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Three essays on innovation in a historical perspective
A focus on International Exhibitions

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Contents

Introduction to the thesis

«The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates.»

Thus wrote the 'father' of the economics of innovation, J. A. Schumpeter, in one of his most famous works, *Capitalism, Socialism and Democracy* (1942). This quote gives a taste of how central a topic innovation is in economics and of how long a tradition its study has. In particular, economic history has a double-headed connection with the field properly known as the 'economics of innovation': on the one hand, technology and innovation are among the main subjects of the former, as they lie at the heart of the start of modern economic growth, and even of the institutional setting prevailing at a certain time; on the other hand, a historical perspective is not only valuable, but crucial, to the study of innovation. This latter belief is the main motivation, behind my decision to write this thesis. Technology and its change are indeed the common denominator of the three papers of which this thesis is composed, connecting works that are diverse, as for inspiration, context, addressed topics, and methodologies.

A second *fil rouge* that ties together the three papers presented in this thesis is the use of data from international exhibitions. Despite being among the most characteristic events of the second half of the nineteenth century and of the early twentieth century, the *expos* have so far been devoted limited attention by economic historians, especially as for the exploitation of the massive amount of information that can be retrieved from them. The profusion of these events in the above-mentioned period, and the bulk of catalogues, reports, and other types of publications they produced, make them in fact an attractive object for economic historians, especially for those interested in innovation. This thesis aims at contributing to a deeper knowledge of what international exhibitions represented, and of what use economic historians can make of data from them.

If, as argued above, a historical perspective is relevant for the study innovation, then a fundamental issue is how to represent and quantify historical innovative activity. Studies using contemporary data can employ a variety of different indicators, including patents, R&D expenditure, Total Factor Productivity, and, increasingly, data collected from the *Community Innovation Survey* and similar analyses. But as we move back in time, the availability of these data becomes scarcer; so that, when dealing with the pre-Second World War era, little is left, apart from patents, the availability of which in long time series for many countries make them the standard proxy for representing innovation in history. Yet alternatives may be found by economic historians, resorting to their creativity and data-mining ability. The most relevant research in this sense is that of Moser (2005; 2011; 2012), who has employed, as a proxy for innovation other than patents, data from London's 1851 *Crystal Palace* Exhibition and (partly) from four other international exhibitions, held in the United States between 1876 and 1915. Using this kind of data, she has shown that patents provide a limited representation of historical innovation: in fact, most of the innovations that were exhibited at the London 1851 exhibition do not find a correspondence in patent data.

The first paper of my thesis moves from this point, assessing two critical arguments: first, a small correspondence between exhibition data and patent data does not imply that the former is a more comprehensive proxy for innovation, and a larger set, of which the latter represent a subset. Exhibits and patents might rather be two largely disjoint sets, i.e. having a small intersection. Second, exhibits might represent *not only* innovations, which feeds back into the previous point. A central assumption behind the use of exhibition data as a proxy for innovation is that exhibits are characterised by novelty, a requirement that was indeed present at London's 1851 Great Exhibition, but, as argued in the paper, cannot be observed in the rules of subsequent expos. The failure to meet this assumption implies that, in most cases, exhibits cannot be straightforwardly employed as a proxy for innovation; which calls for a better understanding of what exhibition data represent, and of what their relationship is with patent data. These questions go along with broader ones, such as what were the functions exhibitions played, and what were the reasons why economic agents decided to attend them (to be compared to the reasons for making use of the patent system).

The paper addresses these questions, by performing an in-depth analysis of Turin's 1911 International Exhibition, representative of the numerous *expos* held in the early twentieth century. A newly-built database from this exhibition is matched to Italian patent data. It is found that exhibition data and patent data do indeed represent largely disjoint sets, which is motivated with the reasons for exhibiting and for patenting being different. Exhibitions were primarily market for products (as represented by their alternative wording, *world's fairs*): as such, they were mainly attractive for firms, willing to promote their products on international markets. Another function of exhibitions can in fact be observed, as 'markets for ideas', where independent inventors could promote their findings; but this is of a secondary relevance, and is restricted to particularly skilled and well-known individuals. Exhibition data appear therefore to be characterised, as a proxy for innovation, by a specular drawback from that typically attributed to patents: on the one hand, patents strictly speaking represent inventions, which may eventually fail to reach the market (i.e. to become innovations); on the other hand, exhibits represent products on the market, but not necessarily innovative ones.

Another central question in the economics of innovation concerns the effects of innovation on firms that perform it. Indeed, this is crucial for understanding the incentives that push – in Schumpeter's words – the 'capitalist enterprise' to generate innovation, setting and keeping the 'capitalist engine' in motion. The nexus between innovation and firm performance has been analysed by several empirical studies; but they have generally focused on the pre-Second World War era. The second paper of my thesis addresses this topic, focussing on the years 1913-1936, a fundamental transition period between the 'age of the independent inventor' and a new framework, under which the role of businesses in the generation of innovation became dominant. The geographical focus of the work, as in the case of the first paper, is Italy: the choice of this country is motivated by the abundance and accuracy of the relevant data to perform this task, as well as by the attractiveness of its case. Indeed, Italy turned into an industrial economy in the first half of the twentieth century; and, in the second half, it managed to catch up with the most advanced economies. However, innovation was hardly among the causes of these achievements.

The paper is based on data from IMITA.db, a database providing extensive information (including balance sheets) about the largest Italian companies in several benchmark years. This is connected to data about Italian patents, as well as to the database about Turin 1911 International Exhibition, introduced in the first paper of this thesis: in the same spirit, exhibition data are used as an alternative proxy for innovation, besides more 'traditional' patent data.

The contributions of the paper are various. On a more 'economic' ground, in line with the conclusions of similar empirical works, it provides evidence that the 'product view' of the innovation-performance nexus (i.e. the claim that the introduction of an innovation entails a temporary advantage over competitors) is less relevant than the 'process view' (according to which the process of innovating 'transforms' firms, in such a way that they acquire permanently superior features and capabilities). Indeed, while innovation, as signified by patents, is not significantly associated to firm performance in the short run, a marked divide can be observed, between patentees and non-patentees, as for their likelihood to survive in the long run.

Furthermore, on a more economic-historical ground, it is shown that, unlike patenting, exhibiting activity is associated to a short-run improvement in firm performance, but not to a long-run one. This can be interpreted as a piece of evidence about the relevance of exhibitions as markets for products, and of the benefits they provided to participants, in terms of advertisement and reputation, boosting their commercial performance. Associated to the findings from the first paper, the failure of exhibiting activity to endow firms with a permanent competitive advantage – acknowledged by the empirical literature to be the main effect of the process of innovating – casts a shadow on the suitability of exhibition data for proxying innovation.

Based on the recognition that the products displayed at international exhibitions were not only innovative ones, and that the main motivation for participating in exhibitions was commercial, an alternative interpretation of exhibition data is suggested in the third paper of my thesis, as an indicator of what was produced and promoted on international markets by countries that participated in these events. It is argued in the paper that this interpretation of exhibition data is not pushed as far as to claim that it can work as a proxy for export data. Rather, from the observation that a country was exhibiting a certain staple, it can be inferred that that staple's production was established in that country, and was mature and competitive enough to be promoted on international markets.

The paper employs data from five *expositions universelles*, held in Paris at regular intervals during the second half of the nineteenth century (1855, 1867, 1878, 1889, and 1900). For each country, participating in each expo, it is known how many exhibits it presented in each class of the official classification. Based on these data, measures are constructed, describing the sophistication of countries' economies, an analysis of which reveals general economic development trends, in a wide geographical and long diachronic perspective. In particular, specialisation indices *à la* Balassa (1965), and *Economic Complexity Indices* (Hidalgo and Hausmann, 2009) are computed, for participating countries. The former indicate how much each country exhibited in each product category, relative to the 'world' average; the latter, inspired by a recent strand of literature, evaluates the capabilities each country possessed to produce (in a competitive way) a range of products. In the discussion of the complexity indices, it is observed that, consistently with the findings of existing literature, complexity is correlated with the level of income, but only to a limited extent with the latter's growth.

The last paper stands out from the others in two regards. First, it has a different focus, in that its perspective is *macro*- rather than *micro*-economic. Second, it is an exploratory work, which aims at suggesting a new interpretation for exhibition data and to show some (but not all) possible analyses that can be based on it. Among the main strengths of this interpretation can be listed the expos' comprehensive and detailed classifications, allowing a large product coverage (encompassing both primary products and manufactures) and a good degree of disaggregation; and the real 'world-wide' perspective ensured by the various geographical origin of participating countries. All the more so, exhibition data may provide unique insights, about some products and countries, for which production and trade data might be scarce or even missing over the observed period.

The summaries of the three papers made above reveal that the spirit of the thesis is eminently empirical, and that it endeavours to pay adequate attention to both the historical side of the analysis, and to the more strictly economic one. Not only recent economic literature is amply referred to in all papers; but attention is also paid to some of the newest developments in the discipline: remarkably, the concepts and methods of the literature on 'economic complexity' are applied for the first time to a historical context in the third paper of this thesis.

The main original contribution of the present thesis to economic historical knowledge is constituted by its focus on data from international exhibitions, the critical assessment of their goodness as a proxy for innovation, and the constructive suggestion of a new interpretation, whereby exhibition data represent the range of products that participants produced and promoted on international markets. Other contributions are the speculation on the functions international exhibitions played, and the display of their commercial relevance for businesses. The attention this thesis pays to this topic is motivated by my belief that the study of international exhibitions is a promising field for economic history, and by the hope that the three papers presented here can represent a stimulus to additional research in the years to come.

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Patents, exhibitions and markets for innovation in the early twentieth century: Evidence from Turin 1911 International Exhibition

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Abstract. This work contributes to the recent literature on international exhibitions, and on the use of data from these events as a proxy for innovation in economic history. In particular, it investigates the nature of international exhibitions, the role they played in the early twentieth century, the reasons why economic agents attended them, the relationship between exhibition data and patent data, and their suitability for measuring innovation. To do so, it makes an in-depth analysis of the International Exhibition held in Turin in 1911, and it matches a new database, built from the catalogue of this event, with data about patents granted in Italy. It is found that exhibiting and patenting did mostly occur separately, as exhibitions mainly worked as markets for products, which attracted firms, while patents were primarily taken out by individuals, most of whom might not be interested in that function. Yet, the presence is observed of a qualified niche of independent inventors, using the exhibition as a market for ideas, i.e. to advertise their findings to a selected public of potential investors, buyers or licensees.

Keywords: international exhibitions; Italy; markets for innovation; patents

JEL classification codes: N74, O31, O33

1. Introduction

Patents occupy a primary position among the measures of innovation. Their popularity is motivated by a solid tradition in the literature on the economics of innovation (the first, pioneering studies making use of them date back to the 1950s and 1960s, notably Scherer 1965, and Schmookler 1957, 1966), and by their large availability for most countries and since very long ago in time. They are particularly important when pre-Second World War years are considered, due to other proxies for innovation, such as R&D expenditure, not being available for that period.

Patents, however, represent only a part of the universe of innovation. Industrial surveys over the last three decades (Arundel, van de Paal and Soete., 1995; Cohen, Nelson and Walsh, 2000; Levin, Klevoric, Mansfield, 1986; Nelson and Winter, 1987) have revealed that firms typically protect their innovations by a variety of different means, of which patents are not deemed the most effective, but in few industries such as chemicals and pharmaceuticals. As the perceived effectiveness of these mechanisms varies across industries, the propensity to patent and the reasons why patents are taken out also vary. Indeed many patents are not exploited economically, but just used for strategic purposes.[1]

It may be argued that the results of these surveys cannot be extended too back into history, as they focus on the model of the big innovative corporation, which has become dominating only well into the twentieth century. In fact, in the decades between the nineteenth and twentieth century, a relevant contribution in both quantitative and qualitative terms was still coming from individual inventors, who were increasingly specialised and behaved entrepreneurially in the market for ideas, wherever this was endowed with adequate institutional arrangements (Hughes, 1989; Lamoreaux and Sokoloff, 1999; Nicholas, 2010, 2011; Nuvolari and Vasta, 2015a). In such a context, patents were an important instrument to make inventions safely marketable assets.

Yet evidence that patents fall short of representing a comprehensive measure of innovation also in a historical context has come from recent research, in particular from the works published by Moser (2005, 2011, 2012), using data from international exhibitions. These events were among the most important and characteristic of the second half of the nineteenth century and of the early twentieth century: in an era of breakthrough technological changes, they celebrated 'the splendours of progress' (Schroeder-Gudehus and Rasmussen 1992), and played an important function in the diffusion of new technologies (Ahlström, 1996; Roca Rosell, 2015). Their size, frequency, geographical coverage, and popularity, grew ever larger since their inception with London's 1851 Great Exhibition, and only entered decline after the First World War. Moser has presented data from the exhibitions' catalogues as an alternative proxy for historical innovation, including both patented and non-patented items; and, matching exhibition data to patent data, she has found that as much as 89% of British exhibits at the 1851 exhibition were not patented.[2]

While effective in conveying the idea that much innovation occurred outside the patent system,[3] the finding of a small correspondence between exhibition data and

[1] For a thorough account of the advantages and disadvantages of patents as a proxy for innovation, see Griliches (1990) and Nagaoka, Motohashi and Goto (2010).

[2] A similar conclusion is reached, for a more recent time period, by Fontana, Nuvolari, Shimizu and Vezzulli (2013), showing that 91% of innovations awarded the 'R&D 100 Award' by magazine *Research and Development* between 1977 and 2004 were not patented.

[3] A further reason why this was the case, pointed out by Moser, is that at that time some countries lacked patent laws, or excluded specific industries from patent protection. Also, it was not infrequent that innovation was let freely accessible: for example, Allen (1983) and Nuvolari (2004) have shown

patent data does not imply *per se* that the former is a more comprehensive proxy for innovation, of which the latter represent a subset: rather, the sets of patents and exhibits might be largely disjoint, i.e. having a small intersection. To assess the real relationship between exhibits and patents, one should not only check how many of the former were patented, but also what proportion of the latter was exhibited.

Even before this issue, however, comes the question whether exhibits do represent innovations. This is certainly the case for a part of them, but not for all – which feeds back into the above-mentioned point of the sets of exhibits and patents being largely disjoint.[4] A central assumption behind the use of exhibition data as a proxy for innovation is that exhibits are characterised by novelty, which, as pointed out by Moser (2005, p. 1218), was a requirement for admission at the first international exhibition, namely London 1851. However, already at the second such event, namely the *Exposition Universelle* of Paris 1855, no selection was made, based on novelty; and this approach was maintained at the successive *expos* organised by France, which, being the leading country in the field of exhibitions,[5] strongly influenced those held in other countries.[6] A reason for the disappearance of novelty as an admission criterion might be the success and the profusion of those events themselves: indeed, the preface to the *Relazione della giuria* (jury report) of Turin 1911 International Exhibition acknowledged that 'too many and recent exhibitions quickly followed each other, for true, highly-interesting novelties to be observed here' (p. 2).

Furthermore, the multifarious nature of international exhibitions resulted in a variety of different kinds of exhibitors taking part to these events. Exhibitions were great opportunities for innovators to advertise their products to a selected public, particularly keen on the newest advances of science and technology; but not only innovators took part in exhibitions. In fact, an alternative phrasing by which international exhibitions are known, namely *world's fairs*, stresses their nature of big marketplaces, providing visibility on a worldwide scale: this made them particularly attractive for firms – not necessarily innovative – that operated in the wide national and international markets, and aimed at advertising their products and strengthening their reputation (Khan 2013, 2015).

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that 'collective invention', involving the 'free exchange of information about new techniques and plant designs among firms in an industry' (Allen, 1983, p. 2), represented a major source of invention in the nineteenth century.

[4] In the words of Khan (2015, p. 32), 'numerous items on display were not patentable or even innovations; many comprised agricultural produce, interesting specimens of minerals and taxidermy, embroidery, and final goods that illustrated good workmanship or attractive design elements rather than innovation'.

[5] Although London's 1851 Great Exhibition was the first such event on an international scale, it was France that developed the modern industrial exhibition 'format', organizing 11 *expositions publiques des produits de l'industrie française* between 1798 and 1849; and it was still France that organized the largest number of *expositions universelles* in the second half of the nineteenth century (Paris 1855, 1867, 1878, 1889, and 1900).

[6] At Paris 1855, art. 13 of the *Règlement general* stated as admissible (my translation) 'all products of agriculture, industry and art', except for selected categories, like dangerous materials. The Imperial Commission only had the right of excluding French products that would be 'detrimental or incompatible with the aim of the Exhibition' (art. 15). The principle was identical at the last of the five Parisian expos of the nineteenth century (i.e. that of 1900), where 'all industrial or agricultural products, and in general all the objects that fall into the attached classification' could be admitted (art. 29), with the exception of 'dangerous materials, notably explosives' (art. 30). At Turin 1911, the purpose of the organisers was to gather 'all products of agricultural and industrial work, and generally all expressions of economic and civil life' (art. 3). Art. 16 of the *Regolamento generale* stated that the Executive Commission had to 'reject those [items] having no industrial value': this vague formulation, however, does not appear to imply novelty as a requirement.

The present paper aims at shedding further light on the nature of international exhibitions, on the role they played in the early twentieth century, on the reasons why economic agents attended them, on the relationship between patent data and exhibition data, and on the suitability of the latter as a proxy for innovation. To do so, it makes an in-depth analysis of the International Exhibition held in Turin in 1911, and it matches a new database, built from the catalogue of this event, with data about patents granted in Italy. Section 2 introduces and describes Turin 1911 database. In Section 3, these data are matched to patent data, and the intersection between these two sets is evaluated. This also involves speculating about the function(s) played by the exhibition. Section 4 investigates by econometric means the drivers leading to economic agents' choices to exhibit and patent. One of these factors, i.e. cost, is dedicated a detailed analysis in Section 5. Finally, Section 6 makes conclusive remarks on the findings of the paper.

2. Turin 1911 database: presentation and descriptive statistics

The exhibition data employed in this paper come from a new database, based on the *Catalogo Generale Ufficiale* of Turin 1911 International Exhibition. The choice of this event is motivated by its representativeness: the *Esposizione internazionale delle industrie e del lavoro* (International Exhibition of Industries and Labour), taking place from the 29th of April to the 19th of November 1911, was officially joined by 22 foreign countries from Europe, Asia and the Americas; but exhibitors came from even more countries (*Relazione della giuria*, pp. 78-79). It was based in the *Parco del Valentino* of the cosmopolitan former capital of the Kingdom of Italy, both geographically and culturally close to continental Europe, and it was visited by 7.4 million people. While considerably smaller than the exhibitions hosted by France and the United States, the size of Turin's exhibition was of the same order as that of similar events in other countries in the same period, such as Belgium (Antwerp 1885 and 1894; Brussels 1897 and 1910, Liège 1905, Ghent 1913), Spain (Barcelona 1888) and Italy itself (Milan 1906). This exhibition has a particular historical relevance for Italy, as it took place at the end of its first important phase of economic development (Toniolo, 2013), and was seen by the organisers as a unique opportunity to show the progress of the country to the world, in the occasion of the 50th anniversary of its Unification.[7]

Official sources indicate that a total of 22,271 exhibits were presented at Turin's International Exhibition, classified into 26 groups, further divided into 167 classes.[8] A large amount of the products on display, however, consisted of primary commodities (e.g. agricultural and mining products), having nil technological content. To tackle this issue, the database does not list every single item that was displayed in Turin. Rather, it provides an account of the *manufactured* products on display. Following a widely diffused practice, those products (theoretically) falling into divisions 0 to 4 of the *Standard International Trade Classification* (SITC), are considered as primary, the others as manufactured.[9] As a consequence, entire groups and classes, only containing primary products, are kept out of the database; while in some other classes a selection is performed. The adopted criterion does not ensure that all included observations are

[7] In the preface to the *Relazione della giuria*, Turin's Exhibition is rhetorically claimed to demonstrate that 'the intelligence of the country does not only apply to painting and making music, speaking or writing, but also acts on markets' (p. 1, my translation).

[8] Official data are available in Table A1 of the appendix.

[9] An exception to this criterion is made for SITC sub-group 6511 (raw silk), which is treated as primary, based on the finding, by Federico (1997), that around 80% of raw silk's value was coming from the agricultural raw material, i.e. silk cocoons.

innovative – which cannot be done without introducing arbitrary and prone-to-error definitions –,[10] but it excludes items that obviously had no technological content.[11] Also excluded from the database are some groups (*Teaching*, *Social economy*, and *Colonisation and migration*) which mainly had illustrative purposes, as items largely consisted of paternalistic displays of the work of schools and third-sector organisations – not to cite class 164, dedicated to the 'Work of Italians abroad', which 'highly interested, as well as moved, the Italian visitors of the Exhibition' (*Relazione della giuria*, p. 147; my translation).

Table 1 provides some descriptive statistics about Turin 1911 database. A total of 7,671 exhibits is included:[12] this figure is what is left, after performing the selection described above, and amounts to 34% of the official total, showing that non-manufactured products were preponderant, among the items on display at the exhibition. Indeed, 7,740 of total official exhibits were in the groups of *Agriculture* and *Foodstuffs*, where displayed items were mostly primary;[13] while 3,758 were in the three 'illustrative' groups mentioned above.

Italian exhibitors account for more than one-third of total entries in the database. France is the most represented foreign country (20%), followed by Germany (11%) and Great Britain (7%). All other European countries together (including Russia and Turkey) sum up to less than 10%; American ones to slightly more than that; Asian ones to 6%.[14]

[10] Unfortunately, there is no easy way to distinguish innovative exhibits from non-innovative ones. The exhibitions' classifications did not do so, and any distinction based on the exhibits' wordings in the catalogues would imply too high a degree of arbitrariness and a considerable margin of error. A possible solution could be to use prizes conferred at exhibitions, but awarding procedures look quite opaque: while theoretically based on technical merit, they were in fact influenced by a number of different motivations, as pointed out by various studies (reviewed by Khan, 2015, pp. 29-39). In the case of Turin's International Exhibition, art. 14 of the *Regolamento della giuria internazionale* stated that awards were based on the exhibitors' 'industrial and scientific merit', but not novelty.

[11] It should be noticed that still, among the manufactured products that have been included into the database, many appear to be fashionable goods, works of art, traditional artisanal products, or consumer goods, the technological content of which is dubious. These are particularly serious issues in the groups of *Furniture* and *Jewellery and accessories*, as well as in *Apparel* and *Leather*. However, a further selection of these products would imply too high a degree of arbitrariness.

[12] Each observation of the database corresponds to a single entry from the catalogue, typically representing an exhibit by a certain exhibitor, in a certain class. However, in some cases, the same item can be observed in several classes, under the same writing or a similar one. In addition to this, some entries correspond to more than one single item. Many of these 'multiple' entries, however, do not precisely list the number of items on display. This makes it impossible to refine the database, in such a way that each observation corresponds to a single displayed item. In the rest of this work, the term 'exhibit' will therefore be used to mean a catalogue entry in a certain class.

[13] An additional reason for filtering primary products out is to improve the comparability between exhibition data and patent data in the next sections' empirical analysis. In the sector of agriculture, primary commodities dominate among the former, while all patents granted in 1911 refer to agricultural equipment. Likewise, in the sector of foodstuffs, simple foods and beverages prevail among exhibits; whereas a patent about a 'gluten-rich bread' appears to be the only, introducing a somewhat new alimentary product – all the others being about industrial material and processes.

[14] It is worth noting that the actual presence of Latin American countries at Turin's Exhibition was much larger, than it emerges from the database: official statistics (displayed in Table A1 in the appendix), show that they exhibited 5,365 items, corresponding to almost one-fourth of total items on display. The filtering process, upon which the database is constructed, considerably downsizes these countries, as a large share of their exhibits consisted of primary products.

Table 1. Turin 1911 database: descriptive statistics.

	Total	Italy	Belgium	France	Germany	Great Britain	Switzerland	United States	Rest of Europe	Asia	Latin America
Total	7,671	2,734	218	1,552	861	554	86	95	426	437	708
Country %		35.6	2.8	20.2	11.2	7.2	1.1	1.2	5.6	5.7	9.2
Type of exhibitor											
Firm %	65.8	59.2	74.3	69.9	89.7	96.2	88.4	90.5	69.2	33.2	38.6
Individual %	28.2	35.8	21.1	26.7	9.1	3.2	11.6	4.2	22.5	49.0	42.8
Other types %	*6.0*	*5.0*	*4.6*	*3.4*	*1.3*	*0.5*	*0.0*	*5.3*	*8.2*	*17.8*	*18.6*
Average exhibits per exhibitor	1.2	1.1	1.2	1.1	1.9	1.8	1.4	1.0	1.1	1.1	1.2
Product class											
Agriculture	277	123	2	56	25	11	5	12	21	4	18
Chemicals	794	268	16	163	34	91	0	3	42	25	152
Construction and construction materials	913	343	44	241	60	40	5	3	45	52	80
Electricity	461	154	3	100	100	22	18	4	26	1	33
Food and beverages	225	133	7	10	25	24	6	1	6	0	13
Machine tools, machinery, components and metalworking	281	84	2	33	85	12	13	30	18	1	3
Mining	125	45	3	26	12	7	2	3	3	3	21
Other manufactures	785	291	5	156	77	27	1	2	66	101	59
Paper and printing	527	179	18	106	65	45	2	9	29	17	57
Scientific instruments	500	181	4	71	101	83	7	7	15	4	27
Steam engines	274	93	3	24	73	38	19	8	7	0	9
Textiles, apparel & leather	1,739	555	65	413	64	80	5	7	135	220	195
Transport	629	250	33	121	117	59	3	6	9	8	23
Weapons	141	35	13	32	23	15	0	0	4	1	18

Source: own database (see Section 2).

The dominant exhibitor type is by far the firm, accounting on average for two-thirds of the displayed items.[15] Individuals account for 28%, while the remainder is accounted for by exhibitors of other types, namely third-sector associations (e.g. charities and clubs), governmental bodies (ministries, municipalities, etc.), and educational and research institutions (schools, universities, scientific institutes). Two non-mutually exclusive reasons can be advanced for the prevalence of firms among exhibitors: on the one hand, exhibiting involved costs, which could be negligible for firms, but could represent a substantial barrier for individuals, as will be illustrated in Section 5. On the other hand, while firms could expect a return from joining the exhibition, given by advertisement and reputation-building,[16] expected benefits might be uncertain for individuals; hence, even in the case costs did not represent a significant barrier, the net present value from participating in the exhibition might be negative for many individuals.

[15] It should be noticed that the source is not providing clear information about the type of some exhibitors. Particularly ambiguous are the cases when only a name and a family name are shown: all such cases have been treated as individuals, although they might in fact be firms, having the names of their founders/owners. Therefore, the share of firms presented above might be an underestimation of the actual one.

[16] Direct sale in the exhibition's premises was forbidden without an authorisation by the Executive Commission (art. 34 of the *Regolamento generale*).

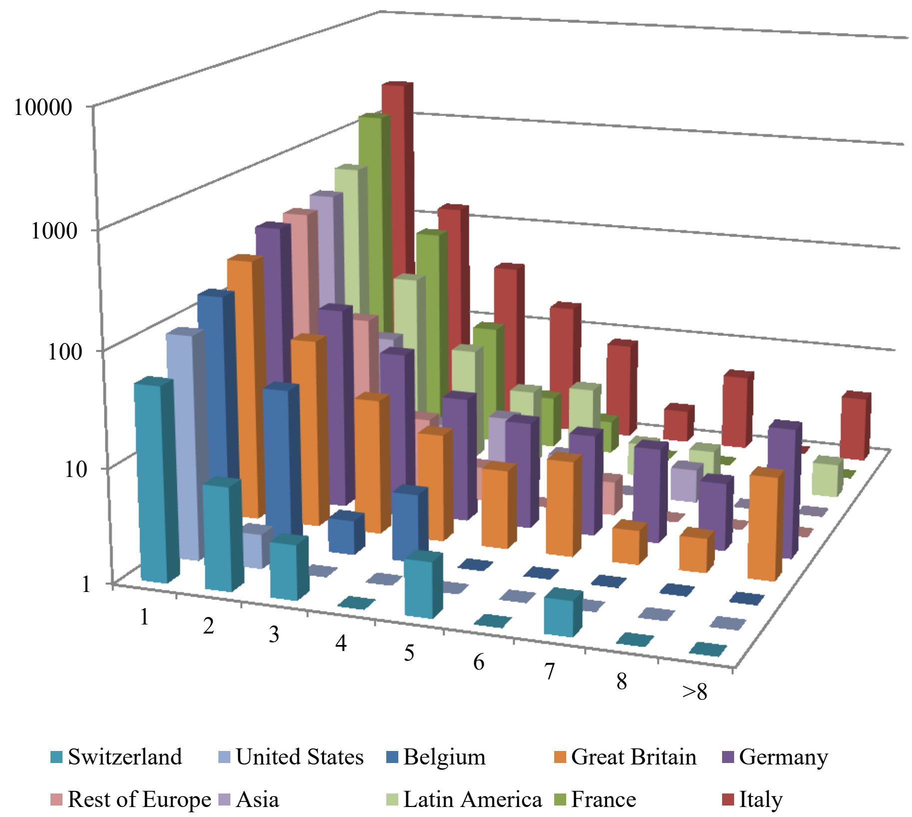
Italy features a larger share of individuals than average, which can be justified by the lower costs of transport and travel that Italians had to face; as well as by the absence of cultural barriers, and by the fact that this domestically-hosted exhibition was a more direct reference for Italians than for foreigners. By the contrary, for Germany, Switzerland, and the United States, firms account for around 90%, and even more than that for Great Britain. The values for Belgium, France and the 'rest of Europe' are broadly around the general average. Extra-European countries (except for the United States) present a very different distribution, characterised by a low share of firms (below 40%), and a high weight of other types of exhibitors than individuals and firms (18%).

Great Britain, Germany, and Switzerland also feature a higher-than-average number of items per exhibitor, respectively 1.8, 1.9, and 1.4, *vis-à-vis* an average 1.2. The same fact can be seen from Figure 1, showing the distribution of exhibitors by country and number of exhibits: the above-mentioned countries feature thick tails of exhibitors with a large number of items. A close inspection reveals that these 'great' exhibitors correspond to firms, such as the German *Passburg Emil Maschinenfabrik* (21 entries in the database), *Deutsche Waffen- und Munitionsfabriken* (17), and *Heintze & Blanckertz* (16), and the British *Boake A., Roberts & Co.* (20), *Aerators* (18), and *The Swift Manufacturing Co.* (16).[17] By the contrary, cross-country differences in the number of exhibits by individuals are marginal. The 'greatest' individual exhibitors were Italian, namely Ercole Gardini, presenting seven different inventions in seven classes belonging to six distinct groups, and Giuseppe Pascoli (the eclectic brother of the famous Italian poet Giovanni), who presented four inventions in four different groups.

The breakdown by product class, shown in the bottom part of the table, does not follow the original classification of the exhibition: in fact, observations have been re-classified into the simplified 14-industries version of the Italian patent classification, introduced by Nuvolari and Vasta (2015a). The reason for this is that groups and classes in the original scheme were highly heterogeneous, as they mixed products of different nature, for instance the group *Sports* included clothing alongside cars. Furthermore, the adoption of the Italian patent classification ensures full comparability with patent data. The largest product class is *Textiles, apparel and leather* (henceforth referred to simply as *'Textiles'*), accounting for 23% of total exhibits included in the database. This is followed by *Construction and construction materials* (including glass and ceramics; henceforth *'Construction'*), *Chemicals*, and *Other manufactures* (a residual category, mainly consisting of furniture). However, large country differences can be noticed: while Italy, Belgium, and France follow quite closely the average pattern (to determining which they largely contribute), Germany, Great Britain, Switzerland, and the United States are characterised by larger shares of sectors with high engineering content, like electricity, instruments, machinery, and transport. By the contrary, countries from the rest of Europe, and from outside the continent (except for the United States) feature a disproportionate amount of items in the class of textiles (e.g. carpets from Persia, and silk fabrics from China and Japan).

[17] Among Italians, the 'greatest' exhibitors were *Ferrovie dello Stato* (20), *Ansaldo* (14), and *FIAT* (12). Figure 1 also shows one 'great' exhibitor from Latin America, corresponding to the Peruvian Organising Committee.

Figure 1. Distribution of exhibitors in Turin 1911 database, by country and number of exhibits, logarithmic scale.



Source: own database (see Section 2). Note: all original values have been added one before taking the logarithm, to ensure that the transform of original values equal to unity is different from zero.

3. Exhibitors and patentees in Italy in 1911

This section provides an evaluation of the extent to which exhibition data and patent data overlap. To do so, it matches the names of exhibitors in Turin 1911 database with those of economic agents granted a patent in Italy in the same period, retrieved from the *Bollettino della Proprietà Intellettuale* of the *Ministero di Agricoltura, Industria e Commercio* (MAIC). Not all data from Turin 1911 database are employed for this task, though. The exhibitor types other than individual and firm are excluded because such types did not take out patents, apart from very rare exceptions.[18] Furthermore, unlike firms and individuals, those agents might join the exhibition because of non-economic reasons. In other words, while it seems reasonable to think that individuals, and especially firms, joined the fair by rationally evaluating the net present value from participating, this might not be the case for other exhibitor types. For example, governmental bodies might want to join for national prestige; third-sector organisations for informing the public about their missions and achievements; educational and research institutions for diffusing their most recent findings. Therefore, including these 'other' exhibitors alongside firms and individuals would undermine the consistency of the following analysis. Also a selection by country is performed: besides Italy, Belgium, France, Germany, Great Britain, Switzerland, and the United States are

[18] In 1911, the only patent granted in Italy to such a type of exhibitor was an 'improvement in artillery spyglasses', by the Artillery Precision Laboratory of the Italian Ministry of War.

included, because of their being the main industrial economies, as well as the most active ones in exhibiting and patenting. Indeed, the host country plus the above-listed foreign countries account for 80% of all observations included in Turin 1911 database, and for 93% of patents granted in Italy in 1911. In either case, the above-mentioned foreign countries jointly account for a larger share than Italy's (the latter equalling 36% of total exhibits, and 44% of total patents).[19]

Table 2 displays the results of the matching of exhibition data and patent data. In the left-hand block, it is verified whether each exhibitor from Turin 1911 database, belonging to the selected types and countries, was granted a patent in Italy in the years 1908-12.[20] In the right-hand block, the names of agents granted a patent in year 1911 are matched to those of exhibitors in Turin 1911 database.[21] A look at the first rows reveals a sharp contrast in the distribution by type, between exhibitors and patentees: almost 70% of the former are firms, while more than 80% of the latter are individuals.[22] In both cases, individuals represent a larger share for Italy, thanks to the 'home-court advantage', allowing a larger share of individuals to overcome cost- and non-cost related barriers.

