DISCUSSION PAPER SERIES

DP15620

BRITISH-FRENCH TECHNOLOGY TRANSFER FROM THE REVOLUTION TO LOUIS PHILIPPE (1791-1844): EVIDENCE FROM PATENT DATA

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ECONOMIC HISTORY

ISSN 0265-8003

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Discussion Paper DP15620
Published 30 December 2020
Submitted 28 December 2020

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Abstract

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JEL Classification: N73, O3

Keywords: Technology Transfer, patents, industrial revolution, France, Britain

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Acknowledgements
We are particularly grateful to Steeve Gallizia for allowing us to use the Institut National de la Propriété Industrielle (INPI) dataset and for his insightful comments on the data and their historical context. We would like to thank Julio Garbers for his outstanding research assistance, Nico Voigtlander and Mara Squicciarini for sharing their data on the Encyclopédie subscribers, Olivier Gergaud, Morgane Louenan and Etienne Wasmer for sharing their data on historically notable inventors and Michel Serafinelli for useful advice on historical biographic databases. We also thank Pierre Alexandre Balland, Jérôme Baudry, Alexander Donges, Bart Los, Felix Selgert, Jochen Streb and other participants to seminars at the University of Utrecht and the University of Mannheim for helpful comments and suggestions. Michelangelo Vasta gratefully acknowledges Université Paris 1 – Panthéon-Sorbonne for financial support during his visiting period.

British-French technology transfer from the Revolution to Louis Philippe (1791-1844): evidence from patent data

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ABSTRACT

This paper examines the patterns of technology transfer from Britain to France during the early phases of industrialization; it does so by making use of a dataset comprising all patents granted in France during the period 1791-1844. Exploiting the peculiarities of the French legislation, we construct an array of patent quality indicators and econometrically investigate their determinants. We find that patents filed by British inventors or French inventors personally linked with British ones were of relatively higher quality. Overall, our results show that the French innovation system was effectively capable of attracting and absorbing key technologies from Britain.

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December 2020

1. Introduction

French industrialization performance has been a highly debated theme in European economic history since the early contribution by Clapham (1921), who maintained that France did not actually experience a genuine industrial revolution before the end of the 19th century. In line with this pessimist perspective, Landes (1949, 1969) argued that French industrialization was slowed down by weak entrepreneurship – leading to an industrial structure largely characterized by small family firms –, and by institutional rigidities arising from the considerable state intervention. This view has been sharply criticized by O'Brien and Keyder (1978) who suggested, through a detailed comparative analysis of the dynamics of labor productivity in Britain and in France during the 19th century, a more optimist interpretation of French industrialization. In particular, they highlighted how peculiar the French path to industrialization was, since "it took place in a different legal, political and cultural tradition" (O'Brien and Keyder 1978, p. 21). Indeed, when these contextual specificities are properly considered, French economic performance stands the comparison with Britain quite well. Early estimates of GDP and manufacturing growth have supported this idea, documenting that while French industrialization was slower than the British, it was better than previously thought (Crafts 1984).[1] More recently, in the same vein, Horn (2006) has claimed that, since the Congress of Vienna up to the mid-19th century, France industry grew rapidly, even if not as fast as in Britain. Furthermore, in his account, Horn provides a decidedly favorable picture of the industrial and innovation policies adopted by the French state.[2]

The debate is still ongoing and some recent contributions have provided additional elements that shed light on the crucial question as to why the Industrial Revolution did occur in England and not in France. For instance, Daudin (2011) has pointed out the limits of French market integration in the late 18th century; Allen (2009), in the context of his high-wage

[1] The literature on the subject is exceedingly voluminous and here we have provided just an indicative summary. For a thorough survey of the historiography of French economic growth during the nineteenth century, see Crouzet (2003). For recent estimates of French GDP over the period 1280-1850, see Ridolfi and Nuvolari (2020).

[2] Juhasz (2018) documents a positive impact of the Napoleonic Blockade on the expansion of mechanized cotton spinning.

economy interpretation of the Industrial Revolution, claimed that low wages hindered the diffusion of the spinning Jenny in France.[3] Similarly, Sharp and Weisdorf (2012) also suggested that the low level and volatility of French real wages may have played an important role in delaying the industrial revolution.

