
1865	12	0.000	0.000	0.000	0.099
1865	13	0.000	0.001	-0.001	0.012
1865	14				
1865	15	0.016	0.033	-0.017	-0.014
1865	16	0.001	0.004	-0.003	-0.036
1865	17				
1865	18	0.028	0.003	0.024	-0.111
1865	19	0.300	0.614	-0.314	-0.139
1865	20	0.309	0.061	0.249	-0.065
1865	21				
1865	22				
1865	23	0.000	0.001	0.000	0.050
1865	24	0.295	0.087	0.208	0.034
1865	25				
1881	1	0.005	0.058	-0.053	0.218
1881	2	0.000	0.000	0.000	0.069
1881	3	0.007	0.114	-0.106	-0.072
1881	4				
1881	5	0.000	0.023	-0.023	-0.135
1881	6	0.002	0.049	-0.047	0.058
1881	7				
1881	8	0.000	0.006	-0.006	-0.235
1881	9	0.000	0.000	0.000	-0.129
1881	10	0.007	0.031	-0.024	-0.080
1881	11	0.007	0.002	0.005	-0.106
1881	12	0.000	0.000	0.000	-0.061
1881	13	0.001	0.003	-0.002	0.237
1881	14				
1881	15	0.044	0.021	0.023	0.172
1881	16	0.015	0.005	0.009	-0.163
1881	17				
1881	18	0.026	0.006	0.021	0.321
1881	19	0.271	0.537	-0.266	-0.122
1881	20	0.105	0.016	0.089	0.158
1881	21	0.044	0.036	0.008	-0.210
1881	22	0.000	0.000	0.000	0.076
1881	23	0.000	0.000	0.000	0.121
1881	24	0.021	0.022	-0.002	-0.087
1881	25	0.444	0.070	0.374	-0.201
1891	1	0.007	0.038	-0.031	0.351
1891	2	0.000	0.000	0.000	0.157
1891	3	0.002	0.088	-0.085	-0.090
1891	4	0.013	0.061	-0.048	-0.271
1891	5	0.003	0.016	-0.013	-0.003
1891	6	0.001	0.010	-0.009	-0.057
1891	7	0.003	0.001	0.002	-0.116
1891	8	0.001	0.001	0.000	-0.112

year	cat	XSHA	MSHA	MI	RSTA
1891	9	0.013	0.005	0.008	-0.241
1891	10	0.007	0.056	-0.049	-0.032
1891	11	0.006	0.003	0.003	-0.263
1891	12	0.000	0.000	0.000	0.093
1891	13	0.007	0.001	0.006	0.227
1891	14	0.000	0.000	0.000	0.222
1891	15	0.042	0.021	0.021	0.291
1891	16	0.008	0.002	0.006	0.046
1891	17	0.000	0.002	-0.002	0.018
1891	18	0.046	0.009	0.037	0.088
1891	19	0.423	0.493	-0.070	-0.018
1891	20	0.127	0.046	0.081	-0.098
1891	21	0.036	0.048	-0.012	0.112
1891	22	0.010	0.002	0.008	-0.024
1891	23	0.002	0.002	0.000	-0.175
1891	24	0.042	0.041	0.002	-0.285
1891	25	0.201	0.055	0.146	0.094
1901	1	0.009	0.058	-0.050	0.360
1901	2	0.000	0.001	-0.001	0.155
1901	3	0.002	0.106	-0.104	-0.026
1901	4	0.012	0.076	-0.065	-0.196
1901	5	0.014	0.030	-0.016	-0.032
1901	6	0.002	0.045	-0.043	-0.065
1901	7	0.002	0.007	-0.005	0.108
1901	8	0.006	0.018	-0.012	0.065
1901	9	0.009	0.033	-0.024	-0.121
1901	10	0.017	0.080	-0.063	-0.016
1901	11	0.001	0.002	-0.001	0.072
1901	12	0.000	0.000	0.000	0.025
1901	13	0.008	0.001	0.007	0.193
1901	14	0.000	0.000	0.000	0.061
1901	15	0.023	0.016	0.006	-0.304
1901	16	0.012	0.002	0.010	0.051
1901	17	0.000	0.013	-0.012	-0.064
1901	18	0.032	0.007	0.025	0.111
1901	19	0.536	0.287	0.249	-0.117
1901	20	0.133	0.047	0.086	-0.077
1901	21	0.020	0.044	-0.024	-0.088
1901	22	0.003	0.009	-0.006	-0.086
1901	23	0.001	0.002	-0.001	-0.186
1901	24	0.032	0.050	-0.018	-0.157
1901	25	0.127	0.065	0.062	-0.011
1911	1	0.016	0.090	-0.074	0.141
1911	2	0.000	0.002	-0.002	0.221
1911	3	0.001	0.072	-0.071	-0.091
1911	4	0.016	0.096	-0.080	-0.186
1911	5	0.005	0.031	-0.026	-0.076
1911	6	0.002	0.012	-0.010	0.062
1911	7	0.049	0.019	0.029	0.090
1911	8	0.018	0.013	0.005	0.124
1911	9	0.011	0.029	-0.017	0.049
1911	10	0.025	0.092	-0.067	-0.058
1911	11	0.001	0.004	-0.003	-0.112
1911	12	0.000	0.000	0.000	0.120
1911	13	0.002	0.001	0.001	0.161
1911	14	0.000	0.000	0.000	0.188
1911	15	0.011	0.018	-0.008	-0.236
1911	16	0.009	0.007	0.002	-0.027