Overall, 17% of the considered exhibitors can be found in the patent records of years 1908-1912. This share is larger for firms than for individuals, although the difference is not very large. It is also larger for Italy than for foreign countries, with two exceptions, namely Germany and Switzerland: the former country's patenting rate is slightly higher than Italy's, the latter's is more than twice as large. The particularly high patenting rates of these countries are driven by firms; in fact, for German and Swiss individuals, exhibitor-patentee matches are broadly as frequent as for other foreign individuals, and much less frequent than for Italians.

On the other side, 7% of agents granted a patent in Italy in 1911 can be observed in Turin 1911 database. As in the case of exhibitors, firm patentees feature a higher matching rate than individual ones; but in this case the difference is very large (21% for firms, *vis-à-vis* 4% for individual patentees). This is in accordance with the arguments made above, that cost- and non-cost-related barriers might be relevant for individuals; and that the latter might expect a limited, or even negative, net present value from participating in the exhibition.

[19] As Nuvolari and Vasta (2015a, pp. 865-6) point out, patenting in Italy was appealing for foreigners because of the country's system being very cheap by international standards and not discriminating foreign inventors, as well as because of the technological backwardness and size of the Italian market. Moreover, taking out a patent in Italy was 'easy', since the Italian system did not entail any examination regarding the invention's novelty, but only checked formal requirements.

[20] It should be noticed that a large deal of patent granted in 1912 were applied for in 1911: for patents granted in the latter year, the average time between the application for a patent and its grant was around six months.

[21] In the right-hand block of Table 2, 1911 is taken as a representative year for the period 1908-1912. Notice that this causes the number of total matches to be different in the two blocks of Table 2 (782 to the left, *vis-à-vis* 254 to the right): in fact, it would be the same on either block, if all patentees in the period 1908-1912 were considered also on the right-hand one. The use of 1911 as a representative year is motivated by the matching rate in that year being similar to the average rate for the period 1908-1912, and by the availability of complete information about patents granted in 1911 from the database by Nuvolari and Vasta (2015a). These authors have fully digitised patent data for five benchmark years over the Italian 'Liberal age' (1861-1913). I am grateful to them for disclosing their data.

[22] Such a large share was not an Italian peculiarity: in fact, Nuvolari and Vasta (2015a, Figure 5) show that the share of patents accounted for by individuals was similar (between 70% and 80%, in 1911) in the patent systems of Italy and of other countries, including technological leaders such as Great Britain and the United States.

Table 2. Results from exhibitor-patentee matching.

	Exhibitors 1911 matched to patentees 1908-1912								Patentees 1911 matched to exhibitors 1911							
	Italy	Belgium	France	Germany	Great Britain	Switzer-land	United States	Total	Italy	Belgium	France	Germany	Great Britain	Switzer-land	United States	Total
Total observations	2,271	174	1,376	455	307	61	89	4,733	1,693	60	342	728	316	102	311	3,552
Firm	1,342	132	981	382	292	51	85	3,265	177	13	70	205	57	20	78	620
Individual	929	42	395	73	15	10	4	1,468	1,516	47	272	523	259	82	233	2,932
Total matched %	20.9	7.5	44.3	22.0	9.4	11.4	8.0	16.7	9.8	11.7	8.5	4.8	2.8	7.8	0.3	7.2
Firm matched %	22.4	9.1	11.3	25.4	11.6	51.0	8.2	18.0	37.3	30.8	25.7	13.2	14.0	25.0	1.3	20.8
Individual matched %	18.4	2.4	4.6	4.1	6.7	10.0	0.0	13.3	6.6	6.4	4.0	1.5	0.4	3.7	0.0	4.3
Total matched	472	13	129	100	35	27	7	783	166	7	29	35	9	8	1	255
Firm exhibitor - Firm patentee	178	8	75	87	23	17	6	394	66	4	18	27	8	5	1	129
Firm exhibitor - Individual patentee	123	4	36	10	11	9	1	194	43	2	6	7	1	2	0	61
Individual exhibitor - Individual patentee	171	1	18	3	1	1	0	195	57	1	5	1	0	1	0	65

Source: for Turin 1911 exhibition data, own database (see Section 2); for Italian patent data, MAIC (1909-12).

Unsurprisingly, Italian patentees have a higher propensity to exhibit than average. More interestingly, this is also the case for the two small economies considered, namely Belgium and Switzerland, which feature larger exhibiting rates than Italy's (again, more than double in the case of Switzerland). The reason for this is the large industrial and technological involvement in the Italian economy of these two countries, which ranked top, among the countries-of-origin of Foreign Direct Investments in Italy before the First World War (Colli, 2010, Table 4.2).[23] Shifting attention to larger foreign economies, Germany and France feature higher propensities to exhibit than farther-away Great Britain and the United States.

The bottom rows of Table 2 provide more detailed information on matched observations, as they distinguish the types (i.e. firm/individual) by which matches appear in exhibition data and in patent data. These need not be the same: in fact, besides 'firm-firm' and 'individual-individual' matches, also the mixed case is observed, corresponding to observations that patented as individuals, but exhibited as firms.[24] One-half of matches are firm-firm; let us call them 'pure firms'. One-fourth is represented by individual patentees, who exhibited as firms: these can be interpreted as 'inventors-entrepreneurs', who had managed to set up innovative firms, exploiting commercially their patents, and regarded the exhibition as a *market for products*, in the same manner as pure firms did. By the contrary, this function of the exhibition was not relevant for individuals who both patented and exhibited as such, constituting the remaining fourth of matched exhibitors, since they were not producers. In fact, these appear to be independent inventors, using the exhibition as a *market for ideas*, i.e. to advertise their patents to potential investors, who could allow them setting up new businesses, or to existing firms, willing to buy or license the patents. Foreigners represent one-half of pure firms, around one-third of inventors-entrepreneurs, and just one-eighth of independent inventors. This comes as no surprise, as most of the latter probably did not have sufficient means to operate at an international scale.

Therefore, a substantial mismatch emerges, between exhibition data and patent data, which can be interpreted as a consequence of the reasons for exhibiting and for patenting being different. On the one hand, the main function of the exhibition appears to be that of a market for products; on the other hand, patents were mostly taken out by individual inventors, the majority of whom might never engage in production and sale, either because of the quality of their inventions being low,[25] or because of financial constraints, that even good-quality independent inventors might face. As a consequence, most patentees were not interested in participating in the exhibition, as a market for products. Yet the presence of some patentees who joined the exhibition as individuals reveals a second function of the exhibition, as a market for ideas, the relevance of which is minor but not negligible, as those observations (corresponding to 'individual-individual' matches) represent 4% of exhibitors from all countries considered, and 8% of Italian ones.

[23] Colli's study is based on the IMITA.db database, including Italy's largest joint-stock companies in various benchmark years, among which 1913. In that year, Belgium ranked first, based on the number of Italian firms characterized by the presence of that country's capital (41), on its share of total foreign-controlled capital (28%), and on its share of total foreign-controlled assets (31%). Based on the same measures, Switzerland ranked, respectively, second (33), third (19%), and fourth (16%).

[24] The other combination, corresponding to observations that exhibit as individuals, but patent as firms, is never observed.

[25] This was particularly likely to be the case for Italians: Nuvolari and Vasta (2015a) show that Italian independent inventors, unlike their American, British and Japanese counterparts (Nicholas, 2010, 2011), patented lower-than-average-quality inventions.

4. Econometric analysis

The insights from the descriptive statistics presented above can be verified, and new ones can be added, by making use of econometric techniques. Table 3 displays the results of regressions, investigating the determinants of exhibitors' and patentees' decisions, respectively, to patent and to exhibit. In either case, the following specification is considered:

$$Y = \propto + \beta_1 Firm + \beta_2 Product\_class + \beta_2 Location + \varepsilon \qquad (1)$$

In addition to this 'baseline' specification, when analysing patentees' choice to exhibit, the following 'alternative' specification is added:

$$Y = \propto + \beta_1 Firm + \beta_2 Product\_class + \beta_3 Transport\_cost + \varepsilon \qquad (2)$$

Each equation is estimated by two different econometric models, namely probit and negative binomial, the difference between which lies in the dependent variable being, respectively, a binary variable or a 'count' variable (taking non-negative integer values). More precisely, in the probit, the dependent variable denotes whether Turin 1911 exhibitors were granted at least one patent in Italy over the period 1908-1912, or whether agents, who were granted at least one patent in Italy in 1911, exhibited at Turin's expo, irrespective of the number of patents they took out, or exhibits they displayed. By the contrary, the negative binomial's dependent variable indicates the number of patents or exhibits.

Three types of independent variables are inserted on the right-hand side of the equations, denoting exhibitors/patentees' type, geographical origin, and product class. In particular, *Firm* is a binary variable, equalling unity for firms, and zero for individuals; and *Product class* is a categorical variable, taking the values of the 14-industries reduced version of Italian patent classification. The difference between the two specifications presented above lies in the employed geographical-origin variable, respectively being *Location* and *Transport cost*. The first is a categorical variable, constructed as follows: each foreign country is attributed a category; Italy is divided into several 'tiers', based on distance from Turin (*Rest of North-West*, *North-East and Tuscany*, *Centre and South*, *Extreme South and Islands*);[26] finally, Italy's main economic centres, i.e. the cities of the 'Industrial Triangle' (Genoa, Milan, and Turin) and the capital Rome, are dedicated separate categories. Instead, *Transport cost* is a continuous variable, indicating the cost (per unit of weight) of shipping to Turin from each patentee's place, which does not only depend on geographical distance, but also on national railway fares, and on the availability of alternative modes of transport (railway, sea).[27]

Let us start from the first column of Table 3, investigating whether the exhibitors of Turin 1911 were granted patents in Italy over the period 1908-12. The coefficients reported in Table 3 are marginal effects, which, since all regressors are categorical, indicate, for each value taken by a regressor, the effect on the dependent variable resulting from the regressor taking that value, rather than its selected baseline value. Therefore, the (highly significant) coefficient on dummy *Firm* implies that firm

[26] Italian regions are distributed as follows: Liguria, Lombardy, and Piedmont (including present-day Aosta Valley) in *Rest of North-West*; Emilia-Romagna, Tuscany, and Venetia (including present-day Friuli) in *North-East and Tuscany*; Abruzzi (including present-day Molise), Campania, Latium, Marches, and Umbria in *Centre and South*; Apulia, Basilicata, Calabria, Sardinia, and Sicily in *Extreme South and Islands*.

[27] The land and sea distance, cost-minimising mode of transport, and unit transport cost, of a set of most representative nodes are provided in Table A2 in the appendix.

exhibitors were on average 5% more likely to patent than individuals, which is in line with evidence from the previous section.

Table 3. Probit regression results (average marginal effects).

	Do exhibitors patent?	Do patentees exhibit?	
	Equation (1)	Equation (1)	Equation (2)
Firm	0.046***	0.195***	0.185***
Product class			
Agriculture	-0.001	0.065*	0.054
Chemicals	-0.098*	0.045	0.036
Construction and construction materials	-0.068	0.021	0.010
Electricity	0.174***	0.024	0.020
Food and beverages	-0.038	0.029	0.026
Machine tools, machinery, components and metalworking	0.033	0.033	0.021
Mining	-0.003	0.004	0.005
Other manufactures	-0.141***	-0.040	-0.046
Paper and printing	-0.098*	0.033	0.027
Scientific instruments	-0.056	0.002	-0.005
Steam engines	0.217***	0.002	-0.005
Textiles, apparel and leather	-0.141***	-0.015	-0.026
Transport	0.134**	0.027	0.023
Location			
Italy			
Center and South	-0.012	-0.149***	
Extreme South and Islands	-0.124***	-0.191***	
Genoa	-0.010	-0.172***	
Milan	0.079***	-0.118***	
North-East and Tuscany	-0.026	-0.189***	
Rest of North-West	0.008	-0.121***	
Rome	0.170***	-0.192***	
Belgium	-0.122***	-0.141***	
France	-0.103***	-0.172***	
Germany	-0.036	-0.211***	
Great Britain	-0.122***	-0.219***	
Switzerland	0.082	-0.167***	
United States	-0.156***	-0.244***	
Transport cost			-0.004***
Number of observations	4,733	3,552	3,552

*Notes: (i) *, ** and *** denote p < 0.1, p < 0.05 and p < 0.01, respectively (based on heteroskedasticity-robust standard errors); (ii) (omitted) baseline categories are Turin for the categorical variable* Location*, and Weapons for the categorical variable* Product class.

The coefficients about the *Product class* variable indicate that exhibitors in the classes of *Electricity*, *Steam engines*, and *Transport* were granted significantly more patents than those belonging to the class of *Weapons*, which has been chosen as the baseline, because of its exhibitor-patentee matching rate being close to the average. This does not surprise, since in these engineering-related classes items typically constitute patentable matter, and patenting activity is particularly high. As a further explanation, it can be advanced that reverse-engineering was relatively easy in mechanical industries (Moser, 2012, p. 65), which rendered risky to exhibit without being protected by a patent. By the contrary, significant negative coefficients are attached to the classes of *Other manufactures* (i.e. furniture) and *Textiles* (-14% in either case), where most exhibits are traditional low-tech consumer goods, produced with well-established and mature technologies. Also negative, but lower in absolute value (-10%) and only significant at the 10% level, are the coefficients attached to classes *Chemicals* and *Paper and printing*. The puzzling negative coefficient of the first of these – a science-based sector, linked to the technological trajectories of the Second Industrial Revolution – is explained by the prevalence, at the exhibition, of chemical products characterised by low technological content, like fertilizers and perfumes.

As for the variable *Location*, the only geographical areas, the exhibitors from which turn out to be significantly more likely to patent than those from Turin (the baseline category), are Milan and Rome. All other Italian geographical categories display non-significant coefficients, except for the extreme South, displaying significantly negative ones, the magnitude of which (-12%) is comparable to that of foreign countries – a symptom of the low inventive activity in the most remote Italian regions (cf. Nuvolari and Vasta, 2015b). Indeed, most foreign countries present significant negative coefficients, since the Italian market was not as important for foreigners, as it was for Italians, resulting in a lower co-occurrence of exhibiting and patenting; but exceptions can be observed, namely Germany and Switzerland, displaying non-significant coefficients. These exceptions can be motivated by those countries' particular degree of involvement and interest in the Italian market; as well as by the concentration of their exhibits in the product classes related to mechanics, where the propensity to patent is particularly high.

The remaining columns of Table 3 investigate whether agents granted patents in Italy in 1911 participated in Turin's International Exhibition. The coefficient on the dummy *Firm* is again positive and highly significant, but much larger than previously observed (19%). This means that firms were less likely than individuals to be involved in exhibiting only or patenting only, than to perform both activities; but patenting only was especially unlikely.

The coefficients attached to product categories are generally not significant: in fact, that of category *Agriculture* is significant at the 10% level, but only under the baseline specification (1). Therefore, unlike propensity to patent, propensity to exhibit emerges not to vary significantly across sectors.

Instead, from the results concerning the variable *Location*, it clearly emerges that all patentees outside Turin were significantly less likely to exhibit than those based in the exhibition's host city, as coefficients are all negative and significant at the 1% level. The magnitude of coefficients broadly increases in distance, but a strict monotonicity cannot be observed: indeed, they are lowest for Milan and the *Rest of North-West*, and highest for Great Britain and the United States; but they are higher for the *North-East and Tuscany* than for the *Centre and South*, despite the latter being father away from Turin than the former. To solve this puzzle, it should be considered that a marked divide existed, in patenting activity, between the North plus, in the centre, Tuscany and Rome, on one side, and the rest of the Centre, the South, and the islands, on the other.[28] The relatively few patentees from the latter regions, however, might be particularly motivated to present their items at a distant and internationally relevant venue like Turin's exhibition, and in so doing they were helped by a capillary organisational network.[29] Among foreigners, Belgium, France, and Switzerland display the smallest

[28] This divide is apparent from the maps in Nuvolari and Vasta (2015b), showing the geographical distribution (at the provincial level) of patents per million inhabitants in five benchmark years over the Liberal age (1861-1913). In the sample used in this analysis, 766 patentees are from the 'Industrial Triangle' cities (Genoa, Milan, Turin), 298 from the *Rest of North-West*, 277 from the *North-East and Tuscany*, 187 from Rome, and only 165 from the rest of the country.

[29] Art. 6 of the *Regolamento generale* invited the Chambers of Commerce to establish local committees that would act as intermediate bodies between the Exhibition's organisers and the general public.

coefficient (in absolute value), meaning the highest likelihood to exhibit. The latter two countries were geographically close to the exhibition's host city; while Belgium, as observed above, was the largest foreign investor in Italy at that time, as well as the most frequent organiser of international exhibitions in the early twentieth century. Under the alternative specification (2), the same result emerges: propensity to exhibit (unsurprisingly) decreases in the continuous variable *Transport cost*, indicating the cost per unit of weight, which depends on distance, as well as on national railway fares and access to the sea.

Table 4. Negative binomial regression results (average marginal effects).

	Do exhibitors patent?	Do patentees exhibit?	
	Equation (1)	Equation (1)	Equation (2)
Firm	0.250***	0.476***	0.481***
Product class			
Agriculture	-0.145	0.036	-0.021
Chemicals	-0.389*	-0.035	-0.073
Construction and construction materials	-0.314	-0.002	-0.048
Electricity	0.769**	-0.033	-0.065
Food and beverages	-0.251	-0.039	-0.069
Machine tools, machinery, components and metalworking	-0.015	0.008	-0.034
Mining	-0.164	-0.088	-0.122
Other manufactures	-0.445**	-0.142*	-0.178*
Paper and printing	-0.353	-0.047	-0.084
Scientific instruments	-0.278	-0.077	-0.113
Steam engines	1.424***	0.031	0.002
Textiles, apparel and leather	-0.448**	-0.096	-0.133
Transport	0.489**	-0.032	-0.070
Location			
Italy			
Center and South	-0.107	-0.422***	
Extreme South and Islands	-0.394***	-0.490***	
Genoa	0.158	-0.393***	
Milan	0.443**	-0.349***	
North-East and Tuscany	-0.211**	-0.490***	
Rest of North-West	-0.037	-0.354***	
Rome	0.003	-0.499***	
Belgium	-0.312***	-0.427***	
France	-0.331***	-0.448***	
Germany	0.064	-0.468***	
Great Britain	-0.397***	-0.521***	
Switzerland	0.522	-0.413***	
United States	-0.452***	-0.559***	
Transport cost			-0.007***
Number of observations	4,733	3,552	3552

*Notes: (i) *, ** and *** denote $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively (based on heteroskedasticity-robust standard errors); (ii) (omitted) baseline categories are Turin for the categorical variable* Location*, and Weapons for the categorical variable* Product class.

These were charged not only with promotional and communicating tasks, but also with real decision-making competencies, like the preselection of items to be sent to the Executive Commission for admission. The establishment of such committees was also promoted abroad (art. 7) by foreign Chambers of Commerce, consulates, institutes and associations.

Results from the negative binomial model, shown in Table 4, are very similar to those from the probit. The main difference is constituted by the size of the coefficients, being larger than in the probit: for example, in the first column, the coefficient on dummy *Firm* is 25%, meaning that the number of patents taken out by firms is one-fourth larger than that of individuals, *vis-à-vis* 5% in the probit. The reason for this is that, while in the latter model the dependent variable is limited between zero and one, in the negative binomial it can take larger values. Furthermore, the significance of a few coefficients also changes: notably, in the first column, the negative coefficient on the geographical category *North-East and Tuscany* gains significance, while *Rome* loses it. In other words, economic agents from Italy's capital were more likely than those from Turin to patent, but the average number of patents they were taking out was not larger. By the contrary, agents from Milan were both more likely to patent, and taking out a larger number of patents, on average, which confirms that city's status as the actual economic and technological 'capital' of Italy. In the other columns, investigating how many exhibits were taken by agents who were granted at least one patent in Italy in 1911, the negative coefficient of the 'residual' product class *Other manufactures* displays significance at the 10% level, consistent under either specification, which did not emerge from the probit. This may denote that in this class not only the mismatch between patentees and exhibitors was particularly severe, but 'small' exhibitor prevailed.

5. Considerations about the cost of exhibiting and patenting

With the exception of transport costs, the econometric analysis from the previous section has not kept into account the cost of patenting and exhibiting, which could in fact be a crucial factor, determining the choice of performing those activities. In the absence of individual-level data about all expenses actually made by the economic agents considered, the best alternative is to construct 'synthetic' costs, based on pieces of information from official sources about the type and amount of costs incurred by exhibitors and patentees. Two caveats are in order: first, most sources report unitary costs (e.g. the cost per occupied square metre at the exhibition, and transport fares per kilometre per tonne), which must be multiplied by some imputed values (e.g. occupied surface, and the weight of exhibits) to obtain costs in monetary units. Though some information exists that could 'guide' the quantification of those values, a high degree of arbitrariness cannot be avoided; moreover, values cannot realistically be imputed per single economic agent, but only per homogeneous groups, e.g. by product class or geographical origin. This generates a second issue: synthetic costs depend on the variables used in the econometric model above. The approximation and arbitrariness of the costs thus obtained, their limited variability, and the potential for collinearity, suggest not to attempt including them in an econometric model. Rather, this section provides a description of the costs faced by exhibitors and patentees, tries to quantify them, and speculates on how they could influence participation in the exhibition and in the Italian patent system.[30]

The costs that exhibitors had to bear are well specified in the *Regolamento generale* of Turin's International Exhibition. Enrolment itself involved the following disbursements: i) a fixed fee of 20 lire; ii) a surface occupation fee that was proportional

[30] Costs are expressed in 1911 lire. In that year, one lira exchanged for 0.19 United States dollars, 0.81 German marks, 0.99 French francs, and 0.04 British pounds (Ciocca and Ulizzi, 1990, Table 1).

to the occupied area, and depended on location quality;[31] iii) the cost of 'technical services' (if required), i.e. the supply of water, steam, gas, and electricity. If the total did not exceed 100 lire, it had to be paid outright (article 17). Furthermore, exhibitors had to bear all the costs related to the transport to and from the exhibition's venue, delivery and pick-up, opening and repacking, storage of boxes and tools, as well as for exhibiting material (tables, etc.) and maintenance (article 18). As a facilitation for foreigners, exhibits could be temporarily imported in Italy duty-free (article 27).[32]

Occupied surface can be estimated by matching data about the size of the exhibition's pavilions (from the exhibition's guide edited by the *Touring-Club Italiano*), to data about the distribution of exhibitors across them (from the catalogue). Substantial regularities emerge: most exhibitors occupied an average surface of 12 square metres, determining a cost of 200 lire (inside galleries). For those presenting mechanical items, however, occupied average surface and cost doubled. Some of the latter exhibitors displayed their machinery at work in the *Galleria delle machine in azione*: in this case, average occupied surface would rise to 40 square metres, and cost to 625 lire. On top of this, technical services were probably another relevant cost component, although no hint can be obtained in this regard from any official source.

Table 5. Unit transport cost (in lire per tonne) from selected nodes to Turin.

Node	Cost	Node	Cost	Node	Cost
Italy		*Belgium*		*Great Britain*	
Bologna	18.5	Brussels	27.5	Birmingham	32.3
Catania	21.5			London	25.8
Florence	21.9	*France*			
Genoa	10.0	Lyon	8.6	*Switzerland*	
Milan	8.5	Paris	15.1	Zurich	12.9
Naples	20.8				
Rome	24.2	*Germany*		*United States*	
Venice	22.1	Berlin	33.1	Chicago	45.6
		Cologne	25.6	New York	30.5
		Munich	19.4		

Source: based on railway and shipping rates from Missiaia (2016) (for Italy, Ferrovie dello Stato 1912; cf. fn. 33). Note: full information about how these costs are calculated is available in Table A2 in the appendix.

Transport costs can be estimated, based on the railway and shipping rates (in lire per km per tonne) provided by Missiaia (2016, Tables 2 to 4).[33] In this case, two parameters must be imputed, namely distance and weight. While the former can be straightforwardly calculated, based on each exhibitor's location of origin, for the latter only few helpful elements can be obtained from official sources, which are specific to

[31] The surface occupation fee was 15 lire/m^2 (20 for the first square metre) inside galleries; 10 lire/m^2 under porticoes and in open galleries; 5 lire/m^2 (10 for the first square metre) outdoor. In all galleries and porticoes, fees were increased by 30% if areas could be accessed by two sides; by 60% if they could be accessed by three sides; and by 100% if they were isolated.

[32] Art. 27 of the *Regolamento* also envisaged that special transport fees would be arranged for exhibitors. No source could be retrieved, however, reporting such benefits.

[33] A caveat is in order: the fares indicated by Missiaia refer to coal and grain, as representative goods. Fares for other staples might actually be higher. To tackle this issue, in the case of Italy, the fare reported in Missiaia's work is substituted with the general fare for shipping 'merchandise', provided by the source she employed (Ferrovie dello Stato, 1912). This fare was structured into eight classes, of which the lowest (i.e. the cheapest) is considered. For other countries, Missiaia's fares are maintained, since they do not appear to introduce a significant bias: in the case of France, the main foreign participating country, the source employed by Missiaia (Bureau of Railway Economics, 1915) reveals that the fare for shipping fabricated iron goods was close to the average of those for coal and grain (in fact, it was even marginally lower than that).

single observations and not suitable for being generalised.[34] Therefore, total transport costs can only be estimated, at the price of discretionary assumptions on weight. Let us rather pay attention to the unitary transport cost, displayed in Table 5 for major Italian and foreign cities, resulting from a cost-minimisation problem that keeps into account the availability of various modes of transport.[35] For shipping an item weighing one tonne to Turin and back, an Italian from Milan (the second largest location of origin of Italian exhibitors, after Turin) and a French from Paris (the most frequent location of origin, over all countries joining the exhibition) would spend, respectively, 17 lire and 30 lire. Even for the 'extreme' case of an exhibitor from Chicago, return transport costs would be less than 100 lire. Transport costs, therefore, appear to constitute a minor fraction of the total cost of exhibiting.

As for patenting, the cost scheme of the Italian patent system is described by Nuvolari and Vasta (2015a, p. 862), who point out that it was a very flexible and cheap system, by international standards. It involved an initial fee that was proportional to the requested number of years (10 lire per year), and a series of annual renewal fees that had to be paid to keep the patent 'alive', which increased over time (from 40 lire to 150 lire). It was possible to extend the duration of the patent, initially applied for, by an extra cost of 40 lire. Patenting can be treated as not involving other costs: in fact, the cost of displacement for presenting patent applications was negligible, as a capillary network was in place.[36] 'Synthetic' patenting costs can therefore be computed by making assumptions on patent length and extensions. For either parameter, the actual values for 1911 can be imputed: in that year, individual patentees applied for an average initial duration of 3.8 years, and extended that duration by 1.1 years; for firms, the respective values were 6.0 and 2.0. Based on these values, a cost of 340 lire is obtained for individuals, and of 615 for firms.

Although the computations made in the present section are general and rough approximations, they can still provide useful insights. Indeed, comparing these costs with the average daily wage of an Italian worker in 1911, equalling 2.7 lire (peaking at 3.9 lire in the metal-engineering sector; Scholliers and Zamagni, 1995, Table A.6), reveals that they represented a large fraction of an individual's yearly earnings. This goes along well with the finding that most exhibitors were firms, as it shows that costs represented a significant barrier for individuals to exhibit. Yet, individuals constituted the majority of patentees, in spite of the cost of patenting having a similar magnitude as that of exhibiting. To explain this difference, it should be considered that patents were assets, which remained in the inventors' portfolios, whereas the exhibition was a temporary event, the benefits from which might be uncertain. This could discourage independent inventors from exhibiting: rather, if their intention was to promote their

[34] In a few cases, mostly belonging to mechanical classes, data about the weight of exhibits are provided by the jury reports. The following examples give a taste of the heterogeneity of the various item's weight, even within the same product class. The rotating part of the tree-phase electrical generator exhibited by the *Officine di Savigliano* weighted 19 tonnes; the dynamo of the same company weighted 9 tonnes, and that presented by the firm *Ganz* 7.2 tonnes (*Relazione della giuria*, pp. 410-411). A locomotive presented by *A.E.G.* weighted 3.5 tonnes (p. 419). The airplane engine displayed by the car-maker *Itala* weighted 150 kg (p. 522), that of Roberto Rebaudi 65 kg (pp. 522-523). *Alti Forni Terni* was displaying a massive armor-plate of 62.5 tonnes (p. 679). A security machine for textile industry, by the *Société Anonyme Verviétoise pour la construction de machines - Ancienne Maison Houget & Teston*, weighted only 25 kg (p. 727-728).

[35] Detailed data about this problem, and a larger set of nodes, are presented in Table A2 in the appendix.

[36] Art. 24 the *Regio decreto* no. 1,674 of 1864, regulating the patent system, stated that patent applications could be presented at each *prefettura* (corresponding to the administrative level of the *provincia*) or *sotto-prefettura* (an even more decentralised level).

patents, the services of patent agents might prove much more an effective instrument than participating in an exhibition (Nicholas 2010, 2011; Andersson and Tell, 2016).

Evidence in favour of the latter argument comes from the fact that the few individuals that have been observed in Section 3 to both patent and exhibit, seem to be particularly qualified independent inventors, whose experience and reputation allowed them to move independently in the market for ideas. Many had their profession or title specified, in the exhibition's catalogue, e.g. 'engineer' or 'professor', arguably in order to signal their quality. Moreover, some of them, for instance Riccardo Arnò, Alessandro Artom, and Gino Campos, did not only patent their findings in Italy, but also in the United States, which is an indicator of a particularly high quality.[37] It appears therefore that prominent skills, experience, and renown were a requisite for inventors to exploit the exhibition as a market for ideas. In fact, this might not be a viable option for the majority of independent inventors.

6. Conclusions

This work contributes to the recent literature on international exhibitions and on the use of data from these events as a proxy for innovation in economic history. It provides an in-depth analysis of one representative exhibition, namely Turin 1911, and compares data from this event to Italian patent data. A substantial mismatch emerges, between these two types of data, as they appear to be largely disjoint sets. It is argued that the main reason, behind the difference between exhibition data and patent data, lies in the reasons for exhibiting and for patenting being different: on the one hand, the main function of the exhibition appears to be that of a market for products, as the preponderance of firms among exhibitors clearly reveals; on the other hand, patents were mostly taken out by individuals, the majority of whom might not be interested in that function. As a matter of fact, the presence has been observed of a secondary function of the exhibition, as a market for ideas, which could however only be profited from by particularly skilled independent inventors.

The degree of overlapping, between exhibition data and patent data is not homogeneous; in fact, it is much larger for firms than for individuals. Furthermore, exhibitors have a significantly higher propensity to patent in engineering-related product classes than in other ones, because of the risk of reverse-engineering being particularly high. By the contrary, the propensity to exhibit of patentees does not emerge to be significantly affected by product class; while it is largely determined by the location of economic agents.

The limited overlap between exhibition data and patent data can be interpreted as due to the former being characterised, as a proxy for innovation, by an opposite drawback to that attributed to the latter. As it is widely acknowledged, patents strictly speaking represent *invention*, rather than innovation. They can be used to measure innovation in as much as they indicate 'the presence of a non-negligible expectation as to its ultimate utility and marketability' (Griliches, 1990, p. 1,669). Many patents, however, fail to reach the market, thus becoming innovations. Exhibits suffer from an opposite drawback: they do represent goods brought to the market, but not necessarily

[37] Between 1899 and 1919, seven patents were granted in the United States to Arnò, ten to Artom, and five to Campos. All three were electrical engineers. Arnò and Artom were also academics: the former was a professor of electrical engineering at the Polytechnic University of Milan, the latter was a professor of radiotelegraphy at the University of Turin. Campos worked for CGS, one of the leading Italian firms in the field of electrical engineering, founded by Camillo Olivetti.

innovative ones. In fact, many are primary products, and a large fraction of manufactured ones is constituted by traditional low-tech consumer goods, produced with well-established and mature technologies, e.g. textiles and furniture.

This calls for a reconsideration of the use of exhibition data as a proxy for innovation. First, it should be adequately stressed that these data are mostly informative about the activity of firms. This is important, because exhibition data can provide a valuable overview on these economic agents during the ‘age of the independent inventor’, and therefore be a useful complement to patent data, which by the contrary is dominated by individuals. Second, while exhibition data have so far been considered on a par with patent data, they can actually be more representative of ‘pettier’ innovative activities. Future works should explore the relationship of exhibition data with designs and trade-marks, which might prove closer than that to patent data. Furthermore, most present-day analyses follow the guidelines for collecting and interpreting innovation data, set out by the OECD (2005) in the ‘Oslo manual’, according to which any new product or service brought to the market is an innovation – a much looser criterion than those required for patentability, which fits exhibition data quite well. Therefore, research on exhibitions can not only add new insights to research on innovation in a historical perspective, but can also ensure an improved comparability to the most up-to-date non-historical works.

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Appendix

Table A1. Official distribution of exhibits, by country and group.