Clearly, one of the fundamental ingredients of national industrialization processes is the level of scientific and technological capabilities (Mokyr 1990). For the period in question, it is obviously difficult to develop sophisticated measurements. However, Figure 1 provides an exploratory sketch of the evolution of scientific and technological capabilities in Britain, France and United States using two sources containing lists of major scientific and technological discoveries and inventions (Sorokin 1947, p. 150, Streit 1954, p. 239 ff.). Remarkably, even if constructed independently, the two sources offer a rather consistent picture. Looking at the Sorokin (1947) data, France is never too far away from the English level over the entire period considered. As for the Streit (1954) data, the gap is larger, but the French performance is remarkable and visibly better than the American one, at least since the mid-19th century. Using alternative sources, Grinin and Korotayev (2015, p. 170 ff.), have recently shown that in the 18th and 19th century, France is only behind Britain in terms of major technological inventions. Overall, this descriptive evidence is fully in line with the view that emphasizes the prominence of French science, with significant reflections on technological developments after the Revolution (Fox 2012).

Figure 1 about here

However, a good performance in terms of scientific discoveries and inventions does not automatically translate into the adoption and diffusion of innovations. Technological breakthroughs (macro-inventions) usually emerge in a very rudimentary form and many incremental improvements – stemming from learning processes both at the producer and user side – are necessary before they become susceptible of widespread economic adoption.

[3] Gragnolati, Moschella and Pugliese (2011) have argued that Allen's profitability assessments of the spinning jenny in England and France are based on very specific assumptions. See also the rejoinder by Allen (2011).

Mokyr (1990) notes that England's technological leadership in this period was not so much in the generation of macro-inventions, but rather in the capability of refining and improving them so that they could be implemented and adopted. He cites, approvingly, this statement of a Swiss calico printer, Jean Ryhiner, who in 1766 characterized French and English technological capabilities in these terms: "They [the British] cannot boast of many inventions of others; whence comes to the proverb that for a thing to be perfect must be invented in France and worked out in England".[4]

Against the background of these debates on French economic performance during the 19th century and on its level of technological capabilities since the Revolution, there is a general consensus that technological transfer from Britain represented a critical source of innovation during the early phases of French industrialization. Historians such as Henderson (1972) and Crouzet (1996) have documented several revealing instances of the successful importation of technology from Britain to France. Harris (1998) has shown that from the early 18th century, there was a systematic interest in the technological developments made in England, with the intention of importing the most successful innovations to France. Even though technological transfer from England to France has been touched upon by business history or history of technology studies that exploit qualitative and descriptive evidence, a general quantitative assessment of this process is still missing (Cotte 2010a).[5] Additionally, even when set in the broader perspective of economic history as a whole, technology transfer during the 19th century are still an under-researched issue, not only in the French case.[6]

The main goal of this paper is to provide a quantitative assessment of the patterns of technology transfer from Britain to France during the early phases of industrialization using patent data. Indeed, since the seminal contribution by Schmookler (1966), patents have

[4] Mokyr (1990, p. 82), originally cited by Wadsworth and Mann (1931, p. 413).

[5] For an interesting pleading advocating the implementation of quantitative perspective on this issue, see Cotte (2010a, p. 129): "Il nous manque toutefois une vision d'ensemble plus large, plus complète et surtout quantifiée. L'impact direct des techniciens britanniques sur le décollage industrielle de la France peut être affirmé, ses limites également, mais sa mesure plus précise reste a faire".

[6] For one of the first systematic attempts to study historical patterns of technology transfer, in this case from Britain to the United States, see Jeremy (1973).

become one of the preferred sources to investigate inventive activities.[7] One of the main limitation of patent data is related to the large difference in quality amongst their underlying inventions, ranging from small improvements to major radical innovations (Streb 2016). We tackle this issue by developing a number of patent quality indicators and we reconstruct the impact of technology transfer from Britain to France by means of a systematic comparison between the quality of patents with British origins and domestic ones. Our results show that, in this key historical phase, technology transfer from Britain represented a crucial source of technical progress for France. In a broader perspective, our results also point to a remarkable capacity of French inventors and entrepreneur to implement and adapt British technology to the French context. At least from this technology standpoint, pessimistic accounts of the French industrial retardation seem wide off the mark.