year	cat	XSHA	MSHA	MI	RSTA
1911	17	0.002	0.011	-0.010	0.019
1911	18	0.021	0.015	0.005	0.097
1911	19	0.537	0.229	0.308	-0.260
1911	20	0.113	0.077	0.036	-0.048
1911	21	0.023	0.066	-0.043	0.033
1911	22	0.001	0.003	-0.002	-0.048
1911	23	0.009	0.010	-0.001	-0.064
1911	24	0.036	0.056	-0.020	-0.322
1911	25	0.092	0.044	0.047	-0.052
1925	1	0.003	0.054	-0.051	0.176
1925	2	0.001	0.001	0.000	0.190
1925	3	0.003	0.109	-0.107	-0.361
1925	4	0.011	0.084	-0.073	-0.165
1925	5	0.019	0.054	-0.035	-0.046
1925	6	0.007	0.006	0.001	0.050
1925	7	0.089	0.025	0.064	0.076
1925	8	0.003	0.004	0.000	-0.012
1925	9	0.011	0.036	-0.026	-0.085
1925	10	0.006	0.035	-0.029	-0.035
1925	11	0.005	0.002	0.003	0.081
1925	12	0.000	0.001	-0.001	0.071
1925	13	0.000	0.003	-0.003	0.116
1925	14	0.000	0.000	0.000	0.098
1925	15	0.008	0.023	-0.015	-0.456
1925	16	0.004	0.010	-0.006	0.085
1925	17	0.001	0.009	-0.008	-0.100
1925	18	0.008	0.022	-0.013	0.175
1925	19	0.665	0.270	0.394	-0.161
1925	20	0.096	0.048	0.048	0.110
1925	21	0.010	0.093	-0.082	0.046
1925	22	0.002	0.004	-0.002	-0.089
1925	23	0.002	0.017	-0.015	-0.049
1925	24	0.019	0.064	-0.045	-0.282
1925	25	0.027	0.026	0.001	0.078
1930	1	0.005	0.047	-0.042	0.271
1930	2	0.001	0.001	0.000	0.215
1930	3	0.004	0.087	-0.083	-0.366
1930	4	0.012	0.081	-0.069	-0.150
1930	5	0.031	0.060	-0.029	-0.100
1930	6	0.002	0.002	0.000	-0.068
1930	7	0.054	0.030	0.024	0.140
1930	8	0.045	0.009	0.036	0.149
1930	9	0.016	0.069	-0.053	-0.095
1930	10	0.006	0.051	-0.045	-0.099
1930	11	0.010	0.003	0.007	0.235
1930	12	0.000	0.001	-0.001	0.066
1930	13	0.000	0.003	-0.003	0.246
1930	14	0.000	0.000	0.000	0.218
1930	15	0.007	0.023	-0.015	-0.388
1930	16	0.003	0.007	-0.003	0.092
1930	17	0.002	0.010	-0.008	-0.044
1930	18	0.009	0.022	-0.014	0.244
1930	19	0.623	0.227	0.396	-0.193
1930	20	0.109	0.059	0.050	0.215
1930	21	0.007	0.093	-0.086	0.028
1930	22	0.002	0.005	-0.004	0.041
1930	23	0.002	0.019	-0.016	-0.365
1930	24	0.026	0.061	-0.035	-0.475
1930	25	0.024	0.030	-0.006	0.015
1935	1	0.002	0.042	-0.041	0.276
1935	2	0.002	0.003	-0.001	0.138
1935	3	0.027	0.118	-0.091	-0.385
1935	4	0.046	0.149	-0.103	-0.173
1935	5	0.036	0.075	-0.039	-0.062
1935	6	0.006	0.001	0.004	0.055
1935	7	0.109	0.022	0.087	0.153
1935	8	0.029	0.027	0.002	0.074
1935	9	0.018	0.057	-0.039	-0.176
1935	10	0.017	0.064	-0.047	-0.072
1935	11	0.008	0.004	0.004	0.225
1935	12	0.001	0.003	-0.002	0.096
1935	13	0.002	0.003	0.000	0.224
1935	14	0.000	0.000	0.000	0.153
1935	15	0.009	0.023	-0.013	-0.330
1935	16	0.004	0.005	-0.001	-0.096
1935	17	0.003	0.013	-0.010	-0.043
1935	18	0.010	0.022	-0.012	0.182
1935	19	0.539	0.133	0.406	-0.131
1935	20	0.063	0.034	0.029	0.126
1935	21	0.005	0.039	-0.034	0.019
1935	22	0.002	0.005	-0.003	-0.026
1935	23	0.008	0.022	-0.014	-0.260
1935	24	0.026	0.082	-0.056	-0.458
1935	25	0.030	0.054	-0.024	-0.140

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