	Total	Italy	Belgium	France	Germany	Great Britain	Switzerland	United States	Rest of Europe	Asia	Latin America
Total	22,271	6,774	409	6,261	868	755	71	120	878	770	5,365
% country		30.4	1.8	28.1	3.9	3.4	0.3	0.5	3.9	3.5	24.1
1. Teaching	768	376	1	231	4	4	0	8	32	29	83
2. Instruments	310	108	0	78	48	41	4	6	10	0	15
3. Photography	334	125	3	71	39	43	0	1	8	6	38
4. Mechanics	487	168	6	75	119	43	20	35	9	0	12
5. Electricity	285	110	2	87	41	20	15	0	5	0	5
6. Construction	195	63	8	74	11	10	2	1	3	1	22
7. Land transport	316	112	15	74	53	29	3	1	6	4	19
8. Navigation	141	38	11	37	16	14	0	2	5	4	14
9. Aviation	64	14	3	25	18	3	0	0	0	0	1
10. Postal services	13	7	0	0	1	1	0	0	0	1	3
11. Sports	350	123	15	113	26	62	0	3	0	3	5
12. The modern city	277	106	10	101	14	6	0	0	4	0	36
13. Furniture	1,207	373	8	396	61	53	3	7	64	136	106
14. Music and shows	169	69	3	19	43	4	0	5	6	3	17
15. Forestry	707	49	0	108	7	15	0	0	95	11	422
16. Agriculture	2,687	334	6	506	22	66	7	15	127	32	1,572
17. Foodstuffs	5,053	1,312	118	1,795	58	43	7	3	150	85	1,482
18. Mining and chemicals	1,901	516	35	334	88	113	2	15	118	59	621
19. Textiles	929	205	24	153	12	47	4	0	68	211	205
20. Apparel	709	185	15	257	22	14	1	5	39	95	76
21. Jewelry and accessories	390	93	8	121	47	5	0	2	34	64	16
22. Leather	514	154	21	94	20	35	0	2	31	8	149
23. Printing	1,294	264	27	614	64	73	3	9	35	16	189
24. Social economy	1,743	559	65	878	22	4	0	0	22	2	191
25. Colonisation and migration	1,247	1,165	5	20	0	0	0	0	0	0	57
26. National defence	181	146	0	0	12	7	0	0	7	0	9

Source: Relazione della giuria, pp. 286-97.

Table A2. Distance and unit transport cost from selected nodes to Turin.

Geographical area	*Node*	*Port (if different from node)*	*Land distance (km)*	*Distance from port (km)*	*Sea distance (nm)*	*Mode*	*Unit cost (lire per tonne)*
Italy (TC=1.2618 lire per km per tonne; VC=0.0515 lire per tonne)							
Abruzzi	Pescara		710	0	1,209	Sea	22.6
Apulia	Bari		1,000	0	948	Sea	22.0
Basilicata	Potenza	Naples	1,005	160	341	Sea	29.1
Calabria	Catanzaro	Gioia Tauro	1,260	110	590	Sea	27.0
Campania	Naples		870	0	341	Sea	20.8
Emilia-Romagna	Bologna		335	-	-	Railway	18.5
Latium	Rome	Civitavecchia	682	70	220	Sea	24.2
Liguria	Genoa		170	-	-	Railway	10.0
Lombardy	Milan		140	-	-	Railway	8.5
Marches	Ancona		560	0	1,234	Sea	22.6
Piedmont	Turin		0	-	-	Railway	0.00
Sardinia	Cagliari		-	0	387	Sea	20.9
Sicily	Catania		1,500	0	664	Sea	21.5
Tuscany	Florence	Livorno	400	90	53	Railway	21.9
Umbria	Terni	Civitavecchia	625	120	220	Sea	26.7
Venetia	Venice		405	0	1,325	Sea	22.1
Belgium (TC=5.1039 lire per km per tonne; VC=0.0232 lire per tonne)							
Whole country	Brussels	Antwerp	1050	50	2,529	Railway	27.5
France (TC=5.7289 lire per km per tonne; VC=0.0145 lire per tonne)							
South-East	Lyon	Marseille	350	250	190	Railway	8.6
Rest of the country	Paris	Le Havre	800	200	2,364	Railway	15.1
Germany (TC=4.8956 lire per km per tonne; VC=0.0250 lire per tonne)							
South	Munich	Hamburg	650	800	2,897	Railway	19.4
North Rhine-Westphalia	Cologne	Hamburg	900	430	2,897	Railway	25.6
North	Berlin	Hamburg	1,200	315	2,897	Railway	33.1
Great Britain (TC=1.8749 lire per km per tonne; VC=0.0412 lire per tonne)							
South	London		884	0	2,505	Sea	25.8
North	Birmingham	Liverpool	1,049	160	2,453	Sea	32.3
Switzerland (TC=5.1039 lire per km per tonne; VC=0.0232 lire per tonne)							
Whole country	Zurich		420	-	-	Railway	12.9
United States (TC=2.5520 lire per km per tonne; VC=0.0116 lire per tonne)							
North-East	New York		6,428	0	4,483	Sea	30.5
Rest of the country	Chicago	New York	7,285	1,300	4,483	Sea	45.6

Source: based on railway and shipping rates from Missiaia (2016) (for Italy, Ferrovie dello Stato 1912; cf. fn. 33). Notes: (i) railway fares' terminal and variable components (variable cost per km, and fixed cost, denoted by TC and VC, respectively) are shown in brackets, close to each country's name; shipping fares' terminal and variable components (constant across countries) are 7.29 and 0.00112, respectively; (ii) Land distance *is between* Node *and* Turin, Sea distance *between* Port *and Genoa; (iii)* Unit cost *refer to the cost-minimising mode of transport (displayed in column* Mode*), between 'Railway' (denoting fully railway-based shipment) and 'Sea' (denoting shipment from Node to Port, then by sea to Genoa, then again by railway to Turin).*

Does innovation foster business profits?
Evidence from Italy, 1913-1936

Giacomo Domini

Abstract. This paper discusses whether innovation fostered business profits in Italy in the late Liberal age (i.e. the years preceding the First World War) and in the inter-war period. To do this, it connects information from different sources, namely the balance sheets of Italian joint-stock companies (retrieved from the IMITA.db database) in the benchmark years 1913 and 1936; and, as gauges of these companies' innovative activity, Italian patents and data from Turin 1911 International Exhibition.

No evidence is found of a positive short-term relationship between innovation and profitability, which contrasts with the findings of previous empirical economic analyses, but is in line with historiographical accounts, pointing out the scarce relevance of innovation in Italian economic growth. However, a possibly more relevant long-run nexus is observed, as patenting firms are more likely to survive than those which do not innovate.

This pattern is reversed, if exhibition data are employed to gauge innovation, instead of patent data: indeed, exhibiting is associated with a boost in short-term profitability, but not a long run benefit, in terms of survival. In other words, exhibiting, unlike patenting, does not help developing firm capabilities – which questions its validity in effectively representing innovation.

Keywords: innovation; international exhibitions; Italy; patents; profitability

JEL classification codes: M21, N64, NT4, N84, O33

1. Introduction

Investigating the relationship between innovation and profitability means investigating the economic reasons for innovating themselves. An established view in economic theory, the roots of which can be traced back to the thought of Schumpeter (1934), argues that innovation, i.e. the introduction of a new product or process, entails a short-term competitive advantage (if not a real monopoly position), lasting until the time competitors can imitate the novel product or process. This view has been formalised in the models by Aghion and Howitt (1992) and Klepper (1996). The perspective of such an advantage can be seen as lying at the basis of the decision of firms to innovate.

Besides this view, Geroski and Machin (1993, p. 36) argue that innovation enhances firm performance via another, more subtle channel: specifically, 'the process of innovation transforms the firm itself, building up its internal capabilities in a variety of ways that create generic differences between innovating and non-innovating firms'. Unlike the 'traditional' view whereby innovation entails an immediate but temporary competitive advantage, which Geroski and Machin term the 'product view' of the innovation-profitability nexus, the alternative mechanism they illustrate, which they label the 'process view', unfolds over a long time horizon, as its effects 'do not necessarily manifest themselves only after an innovation occurs' (*ibidem*).

On an empirical ground, the same work and a related paper by the same authors (Geroski, Machin and van Reenen, 1993), studying a panel of 721 British manufacturing firms in the years 1972-1983, observe that both effects are at work, but the process view appears to be more relevant than the product view. Indeed, individual innovations do have a significant positive effect on profitability, but small compared to that of market-related variables. In spite of this modest short-term effect, the authors contend that long-term, permanent effects, associated with the development of firms' capabilities, are much more important, and innovating firms appear to be less sensitive to cyclical shocks than non-innovating ones. These results have been substantially confirmed, for various countries and time periods, by subsequent studies,[1] notably Cefis and Ciccarelli (2005; on Great Britain, 1988-1992); Cozza, Malerba, Mancusi, Perani and Vezzulli (2012; on Italy, 2000-2003); Leiponen (2000; on Finland, 1985-1993); and Love, Roper and Du (2009; on Ireland, 1991-2002).[2]

All the mentioned studies refer to recent decades. To my knowledge, the only empirical work, studying the innovation-profitability nexus in a historical perspective is that by Mowery (1983). Analysing several samples of American firms over the period 1921-1946, this author finds that (both large and small) research-performing firms grew faster than their competitors, and that research increased the likelihood of firms' survival among the ranks of the largest manufacturing firms, over the above-mentioned period.

Acknowledging the relevance of a long-term perspective to providing a thorough assessment of the impact of innovation on firm performance, the present paper also analyses the innovation-profitability nexus in a historical context, namely the years 1913-1936. However, unlike Mowery's study, dealing with a technological leader country, this work deals with a peripheral laggard economy, as Italy was in the observed

[1] In fact, the existence of a positive short-term relationship between innovation and profits was also pointed out by earlier studies by Minisian (1962) and Scherer (1965), for the United States, and by Smyth, Samuels and Tzoannos (1972), for the United Kindgom.

[2] Diederen, van Meijl and Wolters (2002) have studied the innovation-profitability nexus in Dutch agriculture, also finding a positive result.

period. A poor and backward country in the aftermath of its Unification (1861), Italy experienced considerable growth and significant structural change over the twentieth century, to the extent that, after the Second World War, it converged to the most advanced economies. Yet innovation does not seem to have played an important role in these achievements, as Italian industry was deeply rooted in traditional sectors (Giannetti and Vasta, 2010), where innovation relies on formal research activities very little if at all, while it was weak in sectors characterised by high technological opportunity and patenting intensity.[3]

Besides the appeal of the Italian case *per se*, a more practical reason for carrying out a historical study about Italy is the abundance of data referring to this country. The IMITA.db database provides extensive information about Italian joint-stock companies, including their balance sheets, for the first three-quarters of the twentieth century. This can be complemented, on the side of innovation, with two different types of data. The first are patents, which are a standard gauge in studies dealing with innovation (Griliches 1990; Nagaoka, Motohashi and Goto, 2010), and are especially important in historical analyses, as they are available since long ago for many countries, whereas data about other common measures, like R&D expenditure, are non-existent before the Second World War. A second proxy for innovation, employed in this study, is data from international exhibitions, recently proposed by Moser (2005, 2011, 2012) as an alternative to patent data, for the second half of the nineteenth century and the first decades of the twentieth. In particular, the database of the manufactured products displayed at Turin 1911 International Exhibition, constructed by me and presented in the first paper of this thesis, is employed. The latter work, matching that original database with Italian patent data, points out relevant differences concerning the identity of exhibitors and patentees, stressing that international exhibitions were primarily markets for products, which attracted firms aiming at advertising their products and at strengthening their reputation. Indeed, it is well known in economic history (Khan, 2013, pp. 107-108; Khan, 2015, p. 39; Schroeder-Gudehus and Rasmussen, 1992, p. 6) that exhibitions were an important means of publicity for firms, at a time when mass advertisement was not yet developed: the exhibitions' catalogues informed their readers about the names of firms in each industrial field; furthermore, the prizes awarded at exhibitions were used by companies as quality signals, boosting their renown and reputation. Using exhibition data besides patent data for quantifying innovation, this work contributes to the evaluation of the goodness of the former as a proxy for innovation, and to the assessment of the economic implications of exhibiting, *vis-à-vis* patenting.

The paper is structured as follows. The next section introduces the IMITA.db database, the measure of profitability, and the proxies for innovation. Section 3 sketches the main trends, over the observed period, in profitability and innovation; and presents descriptive statistics from the employed data. Section 4 presents the econometric analysis, first analysing the short-term relationship between innovation and profitability, then the long-term nexus between the former and firm survival. Section 5 sums up the

[3] In fact, different views exist, about the relevance of innovation in Italian economic development. While there is substantial agreement on the fact that Italian 'original' innovative activity was weaker than in more advanced economies, and the adaptation and imitation of foreign technologies prevailed, 'optimists' argue that this was a rational response to Italy's factor endowment (scarce resources, abundant unskilled labour) and to the consequent relative prices, making labour-saving, resource-intensive technologies non-advantageous (Cohen and Federico, 2001). By the contrary, 'pessimists' stress Italy's prolonged failure to develop an autonomous innovative capacity (Giannetti, 1998; Nuvolari and Vasta, 2015a; Vasta, 1999a, 1999b).

main results of this work, pointing out its contributions to both the more strictly economic literature, and to the economic historical one.

2. The data

Data about firms' characteristics and balance sheets are drawn from IMITA.db (*IMprese ITAliane Data Base*).[4] This database consists of the digitisation of the *Notizie statistiche*, a series of volumes edited and published at (roughly) 3-year intervals, first by *Credito Italiano* from 1906 to 1925, then by the *Associazione fra le società italiane per azioni* (*Assonime*) since 1928, up to the 1970s.[5]

The database provides an overview of the largest Italian joint-stock companies: in effect, it includes those companies that were either listed in one of the Italian stock markets,[6] or exceeding a given share-capital threshold (until 1940, one million lire).[7] This sample represents a share of the total population of Italian joint-stock companies, ranging from 22% in 1913 to 40% in 1936; but in terms of share capital, it represents more than 90%.[8]

The data employed in this work will be limited, on the side of time, to benchmark years 1913 and 1936; and on the side of sectors, to manufacturing industries, corresponding to section D of the ISIC (Rev. 3) classification, structured into 22 divisions, from 15 to 36.[9]

Profitability will be measured by the Return on Equity (ROE),[10] defined as

$$ROE = \frac{Profit/Loss}{Share\ Capital + Provisions + Profit/Loss}$$

In order to prevent the values of the profitability index from being conditioned by occasional swings in a particular year, the ROE in each year will be 'adjusted' by taking its arithmetic average over that year and the preceding one (in the following sections, 'ROE' will denote this adjusted version). In formula:

$$ROE_t^{adj} = \frac{ROE_t + ROE_{t-1}}{2}$$

[4] The database is freely accessible at http://imitadb.unisi.it/en/home.asp.

[5] IMITA.db is a relational database, structured into three parts: the first contains information about firms, such as name, location, foundation year, and ATECO 1991 code (an industrial classification, resulting from the local adaptation by the Italian statistical office, ISTAT, of the Eurostat's NACE Rev. 1, which is in turn based on the United Nation's ISIC Rev. 3), in several benchmark years (1911, 1913, 1921, 1927, 1936, 1952, 1960, 1972, 1983); the second reproduces each firm's yearly balance sheets; the third lists the names, positions, and professions, of each firm's board members.

[6] It should be noticed that listed firms represent a minority: as shown by Giannetti and Vasta (2012, Figure 8.3), the number of companies listed at the *Borsa* of Milan was never larger than 180, until the late 1980s.

[7] This threshold was set at different levels over time, but over the period studied here it was constant at one million lire. As Vasta (2006a, fn. 1) notices, until 1937 a few companies that were members of *Assonime* were included in the source, even though they did not reach the set threshold.

[8] See Vasta (2006a, p. 270). Actually, for benchmark years 1911 and 1913 the computed share is actually 75% and 80%, respectively; but the impossibility to distinguish between nominal capital and paid-up capital in those benchmark years causes these shares to be underestimated.

[9] Actually, section D of the ISIC Rev. 3 includes one more division, namely *Recycling* (37); but since in IMITA.db no firm belongs to it in either 1913 or 1936, it will be omitted from the tables in the following sections.

[10] The more commonly employed Return on Investment (ROI) cannot be computed from IMITA.db data because of a number of issues, including the impossibility of distinguishing the capital actually used in the operative management (Vasta, 2006b, pp. 156-157).

An important caveat is that, although total manufacturing firm population is 624 in 1913, and 1,764 in 1936, the subsequent analysis will be performed on smaller sets of firms (594 in the earlier benchmark year; 1,637 in the latter), because balance sheets are missing for some firms, thus preventing the computation of the ROE and of other variables.[11]

On the side of innovation, as anticipated in the introduction, two different proxies will be employed, namely Italian patent data, and data about Turin 1911 International Exhibition. The source for the former is the *Bollettino della Proprietà Intellettuale*, containing the lists of patents granted in Italy in each year. For each manufacturing firm in either benchmark year employed, it has been checked how many patents were granted to it, over an eight-year time span, including the benchmark and the seven preceding years. For the latter proxy, the source is the database, constructed by me and presented in the first paper of this thesis, listing the manufactured products displayed at Turin 1911 International Exhibition. That event had a particular relevance for Italy, as it took place at the end of its first important phase of economic development (see next section), and was seen as a unique opportunity to show the progress of the country to the world, in the occasion of the 50th anniversary of its Unification. Unfortunately, comparable data are not available in the case of the benchmark year 1936, a general reason being the decline undergone by international exhibitions after the First World War, in terms of both frequency and relevance; and a particular one being that no exhibition took place in Italy during the inter-war period. Therefore, only patent data will be employed to proxy innovation in the benchmark year 1936.

3. Profitability and innovation in Italy, 1900-1939

The first four decades of the twentieth century were a period of development for the Italian economy, which grew at significantly higher rates than in the previous century, and underwent considerable structural change.[12] In the early years of the century (the so-called Giolittian era),[13] economic growth was twice as fast as in the previous decades, as an average annual growth rate of 2.5% was scored in the period 1900-1913, *vis-à-vis* 1.2% in 1861-1900. The Great War brought about recession, but in the 1920s a strong recovery occurred (at an average annual rate of 4.6%), which came to a halt with the 1929 crisis. The following depression was overcome in the mid-1930s, with a strong role of the State that reorganised the industrial sector under its auspices. Growth was particularly strong in industry: indeed, that sector grew faster than the whole economy during all the phases mentioned above, but wartime. As a result of these dynamics, by the eve of the Second World War, value added in industry had equalled that in agriculture, and industrial productivity (which at the time of Unification was as low as that of agriculture) had caught up with that in the service sector.

[11] This issue is augmented when the adjusted ROE is computed, since the number of firms for which balance sheets are missing increases in time distance from the benchmark year, and their identity may vary. This motivates the selection of the above-stated type of 'adjustment' of the ROE. In fact, other formulations would be possible, e.g. a three-year centred average. In the latter case, however, lost ROE values in each benchmark year would be considerably more, because available balance sheets in the year after the benchmark generally refer to the following benchmark's firm population, in which some firms might not be present anymore.

[12] Statements and figures in this paragraph are based on data from Baffigi (2013).

[13] 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.

The following sub-sections describe the main trends in the profitability and innovativeness of the Italian manufacturing sector over the observed period, and present some statistics based on the data employed in this work.

3.1 Profitability

An extensive account of long-term firm profitability patterns, based on data from IMITA.db, has already been made by Vasta (2006b), showing that several phases can be distinguished, based on the *aggregate* performance of Italian manufacturing firms (i.e. the ROE of the manufacturing sector as a whole, calculated as the ratio of the sum of all manufacturing firms' profits/losses, over the sum of their share capitals, provisions, and profits/losses). Profitability was good during the Giolittian era, in particular until 1908, when it fluctuated between 5% and 8%, while it settled down about 5% or lower afterwards. Aggregate ROE soared during the First World War, peaking at 15% in 1917, under the effect of industrial mobilisation programs. These exceptional values shrank after the conflict, though profitability remained high (7-9%).[14] A negative trend started after 1925, which was aggravated by the 1929 crisis, so that in 1930 aggregate ROE fell into negative territory. Then it substantially stagnated around zero until the mid-1930s, when the great reorganisation of Italian industry under the aegis of state intervention brought profitability back to 5% and more. The pattern is the same if *average* ROE (i.e. the average of single-firm ROEs) is considered, instead of its aggregate version; but average values are generally lower than aggregate ones, which reveals the dominance of larger companies in profit-making.

At a sectoral level, a profitability gap in favour of light traditional sectors characterised, in general, the observed period. This temporarily reversed during the First World War, when heavy industries were the main beneficiaries of the State's industrial plans; but it recreated afterwards. Likewise, in the mid-1930s, industrial reorganisation and rearming plans fostered the profitability of heavy sectors, so that the gap closed, by the end of the period observed in this study.

Focussing on the two benchmark years that are employed in this work, namely 1913 and 1936, Table 1 displays the average ROE by sector in those years, which reveals considerable heterogeneity. In 1913, the largest profitability values are displayed by apparel and leather; but these are small divisions. In fact, the most striking feature of the table is the negative average ROE of the largest division, namely textiles. The other large traditional sector of food and beverages, on the contrary, performs much better than the general average (4.3% *vis-à-vis* 2.4%). Good profitability is also shown by chemicals and electrical machinery, two distinctive sectors of the Second Industrial Revolution, defined by Pavitt (1984) as 'science-based'; as well as by the 'mechanical' divisions, related to machinery, instruments, and transport. The industries of metals and non-metalliferous minerals perform in line with the average. Shifting attention to 1936, both similarities and differences can be noticed. The highest profitability is displayed by the small emerging sector of rubber.[15] Interestingly, another small technological-frontier division, namely communication equipment (including telephone and radio), presents the worst performance. With respect to the previous benchmark year, the profitability of food and beverages shrinks, while that of textiles regains positive sign; so that they are practically the same in 1936, about 1.5%. Science-based and mechanical divisions

[14] In fact, in 1921 the aggregate ROE fell to -5%, as a consequence of the political and economic unrest of the *biennio rosso*; but it regained positive values immediately after.

[15] The actual name of this division is 'rubber and plastics'. However, the expansion of this division in the 1920 is connected with the development of rubber production; while it was only in the 1950s, with the boom of oil industry, that the production of plastics grew significantly (Vasta, 2006b, p. 169).

maintain above-average ROEs. Metal production and metalworking double their ROEs, under the push of the economic stimuli mentioned above; whereas non-metalliferous minerals worsen considerably, as their average ROE falls to less than 0.5%.[16]

Table 1. Average ROE by ISIC Rev. 3 division, 1913 and 1936.

		1913		1936	
		ROE	n	ROE	n
15	Food and beverages	4.29	101	1.55	262
16	Tobacco	-	0	3.34	4
17	Textiles	-0.84	138	1.43	324
18	Apparel	6.68	8	0.54	35
19	Leather, bags and footwear	6.61	9	3.72	39
20	Wood	-2.51	7	2.99	21
21	Paper	4.79	25	4.04	56
22	Publishing and printing	-4.19	13	-1.38	62
23	Coke and petroleum	0.00	1	-0.09	34
24	Chemicals	4.42	71	4.24	217
25	Rubber and plastic	0.11	1	5.86	10
26	Non-metallic minerals	2.22	61	0.43	153
27	Basic metals	2.59	40	4.42	86
28	Fabricated metals	1.56	20	3.75	72
29	Machinery and equipment	3.76	21	2.68	63
30	Office machinery	-	0	-8.99	4
31	Electrical machinery	4.79	14	3.59	51
32	Communication equipment	-15.91	1	-9.78	9
33	Instruments	4.74	5	3.57	24
34	Motor vehicles	3.63	17	2.12	19
35	Other transport	2.29	28	3.15	59
36	Furniture and n.e.c.	5.19	13	0.18	33
	Total	2.37	594	2.13	1,637

Source: own elaboration from IMITA.db. Note: on the number of observations (column 'n') being lower than the total number of manufacturing firms in IMITA.db, see Section 2.

Vasta (2006b) also shows that, over the period studied here (and beyond), the profitability of the firms in the IMITA.db database was positively related to their size (as measured by assets)[17] and age, and negatively related to their level of indebtedness (or, conversely, positively related to the degree of financial independence of the firm). This is displayed, for the benchmark years 1913 and 1936, in Tables 2 and 3, respectively. In line with the findings by Vasta (2006b), profitability emerges to be, in general, positively related to both size and age. However, in 1913, a non-monotonic pattern can be observed, involving both variables: as we move from the bottom to the top quartile, profitability first increases, then it plunges to lower values than those in the bottom quartile, then again it steeply increases, and peaks, at the top quartile. One tentative interpretation of this puzzling pattern is that the top of the distributions by size and age constitutes a sort of 'industrial nobility', deeply-rooted and securing high

[16] These patterns are reflected in the lists of the 20 firms scoring the highest ROEs in 1913 and 1936, displayed in Table A1 in the appendix. Consistently with what has just been said, the 1913 ranking is dominated by the divisions of 'chemicals' and 'food and beverages', to which belong six and five firms, respectively, mostly situated in the upper part of the ranking and including the leaders, namely *Prodotti Chimico Farmaceutici A. Bertelli & C.* and *Conserve Alimentari L. Torrigiani* (scoring impressive ROEs at or above 40%). In 1936, chemical firms consolidate their presence among the most profitable ones, with eight companies in the top 20, including the leader *Società Meridionale Ammonia*; whereas food industry practically disappears from the top 20, with the only exception of the cake-producer *Elah*, in the twentieth position.

[17] IMITA.db does not contain information about firms' revenues from sales and number of employees, two widely employed measures of firm size in contemporary studies.

profitability, to the detriment of followers. By the contrary, in 1936 a strictly increasing behaviour can be observed. Finally, the negative relationship between indebtedness (defined as the ratio between total debts and total assets) and profitability is also confirmed, as the Spearman correlation coefficient[18] between these two variables equals -0.44 for 1913, and -0.30 for 1936, in either case statistically significant at the 1% level.

Table 2. Average ROE by size (assets) quartile, 1913 and 1936.

Quartile	1913		1936	
	ROE	n	ROE	n
Top	4.44***	151	4.27***	420
3rd	0.92	148	3.15***	410
2nd	2.90***	147	1.72***	418
Bottom	1.20*	148	-0.82	389

Source: own elaboration from IMITA.db. Note: on the number of observations (column 'n') being lower than the total number of manufacturing firms in IMITA.db, see Section 2.

Table 3. Average ROE by age quartile, 1913 and 1936.

Quartile	1913		1936	
	ROE	n	ROE	n
Top	5.93***	151	3.85***	425
3rd	0.71	130	2.30***	372
2nd	2.22***	115	1.41***	478
Bottom	0.85	198	0.89*	362

Source: own elaboration from IMITA.db. Note: on the number of observations (column 'n') being lower than the total number of manufacturing firms in IMITA.db, see Section 2.

3.2 Innovation

Italian innovative activity, as measured by patents, increased over the period observed. During the Giolittian era, the total number of patents granted in Italy increased at a substantially faster pace than in the past, doubling from around 2,400 in the mid-1890s, to 4,800 in 1905, then again in the following eight years, peaking at 10,560 in 1913. As patents granted to Italian and foreign inventors increased in the same proportion, the degree of openness of the Italian patent system, i.e. the share of patents granted to foreigners, remained stable over those years, at about two-thirds. The war then brought about a fall in the number of patent grants, to which followed a turbulent phase during the 1920s. In the subsequent decade, an increasing patenting activity by Italians counterbalanced a decline in foreign participation in the Italian patent system (related to the international closure during the Great Depression, the isolation of the fascist regime, and its autarchic policies); so that overall patenting remained steady.

Similar trends characterised patents granted abroad to Italians: the shares of patents granted to Italian residents over total patents granted in the major foreign countries steadily increased (if war years are excluded) until the mid-1920s, when they reached a peak; they then declined for some years and, in some cases, recovered during the 1930s (Barbiellini Amidei, Cantwell and Spadavecchia, 2013, Figures 14.1–14.3). The overall picture suggests that Italian innovative activity, as measured by patenting, increased during the Giolittian era and in the first post-war years (though this may be

[18] The non-parametric Spearman rank correlation coefficient is more flexible and robust than the more common Pearson coefficient, since unlike the latter, it does not rely on restrictive assumptions such as linear relationship, absence of significant outliers and approximately normal distribution of variables.

partly attributed to the diffusion of the patent system); while the picture is not clear-cut afterwards. On the one hand, a moderate increase in patent volumes can be observed; on the other hand, the Italian patent system became less internationalised, and Italy lost ground in the most competitive markets.

Individuals were prevalent among Italian patentees. Nuvolari and Vasta (2015b, Table 1) show that the share of patents granted in Italy, accounted for by firms, increased over the Liberal Age (i.e. the era ranging from the Unification of the country in 1861 to the First World War) from 4% in the mid-1860s to 24% in 1911. This appears in line with similar trends in other countries (Nicholas, 2011, Figure 3; Sáiz, 2012, Table 1). If attention is restricted to Italian patentees, however, the latter share becomes significantly lower, namely 14%. By 1936, the share of total patents accounted for by firms had further risen to 46% overall, but to only 22% for Italians. These figures may be interpreted as a symptom of a generally scarce attention, devoted by Italian firms to innovation, *vis-à-vis* their foreign competitors.

Table 4. Number of patenting and exhibiting firms, 1913 and 1936.

	1913						1936		
	Tot.	Patentees		Exhibitors		P+E	Tot.	Patentees	
		n	%	n	%			n	%
15 Food and beverages	106	11	10.4	20	18.9	6	284	24	8.5
16 Tobacco	0	0	-	0	-	0	4	1	25.0
17 Textiles	143	20	14.0	19	13.3	5	350	58	16.6
18 Apparel	8	1	12.5	4	50.0	1	38	12	31.6
19 Leather, bags and footwear	10	3	30.0	5	50.0	2	39	9	23.1
20 Wood	8	1	12.5	0	0.0	0	26	4	15.4
21 Paper	25	3	12.0	8	32.0	2	58	17	29.3
22 Publishing and printing	14	0	0.0	3	21.4	0	70	6	8.6
23 Coke and petroleum	1	0	0.0	0	0.0	0	40	8	20.0
24 Chemicals	74	22	29.7	25	33.8	8	233	57	24.5
25 Rubber and plastic	2	0	0.0	1	50.0	0	10	7	70.0
26 Non-metallic minerals	69	12	17.4	14	20.3	6	162	32	19.8
27 Basic metals	42	16	38.1	19	45.2	8	92	27	29.3
28 Fabricated metals	21	10	47.6	11	52.4	7	79	40	50.6
29 Machinery and equipment	21	12	57.1	14	66.7	9	65	39	60.0
30 Office machinery	0	0	-	0	-	0	5	3	60.0
31 Eletrical machinery	15	11	73.3	10	66.7	10	53	36	67.9
32 Communication equipment	1	1	100.0	1	100.0	1	11	6	54.5
33 Instruments	5	5	100.0	5	100.0	5	26	15	57.7
34 Motor vehicles	17	11	64.7	11	64.7	11	20	11	55.0
35 Other transport	29	10	34.5	10	34.5	7	65	29	44.6
36 Furniture and n.e.c.	13	6	46.2	3	23.1	1	34	14	41.2
Total	624	155	27.1	183	32.0	89	1,764	455	29.7

Sources: see Section 2.

Table 4 provides statistics about the innovativeness of the firms in IMITA.db, by industrial division.[19] For each sector in each benchmark year, it displays firm population, number and share of patentees (i.e. firms granted *at least one* patent in the benchmark or in the seven preceding years). For 1913 only, it also reports the number and share of exhibitors (i.e. firms in the Turin 1911 database), and the number of firms both patenting and exhibiting (column 'P+E').

[19] Notice that, unlike Tables 1 to 3 on profitability, Table 4 reports innovation statistics about the entire firm population in 1913 and 1936, thus including those firms for which balance sheets are not available, which cannot be employed in the empirical analysis. The statements made in the rest of the section are robust to the removal of the latter observations.

In 1913, the largest shares of patenting firms in total firms are scored by the divisions of instruments (100%), electricity (73%), motor vehicles (65%), and machinery (57%);[20] whereas the large traditional divisions of food and textiles feature shares as low as 10% and 14%, respectively. The picture obtained from exhibition data is similar: again, the largest shares of exhibitors are featured by instruments (100%), electricity (67%), machinery (67%), and motor vehicles (65%); whereas in the sectors of food and textiles they are below 20%. Although exhibitors and patentees account for similar shares of total manufacturing firms in IMITA.db (28% and 25%, respectively), the sets of exhibitors and patentees do not overlap: in fact, their intersection (column 'P+E') accounts for 49% of the former, and for 57% of the latter – meaning that around half of either set is not 'shared' with the other. The extent of overlapping, however, largely varies across sectors: it is generally smaller in traditional industries, as well as in those characterised by economies of scale (e.g. publishing, and non-metalliferous minerals); while it is larger in mechanical sectors, including electricity and instruments. These findings are in line with those obtained in the first paper of this thesis.

The situation is similar in 1936: in terms of the share of patentees over firm population, the most innovative sectors turn out to be the same high-mechanical content ones as in 1913, to which must be added division 25 (rubber).[21] The finding that, in both benchmark years, the sectors characterised by high mechanical content are the most innovative ones, comes as no surprise, given their high degree of technological sophistication, and high patent intensity. More interesting is that, in both benchmark years (and, in the earlier one, based on either innovation proxy), chemicals display a share of 'innovators' at or below the average, which is not what one would expect from its being a science-based sector, distinctive of the Second Industrial Revolution.[22] In fact, Italian chemical industry was characterised by a low degree of technological complexity, as it was dominated by less technology-intensive 'new' products, like nitrogenous fertilisers, and by 'old' products, derived from the processing of animal fats (Vasta, 1999b).[23]

[20] Communication equipment also displays a share of 100%; but it contains just one observation.

[21] Table A2 in the appendix shows the top 20 patenting firms in each benchmark year (in fact, for 1936, 21 firms are displayed, since the twentieth position is shared by two firms). Besides confirming the points made in the text, it reveals a substantial mismatch between the top of the firm distributions by profitability and by innovativeness, respectively shown in Tables A1 and A2. A major element, accounting for this mismatch, is the presence of firms characterised by foreign capital, among top-patenting firms, but not among top-profitable ones. Indeed, in the 1913 ranking, top positions are occupied by the Italian branches of foreign companies (*United Shoe Machinery Company d'Italia*, *Western Electric Italiana*, etc.), or by foreign-owned joint ventures (*A.E.G. Thomson Houston*). This is in accordance with what has been said above, about the lower innovativeness of Italian firms, *vis-à-vis* foreign ones. Firms characterised by the presence of foreign capital are still in the top 20 in 1936, but they are fewer, as a consequence of a general decrease of Foreign Direct Investments in Italy in the inter-war period (Colli, 2010). A final point to notice is that, in 1913, all top patentees but two are also exhibitors, which denotes a high degree of overlapping of the two innovation measures, at the high end of the distribution. One of these two exceptions is represented by the firm leading the ranking, namely *A.E.G. Thomson Houston*: however, one of the two founders of this joint venture, the German *Allgemeine Elektricitäts-Gesellschaft*, participated in the exhibition in Turin.