The rest of the paper is organized as follows. Section 2 describes the French patent system, while Section 3 provides a general assessment of patenting activity in France in the period 1791-1844 by illustrating data and methods used in the analysis. Section 4 introduces different patent quality measures by discussing their advantage and limitations, while Section 5 presents our main results. Section 6 concludes.

2. The French patent system

During the *Ancien Regime*, France encouraged both inventive activities and the transfer of technologies from abroad by means of a rather complicated system of 'exclusive privileges'. Requests for privileges had to endure a taxing examination process led by the *Bureau du Commerce* in collaboration with other institutions such as the *Académie de Sciences* or artisans from specific corporations (Hilaire-Perez 1991, 2000, Baudry 2020). The function of this examination process, which led to the approval by the *Parlement*, was to ascertain the genuine

[7] Following the pioneering contributions of Dutton (1984) and Sokoloff (1988), the use of patents as innovation indicators has developed into a consolidated research tradition in economic history. For a survey of this stream of literature, see Moser (2016). Some recent contributions in this field – Saiz (2013) on Spain and Donges and Selgert (2018) on Germany – have also studied patterns of technology transfer using patent data.

utility of each invention from the point of view of the French state. This institutional configuration made the granting of privileges uncertain and highly discretionary.

The aim of the 1791 patent law was to introduce a radically new approach.[8] The philosophical underpinning was the 'natural right' of inventors to enjoy the fruits of their ingenuity. Accordingly, the first objective was to create a system not subject to the discretionary power of the state. In this respect, the inspiration was the English system, where, since the early eighteenth century, patents were liberally granted without examination (Bottomley 2014).[9]

The law contemplated three main types of patents: i) patents for invention (*brevets d'invention*), covering 'every new discovery or invention' (art. 1, Law 7th January); ii) patents for improvement (*perfectionnement*), covering improvements of existing technologies (art. 2, Law 7th January); iii) patents of importation (*brevets d'importation*), covering the first introduction in France of foreign discoveries (art. 3, Law 7th January).[10] The law established that patents had a duration of 5, 10 or 15 years (art. 8, Law 7th January), according to the fee paid by the inventor. The fee structure (which was the same for all types of patents) was the following: 300 francs for patents with a 5-year duration, 800 francs for those with a 10-year duration, 1,500 francs for those with a 15-year duration (*titre* 3, n. IV, Law 25th May).[11] The granting of each patent also

[8] The issuing of patents was actually regulated by two different laws both promulgated in 1791. The first, approved on January 7th, outlined to the general principles concerning the rights of the patentees and the validity of the patents, while the second, approved on May 25th, set out the detailed rules for application and granting of the patents. In the following, we simply refer to these two pieces of legislation as to the 1791 Law.

[9] Baudry (2019) has shown that an unofficial examination process entrusted to the *Comite Consultatif d'Arts et Metiers* was reinstated just few years after the enactment of the 1791 law. However, the inventor was allowed to register his patent, despite the negative assessment of the *Comite.* In any case, the evidence unearthed by Baudry suggests that this examination was not perfunctory. About 20% of patent applications were withdrawn after the assessment of the *Comite* (Baudry 2019, p. 72).

[10] In other words, foreign inventors could take patents in France (i.e., there was no discrimination of foreign inventors) and French patentees might import technologies developed in other countries.