[22] As said above, the sectors of chemicals and electricity are defined by Pavitt (1984) as 'science-based', since 'the main sources of technology are the R&D activities of firms in the sectors, based on the rapid development of the underlying sciences' (*ibidem*, p. 362). In the light of this definition, the average innovative performance of this sector in Italy in the observed period case appears particularly disappointing.

[23] Additional insights, related to the quality of patentees across industries, can be derived from the patent measure. Table A3 in the appendix contains information, for each division, about the number of 'occasional' patentees, i.e. firms granted patents in only one year (column 'P1Y'), and of firms

Table 5. Number of exhibitors and patentees, by size (assets) quartile, 1913 and 1936.

Quartile	1913					1936		
	Tot.	Patentees		Exhibitors		Tot.	Patentees	
		n	%	n	%		n	%
Top	162	63	44.1	69	48.3	484	184	48.2
2nd	154	36	25.2	45	31.5	427	126	32.9
3rd	154	32	22.4	44	30.8	426	94	24.6
Bottom	154	24	16.8	25	17.5	427	51	13.3

Source: see Section 2. Note: 'P+E' indicates firms both patenting and exhibiting.

Table 6. Number of exhibitors and patentees, by age quartile, 1913 and 1936.

Quartile	1913					1936		
	Tot.	Patentees		Exhibitors		Tot.	Patentees	
		n	%	n	%			%
Top	151	44	31.9	59	42.8	431	125	33.2
2nd	130	38	27.3	45	32.4	379	121	32.0
3rd	118	31	27.7	35	31.3	486	126	34.0
Bottom	225	42	23.0	44	24.0	468	83	20.5

Source: see Section 2.

Tables 5 and 6, paralleling Tables 2 and 3 in the previous Subsection, display the number of innovators per each quartile of the distribution by size and age, respectively. Like profitability, innovativeness turns out to be overall positively related to both size and age, although some non-monotonicities can again be observed, as we move up the distribution, both in the case of size and in the case of age.[24]

3.3 A possible nexus?

After reviewing the main patterns and trends in the profitability and innovativeness of Italian firms in the observed period, let us put the two things together. Table 7 displays the average ROE for innovators and non-innovators, and the result of a t-test on the hypothesis that the averages for the two groups are equal. For 1913, innovators are alternatively defined as patentees and exhibitors; for 1936, only as patentees. A

granted a specific number of patents (the five columns, under the label 'Number of patents'). 'Qualitative' insights are in line with the 'quantitative' ones, made in the text. In 1913, three divisions – apparel, communication, and instruments – only have non-occasional patentees, but their number of patentees is limited (five or less). Apart from these, the divisions with the lowest shares of firms with patents in only one year are electricity (9%), machinery (17%), motor vehicles (18%), other transport (30%), and fabricated metals (40%). In all other sectors, more than half of patentees were occasional: indeed, 80 out of 155 total patentees can be so labelled, of which 65 were granted only one patent. To the other extreme, 32 patentees were granted five or more patents, over the observed time span. These 'great' patentees are concentrated in few sectors, particularly electricity (8), machinery (6), and vehicles (5). Also in 1936, 'mechanical' sectors feature the lowest weight of occasional patentees, with shares ranging between 23% and 33%. A difference from the previous benchmark year is that 'great' patentees can now be observed in most industrial divisions – a symptom of the increased general level of innovative activity; even if they are still most frequent in high-mechanical content sectors (plus rubber). Notably, twelve of them can now be observed in chemicals, while none was there in 1913 (*Montecatini* is the most important firm in this group; cf. Table A2). This suggests that, while the average innovativeness of the latter industry did not improve from 1913 to 1936 (in fact, the share of patentees in total firms decreased from 30% to 24%), a number of high innovative firms still emerged.

[24] From the list of the top 20 patenting firms in Table A2, size and age appear less important in 1913 than in 1936, as a number of smaller and younger firms, from the first and second quartiles of the distributions by size and age, can be observed in the earlier benchmark year, but not in the latter.

profitability gap, in favour of innovators, emerges in all cases: in fact, this is only significant at the 10% level for patentees, while it is strongly significant, at the 1% level, for exhibitors.

Table 7. Average ROE of innovators and non-innovators, 1913 and 1936.

	Innovators		Non-innovators		t-statistic
	ROE	n	ROE	n	
1913					
Patentees	3.73	147	1.93	447	-1.93*
Exhibitors	4.76	177	1.36	417	-3.89***
1936					
Patentees	2.75	445	1.90	1,192	-1.73*

Sources: own elaboration from Imita.db. Note: on the number of observations (column 'n') being lower than the total number of manufacturing firms in IMITA.db, see Section 2.

The availability, in IMITA.db, of data for several benchmark years allows investigating whether, besides a short-term profitability improvement, innovation also entails a long-term benefit. This can be done by testing whether innovative firms are more likely to 'survive', on average, than non-innovators. Table 8 shows the share of manufacturing firms from the benchmark years 1913 and 1936 that can be found in the firm population of benchmark years 1936 and 1960, respectively. Notice that the term 'survival', as used in the present analysis, refers to permanence in the database; and a firm's failure to 'survive' may not necessarily denote that it ceases its activity, but also that its share capital does not meet anymore the threshold level for inclusion in the source – which is anyway an indicator of unsuccessful performance. The table distinguishes innovators from non-innovators, using alternative definitions for 1913. It provides strong evidence that innovators have better chances to survive in the long run, especially in the second benchmark year. Interestingly, unlike in the previous table, better results can now be observed for patentees than for exhibitors in 1913. This suggests that, while exhibiting provides a better short-term return, deriving from the publicity and reputation resulting from participation in these events, patenting can be more rewarding in the long run, possibly because of the development of particular capabilities by patentees. Evidence in favour of the conjectures made here will now be sought for in the next section, by means of formal econometric models.

Table 8. Survival rate of innovators and non-innovators, 1913-1936 and 1936-1960.

	Innovators		Non-innovators		t-statistic
	%	n	%	n	
1913 to 1936					
Patentees	54.84	155	43.92	469	-2.37**
Exhibitors	51.37	183	44.67	441	-1.53
1936 to 1960					
Patentees	61.32	455	42.78	1,309	-6.91***

Sources: own elaboration from Imita.db.

4. Econometric analysis

The first econometric model presented in this section is a fixed-effects regression. Inspired by previous empirical analyses of the innovation-profitability nexus, reviewed in the introduction, it employs a market structure-firm performance specification, augmented with variables about innovation. In other words, it contains a series of regressors about the structural traits of the firm and of the industry (division) where it operates, besides the innovation variables that constitute the focus of the analysis. In formula:

$$ROE_t = \alpha + \beta_1 RelSize_{t-1} + \beta_2 Indebt_{t-1} + \beta_3 CapInt_{t-1} + \beta_4 Conc_{t-1} + \sum_{j=0}^{4} \gamma_j \, Pat_{t-j} + \sum_{j=0}^{4} \gamma_j^* IndPat_{t-j} + \delta_t TD_t + \varepsilon_t$$

where α is a firm-specific fixed effect, accounting for time-invariant firm characteristics; while time-varying firm characteristics are relative size (*RelSize*), level of indebtedness (*Indebt*), and capital intensity (*CapInt*). The degree of competition in the industry is measured by its concentration index (*Conc*).[25] Innovation at the firm level is accounted for by a number of lags of the variable *Pat*, measuring patents granted in various years to each firm in the sample. Likewise, the innovation 'spillovers' to which each firm is subject are accounted for by the lags of the variable *IndPat*, measuring total patents granted to all other firms in the same division. Time dummies (TD) are inserted, capturing general macroeconomic conditions in each year. Detailed information about variable definitions is available in Table 9.

Table 9. Variable definitions.

Variable	Definition
Age	Years since foundation of firm
CapInt	Physical assets of firm / Total assets of firm
Conc	Total assets of top 4 firms in division / Total assets of division
Exhibitor	Dummy: =1 if firm exhibits at Turin 1911 International Exhibition
Geo	Categorical: =0 if firm is from North-West, =1 if from North-East or Centre, =2 if from South or Islands
Indebt	Total debts of firm / Total assets of firm
IndPat(t)	Number of patents granted in year t to all other firms in division
Pat(t)	Number of patents granted in year t to firm
Patentee	Dummy: =1 if firm is granted a patent in years [T-7; T] (T: benchmark)
RelSize	Total assets of firm / Total assets of division
Survival	Dummy: =1 if firm survives from 1913 (1936) to 1936 (1960)

Regressions are run separately for the two benchmark years, for each of which (T) the estimation period is [T-3, T]. For 1936, two sets of estimates are shown, respectively making use of all observations,[26] and of a restricted sample, comparable to that of 1913 in terms of share capital, employed as a robustness check. The reason behind this is that, while the capital threshold for inclusion in the database's source was the same in nominal terms (one million lire), in real terms it was much lower in 1936 than in 1913, as an effect of inflation. To ensure full comparability between the estimates in the two benchmark years, the share capital threshold in 1936 should be raised, so that it equals that of 1913 in real terms, thus excluding smaller firms.[27] Finally, for either benchmark year (and, in the case of 1936, also for the restricted sample), a set of three regressions

[25] These variables are entered with a lag, in order to maintain temporal consistency, since the 'adjusted' ROE employed in this analyses is constructed, at time *t*, as an average of the unadjusted ROE at times *t* and *t-1* (cf. Section 2).

[26] In fact, some observations from IMITA.db are not employed, because of missing balance sheets; cf. Section 2.

[27] Based on the deflator from Baffigi (2013), this threshold is set at 3.93 million lire.

is displayed, namely on the whole sample, on patentees only (defined as firms, granted patents over the observed time window), and on non-patentees only. The reason for this separation is to investigate differences in the drivers of profitability, between innovators and non-innovators.

Estimation results, shown in Table 10, clearly reject the 'product view' of the innovation-profitability nexus, as the coefficients of the lags of variable *Pat* are generally not significant: in fact, for the benchmark year 1913, present patenting even has a weakly significant negative coefficient. That is, for the observed firms, innovation is not associated to any immediate temporary competitive advantage. Significance is shown by some lags of the variable *IndPat*; but even in this case the relationship is not well defined, as the sign of the significant coefficients is not consistent. Interestingly, distinguishing innovators (i.e. patentees) from non-innovators reveals that, if anything, profitability is negatively related to spillovers in the case of the former, while the converse holds true for the latter. A possible interpretation of this finding is that innovators suffer from competition in innovating, while non-innovators enjoy 'free-riding' on (e.g. imitating) their competitors' innovative efforts. This implies that innovators do not possess superior capabilities, allowing them to better 'absorb' external knowledge than non-innovators: hence, the 'process view' of the innovation-profitability nexus is also questioned.

Table 10. Fixed-effects regression results.

	1913			1936			1936 (Restricted sample)		
	All	Patentees	Non-pat.	All	Patentees	Non-pat.	All	Patentees	Non-pat.
RelSize(t-1)	-0.539	-1.063	-0.208	-0.633**	-0.480	-2.187**	-0.257	0.015	-1.369*
Indebt(t-1)	-0.116***	-0.199**	-0.104***	-0.000***	-0.095**	-0.000***	-0.171***	-0.186***	-0.164***
CapInt(t-1)	-0.122**	-0.240**	-0.099*	-0.026	-0.081	-0.018	-0.158***	-0.119**	-0.185***
Conc(t-1)	-0.023	-0.095	0.016	-0.012	0.001	-0.027	0.016	-0.001	0.017
Pat(t)	-0.006*	-0.006*		-0.001	-0.001		-0.001	-0.001	
Pat(t-1)	-0.001	-0.002		-0.001	-0.001		-0.001	-0.001	
Pat(t-2)	-0.002	-0.002		-0.002	-0.001		-0.001	-0.001	
Pat(t-3)	-0.003	-0.002		-0.002	-0.002		0.001	0.000	
Pat(t-4)	0.003	0.003		-0.000	-0.000		-0.001	-0.001	
IndPat(t)	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IndPat(t-1)	0.003***	0.002	0.003***	-0.000	-0.001**	0.000	-0.000	-0.000	-0.001
IndPat(t-2)	0.000	-0.001	0.001	-0.000	-0.001**	0.001	-0.001	-0.001*	-0.000
IndPat(t-3)	-0.002*	-0.002	-0.002	-0.000	0.000	0.000	-0.000	-0.000	-0.000
IndPat(t-4)	0.000	-0.003	0.001	0.001*	0.001**	0.000	0.001	0.000	0.000
TD(t-3)	-0.000	-0.016	0.003	-0.054***	-0.047***	-0.056***	-0.037***	-0.051***	-0.032***
TD(t-2)	-0.003	0.004	-0.003	-0.037***	-0.034***	-0.037***	-0.028***	-0.035***	-0.027***
TD(t-1)	0.005	0.004	0.005	-0.012***	-0.012**	-0.013***	-0.013***	-0.018***	-0.010**
Constant	0.140**	0.340***	0.089	0.039	0.131*	0.034	0.165***	0.176**	0.194***
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N. obs.	2,225	577	1,648	6,116	1,679	4,437	2,294	866	1,428
Adjusted R^2	0.046	0.130	0.031	0.096	0.142	0.093	0.154	0.164	0.157

*Notes: (i) Cluster-robust standard errors are employed; (ii) *, **, and *** denote $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively.*

The results on the other variables point to the same direction. The most significant coefficients are the negative ones attached to indebtedness and capital intensity. This is largely expected, not only since less indebted and less capital intense firms are 'freer' and 'more flexible'; but also because lower payments for interest and rent have a direct positive effect on their profitability. Relative size is largely non-significant: in fact, it shows a paradoxical significant negative coefficient for non-patentees, but this loses significance if the sample is restricted as explained above. Finally, year dummies are non-significant for the benchmark year 1913, and highly significant for 1936. In the latter case, their negative sign reflects the state-stimulated economic recovery of the mid-1930s.[28] In general, the profitability of patentees does not appear to be less related to the above-mentioned factors and by the business cycle than that of non-patentees – which, based on the findings of contemporary empirical studies (Geroski and Machin, 1993; Geroski, Machin and van Reenen, 1993; Leiponen, 2000; Love, Roper and Du, 2009), would be another major constituent part of the 'process view'.

In the panel analysis just described, innovation has only been proxied by patents. As anticipated in the first two sections, a contribution of the present paper is the exploitation of an alternative proxy for innovation, namely the products displayed at international exhibitions. However, the data of this kind that can be employed in the present work only refer to a single exhibition (Turin 1911). As a consequence, this proxy can only be employed for the benchmark year 1913; and a panel analysis cannot be performed. Rather, a cross-section OLS regression is run, investigating the drivers of profits in the year 1913 only, the results of which are displayed in Table 11. The shift from a multi- to a single-year analysis imposes some changes in the specification. In particular, firm age, location (*Geo*, a categorical variable), and division dummies (*DD*) are introduced. As the latter 'embed' *Conc* and, to a large extent, *IndPat*, these variables are dropped. Time dummies are also excluded, because the regression is only over one year. As for the innovation proxies, to facilitate their comparison, they are both 'compressed' into dummy variables, namely *Patentee*, indicating whether a firm was granted patents over the period 1906-1913, and *Exhibitor*, indicating whether it exhibited at Turin 1911. Alternative specifications are presented, using these two variables separately (columns 1 and 2), or jointly (3). The most general expression is:

$$ROE = \alpha + \beta_1 RelSize_{-1} + \beta_2 Indebt_{-1} + \beta_3 CapInt_{-1} + \beta_4 Age + \beta_5 Geo + \gamma_1 Patentee + \gamma_2 Exhibitor + \gamma_3 Patentee * Exhibitor + \sum_{j=15}^{36} \delta_j DD_j + \varepsilon$$

The estimation results displayed in Table 11 confirm some of the insights from the panel analysis of Table 10: highly significant negative coefficients are attached to *Indebt* and *CapInt*; while *RelSize* is now consistently positive and significant. In addition to this, *Age* turns out to have a highly significant positive coefficient, in line with the descriptive statistics from the previous section; whereas the categories of the geographical location variable do not show any significance. Regarding the innovation proxies, a marked difference emerges, as the coefficient on *Patentee* is not significant, while that on *Exhibitor* is. This result emerges both if the two variables are considered 'in isolation', and if they are jointly considered and interacted. In fact, in the latter case (column 3) the coefficient attached to *Exhibitor* has both lower magnitude and significance than if variable *Patentee* is omitted from the specification (column 2); furthermore, the interaction between *Patentee* and *Exhibitor* is not significant. These results clearly confirm the point made from Table 7, that patenting is not associated to a short-term increase in the profits of the observed firms, while exhibiting is. This may be read as a piece of empirical evidence in favour of the argument that exhibitions were effective means of commercialisation and advertisement for participating firms.

[28] The dummy associated to the benchmark year is omitted to avoid collinearity.

Table 11. Cross-section regression results (1913 only).

	(1)	(2)	(3)
RelSize(t-1)	0.127**	0.111**	0.103*
Indebt(t-1)	-0.183***	-0.184***	-0.186***
CapInt(t-1)	-0.119***	-0.116***	-0.116***
Age	0.002***	0.002***	0.002***
Geo=North-East and Centre	-0.006	-0.004	-0.005
Geo=South and Islands	0.014	0.017	0.017
Patentee	0.010		-0.003
Exhibitor		0.023***	0.016*
Patentee*Exhibitor			0.018
Division dummies	Yes	Yes	Yes
Constant	0.140***	0.136***	0.138***
N. obs.	594	594	594
Adjusted R^2	0.262	0.27	0.269

*Notes: (i) Heteroskedasticity-robust standard errors are employed; (ii) *, **, and *** denote p < 0.1, p < 0.05 and p < 0.01, respectively.*

A final task to undertake is investigating whether innovation is also associated to a long-term effect on firm performance, which has been pointed out in the introduction to be the major advantage of adopting a historical perspective. Some evidence in favour of this argument has already been provided in Table 8, showing that patentees, though not exhibitors, are more likely to survive over the long run. Table 12 provides more formal evidence, by showing the results of probit regressions of a dummy dependent variable, denoting 'survival' (i.e. permanence in the database; cf. Subsection 3.3) over a period of more than 20 years (until 1936, for the benchmark year 1913; until 1960, for 1936), on the same independent variables as in the regressions of Table 11.[29] In formula:

$$SURVIVAL = \alpha + \beta_1 RelSize + \beta_2 Indebt + \beta_3 CapInt + \beta_4 Age + \beta_5 Geo + \gamma_1 Patentee + \gamma_2 Exhibitor + \gamma_3 Patentee * Exhibitor + \sum_{j=15}^{36} \delta_j DD_j + \varepsilon$$

For 1913, as in the previous table, three regressions are presented, considering dummy variables *Patentee* and *Exhibitor* either separately (columns 1 and 2) or jointly (3). For 1936, two regressions are presented, one run on the whole sample (column 4), the other on a restricted one (5), along the same lines of what has been done in Table 10. In the latter case, the 'real' capital threshold has been equalised for both the start- and the end-years, so that in the regressions referring to either benchmark year, the sample is characterised by the same minimum firm size, and the criterion for survival is the same.[30]

Estimation results show, again, significant positive coefficients attached to *Age* and (especially in 1936) to *RelSize*; however, unlike the previous table, *Indebt* and *Age* present non- or weakly significant coefficients, with the exception of the well-defined negative one, attached to the former in the 1936 restricted-sample regression. Most importantly, variables *Patentee* and *Exhibitor* are characterised by specular behaviours

[29] Unlike in the panel and cross-section regressions of Tables 11 and 12, in the probit the variables related to firm characteristics are not entered with a lag (cf. fn. 25), due to the long-term perspective.

[30] In 1960, the nominal value of the threshold was 25 million lire. Using the price deflator from Baffigi (2013), it emerges that the latter should be raised to 78.84 million lire, in order to equal the 1936 threshold (one million lire) in real terms.

to those displayed in Table 11: in fact, the former is weakly significant in 1913, but highly so in 1936; whereas the latter (only available for 1913) is not significant.

Table 12. Probit regression results (average marginal effects).

	1913			1936	
	(1)	(2)	(3)	(4)	(5)
RelSize	0.822*	0.899**	0.775*	3.571***	1.555***
Indebt	-0.036	-0.037	-0.036	0.000	-0.048***
CapInt	-0.173*	-0.185*	-0.178*	0.065	-0.025
Age	0.008***	0.008***	0.008***	0.007***	0.004***
Geo=North-East and Centre	-0.030	-0.026	-0.027	-0.057**	-0.038
Geo=South and Islands	-0.037	-0.037	-0.032	-0.105**	-0.122
Patentee	0.103**		0.094*	0.119***	0.095**
Exhibitor		0.050	0.030		
Division dummies	Yes	Yes	Yes	Yes	Yes
N. obs	610	610	610	1,698	606
Pseudo R^2	0.049	0.045	0.049	0.074	0.097

*Notes: (i) Heteroskedasticity-robust standard errors are employed; (ii) *, **, and *** denote $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively; (iii) since the coefficients are marginal effects, the constant and the interaction* Patentee x Exhibitor *are omitted.*

Two conclusions can be drawn from this finding. The first is that the 'process view' of the innovation-profitability nexus, which was not supported by the short-run analyses of Tables 11 and 12, is 'brought back' by the probit model of Table 12, since innovative activity, as measured by patenting, appears to entail a differential between innovative and non-innovative firms, in terms of survival. The second, and related, conclusion is that, under this view, exhibiting does not appear to be an 'innovative' activity on the same level of patenting, which is able to transform the firm itself.

5. Conclusions

The present work investigates whether a nexus was holding between the innovativeness and profitability of a large sample of Italian joint-stock firms, in the years 1913 and 1936. Distinguishing features of this paper, with respect to earlier analyses of the same issue, are its historical perspective, its focus on a laggard country, as Italy was in the observed period, and its use of exhibition data, besides patent data, as an alternative proxy for innovation.

The empirical evidence rejects the traditional view about the innovation-profitability nexus, whereby the former has an immediate temporary positive effect on the latter – the 'product view', in the words of Geroski and Machin (1993). What is more, a short-run analysis does not even support the 'process view', according to which innovation transforms the firm itself, as it endows it with superior capabilities. Indeed, unlike previous studies, this does not show that innovative firms are less subject than others to competition and to the business cycle; in fact, they do not even appear to be better in 'absorbing' external knowledge. This seems in line with recent results of Italian historiography, pointing out the scarce relevance of innovation in Italian economic growth (Nuvolari and Vasta, 2015a). However, the product view re-emerges, under a different form, if a long-term analysis is performed, as it turns out from it that innovators were more likely than their non-innovative competitors to survive.

A final contribution of this study is the assessment of the goodness of exhibition data as a proxy for innovative activity, alternative to patent data. Interestingly, the results just expounded are reversed, as being an exhibitor is observed to be associated with a boost in short-term profitability, but not to entail a long run benefit, in terms of survival. On the one hand, this is an important piece of empirical evidence in favour of the argument that exhibitions were effective means of commercialisation and advertisement for participating firms (Khan, 2013, 2015; Schroeder-Gudehus and Rasmussen, 1992). On the other hand, if the effect of innovation is that of developing firm capabilities, in such a way that they are most resilient and better able to survive, then the connection between exhibiting and innovative activity is questioned.

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Appendix

Table A1. Top 20 companies by ROE, 1913 and 1936.

Name	Province	Div.	Size quartile	Age quartile	ROE
1913					
Prodotti Chimico Farmaceutici A. Bertelli & C.	Milan	24	1	4	45.07
Conserve Alimentari L. Torrigiani	Florence	15	2	3	39.67
Dr. L. Zambeletti	Milan	24	1	1	26.38
Esercizio Molini	Genoa	15	4	2	25.64
Dinamite Nobel	Genoa	24	4	4	24.45
Fabbriche Riunite di Fiammiferi	Milan	36	4	4	23.70
Molini Alta Italia	Genoa	15	4	4	18.60
Eridania Società Industriale	Genoa	15	4	4	17.94
Cartiera Italiana	Turin	21	4	4	17.68
Fabbrica Colla Concimi & Affini Sala	Milan	24	1	2	17.11
Baratti & Milano	Turin	15	1	3	16.73
Ambrogio Binda & C.	Milan	21	3	4	16.61
L'appula	Bari	24	3	4	16.05
La Magona d'Italia	Florence	27	4	4	15.94
Fabbrica Automobili e Velocipedi Edoardo Bianchi	Milan	34	3	3	14.26
Fornaci alle Sieci	Florence	26	1	4	13.63
Filatura dei Cascami di Seta	Milan	17	4	4	13.51
Società Italiana dei Cementi e delle Calci Idrauliche	Bergamo	26	4	4	13.40
Borsalino Giuseppe & Fratello	Alessandria	18	4	3	13.38
Lanificio di Stia	Florence	17	2	4	13.31
1936					
Società Meridionale Ammonia	Milan	24	4	2	47.51
Società Generale Italiana Accumulatori Elettrici	Milan	31	4	4	39.12
Palmolive	Milan	24	3	2	30.90
Prodotti Chimico Farmaceutici A. Bertelli & C.	Milan	24	3	4	26.05
A.S.C.A. Sacchi Cemento e Affini	Rome	21	1	1	24.99
I. Kofler	Padua	24	2	3	22.08
Anticromos Dott. Aldo Volpino	Milan	24	1	1	21.68
La Magona D'Italia	Florence	27	4	4	21.46
Vetreria Milanese Lucchini Perego	Milan	26	4	3	20.49
Industriale Carburo	Rome	24	4	3	20.12
Esercizio Stabilimenti Industriali S.E.S.I.	Genoa	27	4	1	19.91
Società Italiana Prodotti Schering	Milan	24	3	2	19.79
Saldatura Elettrica Autogena Arcos	Savona	29	3	1	19.49
Co.Fa	Milan	24	3	2	19.47
Bernardo & Lorenzo Banfi	Milan	17	3	1	19.46
Officine Allestimento e Riparazioni Navi	Genoa	35	4	2	19.30
Piaggio & C.	Genoa	35	4	3	18.38
Carlo Mangini	Pavia	33	3	4	18.35
Compagnia Generale Olii Minerali	Genoa	23	4	2	18.27
Elah	Genoa	15	3	4	18.11

Source: own elaboration from IMITA.db.

Table A2. Top 20 companies by number of patents, 1913 and 1936.

Name	Location	Div.	Size quartile	Age quartile	Exh.	Pat.
1913						
A.E.G. Thomson Houston	Milan	31	4	3	no	66
Società Italiana Gio. Ansaldo & C.	Rome	29	4	3	yes	59
United Shoe Machinery Company d'Italia	Milan	29	2	1	yes	37
Società Italiana Koerting	Genoa	29	2	3	yes	26
Fiat Fabbrica Italiana Automobili Torino	Turin	34	4	4	yes	25
Western Electric Italiana	Milan	32	1	1	yes	25
Compagnia Italiana Westinghouse dei Freni	Turin	31	3	2	yes	22
Officine Galileo	Florence	33	1	1	yes	19
C.G.S. Istrumenti Elettrici Già C. Olivetti & C.	Milan	33	1	3	yes	18
Fiat San Giorgio	Turin	35	4	3	yes	18
Itala Fabbrica Di Automobili	Turin	34	4	3	yes	17
Società Italiana Westinghouse	Genoa	31	4	1	yes	16
Società Anonima per l'Esercizio degli Stabilimenti G. Vianini & C.	Rome	26	3	1	no	13
Società Ceramica Richard Ginori	Milan	26	4	4	yes	13
Laboratorio Elettrotecnico Ing. Luigi Magrini	Bergamo	31	2	3	yes	11
Società Generale Italiana Accumulatori Elettrici	Milan	31	3	1	yes	11
Fabbrica Automobili Isotta Fraschini	Milan	34	4	3	yes	11
S.P.A. Società Ligure Piemontese Automobili	Genoa	34	4	2	yes	10
Società Anonima Dell'Orto	Milan	28	1	1	yes	10
Società Meccanica Lombarda	Milan	29	4	4	yes	10
1936						
C.G.E. Compagnia Generale di Elettricità	Milan	31	4	3		256
Pirelli	Milan	25	4	3		208
F.I.A.T.	Turin	34	4	4		195
Compagnia Italiana Westinghouse Freni e Segnali	Turin	35	4	4		169
Fabbrica Italiana Magneti Marelli	Milan	31	4	3		99
United Shoe Machinery Company d'Italia	Milan	29	3	4		71
Officine di Villar Perosa	Turin	28	4	3		66
Officine Galileo	Florence	31	4	4		61
Osram Società Riunite Osram Edison Clerici	Milan	31	4	3		55
San Giorgio Società Anonima Industriale	Genoa	31	4	4		54
Ansaldo	Genoa	29	4	3		51
Società Italiana Ernesto Breda per Costruzioni Meccaniche	Milan	35	4	4		51
Montecatini	Milan	24	4	4		36
Pignone Officine Meccaniche e Fonderie	Florence	27	4	4		35
Aeroplani Caproni	Milan	35	4	3		33
Fabbriche Riunite Industria Gomma Torino	Turin	25	4	4		30
Ercole Marelli & C.	Milan	31	4	3		30
Officine Meccaniche Stigler	Milan	29	4	4		27
Società Anonima Bergomi	Milan	28	3	4		24
Eternit	Genoa	26	4	4		23
Ing. C. Olivetti & C.	Ivrea	30	4	1		23

Source: see Section 2. Note: patents granted in the benchmark year and in the preceding seven years are considered.

Table A3. Extended statistics on patenting firms, 1913 and 1936.

		1913									1936								
		Tot.	Patentees		P1Y	Number of patents					Tot.	Patentees		P1Y	Number of patents				
			n	%		1	2	3	4	≥5		n	%		1	2	3	4	≥5
15	Food and beverages	106	11	10.4	8	7	2	1	1	0	284	24	8.5	18	16	3	2	1	2
16	Tobacco	0	0	-	0	0	0	0	0	0	4	1	25.0	1	1	0	0	0	0
17	Textiles	143	20	14.0	18	16	3	0	0	1	350	58	16.6	46	40	12	3	2	1
18	Apparel	8	1	12.5	0	0	1	0	0	0	38	12	31.6	6	6	2	2	1	1
19	Leather, bags and footwear	10	3	30.0	2	2	0	0	1	0	39	9	23.1	5	4	3	1	0	1
20	Wood	8	1	12.5	1	1	0	0	0	0	26	4	15.4	3	3	1	0	0	0
21	Paper	25	3	12.0	2	2	0	1	0	0	58	17	29.3	11	6	5	2	2	2
22	Publishing and printing	14	0	0.0	0	0	0	0	0	0	70	6	8.6	6	6	0	0	0	0
23	Coke and petroleum	1	0	0.0	0	0	0	0	0	0	40	8	20.0	5	4	2	2	0	0
24	Chemicals	74	22	29.7	16	10	10	1	1	0	233	57	24.5	34	30	10	2	3	12
25	Rubber and plastic	2	0	0.0	0	0	0	0	0	0	10	7	70.0	5	4	0	1	0	2
26	Non-metallic minerals	69	12	17.4	8	7	2	0	0	3	162	32	19.8	12	9	6	4	4	9
27	Basic metals	42	16	38.1	8	8	3	2	1	2	92	27	29.3	13	12	4	3	2	6
28	Fabricated metals	21	10	47.6	4	3	2	2	1	2	79	40	50.6	16	13	10	3	4	10
29	Machinery and equipment	21	12	57.1	2	1	3	2	0	6	65	39	60.0	9	8	9	2	5	15
30	Office machinery	0	0	-	0	0	0	0	0	0	5	3	60.0	2	2	0	0	0	1
31	Electrical machinery	15	11	73.3	1	1	1	1	0	8	53	36	67.9	12	8	10	4	0	14
32	Communication equipment	1	1	100.0	0	0	0	0	0	1	11	6	54.5	2	2	1	0	0	3
33	Instruments	5	5	100.0	0	0	0	2	1	2	26	15	57.7	6	3	3	1	0	8
34	Motor vehicles	17	11	64.7	2	0	3	1	2	5	20	11	55.0	3	3	2	1	1	4
35	Other transport	29	10	34.5	3	2	2	4	0	2	65	29	44.6	7	6	6	4	1	12
36	Furniture and n.e.c.	13	6	46.2	5	5	1	0	0	0	34	14	41.2	6	4	3	5	0	2
		624	155	27.1	80	65	33	17	8	32	1,764	455	29.7	228	190	92	42	26	105

Sources: see Section 2. Note: 'P1Y' indicates firms patenting in only one year, within the observed time span (corresponding to the benchmark and the seven years preceding it).

The specialisation and economic complexity of countries through the lens of universal exhibitions, 1855-1900

Giacomo Domini

Abstract. This paper advances an interpretation of data from the catalogues of historical universal exhibitions, as an indicator of what countries, participating in these events, were producing and promoting on international markets. Using data from the five *expositions universelles* held in Paris in the second half of the nineteenth century (1855, 1867, 1878, 1889, 1900), potential applications of this view are explored. In particular, specialisation indices *à la* Balassa, and 'economic complexity' indices *à la* Hidalgo-Hausmann are computed for a large number of countries over an extended time period, and their implications for economic development are discussed.

Keywords: economic complexity; specialisation; universal exhibitions

JEL classification codes: N10, O10, O14, O30, O57

1. Introduction

Universal exhibitions were arguably the most characteristic events of the second half of the nineteenth century and of the early twentieth century.[1] They celebrated 'the splendours of progress' (Schroeder-Gudehus and Rasmussen 1992) and played an important function in the diffusion of new technologies (Ahlström, 1996; Roca Rosell, 2015), during an age of breakthrough inventions, when the technological paradigms associated to the Second Industrial Revolution emerged. They displayed all the fields touched by human work and ingenuity (hence the attribute 'universal'), at a time inspired by positivistic and encyclopaedic ideals. They praised the virtues of free trade and peaceful economic competition between countries, during an era characterised by the expansion of world trade (Federico and Tena 16a)[2] and capitalism (see Sassoon, 2015). At the same time, they glorified the power of organising and participating countries, in the age of nationalism. They also left significant social and cultural traces, as they contributed to the birth of the 'general public', and fostered the development of what Marx (1867/1990) defined 'commodity fetishism' (Simoncini, 2015). Their popularity grew ever larger since their inception with London's 1851 Great Exhibition, and only entered decline after the First World War: besides bringing about destruction and geopolitical change, the conflict seriously questioned the faith in human progress and the view of trade as generating peace, which were among the most important traits of the exhibitions' spirit.