[11] Initially the fees were for the same amounts in *livres tournois*. They were converted in francs in 1795 (Galvez-Behar 2019, p. 36). Baudry (2020) properly notices that the structure of the fees shows that the intention of the legislator was to limit the duration of patent protection since a 10-year patent cost more than two 5-year patents, and a 15-year patent cost more than the sum of a 10-year and 5-years patent. This might suggest that the legislation was thought to explicitly limit long-lasting monopolies and stimulate competition.

involved the payment of an additional administrative fee amounting to 50 francs. Upon request, the law offered the possibility to pay the fee in two instalments: about half of the amount when the patent was granted and the second half after six months (Perpigna 1832, p. 57). As mentioned above, it was also possible to introduce improvements on an already existing patent, by paying a fee amounting to 24 francs (*titre* 3, n. IV, Law 25th May). The patenting of these 'improvements' did not alter the expiration date of the original patent. Finally, the law gave the possibility to extend an already existing patent by paying a costly fee equal to 600 francs – plus 12 francs for the registration (*titre* 3, n. IV, Law 25th May). Despite being technically possible, prolongations were only granted in very special cases and had to undergo a very demanding examination by the government.[12] The 1791 laws defined the legal framework pertaining to patenting activity in France until they were replaced by a law passed on July 5th 1844: indeed, only minor changes were made in the period 1791-1844. Amongst them, it is worth noting that, in 1806, the prohibition for the joint stock companies to register a patent was removed (Empotz and Marchal 2002, pp. 202-203; Baudry 2019).

The level and the structure of patent fees was a key-parameter regulating the accessibility of a patent system. According to Khan (2005, pp. 43-44), the relatively high level of French patent fees severely limited access to patent protection for ordinary inventors. As a result, she argues that even if the system was rhetorically founded on the notion of the 'natural right' of the inventors, in practice it granted the opportunity to patent inventions only to a restricted number of individuals. The assessment of the French patent system by Baudry (2020) is definitively more nuanced. In the absence of a stringent examination, the level of patent fees had the function to discourage inventors from patenting trivial inventions, making the entire system self-regulatory, without further governmental or administrative interventions: "In the 1791 law, the patent tax worked as an apparatus designed to incentivize the inventor into

[12] This fee was relatively expensive since it exceeded the fee required to take out a new 5-year patent and it covered only 5-year extensions. As far as 15-year patents are concerned, only the Royal Court could decide whether they could be further extended. According to Perpigna (1832, pp. 87-88), in the period 1791-1832 only 20 patents were prolonged. Unfortunately, Perpigna does not provide a complete list of these prolongations.

becoming a good calculator of his own interest, which was subsequently turned into the general public interest, into the common good" (Baudry 2020, p. 16).[13]

Figure 2 compares French patent fees with those prevailing in England and in the United States according to different measures in the period 1825-30. It examines the costs for the maximum possible patent duration within each system, i.e. 15 years in France and 14 years in both England and in the United States. The histograms on the left hand side provide a comparison by means of simple conversion of the fees of each country in US dollars, while those in the middle and on the right hand side express fees in terms of the prevailing daily wages of skilled workers (respectively a mechanic and a mason). Two points deserve attention: first, the extremely low level of US patent fees corroborates the idea that the US patent system was widely accessible and democratic (Khan 2005). Second, French fees are significantly lower than the English ones – almost half when considering dollar conversions and between 30% and 45% according to wage-related computations. Thus, even if Khan (2020, p. 164) considers both the English and the French system as biased against the poor, this evidence suggests that the 1791 French law, despite having been inspired by English practice, introduced a significantly lower bar for accessing patent protection.

Figure 2 about here

The law also provided for the withdrawal of granted patents (art. 16, Law 7th January). The most obvious case pertained to patents that were not actually new and were deemed so by a court trial. Similarly, patents could be revoked if their specification was found to be obscure or incomplete in court judgments. Should a patentee fail to pay the second instalment of the initial fee, a patents would also be revoked. Finally, the law contemplated a working clause of two years:[14] if the patentee had not put the invention into practice within this term the patent

[13] For a similar interpretation, see also Galvez-Behar (2019).
[14] In addition to patent fees, Khan (2005, pp. 43-44) also points to the working clause as a factor limiting the effective use of the patent system for ordinary inventors.

could be annulled. Importantly, the failure to put the invention into practice also had to be establish formally in a court case (Perpigna 1832, pp. 62-81).[15]

3. Patenting activity in France

This Section provides comprehensive information on our main historical source, the methods used to analyze it (sub-section 3.1) and a first sketch of its contents (sub-section 3.2).