In spite of their relevance, economic historical research making use of data from universal exhibitions has so far been scarce. Two contributions should be cited as relevant for the present study. Ahlström (1996), pointing out that international exhibitions served as 'yardsticks for measuring the relative technological positions of different countries' (p. 11), has made a general overview of a number of expos held in various countries in the second half of the nineteenth century, and, within this context, a particular assessment of Sweden's participation, drawing some inferences about that country's technological and industrial development. Moser (2005, 2011, 2012) has presented data from the catalogues of London's 1851 *Great Exhibition* and from three exhibitions held in the United States between 1876 and 1915 as a proxy for historical innovation alternative to patent data, having the advantage of including both patented and non-patented items. In particular, she has pointed out that most British exhibits at the 1851 exhibition (almost 90%) were not patented.

The latter interpretation of exhibition data, as a proxy for innovation, relies on the assumption that exhibited items were characterised by novelty. As pointed out by Moser (2005, p. 1218) novelty was indeed a requirement for admission at the first universal exhibition of London 1851. However, the rules of international exhibitions did not generally entail such a provision, as a novelty requirement cannot be found in the rules of the following international exhibitions, starting from Paris 1855.[3] As a matter of fact,

[1] Alternative wordings by which these events are known, namely 'international exhibitions' and 'world's fairs', will be use in this work with the same meaning.

[2] In another contribution, the same authors (2016b) point out that the annual rate of growth of world trade experienced a structural break during the period studied here, decreasing from 3.97% over the period 1817-1865, to 3.07% over 1866-1913.

[3] At Paris 1855, art. 13 the *Règlement général* (included in the catalogue) stated as admissible 'all products of agriculture, industry and art', except for selected categories, like dangerous materials. The Imperial Commission only had the right of excluding French products that would be 'detrimental or incompatible with the aim of the Exhibition' (art. 15). The principle was identical at the last of the five Parisian expos of the nineteenth century (i.e. that of 1900), where 'all industrial or agricultural products, and in general all the objects that fall into the attached

‘numerous items on display were not patentable or even innovations; many comprised agricultural produce, interesting specimens of minerals and taxidermy, embroidery, and final goods that illustrated good workmanship or attractive design elements rather than innovation’ (Khan, 2015, p. 32).[4]

This paper advances an interpretation for exhibition data, the starting point of which is the recognition that the products displayed at the expos were not only innovative ones, and that the main motivation for participating in exhibitions was commercial. To this points the identity itself of the ‘founding countries’ of international exhibitions, namely Britain and France, two early industrialisers in search for commercial outlets. Exhibitions were an important means of publicity for firms, at a time when mass advertisement was not yet developed: the exhibitions’ catalogues informed their readers about the names of the firms that were present in each industrial field; furthermore, the prizes awarded at exhibitions were used by companies as quality signals, boosting their renown and reputation.[5] As a matter of fact, the progresses in the field of advertisement and the development of trademarking caused exhibitions to progressively lose this function, after the turn of the century (Khan, 2013, pp. 107-108; Khan, 2015, p. 39; Schroeder-Gudehus and Rasmussen, 1992, p. 6).[6]

Based on this, the present paper contends that the items displayed at universal exhibitions reflect a wide spectrum of products that participant countries produced and wanted to promote on international markets, by exploiting the unique worldwide visibility, provided by the largest world’s fairs. In a sense, under this interpretation, exhibition data might be seen as a proxy for export data – which would be very valuable for the period considered by this study, given the scarcity of this kind of data for that period. However, it appears incautious to infer, from a country’s mere display of a certain staple, that that country had already established itself as a successful exporter of that product. Rather, it seems more reasonable to observe that that country’s production had reached a sufficient degree of international competitiveness to be promoted beyond national borders. In other words, the interpretation of exhibition data that this paper maintains is not pushed as far as to represent a proxy of export data; rather, it lies between production data and export data.

To illustrate the potential of exhibition data under the interpretation maintained here, data are employed from the five universal exhibition, held in Paris at regular intervals during the second half of the nineteenth century (1855, 1867, 1878, 1889, and 1900) – arguably the most representative ones, as motivated in Section 2. Data from these expos, the source and characteristics of which are introduced in Section 3, provide

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classification’ could be admitted (art. 29), with the exception of ‘dangerous materials, notably explosives’ (art. 30).

[4] The first paper of this thesis points out that the sets of patents and exhibits are largely disjoint, i.e. having a small intersection, due to the determinants behind the choices of patenting and exhibiting being different: on the one hand, exhibitions mainly worked as markets for products, which attracted firms; on the other hand, patents were mostly taken out by individuals, who often did not exploit them commercially.

[5] In accordance with this, the second paper of this thesis finds that exhibiting activity entailed a short-term profitability increase for firms.

[6] A 1907 *Report of the Committee appointed by the Board of trade to make enquiries with reference to the participation of Great Britain in great international exhibitions*, quoted by Khan (2015, fn. 83 and 99), contains interesting testimonies, regarding participation in the expos. Notably, these reveal that the decision to exhibit was affected by expected gains, which were related to the conditions of the market of the host country, as well as to the exhibiting firm’s age – as younger firms expected greater advantages. They also confirm that the progress ‘in the art of advertising’ caused ‘the advertisement afforded by displaying goods at an International Exhibition’ to be ‘regarded by many as being of less importance than formerly’.

extensive information about the production and/or export of a large variety of products, by a large number of countries, over a long and extremely relevant period, characterised by the emergence of the Second Industrial Revolution. This allows constructing measures, describing the sophistication of countries' economies, the discussion of which reveals general economic development trends, in a wide geographical and diachronic perspective. In particular, specialisation indices *à la* Balassa (1965) are computed, based on exhibition data: these are presented, discussed, and contrasted to the export-based *Revealed Comparative Advantages*, in Section 4. Furthermore, inspired by a recent strand of literature initiated by Hidalgo and Hausmann (2009), the *Economic Complexity Indices* (ECI) of the countries that participated in the Parisian expos are calculated and presented in Section 5. The relationship between the complexity of an economy, and the level and growth of its income is discussed in the same section. Finally, Section 6 sums up the main results, points out advantages and disadvantages of the advanced interpretation of exhibition data, and outlines possible avenues for future research.

2. The *expositions universelles* in Paris, 1855-1900

France was the leading country in the field of modern industrial exhibitions, of which it can be considered the 'inventor'. Although London's 1851 Great Exhibition was the first such event on an international scale, the 'expo format' had already been developed on a national scale by France, which organized eleven *expositions publiques des produits de l'industrie française* between 1798 and 1849;[7] and it was still France that organized the largest number of *expositions universelles* in the second half of the nineteenth century, as can be seen from the list provided in Table 1. France was not only the most active organiser of these events in that period, but also the most successful one, in terms of number of exhibits and visitor turnout. In fact, the exhibition of 1855 was comparable to those of 1851 and 1862, hosted by London; but the Parisian expo of 1867 brought about a considerable increase, both in terms of the fair's size and of visitor turnout. Since then, the figures of the Parisian expos were unrivalled by those held in other countries, with the only exception of Chicago's 1893 'Columbian' exhibition.[8] These figures make it clear that the exhibitions organised by France in its capital city were the most attractive and prestigious of that time, as they were those providing the largest audience (hence, publicity) to exhibitors.

The success of the Parisian expos was also reflected into the large participation of foreign countries. As Table 2 shows, over time not only the number of countries joining the Parisian expos increased,[9] but their representativeness of different regions of the

[7] Ahlström (1996, p. 15) points out that the British *Society of Arts* 'presented from 1756 onwards a series of displays which can be characterised as elementary forerunners of the industrial exhibitions'. However, since patented items were excluded, and information or publicity material concerning the exhibition was not available, 'it is not to any material degree possible to consider it the "parent" of the subsequent industrial exhibitions of the eighteenth and nineteenth centuries.'

[8] What is more, the 50 million visitors of Paris 1900 remained a historical record for 70 years, until the expo of Osaka scored a turnout of 64 million.

[9] German and Italian pre-unitary states are grouped together in 1855 (24 and 3, respectively) and 1867 (5 and 2, respectively). Furthermore, in order to keep consistency over exhibitions, Austria-Hungary is always considered as a single entity: hence, its constituent parts are grouped together in 1878 and 1900, when the catalogues distinguish them (in the latter year, Bosnia-Herzegovina and Croatia-Slavonia are also distinguished). For the same reason, Finland is grouped together to Russia, though distinguished in the 1889 catalogue. It should be noticed that, in the same way as Bosnia-Herzegovina, Croatia-Slavonia, and Finland are listed as distinguished components,

world also expanded.[10] In fact, the *expositions* were largely European events, at a time when the centre of political and economic power was firmly situated in the Old Continent. This is particularly true of the first Parisian universal exhibition (1855), at which one-half of total exhibits were coming from the host country, and the other half was almost completely accounted for by other European countries. Ten countries from the Americas joined that exhibition, but they participated with very small contingents, typically from governmental initiative, with the only exceptions of the United States and Mexico, having larger delegations.[11]

Table 1. Comparative data about universal exhibitions, 1851-1915.

Year	City	Visitors	Surface (Ha)	Participating Countries	Total exhibits	(from the host country)
1851	London	6,039,195	10	25	14,000	(6,861)
1855	Paris	5,162,330	15	27	23,954	(11,986)
1862	London	6,096,617	11	39	29,765	(9,140)
1867	Paris	15,000,000	69	42	52,200	(15,969)
1873	Vienna	7,255,000	233	35	53,000	(9,104)
1876	Philadelphia	10,000,000	115	35	30,864	(8,175)
1878	Paris	16,156,626	75	35	52,835	(25,872)
1880	Melbourne	1,330,000	25	33	12,791	(2,130)
1888	Barcelona	2,300,000	47	30	12,900	(8,600)
1889	Paris	32,250,297	96	35	61,722	(33,937)
1893	Chicago	27,500,000	290	19	70,000	(25,000)
1897	Brussels	6,000,000	36	27	13,263	(5,521)
1900	Paris	50,860,801	120	40	83,047	(38,253)
1904	Saint Louis	19,694,855	500	60		(15,009)
1905	Liège	7,000,000	70	35	17,000	(4,000)
1906	Milan	7,500,000	100	40	27,000	(3,995)
1910	Brussels	13,000,000	90	26	29,000	(6,500)
1913	Ghent	9,503,419	130	24	18,932	(5,000)
1915	San Francisco	18,876,438	254	24	30,000	

Source: Schroeder-Gudehus and Rasmussen (1992). Note: the source does not provide data about all international exhibitions held in the period.

respectively, of the Austrian and Hungarian delegations in 1900, and of the Russian one in 1889, so Cuba is a distinguished component of the United States in 1900. However, Cuba is treated as an independent country, since it never was a constituent part of the United States': in fact, it was under the control of the latter in 1900, following the American victory of the Spanish-American war and the consequent Treaty of Paris (1898); but it gained independence as soon as in 1902.

[10] Apart from Table 1, which is based on the indicated secondary source, the figures presented in this paper, as well as all shares and indices based on them, do not refer to the total number of items actually on display at the Parisian expos, because of a couple of reasons (which will be discussed in greater detail in the next section). First, exhibits from the colonies of France and of other participating countries are not included. Second, a selection is performed, aimed at discarding products with no 'economic relevance'. Furthermore, for 1900 only, a modification is made to class 60 (*Wines*): the huge French contingent in that class (more than 6,000 items – one-tenth of *total* items at that expo!) is resized. In particular, as most of it is due to the capillary exhibition of wines from each French *département*, only exhibitors who participated as *exposant individuels*, who can be considered as truly representative of private initiative, are kept; while others are discarded. If this change is made, then France's exhibit share at the 1900 expo considerably diminishes, from 36.6% to 28.3%.

[11] Detailed information about each foreign country's number of exhibits at each expo is provided in Table A1 in the appendix.

In 1867, not only the total number of items on display more than doubled, but the geographical representativeness of the exhibition widened: Latin American delegations became larger and also reflective of private initiative (in particular, Brazil presented more than 1,000 items); moreover, Asian countries, like China and Siam, made their appearance. This trend continued at the following exhibitions: the share of items on display accounted for by extra-European countries peaked in 1889, at 22.3%, as an effect of the massive boycott of that exhibition, dedicated to the 100th anniversary of the French Revolution, by many European monarchies. In absolute terms, however, the number of items from outside of Europe further increased at the following, record-setting exhibition of 1900, as did the total number of exhibits.

Table 2. Participation in the Parisian expos.

	1855	1867	1878	1889	1900
Number of participating countries	28	32	36	46 (*)	37
Number of exhibits	17,070	36,221	34,993	28,862	46,310
France	8,488	9,071	13,456	12,246	13,366
Europe	8,311	24,974	18,411	10,167	21,597
Americas	244	1,961	1,986	5,731	9,579
Asia	0	96	893	628	1,731
Africa	27	119	247	90	37

Note: (*) The separate special catalogues of Colombia, Costa Rica, Honduras, and Peru, could not be retrieved; hence the respective observations could not be added.

Participation by extra-European countries, however, was not 'stable', meaning that most of these countries did not participate in all exhibitions. In fact, the only non-European member of the group of 14 foreign countries that joined all Parisian exhibitions was the United States.[12] Among European countries, an exception of primary importance is represented by Germany: participation from Prussia and the other German states was strong in 1855 and 1867 (more than 2,000 exhibits in either exhibition); but the unified German Reich did not participate in the exhibition of 1878, held only seven years after the end of the Franco-Prussian war, and was one of the European monarchies that most intensively boycotted the *expo* of 1889, which was only joined by a handful German exhibitors. A large delegation from Germany only reappeared in the great exhibition of 1900.[13] Finally, from the European periphery, Russia joined all Parisian exhibitions since 1867 with large contingents; whereas Turkey – also officially joining four exhibitions (not participating only in 1878) – did generally present few exhibits, with the notable exception of 1867, when it displayed as many as 4,500 items.

3. Sources and methods

The data employed in this paper have been retrieved from the official catalogues of the five nineteenth-century Parisian universal exhibitions. Datasets have been constructed, for each expo, listing the number of exhibits displayed in each class of the original

[12] These countries are: Austria, Belgium, Denmark, France, Great Britain, Greece, Italy (in 1855: Piedmont, Papal States and Tuscany), Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United States (see Table A1 in the appendix).

[13] A non-negligible reason behind Germany's absence from the 1878 expo, and its boycott of the 1889 one, is the low regard devoted to them by Bismarck, chancellor of the German Empire from its foundation in 1871 until 1890. In fact, he considered exhibitions to be useless, and even boring (Pellegrino, 2015, p. 64).

classification by each independent country joining the exhibition. Data about colonies are excluded from the present work.[14]

Since this work relies on the original classification of products from the source, a quick history and discussion of the Parisian expos' classifications is opportune. The exhibition of 1855 had a very detailed classification, structured into two main *divisions*, namely 'products of industry' and 'works of art', respectively consisting of 27 and 3 *classes*. 'Products of industry' were more finely divided into 242 *sections*: the latter level was extremely detailed, as in many cases it not only distinguished products by their type, but also by their materials and production processes (especially in the group of textiles). However, for most foreign countries the finest level of detail is not available in the exhibition's catalogue, or not in a systematic way. Most importantly, it is available for Britain; but the other countries, having all products classified at the level of the section, are relatively small economies (Denmark, Greece, Hawaii, Mexico, Piedmont, Switzerland, and some German states, but not Prussia). As a consequence, the finest classification level cannot be employed in comparative analyses, involving all countries participating in the exhibition of 1855. Classification underwent major restructuring at the subsequent Parisian expo of 1867: on the one hand, the number of categories at the finest classification level (now the *class*) was reduced to 95 (aggregated into 10 *groups*); but, on the other hand, all products from all countries were systematically classified at the finest level. Between 1867 and 1889, the classification system remained quite stable; while it expanded in 1900, when the number of classes increased to 121, due to a refined distinction of products in some groups, like beverages, general machinery, electricity, and military material.[15]

The product categorisation employed in the next section attempts at providing the best harmonisation of the various Parisian expos' classifications. It is largely based on the classification of the first expo (at the level of the *class*),[16] which is expanded over time. In particular, some sectors, which share the same class in 1855, are distinguished in following exhibitions, namely *Glass* and *Ceramics*, and *Leather* and *Chemicals*; while *Electricity* (previously included in *Lighting and heating*) becomes a separate category in 1889 in 1900.[17] Textiles are distinguished by type of fibre (*Cotton*, *Flax and Hemp*, *Silk*, *Wool*). Likewise, machinery is distinguished into *General machinery and*

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[14] The only exceptions are, in 1900, British and Portuguese colonies, as that year's catalogue lists exhibitors from those colonies, together with those from the homelands.

[15] In the latter year, group *Army and Navy* comprises five classes, namely *Armament and artillery material* (116), *Military engineering* (117), *Maritime engineering* (118), *Cartography, hydrography, and miscellaneous instruments* (119), *Administrative services* (i.e. supplies; 120), and *Hygiene* (121). Apart from classes 116 and 120, the others have been merged to their respective 'civil' classes.

[16] In fact, some classes of the original 1855 classification are merged. Namely, 1855's classes *Forestry*, *Agriculture*, and *Food and beverages*, are merged into *Agro-food*; and *Mining and metallurgy*, *Steel*, and *Other metals*, are merged into *Mining and metallurgy*.

[17] A couple of sections of the fine-grained classification of the exhibition of 1855 contained the word 'electricity' (namely, *Processes about the use of natural sources of heat or cold, of light and electricity*, and *Production and use of electricity*); but this disappeared from the classifications of the two following Parisian exhibitions, where *Telegraphy* was the only class belonging to this field. A class named *Electricity* reappeared in 1889; and finally, in 1900, a whole group consisting of five classes was dedicated to electricity. This evolution is clearly connected to the development of electrical industry over the observed decades: scientific principles had been known since the eighteenth century, and fundamental inventions, like Faraday's electric motor, had been made in the early nineteenth century; but telegraphy was the main application of electricity, until a series of inventions in the 1870s and 1880s laid the bases for its effective employment in lighting and energy transmission.

machine tools, *Agro-food machinery and equipment*, *Textile machinery and equipment*, and *Other industrial machinery and equipment*.[18]

In order to focus on exhibits having 'economic relevance', meaning that they were displayed for the purpose of commercial promotion, but also in order to keep consistency across different expos, the present analysis excludes the groups of *Works of art*, *Education* and *Social economy*. Likewise, the groups *Living animals* and *Horticulture* are discarded, except for the classes, within these groups, about equipment for cattle breeding and horticulture. Besides the above-mentioned reasons, the technological content of the latter groups and their relevance in international exchanges were limited: indeed, participation in the latter groups was mainly from the host country, possibly as a result of the perishable nature of exhibits in those groups.

Table 3. Technological classification.

Label	Categories
Primary (P)	Agro-food; Beverages.
Low-tech (L)	Agro-food machinery and equipment; Ceramics; Clothing and apparel; Construction; Cotton; Flax and hemp; Furniture; Glass; Jewellery; Leather; Mining and metallurgy; Paper and printing (H: Photography); Silk; Textile machinery and equipment; Wool.
High-tech (H)	Chemicals (L: Perfumery); General machinery and machine-tools; Instruments (L: Cartography and topography; Musical instruments); Lighting and heating; Other industrial machinery and equipment; Transport; Weapons (L: Army supplies).

In addition to this product classification, a distinction by technological level is also implemented. This is inspired by that developed by Lall (2000), in that it not only separates primary products from manufactured ones, but further distinguishes the latter by their technological sophistication level.[19] The criterion to do so relates to the great technological changes that characterise the period studied here: in particular, industries that emerged or significantly developed during the Second Industrial Revolution (notably machinery, transport, electricity, chemicals), are labelled as 'high-tech'; while those that were mainly affected by the First Industrial Revolution (notably textiles), or were based on traditional techniques, are labelled as 'low-tech'. A comprehensive list of product categories that fall under each label is available in Table 3. Notice that the borders between the technological levels do not perfectly overlap those among product categories, since some classes from the original classification are moved to an upper or lower level, when appropriate. The division by technological level is not carried out for 1855, because that expo's classification is not fine enough to unambiguously evaluate each category's level.

Some clarifications and caveats must be made, about the adopted technological classification. First, unlike Lall's classification, it does not consider food and beverages as manufactured products, but on a par with primary products. The reason for this is that most classes referring to foodstuffs do not separate raw products from processed foods. Other sectors are also affected by this kind of issue, a relevant example being *Mining*

[18] The latter class includes machine tools and agro-food machinery in 1855; and is absent from 1900, when some industries' equipment is included in the relevant classes (namely, *Chemicals*, *Mining and metallurgy*, and *Paper and printing*). Other inconsistencies involve the sectors of paper and tobacco, both included in the class of *Chemicals* in 1855, while being afterwards part of *Paper and printing* and *Agro-food*, respectively.

[19] This author distinguishes the Standard International Trade Classification (SITC) 3-digit groups into primary products and *resource-based*, *low-technology*, *medium-technology*, and *high-technology* manufactures. With respect to the widely-adopted criterion considering SITC divisions 0-4 to be primary products and divisions 5-9 to be manufactures, Lall reduces the scope of primary products, by considering food and beverages (divisions 0 and 1) as resource-based manufactures.

and metallurgy, where minerals can be found in the same class as metal castings and worked metal objects.[20]

Furthermore, the adopted criterion, whereby a manufacturing industry is considered to be 'high-tech' if affected by the Second Industrial Revolution, is 'slippery' and might prove misleading, since that revolution also affected sectors which usually are not straightforwardly associated with it.[21] The sectors defined as 'high-tech' in the present paper are those most closely connected with engineering and science, consistently with the nature of the Second Industrial Revolution, as being characterised by the application of technological and scientific knowledge (Mokyr 1990, pp. 113-116).[22]

Table 4. Technological composition of exhibits.

	Original composition				After rescaling France			
	1867	1878	1889	1900	1867	1878	1889	1900
Primary products	29.7	33.6	33.2	28.6	31.8	38.3	41.2	31.5
Low-tech manufactures	50.2	45.5	45.2	50.8	49.4	43.3	41.5	49.2
High-tech manufactures	20.1	20.8	21.6	20.7	18.8	18.4	17.3	19.3

Before moving to the next section, which presents and discusses the specialisation patterns of the major countries that participated in the Parisian expos, an important point must be made, concerning the technological composition of exhibits at different exhibitions. Almost 60 foreign countries took part into at least one of the five Parisian universal exhibitions (excluding the numerous German and Italian pre-unification states, participating in 1855 and 1867); but only one-fourth of these joined all of them. In fact, each exhibition was characterised by a different set of participating countries, the economies of which were at different stages of economic development, and which consequently displayed products of various technological sophistication. In 1889, in particular, exhibits from extra-European countries increased both in absolute terms and as a share of the world total, because of the boycott of that exhibition by European monarchies. This caused the composition of the exhibit mix on display to shift towards primary commodities and unsophisticated manufactured products. The left side of Table 4 shows the technological composition of exhibits in the Parisian expos since 1867: a clear difference emerges, between the expos of 1878 and 1889, on the one hand, and those of 1867 and 1900, on the other, as the latter are characterised by a larger share of primary products (33%, *vis-à-vis* 29%), and a correspondingly lower share of low-tech manufactures (45%, *vis-à-vis* 50%); while the share of high-tech manufactures remains stable, over time, at 20-21%.

[20] An additional problem, involving this class, is that different metals, unlike textiles, are not dedicated different classes. This is relevant, because many important progresses in metallurgy, notably regarding iron, occurred during the First, rather than Second, Industrial Revolution. The distinctive and fundamental metallurgical progresses that took place during the latter concerned the production of steel.

[21] For example, agriculture experienced increases in the productivity of land and labour, thanks to the development of chemical fertilisers and to the mechanisation of some processes; food industry was radically transformed by the progresses in the techniques for preserving and canning; and constructions were revolutionised by structural steel.

[22] A final remark is that, as the observed time period was characterised by major and increasing technological and industrial transformations, adopting the same technological classification over its entire span could be misleading, due to technologies' maturation and obsolescence causing some of them to be innovative and complex at the beginning of the period, but 'old' and standardised at the end.

4. The specialisation and technological content of exhibiting economies

As argued in the introduction, the interpretation of exhibition data maintained by the present paper is that exhibits represent the productions of participating countries that were established and mature enough to be promoted at an international level. In other words, under this view, exhibition data 'lie between' production data and export data. As a consequence, this work, studying the five Parisian universal exhibitions, provides a very important opportunity to look into the productive structure of a large number of countries, over a time span of almost half a century. Major differences in these structures over space and time are unveiled, as different countries specialise into different productions. Since the size and nature of various countries' contingents at exhibitions was considerably different, the absolute numbers of items in each product class cannot be directly compared, over different countries; instead, the shares of each country's exhibits, accounted for by each product class, should be considered. These shares can be employed to compare one country's product structure not only to that of another country, but also to the 'world average', by computing specialisation indices *à la* Balassa (1965). Along the lines of this author's *Revealed Comparative Advantage* (RCA), the following *Exhibit Specialisation Index* (ESI) can be defined:

$$ESI_{cp} = \frac{X_{cp}/X_c}{X_{wp}/X_w}$$

where X_{cp} are country c's exhibits in product category p; X_c are total country c's exhibits; X_{wp} are all countries' ('world') exports in category p; and X_w are total world exhibits. Hence, the numerator is the share of product category p in country c's exhibits; and the denominator is the same category's share in total world's exhibits. By taking the ratio, these shares are compared: if category p represents a larger (lower) share in the export of country c than in the world average, then the ratio will be larger (lower) than one, indicating that country c is (under)specialised in product p,[23] thus revealing, with a degree of abstraction, the relative relevance of product category p in that country's set of produced and/or exported goods.

As said, the fraction at the denominator of the ESI indicates the 'world share' of a certain product category. In the present case, this is given by the total number of items displayed in that category at a certain exhibition. As shown by Table 2, this total is largely accounted for by exhibitors from the host country: France's share in total exhibits displayed at the Parisian expos ranges from a minimum of one-fourth (in 1867) to a maximum of one-half (in 1855). This is such that it largely influences the distribution of world exhibits over classes. A possible solution to this problem could be to exclude France from 'world's' totals;[24] but this remedy would introduce a specular bias to that just described, since, while its share of exhibits at the Parisian expos was certainly inflated by its status of host country, France was one of the major economic powers of the time, and its contribution to the world economy cannot be considered negligible. As a midway solution, for the purpose of computing specialisation indices in the present work, the number of exhibits by France is rescaled, in such a manner that its

[23] Alternatively and equivalently, the index can be interpreted as the ratio between country c's share of product p's world exhibits, and its share of total world exhibits.

[24] This solution is typically adopted when constructing the *Revealed Technological Advantage* (Soete, 1987), an application of the Balassa index to the domain of innovative activity, where patents are used in the place of exports: patents granted to the residents of the granting country are usually excluded from the world totals, as they represent a very large share (usually the absolute majority) of total patenting activity in the granting country.

share shrinks to a size, comparable to that of the second largest exhibiting country.[25] The latter share is stable over the three first Parisian expos, slightly above 12%; but it is less than half (5%) in 1889, and also marginally lower (11%) in 1900. To account for this, in 1889 the rescaling criterion is modified in such a way that France's share equals the second largest, multiplied by a factor 2.5; likewise, a factor 1.1 is employed in 1900. After these adjustments, France's share is constant across all Parisian expos, at around 14%.

Since the rescaling is uniformly performed over the classes of a given exhibition, the product composition of France's exhibit contingent is not altered; but that of world exhibits is: as the right part of Table 4 shows, the share of primary products increases from a minimum of 2% in 1867, to a maximum of 8% in 1889; while the shares of both low-tech and high-tech manufactures decrease.

The specialisation patterns of the most important countries, participating in the Parisian universal exhibitions, are presented in Table 5.[26] In addition to the specialisation by product category, specialisation indices by technological level are also displayed at the bottom of the table. An inspection of the indices reveals regularities over time and space,[27] which allow dividing the selected countries in several groups.

(1) France and Great Britain form a European industrial 'core', characterised by persistent specialisation in both low-tech (*Construction*, *Glass*, *Paper and printing*, and various textiles; for Britain, also *Clothing and apparel*, and *Mining and metallurgy*) and high-tech (engineering-related) manufactures, but stronger in the latter than in the former. To this core can also be added Belgium and the Netherlands, although these two countries present puzzling indices in 1900 and in 1889, respectively, which can be attributed to particularly abundant displays of Belgian beers and of Dutch alimentary products (especially cheese), in those years.[28] It should be noticed, however, that the Netherlands are characterised by a narrower set of advantages than the other countries.

(2) An even 'deeper core' is formed by Switzerland and the United States, featuring under-specialisation not only in primary products, but also in low-tech manufactures, and correspondingly having extraordinary levels of specialisation in high-tech categories. In particular, the former country features a persistent and strong advantage in *Instruments* – an unsurprising result of its traditional excellence in watch-making –, and it develops, over the observed period, advantages in general and special-industry machinery, while reducing its initially strong specialisations in *Cotton* (turning into a deep under-specialisation since the 1880s) and *Silk*. Instead, the United States displays high levels of specialisation in all mechanical categories since the first Parisian expo, and maintains them over the following ones. Only in 1900 the American exhibit contingent appears more

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[25] It should be noticed that the identity of the second largest exhibitor varies across the expos, being Germany (i.e. the sum of German states) in 1855, Turkey in 1867, Spain in 1878, Argentina in 1889, and the United States in 1900.

[26] The specialisation indices of a larger set of countries, participating in each expo, are presented in Tables A3 to A7 in the appendix.

[27] In fact, the specialisation patterns resulting from the expo of 1889 are, for many countries, substantially different from those resulting from other expos. The reason for this is the peculiarity of that event, in terms of the origin and technological level of exhibited items, due to its boycott by European monarchies, mentioned in the previous section. Indices for that expo are reported in Table 5, for the sake of completeness; however, the reader should be aware of their shortcomings, and should rather exclude them, when tracing long-term trends.

[28] Unlike the exhibition of French wines, that of Belgian beers is not resized, as it is completely coming from private initiative (cf. fn. 10).

diversified, and representative of less sophisticated manufactures, as well as of the primary products resulting from that country's exceptional resource endowment.

(3) Germany deserves a separate mention, because of its spectacular shift from a not very marked pattern of specialisation, before its political unification (1871), to one dominated by high-tech manufactures. While chemicals were a traditional advantage of the German economy even in pre-unitary times, strong advantages were developed in general machinery and transport, and that in instruments was increased. Germany thus appears to be the country that most profited of the sweeping technological changes of the observed period, as its economic development was closely associated to the emerging technological paradigms of the Second Industrial Revolution. Yet at the same time it also gained high specialisation levels in the traditional, low-tech manufactures of furniture and jewellery.[29] Likewise, evidence of a structural shift towards a pattern dominated by high-tech manufactures is observed, since the 1870s, in Norway and Sweden: the former acquired high levels of specialisation in transport;[30] the latter in general machinery, lighting and heating, and electricity.[31] The other Nordic country, i.e. Denmark, does not share the same tendency, and presents a specialisation pattern based on low-tech manufactures, more similar to Austria's and Italy's than to its neighbours'.

(4) Southern European and South-American countries stand out as being backward economies, characterised by persistent strong specialisations in primary products, though with some individual peculiarities. Greece's economy appears less characterised than Iberian countries' by agriculture, food, and beverages, as it displays advantages in textiles and apparel, especially since 1878. It appears puzzling that Brazil and Greece show indices larger than unity in chemicals: in fact, this category comprises a very wide range of products, ranging from traditional products, like soaps, to modern pharmaceuticals, which can

[29] Germany's pattern of specialization in 1900 might appear puzzling, as the largest specialisation indices are displayed by traditional sectors (although high-tech industries, like chemicals, electricity, machinery, and transport, still feature indices larger than unity). This puzzling finding can be motivated with the better suitability of the expo format for displaying traditional consumer goods, and especially fashionable ones, than the complex industrial productions constituting the backbone of German industry. Yet even specialisation in a low-tech sector may be a symptom of excellence: notably, the high degree of specialisation in jewellery is largely contributed to by exhibitors from Pforzheim, in Baden-Württemberg, known as the 'golden city' because of its long tradition in jewellery-making.

[30] Norway's specialisation in high-tech industries may appear at odds with its being, over the period observed, one of the poorest countries in Europe. In fact, it is in line with the significant development, involving the Norwegian economy in those decades: 'the traditional export staples, fish and sawn wood, were overtaken by shipping services. Roughly speaking, while the former commodities constituted one-fifth each of the exports of goods and services, shipping accounted for two-fifths during the last third of the century. […] In tonnage, Norway now ranked third in the world. About the same time ashore pulp processing grew to a significant industry' (Ljungberg, 2003). Consistently with this, Norway's high Exhibit Specialisation Indices in the category of *Transport* (as well as in *Weapons*, in 1855) are driven by maritime exhibits; while specialisation in *Other industrial machinery and equipment* is accounted for by the industry of paper.

[31] From its study of the Swedish participation in international exhibitions, Ahlström (1996, p. 214) concludes that 'as early as the middle of the century, Sweden was achieving very creditable results in this industrial and national race', and that it 'was not merely a passive recipient of international scientific and technological discovery but in many instances, on the contrary, was at the forefront of technological expertise'.

furthermore be produced by processes of different sophistication.[32] Very interesting is the ‘regressive’ trajectory followed by Argentina, which from 1867 to 1889 lost the advantages it initially displayed in a few manufacturing industries, and strengthened its position in agriculture and food, also developing a strong specialisation in leather.

(5) The only country that clearly distinguishes itself from the rest of the ‘Southerners’ is Italy, with a persistent specialisation in some traditional manufacturing industries, notably furniture, glass, and silk.[33] Most significantly, over the observed period Italy lost its specialisation in agriculture and food. On the other hand, it could never achieve an advantage in the most sophisticated industries: the persistent advantage in chemicals may in fact be misleading, as was pointed out above.[34] A similar specialisation pattern to Italy’s, dominated by low-tech manufactures, is featured by Austria-Hungary. Finally, Russia is also characterised by specialisation in a varied set of primary and manufacturing categories (agro-food, chemicals, textiles, leather, mining and metallurgy, weapons).

(6) China and Japan are characterised by a remarkably neat and persistent pattern, dominated by traditional low-tech manufactures: ceramics, apparel, furniture, jewellery, and silk. Primary classes typically display indices below unity, denoting under-specialisation, and so do the classes most closely connected to the Second Industrial Revolution, in particular those related to engineering.

[32] Indeed Greece’s specialization in chemicals in 1889 and 1900 is largely accounted for by the display of soaps and waxes (including candles); while in 1855 it can be considered ‘spurious’, as it results from leather, paper, and tobacco – all of which fall under different categories in the other years.

[33] Actually, studies on Italy’s economic history typically treat silk as a primary product, based on Federico’s (1997) point that most of the value in its production (around 80%) was coming from the agricultural raw material, that is, silk cocoons. This product had a huge importance in Italian economy, as it accounted for as much as 30% of total Italian exports until the 1900s. This is clearly reflected into exhibition data, as Italy displays high specialisation levels at all expos, with the exception of the 1889 one, the data from which are however largely biased by that event’s boycott by European monarchies (cf. fn. 27)

[34] Indeed, Vasta (1999) points out that Italian chemical industry was dominated by less technology-intensive ‘new’ products, like nitrogenous fertilisers, and by ‘old’ products, derived from the processing of animal fats.

Table 5. Economic Specialisation Indices of the major countries that participated in the Parisian universal exhibitions.

	Argentina					Austria-Hungary					Belgium					Brazil					China				
	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900
Agro-food	(L)	**1.3**	**1.5**	**2.4**	(NP)	**1.1**	0.9	0.6	0.5	0.8	0.9	0.5	0.2	0.3	0.3	(L)	**2.6**	(NP)	**1.9**	(NP)	(NP)	0.4	0.9	(L)	0.8
Agro-food machinery and equipment		0.5	0.1	0.0			**1.5**	1.0	0.5	**3.5**		**1.4**	**1.6**	**1.5**	1.0		0.1		0.1			1.0	**1.1**		0.9
Beverages		**1.1**	0.9	0.7			**1.3**	0.8	0.9	0.9		0.3	0.4	0.7	**4.4**		**1.1**		0.7			0.0	0.2		0.0
Ceramics		**2.1**	0.6	0.2		**1.2**	0.7	0.6	**2.6**	0.8	**1.3**	0.5	0.8	0.7	0.3		0.0		0.5			**15.0**	**3.7**		**2.2**
Chemicals		**1.2**	0.8	0.3		0.8	**1.1**	**1.1**	0.5	0.6	0.9	**1.4**	1.0	**1.0**	0.6		**1.9**		**1.6**			0.6	0.9		0.6
Clothing and accessories		0.8	0.8	0.4		0.9	0.9	**1.5**	**2.3**	**1.2**	**1.0**	1.0	0.8	0.7	0.4		0.4		0.5			**2.4**	**2.1**		**1.7**
Construction		0.0	0.3	0.4		0.5	0.8	**1.4**	0.2	**1.5**	**1.8**	**2.1**	**1.8**	**2.6**	0.8		0.2		0.7			0.0	0.0		0.0
Cotton		0.7	0.4	0.2		0.9	0.6	0.7	0.6	0.5	**1.6**	**2.2**	0.7	**1.0**	**1.6**		0.3		**1.0**			0.7	**1.5**		**1.3**
Electricity				0.0					0.8	0.8				**1.3**	0.6				0.0						0.0
Flax and hemp		**1.1**	0.4	0.5		1.0	0.8	0.8	**1.1**	0.7	**2.7**	**4.3**	**3.2**	**3.2**	**1.8**		0.5		0.2			0.0	**2.6**		**2.4**
Furniture		0.0	0.7	0.5		0.6	**1.1**	**1.3**	**1.2**	**1.5**	0.8	**1.1**	**1.3**	**1.4**	**1.2**		0.0		0.7			**6.3**	**2.3**		**3.1**
General machinery and machine-tools		0.0	0.4	0.2		0.5	0.9	0.9	0.3	0.7	**1.4**	**1.7**	**1.8**	**1.9**	**1.5**		0.1		0.1			0.0	0.5		0.3
Glass		0.0	0.0	0.3			**1.9**	**1.3**	**12.2**	**2.3**		**3.6**	**3.9**	**3.6**	0.6		0.0		0.6			0.0	**1.1**		**2.4**
Instruments		0.6	0.3	0.1		0.8	**1.0**	**1.5**	**1.4**	**1.1**	0.4	0.4	**1.2**	**1.4**	0.7		0.1		0.4			0.3	0.6		0.9
Jewellery		**1.5**	0.5	0.1		0.7	1.0	**1.9**	**4.4**	**1.1**	0.4	0.6	0.4	0.8	0.5		0.2		0.3			**3.1**	**3.8**		**1.4**
Leather		0.8	**3.4**	**3.2**			0.7	0.7	0.0	0.9		**1.5**	**2.5**	**1.5**	**1.3**		0.0		0.2			0.0	0.8		**1.4**
Lighting and heating		0.0	0.0	0.0		0.8	**1.2**	**1.3**	0.0	0.7	**1.2**	**1.3**	**1.2**	**2.7**	**1.1**		0.0		0.2			**1.5**	0.0		**1.0**
Mining and metallurgy		**1.7**	0.9	0.2		**1.4**	**1.1**	**1.1**	0.2	0.7	0.8	**1.1**	**2.1**	**1.7**	0.5		0.5		**1.0**			0.3	0.8		0.8
Other industrial machinery and equipment		1.0	0.3	0.0		0.5	**1.1**	1.0	**1.2**		**1.6**	**1.7**	**3.3**	**2.2**			0.1		0.2			0.0	0.7		
Paper and printing		0.9	**2.0**	0.2		0.8	**1.2**	**1.3**	**1.1**	0.7	**1.1**	**1.1**	**1.1**	**1.5**	0.7		0.4		0.9			**1.8**	0.5		0.6
Silk		**1.3**	0.4	0.1		**1.4**	**1.1**	0.7	0.0	0.1	0.2	0.1	0.1	0.3	0.1		0.0		0.4			**2.6**	**2.3**		**1.4**
Textile machinery and equipment		**1.0**	0.6	0.1		0.6	0.7	0.7	0.6	0.2	**1.5**	**1.6**	**1.1**	**1.7**	0.9		**1.9**		0.3			0.0	0.2		**2.4**
Transport		**1.0**	1.0	0.4		0.9	0.7	**1.1**	0.5	0.6	**1.6**	**1.1**	**2.0**	**2.0**	**1.1**		0.3		0.6			0.0	0.8		**1.7**
Weapons		**1.4**	**1.1**	0.3		0.5	0.5	**1.2**	0.0	**1.8**	**2.4**	**1.6**	**1.9**	**3.3**	**2.4**		0.1		0.1			**1.5**	0.7		**3.2**
Wool		**1.4**	0.6	**1.1**		**1.4**	**1.1**	**1.2**	0.7	**1.2**	0.7	**1.0**	**2.0**	**1.1**	0.6		0.1		0.2			0.0	0.5		0.0
Primary products		**1.2**	**1.3**	**1.9**			**1.0**	0.7	0.6	0.8		0.5	0.3	0.4	**1.5**		**2.3**		**1.6**			0.3	0.7		0.6
Low-tech manufactures		1.0	0.9	0.4			**1.0**	**1.2**	**1.5**	**1.2**		**1.3**	**1.4**	**1.3**	0.7		0.3		0.6			**1.7**	**1.4**		**1.3**
High-tech manufactures		0.7	0.6	0.2			0.9	**1.1**	0.7	0.8		**1.2**	**1.6**	**1.7**	**1.0**		0.6		0.5			0.4	0.6		0.9

Note: wherever indices are not available for a country in a specific year, 'NP' in the first row after the header indicates that this is due to the country not participating in that year's expo; while 'L' indicates that the number of exhibits from that country at that expo was lower than a selected threshold (60), thus causing the computed indices not to be fully representative of that country's economy, as well as to take extreme values.

	Denmark					France					Germany					Great Britain					Greece				
	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900
Agro-food	0.6	0.6	0.5	**1.1**	0.3	0.9	0.3	0.6	0.4	0.4	0.6	0.6	(NP)	(L)	0.4	0.3	0.3	0.2	0.3	0.9	**2.7**	**2.1**	**2.0**	**1.3**	**1.2**
Agro-food machinery and equipment		0.8	**2.0**	0.4	**5.3**		**1.8**	**2.0**	**3.2**	**1.8**		0.6			0.7		**1.6**	**3.0**	1.0	**1.1**		0.0	0.0	0.0	0.2
Beverages		0.5	0.5	0.5	0.7		0.9	0.4	0.3	0.6		**1.3**			0.7		0.1	0.2	0.2	0.2		**1.3**	0.9	0.8	**2.3**
Ceramics	**1.6**	**1.6**	0.9	**3.7**	**3.4**	**1.3**	**1.2**	**1.3**	**1.7**	0.9	0.7	**1.3**			0.9	**1.2**	**1.1**	**1.0**	**1.1**	0.6	0.0	0.0	0.5	0.0	0.6
Chemicals	**1.1**	**1.0**	**1.3**	0.8	**1.3**	**1.0**	0.9	**1.1**	**1.2**	**1.2**	**1.4**	**1.3**			**1.5**	1.0	**1.2**	**1.3**	**1.3**	**1.1**	**1.5**	0.5	0.3	**1.2**	**2.3**
Clothing and accessories	**1.8**	**1.3**	**2.2**	0.8	**1.1**	0.9	0.8	**1.3**	0.8	0.9	1.0	0.8			0.6	**1.1**	0.9	**1.1**	**1.0**	**1.0**	**2.3**	0.8	**1.3**	**1.7**	**1.7**
Construction	0.0	0.7	0.5	0.7	0.9	**1.4**	**1.7**	**1.9**	**2.7**	**2.7**	0.7	**1.5**			0.8	**1.3**	**1.5**	**1.6**	**1.8**	0.8	0.0	0.4	0.1	0.2	0.0
Cotton	0.7	0.2	**1.6**	0.0	0.0	**1.5**	**1.1**	**1.2**	**1.1**	0.8	0.5	0.9			0.0	0.8	0.7	**1.4**	1.0	0.7	0.5	0.4	**3.4**	**4.3**	**3.3**
Electricity				0.9	**1.1**				**2.6**	**1.4**					**1.6**				**2.1**	**1.1**				0.0	0.1
Flax and hemp	0.3	0.0	**2.0**	0.0	0.0	0.9	1.0	1.0	0.9	1.0	**1.0**	**1.9**			0.1	**1.3**	0.7	**1.4**	0.8	**1.8**	0.2	0.5	0.2	**1.1**	0.3
Furniture	**2.3**	**2.5**	**2.4**	**1.6**	**1.8**	1.0	**1.4**	**1.0**	**1.3**	1.0	0.9	**1.0**			**2.4**	**1.1**	**1.5**	**1.5**	**1.2**	**1.5**	0.2	1.0	0.5	0.2	0.7
General machinery and machine-tools	**1.5**	0.9	**1.3**	**1.2**	**1.1**	**1.6**	**2.2**	**1.9**	**2.1**	**1.7**	0.7	0.9			**1.4**	**1.5**	**2.3**	**2.4**	**4.0**	**2.0**	0.0	0.2	0.1	0.0	0.0
Glass		0.0	0.0	0.0	0.0		**1.2**	**1.6**	**1.2**	**1.4**		**1.5**			**2.3**		**2.1**	**2.0**	**1.2**	**1.3**		0.0	0.3	0.0	0.0
Instruments	**2.2**	**1.3**	**1.4**	0.7	0.8	**1.1**	**1.4**	**1.5**	**1.6**	**1.4**	**1.1**	**1.4**			**2.0**	**1.0**	**1.2**	0.9	**1.4**	0.8	0.3	0.1	0.2	0.4	0.4
Jewellery	0.6	**3.3**	**1.5**	**1.3**	**1.8**	**1.4**	**1.3**	**1.2**	**1.6**	0.9	**1.1**	**1.3**			**3.0**	**1.1**	**1.6**	0.7	**1.1**	**1.1**	0.0	0.5	0.5	0.5	0.2
Leather		**2.2**	**1.1**	0.6	**1.6**		0.6	0.8	0.9	**1.7**		**1.5**			0.0		0.5	0.6	0.1	0.6		0.5	0.9	**1.5**	**2.6**
Lighting and heating	**3.2**	**1.5**	1.0	**1.1**	0.0	**1.3**	**1.6**	**1.7**	**2.4**	**2.4**	0.5	**1.1**			0.7	**1.6**	**3.0**	**1.4**	**2.6**	**1.5**	0.0	0.0	0.1	0.3	0.2
Mining and metallurgy	0.4	0.4	0.0	0.0	0.1	0.6	0.7	0.4	0.8	0.6	**1.4**	**1.1**			0.3	1.0	**1.1**	**1.4**	**1.3**	**1.2**	0.5	**1.4**	0.7	0.5	0.3
Other industrial machinery and equipment	**2.4**	0.5	**1.1**	0.4		**1.5**	**2.5**	**2.1**	**2.4**		0.7	**1.4**				**1.3**	**1.1**	**1.9**	**2.9**		0.0	0.1	0.0	0.1	
Paper and printing	0.8	**2.8**	**1.7**	**3.3**	**1.3**	**1.2**	**1.6**	**1.1**	**1.3**	**1.5**	**1.2**	**1.3**			**1.6**	**1.2**	**2.1**	**1.3**	**1.4**	1.0	0.4	0.4	0.3	**1.1**	0.7
Silk	0.0	0.0	0.0	0.0	0.0	**1.0**	**1.2**	0.2	0.9	0.7	0.6	0.2			0.7	0.4	0.7	**1.8**	**1.3**	0.6	**1.4**	1.0	**2.9**	**3.7**	**1.6**
Textile machinery and equipment	0.0	**2.1**	**1.2**	0.0	**1.8**	**1.5**	**1.6**	**2.3**	**2.2**	**2.9**	0.9	**1.1**			**1.3**	**1.7**	**1.7**	**2.4**	**1.8**	**2.0**	0.0	0.3	0.1	0.1	0.3
Transport	0.0	0.7	0.3	**3.5**	0.7	0.8	**1.8**	**1.6**	**1.8**	**1.3**	0.5	0.6			**2.1**	**2.6**	**2.7**	**2.7**	**3.4**	**1.6**	0.0	0.5	0.2	0.0	0.1
Weapons	0.5	0.4	0.6	0.0	0.0	0.9	0.9	**1.1**	**2.1**	**1.7**	0.2	0.4			0.4	**1.8**	0.9	**1.6**	**2.3**	**3.0**	0.0	0.2	0.0	**1.0**	**1.4**
Wool	0.2	0.8	**1.3**	0.0	0.0	**1.1**	**1.1**	0.9	0.8	0.9	**1.7**	**1.9**			0.4	**1.1**	**1.7**	**2.0**	**1.1**	**1.3**	0.1	0.3	**1.1**	0.9	**1.4**
Primary products		0.6	0.5	0.9	0.4		0.5	0.5	0.4	0.4		0.8			0.5		0.2	0.2	0.3	0.7		**2.0**	**1.7**	**1.1**	**1.5**
Low-tech manufactures		**1.3**	**1.4**	1.0	**1.3**		**1.2**	**1.2**	**1.3**	**1.2**		**1.1**			**1.0**		**1.2**	**1.4**	**1.1**	**1.0**		0.6	0.8	**1.1**	0.9
High-tech manufactures		1.0	**1.1**	**1.3**	**1.1**		**1.5**	**1.5**	**1.8**	**1.4**		**1.1**			**1.8**		**1.8**	**1.7**	**2.4**	**1.4**		0.3	0.2	0.4	0.5

	Italy					Japan					Netherlands					Norway					Portugal				
	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900
Agro-food	**1.1**	**1.2**	**1.0**	0.6	0.8	(NP)	(NP)	0.5	**1.1**	0.4	**1.1**	**1.0**	0.7	**1.3**	0.5	0.8	**1.8**	**1.0**	0.8	0.7	**4.1**	**1.7**	**1.7**	**1.4**	**1.8**
Agro-food machinery and equipment		1.0	0.4	0.5	0.5			0.1	0.3	0.1		0.3	0.7	0.9	0.6		0.6	**1.8**	**1.7**	0.4		0.3	0.1	0.1	0.3
Beverages		**1.8**	**1.1**	**1.2**	**1.4**			0.2	0.5	0.7		0.8	0.7	**1.0**	0.7		0.2	0.5	0.4	0.1		**2.0**	**2.3**	**3.6**	**2.4**
Ceramics	**1.8**	0.8	0.8	**4.7**	**1.2**			**10.8**	**4.6**	**4.4**	0.7	**1.3**	0.4	0.3	**2.9**	0.0	0.0	0.3	0.0	0.3	0.7	**3.2**	**1.1**	0.7	1.0
Chemicals	0.8	**1.1**	**1.4**	**1.2**	**1.3**			0.5	0.6	**1.4**	**1.4**	**2.1**	**1.4**	**1.2**	**1.5**	0.4	**1.4**	**1.5**	**2.3**	0.5	0.5	0.5	0.6	0.5	**1.2**
Clothing and accessories	0.7	0.5	0.7	0.5	0.8			**2.6**	**1.2**	**2.7**	0.9	0.7	0.7	0.5	**1.4**	**1.5**	1.0	1.0	**1.1**	1.0	0.7	0.7	0.7	0.5	0.8
Construction	**1.3**	0.9	1.0	0.4	0.4			0.4	0.2	0.0	**1.5**	1.0	**2.3**	0.9	**2.6**	**2.3**	0.3	0.4	**1.2**	**1.2**	0.3	0.9	0.5	0.0	0.4
Cotton	0.4	0.6	0.5	0.0	**1.5**			0.5	**1.1**	**2.1**	0.6	**2.7**	**2.1**	0.0	0.9	**1.8**	0.1	0.6	0.0	0.0	0.5	0.4	0.8	0.7	0.9
Electricity				0.7	0.6				0.2	0.0				0.0	0.5				0.4	**1.6**				0.1	0.0
Flax and hemp	0.4	0.9	0.8	0.9	0.7			0.8	0.2	0.6	**1.0**	0.0	**1.2**	0.8	0.9	0.7	0.0	0.3	0.0	0.0	0.8	**1.4**	**1.4**	0.5	**1.0**
Furniture	**3.3**	**1.9**	**2.5**	**3.3**	**2.3**			**2.6**	**4.4**	**1.2**	**2.7**	**1.5**	**1.9**	0.3	**1.3**	**2.2**	**1.4**	0.7	0.4	**2.2**	0.2	0.2	0.3	0.2	0.5
General machinery and machine-tools	0.5	0.6	0.6	0.7	0.4			0.0	0.2	0.0	**1.9**	0.7	**1.5**	**1.0**	**1.0**	0.6	0.3	0.8	0.6	**1.6**	0.0	0.1	0.2	0.3	0.1
Glass		0.7	**1.6**	**5.2**	**1.3**			0.0	0.0	0.1		**1.3**	**1.4**	**3.4**	**2.6**		0.0	**1.2**	0.0	0.0		0.6	0.2	0.0	0.4
Instruments	0.7	**1.1**	0.9	**1.0**	**1.3**			0.3	0.2	0.3	0.7	0.9	**1.4**	1.0	**1.1**	**1.4**	**1.1**	0.9	**1.3**	**2.0**	0.2	0.2	0.1	0.2	0.6
Jewellery	0.8	**1.0**	**1.3**	**8.1**	**2.0**			**4.4**	**3.1**	**4.7**	**3.7**	**1.7**	0.6	0.6	**2.7**	0.4	0.7	0.5	**1.3**	1.0	0.5	0.5	0.1	0.0	0.3
Leather		0.8	**1.2**	0.8	**1.6**			0.6	0.2	0.2		0.2	0.1	0.0	0.5		**1.1**	**2.9**	**2.5**	**1.8**		**2.3**	0.5	0.2	0.8
Lighting and heating	**1.1**	0.5	0.7	0.0	0.3			0.8	0.9	0.6	**1.1**	0.7	**1.1**	**2.9**	0.7	0.8	**1.0**	**1.2**	0.5	0.9	0.1	0.2	0.1	0.1	0.6
Mining and metallurgy	0.9	**1.1**	**1.1**	0.8	0.4			0.5	0.3	0.2	0.3	0.2	0.4	0.7	0.1	0.9	0.8	**1.5**	**1.9**	**1.0**	0.7	0.7	0.5	0.4	0.5
Other industrial machinery and equipment	0.6	0.2	0.5	0.3				0.1	0.0		0.7	0.5	0.5	0.0		0.4	0.2	**2.2**	**2.7**		0.3	0.2	0.0	0.0	
Paper and printing	0.8	0.9	0.9	0.9	0.8			0.7	**1.2**	0.6	**2.0**	**1.5**	**1.1**	**2.6**	0.9	**1.2**	1.0	0.6	**1.3**	**1.3**	0.3	0.4	0.4	0.2	0.5
Silk	**3.7**	**1.5**	**2.9**	0.0	**5.1**			**6.0**	**5.5**	**6.6**	0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	**1.7**	0.7	0.2	0.2
Textile machinery and equipment	0.5	0.7	0.6	0.7	0.5			0.2	0.0	**2.1**	0.0	0.5	0.5	0.0	0.9	0.0	0.0	**1.4**	**1.3**	0.0	0.4	0.4	0.4	0.2	0.2
Transport	0.6	0.4	0.7	**1.0**	0.6			0.0	0.1	0.1	**2.0**	**1.2**	**1.8**	**1.4**	**3.1**	**1.3**	**2.1**	**1.9**	**2.2**	**3.6**	0.4	0.5	0.1	0.2	0.2
Weapons	0.4	0.8	0.9	0.0	0.8			0.5	0.0	0.0	**2.4**	**1.8**	**1.9**	0.0	0.0	**2.8**	0.7	**1.1**	0.0	0.0	0.5	0.0	0.1	0.2	0.3
Wool	0.1	0.3	0.1	0.0	0.5			0.4	0.1	0.2	0.1	**1.8**	**3.2**	0.0	0.0	0.9	0.0	0.7	0.0	0.0	0.3	0.9	**1.3**	0.6	**1.3**
Primary products		**1.3**	**1.0**	0.8	1.0			0.4	1.0	0.5		1.0	0.7	**1.2**	0.5		0.8	0.9	0.7	0.5		**1.8**	**1.9**	**2.0**	**2.0**
Low-tech manufactures		0.9	**1.0**	**1.3**	**1.1**			**1.8**	**1.4**	**1.6**		0.9	**1.1**	0.9	**1.1**		**1.1**	1.0	**1.1**	**1.0**		0.8	0.5	0.3	0.6
High-tech manufactures		0.8	0.9	0.7	0.8			0.3	0.2	0.4		**1.3**	**1.4**	0.8	**1.5**		**1.1**	**1.4**	**1.5**	**1.6**		0.3	0.3	0.3	0.5

	Russia					Spain					Sweden					Switzerland					United States				
	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900	1855	1867	1878	1889	1900
Agro-food	(NP)	**1.4**	**1.1**	0.8	**1.3**	**2.4**	**1.9**	**1.9**	0.4	**1.2**	0.8	0.8	0.4	(L)	0.3	0.3	0.5	0.2	0.3	0.2	0.1	0.5	**1.0**	0.6	**1.1**
Agro-food machinery and equipment		0.8	0.9	0.2	**1.2**		0.3	0.1	0.2	0.5		**2.6**	**1.5**		**1.2**		0.8	0.9	**1.8**	**1.2**		**2.6**	0.9	**2.2**	0.5
Beverages		0.5	0.5	**1.3**	0.6		**2.3**	**2.5**	**4.7**	**2.8**		0.5	0.2		0.4		**1.7**	0.6	1.0	**1.4**		0.5	0.3	0.1	0.2
Ceramics		0.4	0.2	0.3	0.4	0.9	0.8	0.7	0.3	0.6	0.5	0.7	0.4		0.4	0.3	0.2	0.5	0.9	0.2	0.0	0.4	0.2	0.2	**1.3**
Chemicals		**1.1**	**1.2**	**1.4**	1.0	0.8	0.6	0.6	0.5	**1.3**	0.7	0.5	0.9		0.5	0.8	**1.3**	**1.1**	0.9	0.2	0.2	0.8	**1.2**	**1.2**	0.2
Clothing and accessories		0.6	**1.1**	0.7	0.9	0.5	0.3	0.3	0.6	0.9	**1.9**	0.8	0.7		0.5	**1.1**	0.7	**1.2**	0.9	0.8	0.3	0.5	0.6	0.5	0.2
Construction		0.2	0.5	**1.4**	**1.2**	0.3	0.8	0.2	0.2	0.4	**1.2**	**1.6**	**1.0**		0.0	0.4	**1.1**	**1.6**	0.7	**1.1**	0.6	**1.3**	0.3	0.9	0.9
Cotton		0.7	**1.5**	**2.5**	**2.3**	**1.5**	0.3	0.1	0.6	**1.4**	0.4	0.6	**3.4**		0.0	**2.8**	**2.6**	**2.5**	0.2	0.1	0.3	0.2	**2.5**	0.7	0.2
Electricity				1.0	0.4				0.3	0.7					**2.5**				**1.5**	**2.3**				**4.5**	**2.6**
Flax and hemp		**1.0**	0.9	**1.3**	**1.8**	0.6	0.4	0.2	0.8	**1.4**	0.4	1.0	**4.8**		0.0	0.2	0.5	0.1	0.0	0.0	0.3	0.0	0.0	0.7	0.1
Furniture		0.7	**1.2**	**1.0**	0.9	0.3	0.3	0.1	0.8	0.4	**1.4**	**1.4**	0.8		**1.2**	0.7	0.7	0.3	**1.8**	0.9	**1.2**	0.7	0.6	**1.1**	0.3
General machinery and machine-tools		0.5	0.6	0.5	0.5	0.1	0.3	0.0	0.2	0.4	0.8	**1.3**	**1.6**		**3.4**	0.5	**1.0**	**1.2**	**1.6**	**2.5**	**4.2**	**3.5**	**3.1**	**3.1**	**2.0**
Glass		0.4	0.3	0.3	0.7		0.1	0.0	0.5	0.6		0.5	0.3		0.6		0.5	0.0	0.6	**2.4**		**1.3**	0.5	**1.9**	0.6
Instruments		0.7	**1.2**	**1.1**	1.0	0.4	0.3	0.1	0.7	1.0	**1.0**	**1.2**	**1.1**		**1.1**	**3.1**	**4.8**	**5.2**	**5.5**	**4.1**	**2.5**	**1.6**	**1.1**	1.0	0.9
Jewellery		0.7	0.7	0.8	0.8	0.7	0.3	0.1	0.5	0.4	0.7	0.6	**1.2**		**1.8**	0.6	0.6	**1.4**	0.9	0.9	0.5	0.2	0.9	0.8	0.3
Leather		**2.5**	**2.2**	**2.4**	**1.3**		0.3	0.2	0.9	0.7		0.3	0.4		0.0		**1.1**	**1.4**	**1.4**	0.0		0.6	**2.2**	0.5	0.3
Lighting and heating		0.7	**1.5**	0.5	0.6	0.8	0.3	0.1	0.2	0.9	**1.6**	0.6	**5.0**		**3.8**	0.7	**1.2**	0.7	**1.2**	**2.5**	**2.0**	**2.6**	**2.3**	**2.0**	1.0
Mining and metallurgy		**1.4**	**1.2**	**2.0**	0.8	**1.5**	**1.5**	**1.0**	0.4	0.5	**1.4**	**2.7**	**2.5**		**2.4**	0.3	0.3	0.5	0.5	0.3	0.5	**1.5**	**1.6**	**2.3**	**2.9**
Other industrial machinery and equipment		0.2	0.3	0.9		0.0	0.6	0.1	0.3		0.6	**2.9**	**2.1**			0.5	**1.9**	0.9	1.0		**8.5**	**2.2**	**1.1**	**2.8**	
Paper and printing		0.6	**1.1**	**1.2**	0.7	0.2	0.5	0.5	**1.1**	0.5	0.5	**1.1**	**1.1**		**2.3**	0.7	0.9	**1.6**	**1.2**	**1.1**	**2.3**	1.0	**1.3**	**1.9**	**1.2**
Silk		**1.8**	**1.2**	**1.1**	0.8	**1.2**	0.3	0.2	0.3	1.0	0.3	0.1	0.3		0.0	**4.6**	0.8	**3.0**	**1.3**	**1.5**	0.2	0.2	0.4	0.2	0.2
Textile machinery and equipment		0.3	0.2	0.0	0.2	0.3	0.2	0.2	0.7	0.2	0.5	0.3	0.3		0.0	0.2	0.8	**2.0**	**1.4**	**3.2**	**5.3**	**4.4**	**1.8**	**2.5**	0.6
Transport		0.9	**1.2**	0.5	**1.6**	0.0	0.1	0.1	0.2	0.2	0.9	0.7	**1.0**		0.6	0.2	0.2	0.6	**1.1**	**1.3**	**1.6**	**1.9**	**1.3**	**2.1**	**1.8**
Weapons		**1.5**	0.5	**1.1**	**1.7**	0.4	0.5	0.7	0.3	0.2	**2.0**	**1.1**	**1.5**		**1.5**	0.8	0.6	0.8	0.4	0.0	**3.0**	**3.0**	**1.4**	**1.0**	0.2
Wool		**1.3**	**1.9**	**1.3**	**2.6**	0.8	0.9	0.3	**2.0**	**3.6**	0.4	0.4	**2.7**		0.0	0.1	0.3	0.3	0.1	0.2	0.0	0.2	0.0	0.4	0.3
Primary products		**1.2**	0.9	0.9	**1.1**		**2.0**	**2.1**	**1.6**	**1.7**		0.7	0.4		0.3		0.8	0.3	0.5	0.5		0.5	0.8	0.5	0.9
Low-tech manufactures		0.9	**1.1**	**1.1**	1.0		0.6	0.4	0.7	0.7		**1.2**	**1.3**		**1.2**		0.8	**1.2**	1.0	0.8		0.9	0.9	**1.1**	1.0
High-tech manufactures		0.8	1.0	0.9	1.0		0.4	0.3	0.4	0.7		**1.0**	**1.5**		**1.5**		**2.0**	**2.0**	**2.3**	**2.2**		**1.9**	**1.5**	**1.9**	**1.3**

Table 6. Export-based Revealed Comparative Advantages

	Belgium	France	Germany	Great Britain	Italy	Japan	Sweden	Switzerland	United States
Iron and steel	**1.4**	0.4	0.8	**1.5**	0.1	0.0	**6.4**	0.1	**1.2**
Non-ferrous metals	**1.9**	0.7	0.7	0.5	0.4	**2.6**	0.2	0.2	**3.7**
Chemicals	**1.6**	0.8	**1.5**	0.7	**1.3**	**1.1**	1.0	0.5	**1.1**
Ceramics, glass and bricks	**5.4**	**1.1**	**1.1**	0.4	**2.2**	0.2	**4.6**	0.1	0.5
Wood, leather, rubber and paper	0.9	**1.2**	**1.5**	0.3	**1.1**	0.4	**2.9**	0.1	**1.7**
Industrial equipment	0.8	0.5	0.9	**1.2**	0.1	0.0	**1.3**	0.8	**2.1**
Electricals goods	0.0	0.3	0.9	**1.0**	0.8	0.0	0.2	**2.4**	**2.8**
Agricultural equipment	0.0	0.2	0.0	**1.1**	0.8	0.0	0.4	0.1	**5.0**
Railways, ships	**1.8**	0.3	0.5	**1.7**	0.3	0.0	0.3	0.0	**1.4**
Motor-cars, aircrafts	0.8	**1.3**	1.0	0.7	0.4	0.0	0.2	0.0	**2.4**
Spirits and tobacco	0.2	**2.8**	0.5	0.6	**4.6**	0.3	0.1	0.2	0.9
Textiles	0.7	1.0	0.6	**1.4**	**1.0**	**1.7**	0.1	**1.8**	0.2
Apparel	0.4	**2.1**	**1.4**	0.7	**1.1**	0.5	0.1	0.4	0.3
Metal manufactures n.e.c.	0.9	0.7	**1.5**	0.7	0.1	0.2	0.9	**2.5**	**1.5**
Books, films and camera	0.3	**1.7**	**2.1**	0.4		0.1	0.3	0.3	0.6
Finished goods n.e.c.	0.5	**1.0**	**1.8**	0.6	**2.7**	**2.5**	0.9	0.7	0.7
Not classified	**2.6**	0.7	0.5	**1.2**		**2.9**	0.4	0.0	**1.3**

Source: my elaboration on data from Tyszinski (1951); for Italy only, Vasta (2010).

Although, as pointed out above, the interpretation of exhibition data maintained here is not pushed as far as to considering it a proxy for export data, but lies between production data and export data, a comparison of the specialisation indices presented here to those resulting from historical export data would not only be of interest, but it would also help better understanding the differences between exhibition data and export data. For this purpose, Table 6 presents Balassa's RCA indices, computed from data about world exports in 1899 from Tyszinski (1951), one of the most cited sources in this regard.[35] The latter source only refers to manufacturing exports; but this does not hinder the validity of the comparison, since none of the considered economies was specialised in primary products as of 1900. The 'exception confirming the rule' is Italy, which is in fact the country with the best correspondence between the export-based and the exhibition-based patterns of specialisation – both hinging upon ceramics, glass, beverages, apparel, and furniture (included in 'finished goods n.e.c.').[36] In general, the

[35] Tyszinski (1951) provides data about the manufacturing exports of eleven polities (those shown in Table 6, plus Canada and India, which are not considered in this work since they were colonies), accounting for 80-85% of world trade, in five benchmark years (1899, 1913, 1929, 1937, and 1950). For Italy, Vasta (2010) has computed RCA indices, which are based on Tyszinski's data for world total exports at the denominator, but make use of new and accurate data from the Bankit-FTV database (cf. Federico, Natoli, Tattara and Vasta 2011) for Italian exports at the numerator. Varian (2016) has recently computed the RCAs of Britain in the late Victorian era (1880-1900), as well as those of Belgium, France, Germany, and the United States, based on official export data from these countries; however, his focus on the five major industrial economies make his indices not appropriate for a comparison to exhibition-based specialisation indices, which refer to a larger and various set of countries.

[36] Italy's excellent congruence between the ESI and the RCA can not only be motivated with that country's desire to present itself on the international stage as an emerging economic power (which, at least for the first two decades after its unification in 1861, was far from true; cf. Toniolo, 2013), but also with the 'expo format' being particularly well-suited to the promotion of Italian semi-artisanal productions (Murano glasses, Tuscan ceramics, silk fabrics from the Northern manufactures) and to the Italian government's free-trade stance. Expos were so valuable to Italy that even in 1889, when, out of political reasons, the country refused to officially join the expo, the Italian government restrained from actively boycotting private participation, unlike e.g. the German one (Pellegrino, 2015, p. 64).

degree of congruence between the two patterns varies over countries.[37] Some well-known historical advantages, like that of Germany in chemicals, that of Switzerland in electricity, and that of the United States in machinery, clearly emerge from both kinds of data.

A common issue involves machinery: the strong specialisation featured at the 1900 expo by France, Germany, and Switzerland, is not consistent with their comparative disadvantages, based on 1899 export data from Tyszinski: in fact, according to the latter, France featured a persistent comparative disadvantage in industrial equipment over the 1899-1950 period; while Germany and Switzerland only developed advantages after the turn of the century. For France, this inconsistency can be motivated with the will of the exhibitions' host country to celebrate its industrial power, even if its high-tech manufactures did not prove to be internationally competitive, and its comparative advantages rather lied in low-tech manufactures. The case of Germany and Switzerland is different: in fact, their mechanical industries were expanding,[38] and a comparative advantage would be conquered soon after the end of the nineteenth century. This confirms the interpretation suggested above: exhibit contingents represent the products that participating countries wanted to promote on international markets. In other words, export was an aim of exhibiting, rather than a reason for it; and to a certain extent specialisation patterns resulting from exhibition data can be expected to anticipate future export patterns. A specular argument may explain why Great Britain's well-know comparative advantage in cotton fabrics does not emerge from exhibition data: precisely because of its primacy in that sector, Britain did not feel the need to further promote it at exhibitions.

5. Another view of technological content: the Economic Complexity Index

The previous section has presented and discussed the patterns of specialisation, emerging from data about the exhibits presented at the Parisian expos by participating countries, not only based on a product categorisation, but also on an attempted division by technological level. In the present section, a different approach to the issue of the technological sophistication of the various countries' exhibit mixes is followed, inspired by the recent strand of literature about 'economic complexity'.

In a seminal work, Hidalgo and Hausmann (2009) have advanced a method to indirectly measure the 'capabilities' of countries, based on observed trade patterns. The idea behind it is that different products require different (levels of) capabilities to be produced and exported; hence, knowing how many and what products a country exports allows evaluating the capabilities it possesses. The way to do so has been labelled as the 'method of reflections', and consists of iteratively calculating a family of measures of countries' 'diversification' and products' 'ubiquity'. In particular, given the 'adjacency matrix' M_{cp}, where c denotes countries and p denotes products, the elements of which equal one if a given criterion is satisfied and zero otherwise, the following variables are calculated:

[37] The correspondence between the indices based on 1899 exports and those based on 1900 exhibits is particularly bad for Belgium. However, as noticed above, the Belgian specialisation pattern in 1900 differed significantly from those at earlier expos; in fact, the fit improves considerably, if earlier indices are used as a term for comparison. In particular, the persistent strong comparative advantages in the export of non-metalliferous mineral products (ceramics, glass, construction materials) and metals find then a correspondence in exhibition-based specialisation indices.

[38] Labuske and Streb (2008, Figures 1 and 2) shows that, since 1890, German machinery exports started soaring.

$$k_{c,0} = \sum_p M_{cp},$$

$$k_{p,0} = \sum_c M_{cp}$$

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_p (M_{cp} k_{p,N-1}),$$

$$k_{p,N} = \frac{1}{k_{p,0}} \sum_c (M_{cp} k_{c,N-1}).$$

$k_{c,0}$ and $k_{p,0}$ represent, respectively, the observed level of diversification of country c, i.e. the number of products for which it satisfies the criterion; and the observed ubiquity of product p, i.e. the number of countries that satisfy the criterion for it. Diversity and ubiquity are then interacted: $k_{c,1}$ is the average ubiquity of products where country c satisfies the criterion; $k_{c,2}$ is the average diversification of countries, satisfying the criterion for the same classes, for which country c satisfies it; and so on. In the same manner, successive even variables ($k_{c,4}$, $k_{c,6}$, …) are generalized measures of diversification; while odd variables ($k_{c,5}$, $k_{c,7}$, …) are generalized measures of the ubiquity of their products (for the equivalent product-based measure family, $k_{p,N}$, the contrary holds true). By 'reflecting' on each other – hence the name of the method –, information on diversity and ubiquity complement each other, so that as the number of iterations (N) increases, the measures' accuracy also improves. At the same time, the countries' ranking, resulting from $k_{c,N}$, evolves: however, changes in $k_{c,N}$ become ever smaller, so that the ranking eventually stabilizes.[39]

Hidalgo and Hausmann's method of reflections represents a good way to 'endogenise' the evaluation of the various products' degree of sophistication, and of the resulting 'complexity' of the economies that presented them at the Parisian exhibitions. Rather than following, as in the previous section, a given (exogenous) criterion, dividing product classes into 'high-tech' and 'low-tech', each product's sophistication is endogenously determined by the data, based on its generalized ubiquity. The latter is then incorporated into the generalized measure of diversification, which indicates country complexity. In this way, the arbitrariness and rigidity of the criterion followed in the previous section are overcome. Furthermore, the whole number of classes of the original classifications can be exploited, as a harmonisation over the different expos is not required.

As pointed out above, at the root of the method of reflections lies the construction of a country-product matrix, the elements of which take as value zero or unity, depending on a certain criterion, which in Hausmann and Hidalgo's original contribution is $RCA_{cp} \geq 1$. However, having a revealed comparative advantage in a certain product is a demanding criterion, requiring not just that a country produces and exports a certain product, but also that it does so better than the world average. In line with the interpretation of exhibition data maintained in this paper, whereby exhibits represent products that countries were producing and promoting on international markets, but in which they not necessarily had an established advantage, a 'softer' criterion is adopted here, namely that the specialisation of country c in product p, resulting from exhibition data, is *at least 0.8*. This requires that product class p accounts

[39] As shown in the author's original contributions, stabilisation already occurs for N=18, which is then chosen as the number of interactions for the computation of this section's indices.

for a sufficiently large share of the exhibits of country c, though not necessarily larger than the world share (in fact, up to 20% lower).

Table 7. Rankings by Economic Complexity Index, 1867-1900.

1867			1878			1889			1900		
	$k_{c,0}$	ECI		$k_{c,0}$	ECI		$k_{c,0}$	ECI		$k_{c,0}$	ECI
United States	31	1.58	Switzerland	29	1.38	Germany	11	2.49	Germany	46	1.19
France	48	1.32	Belgium	38	1.36	Belgium	39	1.65	Switzerland	46	1.13
Great Britain	42	1.32	France	51	1.25	France	50	1.52	Norway	35	1.07
Belgium	33	1.32	Great Britain	46	1.20	Great Britain	45	1.52	France	63	0.84
Germany	41	1.06	Sweden	33	1.17	Switzerland	38	1.46	Sweden	43	0.84
Sweden	31	1.06	Netherlands	33	1.09	United States	35	1.46	Denmark	33	0.84
Austria-Hungary	39	0.93	Austria-Hungary	44	1.02	Denmark	23	1.20	Netherlands	38	0.79
Denmark	34	0.93	Denmark	41	1.02	Luxembourg	22	1.00	Luxembourg	27	0.79
Switzerland	28	0.93	Norway	22	0.75	Norway	29	0.94	Great Britain	58	0.73
Egypt	43	0.53	United States	33	0.67	Austria-Hungary	25	0.74	Belgium	31	0.73
Norway	24	0.53	Siam	26	0.62	Netherlands	28	0.74	United States	30	0.73
China	20	0.53	Tunisia	22	0.59	Italy	26	0.68	Italy	36	0.67
Liou-Kiou	14	0.53	Egypt	28	0.57	Russia	31	0.35	Austria-Hungary	43	0.62
Netherlands	32	0.27	Japan	22	0.57	Uruguay	18	0.35	Persia	9	0.62
Luxembourg	6	0.27	Russia	38	0.51	Egypt	22	0.22	China	50	0.50
Tunisia	36	0.14	China	34	0.51	Spain	15	0.22	Korea	48	0.45
Italy	29	0.01	Luxembourg	15	0.33	Japan	22	0.09	Japan	25	0.45
Siam	12	0.01	Italy	32	0.25	Bolivia	20	0.09	Russia	44	0.39
Russia	30	-0.12	Guatemala	26	0.07	China	12	0.09	Monaco	25	0.39
Hawaii	14	-0.12	Morocco	22	0.07	Turkey	2	0.09	Turkey	27	0.33
Argentina	31	-0.25	Peru	15	-0.07	San Marino	16	-0.10	San Marino	22	0.33
Morocco	17	-0.25	Uruguay	22	-0.12	Venezuela	24	-0.17	Serbia	34	-0.01
Turkey	26	-0.65	Bolivia	13	-0.12	South Africa	23	-0.30	Cuba	26	-0.01
Paraguay	9	-0.78	Venezuela	14	-0.43	Bulgaria	1	-0.30	Greece	31	-0.12
Chile	19	-0.91	Salvador	11	-0.43	Romania	22	-0.49	Spain	28	-0.23
Portugal	19	-0.91	Annam	15	-0.57	Dominican Rep.	21	-0.49	Bulgaria	29	-0.29
Uruguay	17	-1.04	Nicaragua	14	-0.59	Monaco	16	-0.49	Romania	27	-0.29
Greece	17	-1.17	Argentina	22	-0.62	Guatemala	22	-0.55	South Africa	21	-0.29
Spain	14	-1.30	Persia	16	-0.67	Salvador	19	-0.55	Ecuador	27	-0.52
Brazil	12	-1.56	Portugal	17	-1.15	Greece	22	-0.62	Peru	27	-0.69
Peru	4	-1.96	Mexico	7	-1.20	Paraguay	21	-0.62	Portugal	23	-0.69
Costa Rica	9	-2.22	Greece	16	-1.36	Chile	20	-0.62	Mexico	22	-0.97
			San Marino	7	-1.70	Sweden	7	-0.62	Andorra	8	-1.03
			Haiti	12	-1.78	Brazil	17	-0.68	Nicaragua	9	-1.59
			Andorra	7	-2.02	Nicaragua	13	-0.68	Guatemala	7	-2.39
			Spain	10	-2.20	Serbia	13	-0.75	Salvador	6	-2.39
						Hawaii	17	-0.88	Liberia	5	-2.96
						Ecuador	18	-1.07			
						Argentina	12	-1.40			
						Cape Colony	5	-1.66			
						Portugal	4	-1.72			
						Haiti	3	-2.18			

Table 7 provides the rankings, by descending Economic Complexity Index (ECI),[40] of each Parisian universal exhibition's participating countries, except for the

[40] Since the distribution by country of $k_{c,18}$ (cf. previous note) is different, based on data from different exhibitions, the measure is standardised, in order to allow for diachronic comparisons. In formula:

$$ECI_c = \frac{k_{c,18} - \langle k_{c,18} \rangle}{stdev(k_{c,18})},$$

expo of 1855, due to the product classes of that year's classification being too few and comprehensive. Besides the ECI, the initial measure of observed country diversification, $k_{c,0}$, is provided. A quick comparison reveals that, while a positive correlation between the two variables displayed does exist, it is not perfect, and a country with a lower observed diversification, i.e. satisfying the given criterion in fewer product classes, may be more 'complex' than one with a higher $k_{c,0}$. Indeed, the central point of the method devised by Hidalgo and Hausmann is that the average ubiquity of the product mix also matters.

Table 7 confirms some of the points made in the previous section, during the discussion of the specialisation indices; but it also adds new insights and nuances. All the more so, complexity indices are provided for all the countries that participated in the expos. In line with expectations from the previous section, the lower part of the rankings of all exhibitions are occupied by Southern European and South-American countries, to which since 1889 are added the new South-Eastern European states, carved out of the Ottoman Empire, and Sub-Saharan African independent countries.[41] The upper part of the ranking is, by the contrary, generally dominated by Northern European countries, plus the United States; but significant changes can be observed. By 1900, the countries occupying the first positions in 1867, namely the United States, Belgium, France, and Great Britain, have fallen behind, and have been overtaken by the countries, developing the most during the Second Industrial Revolution, i.e. Germany (eventually acquiring the leadership, as the world's most complex economy), Switzerland, and the Nordic countries.[42] Unlike other Germanic countries, Austria-Hungary does not experience a development phase, associated to the Second Industrial Revolution, and loses positions over time, although more because of the other countries' emergence than because of its own decline. By the contrary, Italy, which in 1867 ranks below Tunisia in terms of ECI, gains positions since the 1880s (the decade of its first phase of industrial development); so that in 1900, at the time its modern economic growth properly started,[43] Italy ranks immediately after the group of the most industrialised Northern economies. Other countries do generally fluctuate in the central part of the rankings.

Finally, an interesting task is to analyse the nexus between economic complexity, income, and the latter's growth. Hidalgo and Hausmann (2009; Hausmann and Hidalgo 2010, 2011) demonstrate that, as the number of iterations increases, their generalised measure of diversification becomes better able to predict income levels. Verspagen and Kaltenberg (2015, Figure 5), in the spirit of the theory of constrained convergence (Abramovitz, 1986; Cohen and Levinthal, 1990; Kim, 1980), show that, while at low levels of income very different growth performances can be observed, poor countries with higher 'capabilities', as signified by the complexity of their economies, grow faster, on average, than poor countries with lower capabilities. Figure 1 graphically represents the relationship between economic complexity and the level of per capita income in 1867 and 1900 (top left and top right, respectively); as well as that between

where $\langle k_{c,18} \rangle$ and $\mathrm{stdev}(k_{c,18})$ are, respectively, the mean and the standard deviation of the $k_{c,18}$ values of countries that participated in each exhibition.

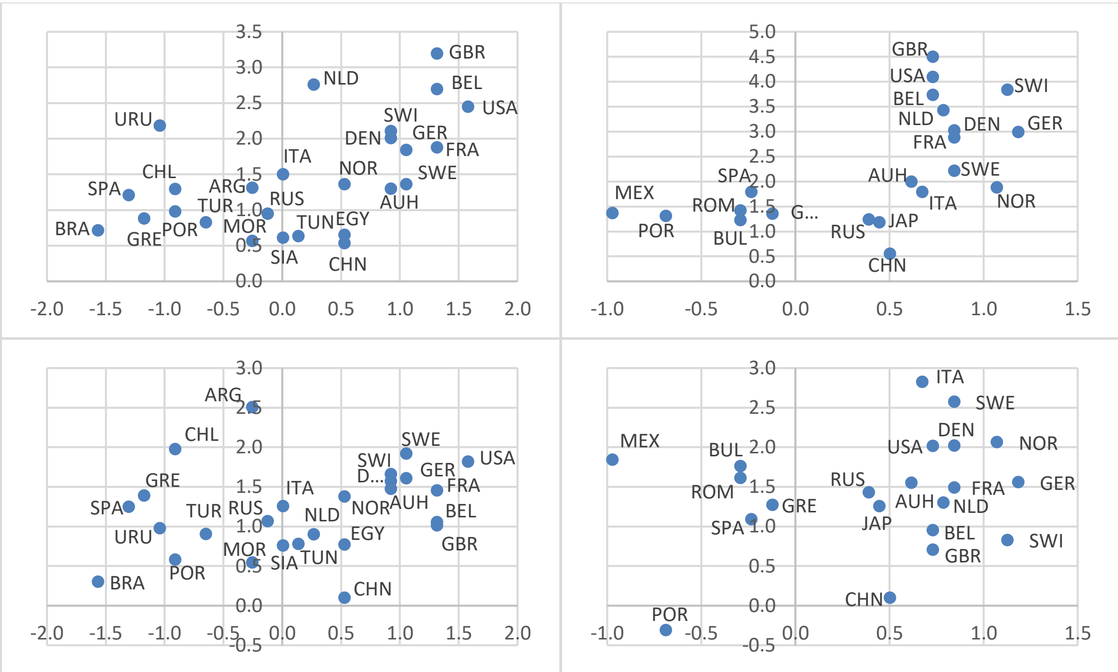
41 The only exceptions are, in 1878, Annam, later becoming a part of the French colony of Indo-China; and, in 1889, Sweden, whose participation was practically nil, because of the massive boycott of that expo by European monarchies.

42 Interestingly, within the latter group, Denmark turns out to gain positions, practically at the same rate as Norway does, although it has been observed above that its technological specialisation did not shift as much at that of the latter.

43 During the period preceding the outbreak of the First World War, named the *Giolittian era* after Giovanni Giolitti, the most important statesman of that time, Italy's rate of growth more than doubled, with respect to the earlier decades (Toniolo, 2013).

the former and the average annual rate of growth of the latter, over the period from the same years to 1913 (bottom).[44] The same relationships are then formally evaluated in Table 8, by means of Spearman's rank correlation coefficients (ρ).[45] In some cases, the coefficient is also computed, on a sub-sample excluding relevant outliers.

Figure 1. (Top-left) x = ECI 1867, y = GDP per capita 1870; (Top-right) x = ECI 1900, y = GDP per capita 1900; (Bottom-left) x = GDP per capita 1870, y = annual GDP per capita growth rate 1870-1913; (Bottom-right) x = ECI 1900, y = annual GDP per capita growth rate 1900-1913.



Note: levels of GDP per capita are expressed in thousands 1990 International Geary-Khamis dollars. Source: for ECI, see text; for GDP per capita, The Maddison-Project (cf. fn.44).

Table 8. Spearman's rank correlation coefficients.

Figure position	Excluded countries	ECI year	GDP per capita year(s)	N	ρ
Top-left		1867	1870	26	0.5306***
Top-left	NLD, URU	1867	1870	24	0.6583***
Top-right		1900	1900	21	0.6938***
Bottom-left		1867	% 1870-1913	26	0.3391*
Bottom-left	ARG	1867	% 1870-1913	25	0.4198**
Bottom-left	ARG, CHL	1867	% 1870-1913	24	0.5466***
Bottom-right		1900	% 1900-1913	21	0.2064
Bottom-right	MEX	1900	% 1900-1913	20	0.2166

[44] Data about GDP per capita are from *The Maddison-Project* (http://www.ggdc.net/maddison/maddison-project/home.htm, 2013 version). 1870, 1900, and 1913 are chosen because they are the benchmark years in which Maddison data are available for the largest number of countries. The plotted dots refer to those countries for which both exhibition data and Maddison's data about GDP are available, in the selected years. The data on which Figure 1 is based is displayed in Table A8 in the appendix.

[45] This non-parametric correlation coefficient has been preferred over the more common Pearson coefficient because, unlike the latter, it does not rely on restrictive assumptions such as linear relationship, absence of significant outliers and approximately normal distribution of variables; which makes it particularly suitable for the present analysis, where the number of observations per year is limited.

A highly significant positive relationship between economic complexity and the level of income emerges, both in 1867 and in 1900, confirming the stylised fact from Hidalgo and Hausmann's work. The coefficient is larger in the latter year than in the former; however, if the Netherlands and Uruguay are excluded, whose dots appear to lie outside the cloud formed by the other ones, then the 1867 coefficient rises to a level, comparable to that of 1900.

More difficult appears to sketch a relationship between complexity and the growth of income. It should be noticed that the (average annual) growth rates presented in the bottom-left and bottom-right graphs refer to time spans of different length, respectively 1870-1913 and 1900-1913. In a sense, therefore, the former is a 'long run' rate of growth, while the latter is 'medium run' one. In general, the positive relationship between complexity and economic growth is much less strict than that between the former and the level of GDP, both in terms of the size of the correlation coefficient and of its significance: in fact, it is significant at the loose 10% level for the 'long period' 1870-1913, while it is not significant for the shorter period 1900-1913. Things change if outliers are removed: dropping Argentina, the fastest-growing country over the 1870-1913 period, scoring an impressive growth rate of 2.5% per year despite (persistently) low complexity, the size and significance of the correlation coefficient increase; and a further improvement is obtained, if the (even less complex) second fastest-growing economy, namely Chile, is dropped as well. However, in the 'medium period' 1900-1913, dropping the outlier Mexico increases the coefficient only marginally, and does not endow it with statistical significance. Based on these findings, it could be argued that economic complexity is more related to growth in the long run than in the medium run; but the two periods might not be straightforwardly comparable, due to different economic conditions. In any case, even over the long period, the emergence of a well-defined relationship is subject to the removal of the top-growing non-complex countries: in other words, the relationship does not really hold 'at the top'.

Likewise, it does not hold 'at the bottom', i.e. for the slowest-growing countries. In the same way as low complexity does not hamper growth, as demonstrated by the Latin American growth champions, so good complexity does not prevent stagnation, as best exemplified by China, whose economy appears to be characterised by an above-average degree of complexity over the whole period considered. More generally, it can be noticed that the countries that were the poorest in 1870 also tended to grow the least over the period 1870-1913, irrespective of their economic complexity: in fact, the only country, having an initial GDP per capita lower than 1,000$,[46] which scored a larger than 1% long-run annual growth rate, i.e. Greece, is characterised by persistently below-average complexity. The poverty into which the poorest countries are trapped does not appear to be due to the product mix they produce and export; in the same way as, to the other extreme, Argentina scores record growth rates, though being specialised in primary products. Alternative and deeper reasons may have to do with demography and institutions, as suggested by the identity of the slowest-growing countries, which are all Asian or Arab, except for Portugal and its South-American offshoot, namely Brazil – the only monarchy of South America until 1889, allowing slavery until 1888.

[46] In 1990 International Geary-Khamis dollars.

6. Conclusions

The present paper explores the use of data about the products displayed at universal exhibitions, as a proxy for what countries produced and wanted to promote on international markets. In particular, it employs data from the five universal exhibitions held in Paris over the second half of the nineteenth century to compute the indices of specialisation and of 'economic complexity' of a large set of countries that participated in those expos – arguably the most important of that time. This unveils clear economic development trends: first and foremost, the structural shift of some Northern European countries, notably Germany, which, building their development on the emerging technological paradigms of the Second Industrial Revolution, attained positions of technological and economic primacy. To this is contrasted the immobility of the (European and American) 'Southerners', which were stuck into a specialisation pattern, dominated by primary products: in this group, the only exception is Italy, whose economic complexity increased over the observed period, in such a way that, by 1900, it stood just behind the group of Northern leaders. Moreover, in accordance with stylised facts from the existing literature on economic complexity, a significant positive relationship is found, between the latter and the level of (per capita) income. By the contrary, the relationship between complexity and income growth is weak at best; and it does not hold at the extremes of the growth distribution, i.e. for the fastest- and the slowest-growing countries. This might indicate that non-technological factors, e.g. demographic and institutional, prevailed over technological ones, as drivers of growth in the observed period.

The possibility of making comparative analyses, in a wide geographical and long diachronic perspective, is possibly the main advantage of the interpretation of exhibition data, maintained in this paper. Indeed, the expos' comprehensive and detailed classifications allow a large product coverage (including both primary products and manufactures), and a good degree of disaggregation; and the various geographical origin of participating countries provides a true 'world-wide' perspective. This differentiates the present study from previous analyses, especially those based on export data, which are typically focussing on a restricted set of products (usually, manufactured ones) and countries (typically, the main industrial economies). Data from exhibition data may provide unique insights, about products and countries, for which production and trade data might be scarce or even missing over the observed period.

On the other hand, the point should be made that exhibition data require some care, in their interpretation: the general commercial motivation of exhibiting, and the wide historical context of each expo, should always be kept in mind; but also national motivations and peculiarities (e.g. the desire to celebrate economic and political power; and the various governments' degree of 'fondness' for the means of exhibitions) should be taken into account.

With this caveat in mind, the study of data from universal exhibition appears as a promising field for the economic history of the second half of the nineteenth century, as well as of the early twentieth century. The potential applications, stemming from the view of exhibition data maintained in this paper, are not limited to those presented here. Further research may carry out studies focused on single countries, rather than comparative analyses; which would allow, in some cases, a much deeper level of detail. Moreover, data about the products displayed by colonies, which have not been exploited in this work, might reveal interesting insights on the economic consequences of colonialism.

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Appendix

Table A1. Number of exhibits at the Parisian expos per participating foreign country.

	1855	1867	1878	1889	1900
Europe					
Andorra			10		8
Austria-Hungary	1,265	2,851	3,240	268	3,208
Belgium	698	1,445	1,268	1,264	1,033
Bulgaria				1	538
Denmark	90	244	327	119	168
Germany	2,079	2,982		24	2,140
Great Britain	1,461	2,025	1,598	931	2,279
Greece	121	892	599	940	599
Italy	440	3,837	1,975	333	2,289
Luxembourg	22	7	34	38	44
Monaco				31	44
Netherlands	258	403	443	184	179
Norway	121	360	383	251	300
Portugal	396	857	1,986	1,292	3,072
Romania				546	1,252
Russia		1,287	1,003	564	1,829
San Marino			10	41	45
Serbia				1,403	302
Spain	498	1,869	4,307	1,181	1,350
Sweden	417	567	479	8	271
Switzerland	436	860	749	746	580
Turkey	9	4,488		2	67
Americas					
Argentina	6	63	537	1,433	
Bolivia			21	184	
Brazil	4	1,068		753	
Chile		28		343	
Colombia	13			0	
Costa Rica	4	9		0	
Cuba					149
Dominican Republic	1			166	
Ecuador				102	617
Guatemala	7		54	555	96
Haiti			15	12	
Hawaii	5	30		18	
Honduras				0	
Mexico	104		14		2,997
Nicaragua			14	569	121
Paraguay		10		86	
Peru		6	92	0	364
Salvador			48	463	111
United States	98	725	834	812	5,124
Uruguay	2	22	234	134	
Venezuela			123	101	
Asia					
Annam			15	(**)	(**)
China		61	424	18	129
Japan			407	610	1,529
Korea					55
Liou-Kiou		22			
Persia			17		18
Siam		13	30		

	1855	1867	1878	1889	1900
Africa					
Cape Colony				7	
Egypt	6	60	66	39	
Liberia					14
Morocco		17	29		
South Africa				44	23
Tunisia	21	42	152	(**)	(**)

Notes: (*) The separate special catalogues of Colombia, Costa Rica, Honduras, and Peru could not be retrieved; hence the respective observations could not be added. (**) Annam and Tunisia joined in 1889 and 1900 as French colonies.

Table A2. Economic Specialisation Indices, 1855.

	Austria	Belgium	Denmark	France	Germany	Great Britain	Greece	Italy	Mexico	Netherlands	Norway	Portugal	Spain	Sweden	Switzerland	United States
Agriculture	**1.1**	0.9	0.6	0.9	0.6	0.3	**2.7**	**1.1**	**2.7**	**1.1**	0.8	**4.1**	**2.4**	0.8	0.3	0.1
Chemicals	0.8	0.9	**1.1**	**1.0**	**1.4**	1.0	**1.5**	0.8	**1.0**	**1.4**	0.4	0.5	0.8	0.7	0.8	0.2
Clothing and accessories	0.9	**1.0**	**1.8**	0.9	1.0	**1.1**	**2.3**	0.7	0.8	0.9	**1.5**	0.7	0.5	**1.9**	**1.1**	0.3
Construction	0.5	**1.8**	0.0	**1.4**	0.7	**1.3**	0.0	**1.3**	0.5	**1.5**	**2.3**	0.3	0.3	**1.2**	0.4	0.6
Cotton	0.9	**1.6**	0.7	**1.5**	0.5	0.8	0.5	0.4	0.6	0.6	**1.8**	0.5	**1.5**	0.4	**2.8**	0.3
Flax and hemp	1.0	**2.7**	0.3	0.9	**1.0**	**1.3**	0.2	0.4	0.3	**1.0**	0.7	0.8	0.6	0.4	0.2	0.3
Furniture	0.6	0.8	**2.3**	1.0	0.9	**1.1**	0.2	**3.3**	0.3	**2.7**	**2.2**	0.2	0.3	**1.4**	0.7	**1.2**
General machinery	0.5	**1.4**	**1.5**	**1.6**	0.7	**1.5**	0.0	0.5	0.7	**1.9**	0.6	0.0	0.1	0.8	0.5	**4.2**
Glass and ceramics	**1.2**	**1.3**	**1.6**	**1.3**	0.7	**1.2**	0.0	**1.8**	**1.1**	0.7	0.0	0.7	0.9	0.5	0.3	0.0
Instruments	0.8	0.4	**2.2**	**1.1**	**1.1**	**1.0**	0.3	0.7	0.2	0.7	**1.4**	0.2	0.4	**1.0**	**3.1**	**2.5**
Jewellery	0.7	0.4	0.6	**1.4**	**1.1**	**1.1**	0.0	0.8	0.0	**3.7**	0.4	0.5	0.7	0.7	0.6	0.5
Lighting and heating	0.8	**1.2**	**3.2**	**1.3**	0.5	**1.6**	0.0	**1.1**	0.0	**1.1**	0.8	0.1	0.8	**1.6**	0.7	**2.0**
Mining and metallurgy	**1.4**	0.8	0.4	0.6	**1.4**	1.0	0.5	0.9	0.9	0.3	0.9	0.7	**1.5**	**1.4**	0.3	0.5
Other industrial machinery and equipment	0.5	**1.6**	**2.4**	**1.5**	0.7	**1.3**	0.0	0.6	**1.7**	0.7	0.4	0.3	0.0	0.6	0.5	**8.5**
Paper and printing	0.8	**1.1**	0.8	**1.2**	**1.2**	**1.2**	0.4	0.8	0.5	**2.0**	**1.2**	0.3	0.2	0.5	0.7	**2.3**
Silk	**1.4**	0.2	0.0	**1.0**	0.6	0.4	**1.4**	**3.7**	0.8	0.1	0.0	0.4	**1.2**	0.3	**4.6**	0.2
Textile machinery and equipment	0.6	**1.5**	0.0	**1.5**	0.9	**1.7**	0.0	0.5	0.7	0.0	0.0	0.4	0.3	0.5	0.2	**5.3**
Transport	0.9	**1.6**	0.0	0.8	0.5	**2.6**	0.0	0.6	**2.0**	**2.0**	**1.3**	0.4	0.0	0.9	0.2	**1.6**
Weapons	0.5	**2.4**	0.5	0.9	0.2	**1.8**	0.0	0.4	0.9	**2.4**	**2.8**	0.5	0.4	**2.0**	0.8	**3.0**
Wool	**1.4**	0.7	0.2	**1.1**	**1.7**	**1.1**	0.1	0.1	0.5	0.1	0.9	0.3	0.8	0.4	0.1	0.0

Notes: (i) countries exhibiting a lower number of exhibits than a selected threshold (60) are not displayed, since the computed indices may not to be fully representative of that country's economy, and take extreme values; (ii) values larger than one are emphasized by bold text, values larger than two are also underlined.

Table A3. Economic Specialisation Indices, 1867.

	Argentina	Austria	Belgium	Brazil	China	Denmark	Egypt	France	Germany	Great Britain	Greece	Italy	Netherlands	Norway	Portugal	Russia	Spain	Sweden	Switzerland	Turkey	United States
Agro-food	**1.3**	0.9	0.5	**2.6**	0.4	0.6	0.8	0.3	0.6	0.3	**2.1**	**1.2**	**1.0**	**1.8**	**1.7**	**1.4**	**1.9**	0.8	0.5	**1.2**	0.5
Agro-food machinery and equipment	0.5	**1.5**	**1.4**	0.1	1.0	0.8	1.0	**1.8**	0.6	**1.6**	0.0	1.0	0.3	0.6	0.3	0.8	0.3	**2.6**	0.8	0.4	**2.6**
Beverages	**1.1**	**1.3**	0.3	**1.1**	0.0	0.5	0.2	0.9	**1.3**	0.1	**1.3**	**1.8**	0.8	0.2	**2.0**	0.5	**2.3**	0.5	**1.7**	0.2	0.5
Ceramics	**2.1**	0.7	0.5	0.0	**15.0**	**1.6**	**2.2**	**1.2**	**1.3**	**1.1**	0.0	0.8	**1.3**	0.0	**3.2**	0.4	0.8	0.7	0.2	**1.2**	0.4
Chemicals	**1.2**	**1.1**	**1.4**	**1.9**	0.6	**1.0**	0.9	0.9	**1.3**	**1.2**	0.5	**1.1**	**2.1**	**1.4**	0.5	**1.1**	0.6	0.5	**1.3**	0.5	0.8
Clothing and accessories	0.8	0.9	1.0	0.4	**2.4**	**1.3**	**1.1**	0.8	0.8	0.9	0.8	0.5	0.7	1.0	0.7	0.6	0.3	0.8	0.7	**2.7**	0.5
Construction	0.0	0.8	**2.1**	0.2	0.0	0.7	0.6	**1.7**	**1.5**	**1.5**	0.4	0.9	1.0	0.3	0.9	0.2	0.8	**1.6**	**1.1**	0.3	**1.3**
Cotton	0.7	0.6	**2.2**	0.3	0.7	0.2	0.8	**1.1**	0.9	0.7	0.4	0.6	**2.7**	0.1	0.4	0.7	0.3	0.6	**2.6**	**2.0**	0.2
Flax and hemp	**1.1**	0.8	**4.3**	0.5	0.0	0.0	**1.2**	1.0	**1.9**	0.7	0.5	0.9	0.0	0.0	**1.4**	**1.0**	0.4	1.0	0.5	0.6	0.0
Furniture	0.0	**1.1**	**1.1**	0.0	**6.3**	**2.5**	**1.3**	**1.4**	**1.0**	**1.5**	1.0	**1.9**	**1.5**	**1.4**	0.2	0.7	0.3	**1.4**	0.7	0.1	0.7
General machinery and machine-tools	0.0	0.9	**1.7**	0.1	0.0	0.9	0.8	**2.2**	0.9	**2.3**	0.2	0.6	0.7	0.3	0.1	0.5	0.3	**1.3**	**1.0**	0.2	**3.5**
Glass	0.0	**1.9**	**3.6**	0.0	0.0	0.0	**2.2**	**1.2**	**1.5**	**2.1**	0.0	0.7	**1.3**	0.0	0.6	0.4	0.1	0.5	0.5	0.0	**1.3**
Instruments	0.6	**1.0**	0.4	0.1	0.3	**1.3**	**1.3**	**1.4**	**1.4**	**1.2**	0.1	**1.1**	0.9	**1.1**	0.2	0.7	0.3	**1.2**	**4.8**	0.4	**1.6**
Jewellery	**1.5**	1.0	0.6	0.2	**3.1**	**3.3**	**2.4**	**1.3**	**1.3**	**1.6**	0.5	**1.0**	**1.7**	0.7	0.5	0.7	0.3	0.6	0.6	**1.1**	0.2
Leather	0.8	0.7	**1.5**	0.0	0.0	**2.2**	0.8	0.6	**1.5**	0.5	0.5	0.8	0.2	**1.1**	**2.3**	**2.5**	0.3	0.3	**1.1**	**1.6**	0.6
Lighting and heating	0.0	**1.2**	**1.3**	0.0	**1.5**	**1.5**	**3.0**	**1.6**	**1.1**	**3.0**	0.0	0.5	0.7	**1.0**	0.2	0.7	0.3	0.6	**1.2**	0.4	**2.6**
Mining and metallurgy	**1.7**	**1.1**	**1.1**	0.5	0.3	0.4	0.5	0.7	**1.1**	**1.1**	**1.4**	**1.1**	0.2	0.8	0.7	**1.4**	**1.5**	**2.7**	0.3	0.8	**1.5**
Other industrial machinery and equipment	1.0	**1.1**	**1.7**	0.1	0.0	0.5	**2.1**	**2.5**	**1.4**	**1.1**	0.1	0.2	0.5	0.2	0.2	0.2	0.6	**2.9**	**1.9**	0.0	**2.2**
Paper and printing	0.9	**1.2**	**1.1**	0.4	**1.8**	**2.8**	0.9	**1.6**	**1.3**	**2.1**	0.4	0.9	**1.5**	1.0	0.4	0.6	0.5	**1.1**	0.9	0.2	1.0
Silk	**1.3**	**1.1**	0.1	0.0	**2.6**	0.0	0.7	**1.2**	0.2	0.7	1.0	**1.5**	0.6	0.0	**1.7**	**1.8**	0.3	0.1	0.8	**1.9**	0.2
Textile machinery and equipment	**1.0**	0.7	**1.6**	**1.9**	0.0	**2.1**	**2.1**	**1.6**	**1.1**	**1.7**	0.3	0.7	0.5	0.0	0.4	0.3	0.2	0.3	0.8	0.5	**4.4**
Transport	**1.0**	0.7	**1.1**	0.3	0.0	0.7	**1.6**	**1.8**	0.6	**2.7**	0.5	0.4	**1.2**	**2.1**	0.5	0.9	0.1	0.7	0.2	**1.0**	**1.9**
Weapons	**1.4**	0.5	**1.6**	0.1	**1.5**	0.4	**1.5**	0.9	0.4	0.9	0.2	0.8	**1.8**	0.7	0.0	**1.5**	0.5	**1.1**	0.6	**2.0**	**3.0**
Wool	**1.4**	**1.1**	**1.0**	0.1	0.0	0.8	**1.4**	**1.1**	**1.9**	**1.7**	0.3	0.3	**1.8**	0.0	0.9	**1.3**	0.9	0.4	0.3	**1.2**	0.2
Primary products	**1.2**	**1.0**	0.5	**2.3**	0.3	0.6	0.6	0.5	0.8	0.2	**2.0**	**1.3**	1.0	0.8	**1.8**	**1.2**	**2.0**	0.7	0.8	1.0	0.5
Low-tech manufactures	1.0	**1.0**	**1.3**	0.3	**1.7**	**1.3**	**1.1**	**1.2**	**1.1**	**1.2**	0.6	0.9	0.9	**1.1**	0.8	0.9	0.6	**1.2**	0.8	**1.2**	0.9
High-tech manufactures	0.7	0.9	**1.2**	0.6	0.4	1.0	**1.2**	**1.5**	**1.1**	**1.8**	0.3	0.8	**1.3**	**1.1**	0.3	0.8	0.4	**1.0**	**2.0**	0.5	**1.9**

Notes: (i) countries exhibiting a lower number of exhibits than a selected threshold (60) are not displayed, since the computed indices may not to be fully representative of that country's economy, and take extreme values; (ii) values larger than one are emphasized by bold text, values larger than two are also underlined.

Table A4. Economic Specialisation Indices, 1878.

	Argentina	Austria	Belgium	China	Denmark	Egypt	France	Great Britain	Greece	Italy	Japan	Netherlands	Norway	Peru	Portugal	Russia	Spain	Sweden	Switzerland	Tunisia	United States	Uruguay	Venezuela
Agro-food	**1.5**	0.6	0.2	0.9	0.5	0.6	0.6	0.2	**2.0**	**1.0**	0.5	0.7	**1.0**	1.0	**1.7**	**1.1**	**1.9**	0.4	0.2	0.6	**1.0**	**1.9**	**1.1**
Agro-food machinery and equipment	0.1	1.0	**1.6**	**1.1**	**2.0**	0.5	**2.0**	**3.0**	0.0	0.4	0.1	0.7	**1.8**	0.0	0.1	0.9	0.1	**1.5**	0.9	0.2	0.9	0.8	0.0
Beverages	0.9	0.8	0.4	0.2	0.5	0.1	0.4	0.2	0.9	**1.1**	0.2	0.7	0.5	0.7	**2.3**	0.5	**2.5**	0.2	0.6	0.0	0.3	0.3	0.7
Ceramics	0.6	0.6	0.8	**3.7**	0.9	0.0	**1.3**	**1.0**	0.5	0.8	**10.8**	0.4	0.3	0.0	**1.1**	0.2	0.7	0.4	0.5	0.4	0.2	0.2	0.5
Chemicals	0.8	**1.1**	1.0	0.9	**1.3**	0.6	**1.1**	**1.3**	0.3	**1.4**	0.5	**1.4**	**1.5**	0.6	0.6	**1.2**	0.6	0.9	**1.1**	**1.6**	**1.2**	0.7	**3.0**
Clothing and accessories	0.8	**1.5**	0.8	**2.1**	**2.2**	0.9	**1.3**	**1.1**	**1.3**	0.7	**2.6**	0.7	1.0	**1.9**	0.7	**1.1**	0.3	0.7	**1.2**	**3.3**	0.6	0.7	0.8
Construction	0.3	**1.4**	**1.8**	0.0	0.5	0.5	**1.9**	**1.6**	0.1	1.0	0.4	**2.3**	0.4	0.0	0.5	0.5	0.2	**1.0**	**1.6**	0.0	0.3	0.0	0.0
Cotton	0.4	0.7	0.7	**1.5**	**1.6**	0.0	**1.2**	**1.4**	**3.4**	0.5	0.5	**2.1**	0.6	0.8	0.8	**1.5**	0.1	**3.4**	**2.5**	0.0	**2.5**	0.0	0.0
Flax and hemp	0.4	0.8	**3.2**	**2.6**	**2.0**	0.0	1.0	**1.4**	0.2	0.8	0.8	**1.2**	0.3	0.0	**1.4**	0.9	0.2	**4.8**	0.1	**5.7**	0.0	0.5	0.9
Furniture	0.7	**1.3**	**1.3**	**2.3**	**2.4**	0.5	**1.0**	**1.5**	0.5	**2.5**	**2.6**	**1.9**	0.7	0.0	0.3	**1.2**	0.1	0.8	0.3	0.2	0.6	0.0	0.0
General machinery and machine-tools	0.4	0.9	**1.8**	0.5	**1.3**	**2.0**	**1.9**	**2.4**	0.1	0.6	0.0	**1.5**	0.8	**1.4**	0.2	0.6	0.0	**1.6**	**1.2**	0.0	**3.1**	0.0	0.0
Glass	0.0	**1.3**	**3.9**	**1.1**	0.0	0.0	**1.6**	**2.0**	0.3	**1.6**	0.0	**1.4**	**1.2**	0.0	0.2	0.3	0.0	0.3	0.0	0.0	0.5	**1.3**	0.0
Instruments	0.3	**1.5**	**1.2**	0.6	**1.4**	**1.5**	**1.5**	0.9	0.2	0.9	0.3	**1.4**	0.9	0.0	0.1	**1.2**	0.1	**1.1**	**5.2**	0.8	**1.1**	0.7	0.3
Jewellery	0.5	**1.9**	0.4	**3.8**	**1.5**	**1.2**	**1.2**	0.7	0.5	**1.3**	**4.4**	0.6	0.5	**1.7**	0.1	0.7	0.1	**1.2**	**1.4**	**4.2**	0.9	0.3	0.0
Leather	**3.4**	0.7	**2.5**	0.8	**1.1**	0.9	0.8	0.6	0.9	**1.2**	0.6	0.1	**2.9**	**1.3**	0.5	**2.2**	0.2	0.4	**1.4**	0.8	**2.2**	**3.0**	**1.9**
Lighting and heating	0.0	**1.3**	**1.2**	0.0	1.0	0.0	**1.7**	**1.4**	0.1	0.7	0.8	**1.1**	**1.2**	0.9	0.1	**1.5**	0.1	**5.0**	0.7	0.0	**2.3**	0.0	0.0
Mining and metallurgy	0.9	**1.1**	**2.1**	0.8	0.0	0.0	0.4	**1.4**	0.7	**1.1**	0.5	0.4	**1.5**	0.9	0.5	**1.2**	**1.0**	**2.5**	0.5	0.1	**1.6**	**2.0**	**1.0**
Other industrial machinery and equipment	0.3	1.0	**3.3**	0.7	**1.1**	0.0	**2.1**	**1.9**	0.0	0.5	0.1	0.5	**2.2**	0.0	0.0	0.3	0.1	**2.1**	0.9	0.0	**1.1**	0.0	0.0
Paper and printing	**2.0**	**1.3**	**1.1**	0.5	**1.7**	**6.1**	**1.1**	**1.3**	0.3	0.9	0.7	**1.1**	0.6	**3.7**	0.4	**1.1**	0.5	**1.1**	**1.6**	0.2	**1.3**	0.4	**4.6**
Silk	0.4	0.7	0.1	**2.3**	0.0	**2.3**	0.2	**1.8**	**2.9**	**2.9**	**6.0**	0.0	0.0	0.0	0.7	**1.2**	0.2	0.3	**3.0**	**4.4**	0.4	**3.5**	0.0
Textile machinery and equipment	0.6	0.7	**1.1**	0.2	**1.2**	0.0	**2.3**	**2.4**	0.1	0.6	0.2	0.5	**1.4**	0.0	0.4	0.2	0.2	0.3	**2.0**	0.5	**1.8**	0.3	0.6
Transport	1.0	**1.1**	**2.0**	0.8	0.3	**1.0**	**1.6**	**2.7**	0.2	0.7	0.0	**1.8**	**1.9**	0.7	0.1	**1.2**	0.1	**1.0**	0.6	**1.6**	**1.3**	0.4	0.0
Weapons	**1.1**	**1.2**	**1.9**	0.7	0.6	**3.1**	**1.1**	**1.6**	0.0	0.9	0.5	**1.9**	**1.1**	0.0	0.1	0.5	0.7	**1.5**	0.8	**4.7**	**1.4**	**1.3**	0.0
Wool	0.6	**1.2**	**2.0**	0.5	**1.3**	**1.2**	0.9	**2.0**	**1.1**	0.1	0.4	**3.2**	0.7	**1.7**	**1.3**	**1.9**	0.3	**2.7**	0.3	**2.9**	0.0	0.5	0.0
Primary products	**1.3**	0.7	0.3	0.7	0.5	0.5	0.5	0.2	**1.7**	**1.0**	0.4	0.7	0.9	0.9	**1.9**	0.9	**2.1**	0.4	0.3	0.4	0.8	**1.5**	1.0
Low-tech manufactures	0.9	**1.2**	**1.4**	**1.4**	**1.4**	**1.3**	**1.2**	**1.4**	0.8	**1.0**	**1.8**	**1.1**	1.0	**1.3**	0.5	**1.1**	0.4	**1.3**	**1.2**	**1.6**	0.9	0.8	**1.1**
High-tech manufactures	0.6	**1.1**	**1.6**	0.6	**1.1**	**1.4**	**1.5**	**1.7**	0.2	0.9	0.3	**1.4**	**1.4**	0.4	0.3	1.0	0.3	**1.5**	**2.0**	0.7	**1.5**	0.5	0.8

Notes: (i) countries exhibiting a lower number of exhibits than a selected threshold (60) are not displayed, since the computed indices may not to be fully representative of that country's economy, and take extreme values; (ii) values larger than one are emphasized by bold text, values larger than two are also underlined.

Table A5. Economic Specialisation Indices, 1889.

	Argentina	Austria	Belgium	Bolivia	Brazil	Chile	Denmark	Dominican Rep.	Ecuador	France	Great Britain	Greece	Guatemala	Italy	Japan	Netherlands	Nicaragua	Norway	Paraguay	Portugal	Romania	Russia	Salvador	Serbia	Spain	Switzerland	Uruguay	United States	Venezuela
Agro-food	**2.4**	0.5	0.3	**1.1**	**1.9**	**1.2**	**1.1**	**1.7**	**1.5**	0.4	0.3	**1.3**	**1.6**	0.6	**1.1**	**1.3**	**1.9**	0.8	**1.0**	**1.4**	0.5	0.8	**1.7**	**1.6**	0.4	0.3	**1.4**	0.6	1.3
Agro-food machinery and equipment	0.0	0.5	**1.5**	0.2	0.1	0.1	0.4	0.0	0.0	**3.2**	1.0	0.0	0.2	0.5	0.3	0.9	0.0	**1.7**	0.0	0.1	0.2	0.2	0.2	0.2	0.2	**1.8**	1.0	**2.2**	0.0
Beverages	0.7	0.9	0.7	0.0	0.7	**2.2**	0.5	0.7	0.6	0.3	0.2	0.8	0.1	**1.2**	0.5	**1.0**	0.2	0.4	0.5	**3.6**	**1.0**	**1.3**	0.1	0.3	**4.7**	1.0	0.5	0.1	0.7
Ceramics	0.2	**2.6**	0.7	**1.0**	0.5	0.0	**3.7**	0.0	0.0	**1.7**	**1.1**	0.0	**1.5**	**4.7**	**4.6**	0.3	0.3	0.0	**3.7**	0.7	0.6	0.3	0.8	0.4	0.3	0.9	0.9	0.2	0.0
Chemicals	0.3	0.5	**1.0**	0.9	**1.6**	**1.7**	0.8	**2.3**	0.9	**1.2**	**1.3**	**1.2**	**1.2**	**1.2**	0.6	**1.2**	**2.0**	**2.3**	**2.8**	0.5	**1.0**	**1.4**	**1.3**	0.1	0.5	0.9	**1.4**	**1.2**	1.6
Clothing and accessories	0.4	**2.3**	0.7	0.6	0.5	0.9	0.8	0.9	**1.9**	0.8	**1.0**	**1.7**	**1.2**	0.5	**1.2**	0.5	1.0	**1.1**	**2.9**	0.5	**2.7**	0.7	0.8	**2.6**	0.6	0.9	0.7	0.5	0.7
Construction	0.4	0.2	**2.6**	0.5	0.7	**1.1**	0.7	0.0	0.0	**2.7**	**1.8**	0.2	0.1	0.4	0.2	0.9	0.0	**1.2**	0.0	0.0	0.2	**1.4**	0.4	0.0	0.2	0.7	0.6	0.9	0.9
Cotton	0.2	0.6	**1.0**	**1.7**	**1.0**	0.2	0.0	0.0	**2.3**	**1.1**	1.0	**4.3**	**1.8**	0.0	**1.1**	0.0	0.1	0.0	0.9	0.7	**1.8**	**2.5**	0.5	0.9	0.6	0.2	0.0	0.7	0.8
Electricity	0.0	0.8	**1.3**	0.0	0.0	0.6	0.9	0.0	0.0	**2.6**	**2.1**	0.0	0.0	0.7	0.2	0.0	0.0	0.4	0.0	0.1	0.0	1.0	0.0	0.0	0.3	**1.5**	0.0	**4.5**	0.0
Flax and hemp	0.5	**1.1**	**3.2**	0.0	0.2	0.4	0.0	0.0	**5.9**	0.9	0.8	**1.1**	**2.2**	0.9	0.2	0.8	0.0	0.0	**1.7**	0.5	**3.8**	**1.3**	0.3	**1.2**	0.8	0.0	0.0	0.7	1.5
Furniture	0.5	**1.2**	**1.4**	0.0	0.7	0.0	**1.6**	0.3	0.0	**1.3**	**1.2**	0.2	0.6	**3.3**	**4.4**	0.3	0.2	0.4	0.0	0.2	0.9	**1.0**	0.5	0.8	0.8	**1.8**	0.0	**1.1**	0.5
General machinery and machine-tools	0.2	0.3	**1.9**	0.0	0.1	0.1	**1.2**	0.0	0.0	**2.1**	**4.0**	0.0	0.0	0.7	0.2	**1.0**	0.0	0.6	0.0	0.3	0.2	0.5	0.0	0.2	0.2	**1.6**	0.0	**3.1**	0.0
Glass	0.3	**12.2**	**3.6**	0.0	0.6	0.5	0.0	0.0	0.0	**1.2**	**1.2**	0.0	0.3	**5.2**	0.0	**3.4**	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.1	0.5	0.6	0.0	**1.9**	0.0
Instruments	0.1	**1.4**	**1.4**	**1.2**	0.4	**1.5**	0.7	0.5	0.0	**1.6**	**1.4**	0.4	0.5	**1.0**	0.2	1.0	0.2	**1.3**	0.5	0.2	0.3	**1.1**	0.3	0.1	0.7	**5.5**	**1.0**	1.0	0.4
Jewellery	0.1	**4.4**	0.8	**3.2**	0.3	0.0	**1.3**	0.6	0.5	**1.6**	**1.1**	0.5	0.0	**8.1**	**3.1**	0.6	0.9	**1.3**	0.6	0.0	0.6	0.8	0.8	0.3	0.5	0.9	0.0	0.8	1.1
Leather	**3.2**	0.0	**1.5**	0.4	0.2	**1.4**	0.6	**1.6**	0.7	0.9	0.1	**1.5**	0.5	0.8	0.2	0.0	0.0	**2.5**	**1.6**	0.2	0.4	**2.4**	0.7	0.1	0.9	**1.4**	**6.6**	0.5	2.0
Lighting and heating	0.0	0.0	**2.7**	0.0	0.2	0.0	**1.1**	0.0	0.0	**2.4**	**2.6**	0.3	0.2	0.0	0.9	**2.9**	0.0	0.5	0.0	0.1	1.0	0.5	0.0	0.0	0.2	**1.2**	0.0	**2.0**	0.0
Mining and metallurgy	0.2	0.2	**1.7**	**5.6**	**1.0**	0.4	0.0	**1.7**	**1.1**	0.8	**1.3**	0.5	**1.2**	0.8	0.3	0.7	**2.7**	**1.9**	0.3	0.4	0.7	**2.0**	**2.2**	0.5	0.4	0.5	**1.0**	**2.3**	3.9
Other industrial machinery and equipment	0.0	**1.2**	**2.2**	0.6	0.2	0.2	0.4	0.3	0.0	**2.4**	**2.9**	0.1	0.1	0.3	0.0	0.0	0.0	**2.7**	0.0	0.0	0.0	0.9	0.0	0.0	0.3	1.0	**1.2**	**2.8**	0.5
Paper and printing	0.2	**1.1**	**1.5**	**1.2**	0.9	0.5	**3.3**	0.5	0.4	**1.3**	**1.4**	**1.1**	0.7	0.9	**1.2**	**2.6**	0.5	**1.3**	0.2	0.2	0.5	**1.2**	**2.0**	0.0	**1.1**	**1.2**	**1.5**	**1.9**	0.7
Silk	0.1	0.0	0.3	0.0	0.4	0.0	0.0	0.0	0.0	0.9	**1.3**	**3.7**	**1.6**	0.0	**5.5**	0.0	0.7	0.0	0.0	0.2	**5.1**	**1.1**	0.4	0.6	0.3	**1.3**	**1.8**	0.2	0.0
Textile machinery and equipment	0.1	0.6	**1.7**	0.0	0.3	0.0	0.0	0.5	0.0	**2.2**	**1.8**	0.1	0.9	0.7	0.0	0.0	0.3	**1.3**	1.0	0.2	0.7	0.0	0.0	0.7	0.7	**1.4**	0.6	**2.5**	0.8
Transport	0.4	0.5	**2.0**	0.5	0.6	0.5	**3.5**	0.5	0.0	**1.8**	**3.4**	0.0	0.6	**1.0**	0.1	**1.4**	0.2	**2.2**	0.0	0.2	0.7	0.5	0.6	0.1	0.2	**1.1**	0.0	**2.1**	0.4
Weapons	0.3	0.0	**3.3**	0.0	0.1	0.6	0.0	**1.9**	**2.1**	**2.1**	**2.3**	**1.0**	0.6	0.0	0.0	0.0	0.6	0.0	**1.2**	0.2	0.2	**1.1**	0.2	0.4	0.3	0.4	0.0	**1.0**	1.0
Wool	**1.1**	0.7	**1.1**	**2.9**	0.2	0.6	0.0	0.0	**2.4**	0.8	**1.1**	0.9	**1.9**	0.0	0.1	0.0	0.0	0.0	0.0	0.6	**3.9**	**1.3**	0.0	**2.7**	**2.0**	0.1	0.0	0.4	0.0
Primary products	**1.9**	0.6	0.4	0.8	**1.6**	**1.5**	0.9	**1.4**	**1.3**	0.4	0.3	**1.1**	**1.2**	0.8	1.0	**1.2**	**1.4**	0.7	0.9	**2.0**	0.7	0.9	**1.3**	**1.3**	**1.6**	0.5	**1.2**	0.5	1.2
Low-tech manufactures	0.4	**1.5**	**1.3**	**1.4**	0.6	0.6	1.0	0.7	**1.0**	**1.3**	**1.1**	**1.1**	**1.0**	**1.3**	**1.4**	0.9	0.7	**1.1**	**1.2**	0.3	**1.5**	**1.1**	0.9	**1.1**	0.7	1.0	1.0	**1.1**	1.0
High-tech manufactures	0.2	0.7	**1.7**	0.5	0.5	0.9	**1.3**	0.8	0.3	**1.8**	**2.4**	0.4	0.5	0.7	0.2	0.8	0.6	**1.5**	0.7	0.3	0.5	0.9	0.6	0.1	0.4	**2.3**	0.6	**1.9**	0.6

Notes: (i) countries exhibiting a lower number of exhibits than a selected threshold (60) are not displayed, since the computed indices may not to be fully representative of that country's economy, and take extreme values; (ii) values larger than one are emphasized by bold text, values larger than two are also underlined.

Table A6. Economic Specialisation Indices, 1900.

	Austria	Belgium	Bulgaria	China	Cuba	Denmark	Ecuador	France	Germany	Great Britain	Greece	Guatemala	Italy	Japan	Mexico	Netherlands	Nicaragua	Norway	Peru	Portugal	Romania	Russia	Salvador	Serbia	Spain	Sweden	Switzerland	Turkey	United States
Agro-food	0.8	0.3	**1.8**	0.8	**1.6**	0.3	**1.2**	0.4	0.4	0.9	**1.2**	**4.1**	0.8	0.4	**1.5**	0.5	**3.9**	0.7	**1.7**	**1.8**	**2.0**	**1.3**	**3.2**	**1.6**	**1.2**	0.3	0.2	0.5	**1.1**
Agro-food machinery and equipment	**3.5**	1.0	0.1	0.9	0.2	**5.3**	0.2	**1.8**	0.7	**1.1**	0.2	0.0	0.5	0.1	0.3	0.6	0.0	0.4	0.2	0.3	0.3	**1.2**	0.0	0.9	0.5	**1.2**	**1.2**	0.3	0.5
Beverages	0.9	**4.4**	**1.5**	0.0	**1.3**	0.7	0.3	0.6	0.7	0.2	**2.3**	0.1	**1.4**	0.7	0.6	0.7	0.0	0.1	0.9	**2.4**	**1.2**	0.6	0.0	**1.5**	**2.8**	0.4	**1.4**	**1.6**	0.2
Ceramics	0.8	0.3	0.5	**2.2**	0.3	**3.4**	0.5	0.9	0.9	0.6	0.6	0.0	**1.2**	**4.4**	0.7	**2.9**	0.0	0.3	0.8	1.0	0.5	0.4	0.0	0.5	0.6	0.4	0.2	0.7	**1.3**
Chemicals	0.6	0.6	**1.7**	0.6	**2.7**	**1.3**	0.6	**1.2**	**1.5**	**1.1**	**2.3**	0.6	**1.3**	**1.4**	**1.1**	**1.5**	0.4	0.5	**1.4**	**1.2**	**1.1**	1.0	**3.4**	0.3	**1.3**	0.5	0.2	**2.0**	0.2
Clothing and accessories	**1.2**	0.4	**1.3**	**1.7**	0.6	**1.1**	**3.9**	0.9	0.6	**1.0**	**1.7**	0.0	0.8	**2.7**	**1.5**	**1.4**	0.4	1.0	**1.1**	0.8	**1.1**	0.9	0.2	**2.4**	0.9	0.5	0.8	**3.0**	0.2
Construction	**1.5**	0.8	0.4	0.0	0.0	0.9	0.2	**2.7**	0.8	0.8	0.0	0.0	0.4	0.0	0.5	**2.6**	0.0	**1.2**	**1.2**	0.4	0.7	**1.2**	0.0	0.1	0.4	0.0	**1.1**	0.0	0.9
Cotton	0.5	**1.6**	0.9	**1.3**	0.0	0.0	**1.8**	0.8	0.0	0.7	**3.3**	0.0	**1.5**	**2.1**	**2.1**	0.9	0.0	0.0	**1.9**	0.9	0.8	**2.3**	0.0	0.8	**1.4**	0.0	0.1	0.0	0.2
Electricity	0.8	0.6	0.0	0.0	0.3	**1.1**	0.0	**1.4**	**1.6**	**1.1**	0.1	0.0	0.6	0.0	0.4	0.5	0.0	**1.6**	0.1	0.0	0.2	0.4	0.0	0.2	0.7	**2.5**	**2.3**	0.0	**2.6**
Flax and hemp	0.7	**1.8**	0.9	**2.4**	**4.2**	0.0	**5.0**	1.0	0.1	**1.8**	0.3	0.0	0.7	0.6	**1.7**	0.9	0.0	0.0	0.4	**1.0**	**1.7**	**1.8**	0.0	**3.1**	**1.4**	0.0	0.0	0.0	0.1
Furniture	**1.5**	**1.2**	0.9	**3.1**	0.4	**1.8**	0.6	1.0	**2.4**	**1.5**	0.7	0.0	**2.3**	**1.2**	0.3	**1.3**	0.0	**2.2**	0.2	0.5	0.6	0.9	0.0	0.7	0.4	**1.2**	0.9	**1.6**	0.3
General machinery and machine-tools	0.7	**1.5**	0.0	0.3	0.7	**1.1**	0.2	**1.7**	**1.4**	**2.0**	0.0	0.0	0.4	0.0	0.2	**1.0**	0.0	**1.6**	0.0	0.1	0.2	0.5	0.0	0.1	0.4	**3.4**	**2.5**	0.0	**2.0**
Glass	**2.3**	0.6	0.3	**2.4**	0.0	0.0	0.2	**1.4**	**2.3**	**1.3**	0.0	0.0	**1.3**	0.1	0.3	**2.6**	0.0	0.0	0.8	0.4	0.4	0.7	0.0	**1.0**	0.6	0.6	**2.4**	0.0	0.6
Instruments	**1.1**	0.7	0.2	0.9	0.7	0.8	0.7	**1.4**	**2.0**	0.8	0.4	0.0	**1.3**	0.3	0.5	**1.1**	0.1	**2.0**	0.6	0.6	0.5	1.0	0.0	0.4	1.0	**1.1**	**4.1**	0.8	0.9
Jewellery	**1.1**	0.5	0.3	**1.4**	0.0	**1.8**	0.7	0.9	**3.0**	**1.1**	0.2	0.0	**2.0**	**4.7**	0.1	**2.7**	0.0	1.0	0.3	0.3	0.2	0.8	0.0	0.8	0.4	**1.8**	0.9	**2.2**	0.3
Leather	0.9	**1.3**	**3.1**	**1.4**	0.0	**1.6**	**1.0**	**1.7**	0.0	0.6	**2.6**	0.0	**1.6**	0.2	**1.5**	0.5	0.0	**1.8**	**1.3**	0.8	**1.2**	**1.3**	0.0	0.6	0.7	0.0	0.0	**1.4**	0.3
Lighting and heating	0.7	**1.1**	0.0	**1.0**	**1.7**	0.0	0.2	**2.4**	0.7	**1.5**	0.2	0.0	0.3	0.6	0.2	0.7	0.0	0.9	0.0	0.6	0.8	0.6	0.0	0.0	0.9	**3.8**	**2.5**	**3.9**	1.0
Mining and metallurgy	0.7	0.5	0.3	0.8	**1.1**	0.1	0.6	0.6	0.3	**1.2**	0.3	0.4	0.4	0.2	**1.7**	0.1	0.3	**1.0**	**1.9**	0.5	0.6	0.8	**1.7**	0.4	0.5	**2.4**	0.3	0.3	**2.9**
Paper and printing	0.7	0.7	0.7	0.6	**1.3**	**1.3**	0.8	**1.5**	**1.6**	1.0	0.7	0.0	0.8	0.6	**1.4**	0.9	0.5	**1.3**	0.4	0.5	0.6	0.7	0.0	0.3	0.5	**2.3**	**1.1**	0.2	**1.2**
Silk	0.1	0.1	0.7	**1.4**	0.0	0.0	0.4	0.7	0.7	0.6	**1.6**	0.6	**5.1**	**6.6**	0.2	0.0	0.0	0.0	0.0	0.2	0.7	0.8	0.0	**1.0**	1.0	0.0	**1.5**	**2.8**	0.2
Textile machinery and equipment	0.2	0.9	0.3	**2.4**	**1.0**	**1.8**	0.5	**2.9**	**1.3**	**2.0**	0.3	0.0	0.5	**2.1**	0.1	0.9	0.0	0.0	0.4	0.2	0.5	0.2	0.0	0.0	0.2	0.0	**3.2**	0.0	0.6
Transport	0.6	**1.1**	0.3	**1.7**	0.3	0.7	0.2	**1.3**	**2.1**	**1.6**	0.1	0.0	0.6	0.1	0.3	**3.1**	0.0	**3.6**	0.3	0.2	0.3	**1.6**	0.0	0.6	0.2	0.6	**1.3**	0.4	**1.8**
Weapons	**1.8**	**2.4**	0.2	**3.2**	**1.4**	0.0	0.2	**1.7**	0.4	**3.0**	**1.4**	0.0	0.8	0.0	0.7	0.0	0.0	0.0	0.3	0.3	0.7	**1.7**	0.0	0.3	0.2	**1.5**	0.0	**3.1**	0.2
Wool	**1.2**	0.6	**2.1**	0.0	0.0	0.0	**1.5**	0.9	0.4	**1.3**	**1.4**	0.0	0.5	0.2	0.8	0.0	0.8	0.0	**1.0**	**1.3**	**1.6**	**2.6**	0.0	**1.6**	**3.6**	0.0	0.2	0.0	0.3
Primary products	0.8	**1.5**	**1.7**	0.6	**1.5**	0.4	0.9	0.4	0.5	0.7	**1.5**	**3.0**	1.0	0.5	**1.3**	0.5	**2.8**	0.5	**1.5**	**2.0**	**1.8**	**1.1**	**2.3**	**1.5**	**1.7**	0.3	0.5	0.9	0.9
Low-tech manufactures	**1.2**	0.7	0.8	**1.3**	0.7	**1.3**	**1.3**	**1.2**	**1.0**	**1.0**	0.9	0.1	**1.1**	**1.6**	**1.0**	**1.1**	0.2	**1.0**	0.9	0.6	0.7	1.0	0.3	0.9	0.7	**1.2**	0.8	**1.2**	1.0
High-tech manufactures	0.8	**1.0**	0.4	0.9	1.0	**1.1**	0.4	**1.4**	**1.8**	**1.4**	0.5	0.1	0.8	0.4	0.6	**1.5**	0.1	**1.6**	0.5	0.5	0.5	1.0	0.7	0.3	0.7	**1.5**	**2.2**	0.7	**1.3**

Notes: (i) countries exhibiting a lower number of exhibits than a selected threshold (60) are not displayed, since the computed indices may not to be fully representative of that country's economy, and take extreme values; (ii) values larger than one are emphasized by bold text, values larger than two are also underlined.

Table A7. GDP per capita (levels and average annual rate of growth) and ECI, 1870-1913, selected countries.

Country	1870 GDP pc	1913 GDP pc	GDP pc growth 1870-1913	1867 ECI	Final ECI	
Argentina	1.31	3.80	2.50	-0.25	-1.40	(1889)
Austria-Hungary	1.86	3.47	1.45	0.93	0.62	
Belgium	2.69	4.22	1.05	1.32	0.73	
Brazil	0.71	0.81	0.30	-1.56	-0.68	(1889)
Chile	1.29	2.99	1.97	-0.91	-0.62	(1889)
China	0.53	0.55	0.10	0.53	0.50	
Denmark	2.00	3.91	1.57	0.93	0.84	
Egypt	0.65	0.90	0.77	0.53	0.22	(1889)
France	1.88	3.48	1.45	1.32	0.84	
Germany	1.84	3.65	1.61	1.06	1.19	
Great Britain	3.19	4.92	1.01	1.32	0.73	
Greece	0.88	1.59	1.39	-1.17	-0.12	
Italy	1.50	2.56	1.26	0.01	0.67	
Morocco	0.56	0.71	0.54	-0.25	0.07	(1878)
Netherlands	2.76	4.05	0.90	0.27	0.79	
Norway	1.36	2.45	1.38	0.53	1.07	
Portugal	0.98	1.25	0.58	-0.91	-0.69	
Russia	0.94	1.49	1.06	-0.12	0.39	
Siam	0.61	0.84	0.76	0.01	0.62	(1878)
Spain	1.21	2.06	1.25	-1.30	-0.23	
Sweden	1.36	3.07	1.92	1.06	0.84	
Switzerland	2.10	4.27	1.66	0.93	1.13	
Tunisia	0.63	0.88	0.78	0.14	0.59	(1878)
Turkey	0.82	1.21	0.90	-0.65	0.33	
United States	2.44	5.30	1.82	1.58	0.73	
Uruguay	2.18	3.31	0.98	-1.04	0.35	(1889)

Note: the income of Austria-Hungary is constructed as the sum of Maddison's data for Austria, Czechoslovakia, and Hungary. Final ECI *refers to 1900, unless differently stated (in brackets).*