3.1 The historical source

Our paper is based on a digitized dataset pertaining to the universe of patents deposited and granted in France from 1791 to 1844.[16] The dataset has been compiled by the *Institut National de la Propriété Industrielle* (INPI henceforth) and covers about 12,575 patents containing fully detailed information on patent and patentee characteristics.[17] While having already been used in some important contributions (Khan 2016, Galvez-Behar 2019), this collection still remains largely unexplored and lends itself well to further investigation.

The dataset allows to trace the exact date on which a patent was deposited, granted and withdrawn, how long each patent was initially filed for (5, 10 or 15 years), the total number of successive additions to the original invention, a detailed description of the patent itself. A preliminary industry classification of each patent is also available. As far as patentees are concerned, each observation reveals their name, surname, residence address and occupation. While about a sixth of all patents were deposited by groups of (up to 6) individuals, single-patentee inventions are by far the most common. Companies could also patent inventions and represent 6% of the observations. Crucially, the data uncover historical evidence on patent

[15] In addition to the above mentioned cases, a peculiarity of the 1791 French law was that it also established that a patent was withdrawn in case a patentee took out a patent for the same invention in a foreign country. The rationale for this provision is not entirely clear. In any case, it is doubtful that it had a practical relevance in terms of the number of patents withdrawn (Perpigna 1832, p. 76).
[16] The dataset contains all patents granted according to the 1791 laws. Thus, as for the year 1844, with very few exceptions, it ended with patents deposited within October 1844 and granted within the end of the same month.
[17] The documentation is publicly accessible online (http://bases-brevets19e.inpi.fr/index.asp) and allows users to browse through the renditions of the original files.

agents, i.e. intermediaries that handled the bureaucratic procedures *in lieu* of patentees themselves.

While relying on such an impressive bulk of work, we significantly complemented these data by: i) geo-referencing each patent and assigning it to a historical French department, ii) signaling out foreign inventors (and their country of residence), iii) reclassifying occupations for each patentee, iv) categorize all patents according to the 1853 technological classification (Empotz and Marchal 2002, p. 70). Additionally, we also introduced three different measures of patent quality (see Section 4). The following sub-section (3.2), together with Section 4, offers a descriptive account of these efforts and highlight the relevance of our contribution in terms of data improvement and harmonization. In particular, we have cleaned some data errors by looking at the original source and amended the number of additions, residences of patent agents and companies' names.

Note that most figures will be organized around the following periodization: 1791-1815, from the founding of the French patent system to the end of the Napoleonic wars; 1816-1830, from the Congress of Vienna to Louis Philippe ascending the throne; 1831-1844, throughout the reign of Louis Philippe and until the patent system was drastically reformed in 1844.

3.2 An overview of the data

Between 1791 and 1844 patenting activity in France was quite intense: 12,575 patents were registered. To put this figure into perspective, one might compare it with the number of patents were granted in the United States and England within the same timeframe: in the former, although registration was much cheaper, there were 13,833 patents granted (Khan 2008); in the latter, where the system was comparatively more expensive, the number of patents registered was 8,663 (Woodcroft 1854).[18]

Figure 3 shows the evolution of the annual number of patents granted in France in the period 1791-1844. More specifically, it disaggregates the data into three series – France, Great Britain and other countries – based on patentees' residences at the time of the deposit. Should

[18] Normalizing for population (Maddison 2003), in 1840, France granted 37 patents per million inhabitants, the United States 26 and the United Kingdom 16.

a patent be deposited by individuals who were resident in different countries, we assign a fractional number to each of them: for instance, whenever a patent is associated with two people residing in different countries each of them is given a value of 0.5. Looking at the figure, there are three main takeaways. First, patentees who were resident in France account for the lion's share of the observations, amounting to about 90% of the total. Second, among foreigners, patentees who were resident in Great Britain represent the bulk of the contribution, totaling over 70% of foreign patents.[19] Clearly, the flow of technologies from Britain embodied in patents overwhelmingly took place after the end of the Revolutionary and Napoleonic wars. It is also worth noting that until 1843 technology transfer between England and France was still disrupted by British legislation prohibiting the export of machinery and the emigration of skilled workers (Jeremy 1977). Third, all these series are correlated and trending upwards, with pronounced year-to-year fluctuations – especially from the early 1830s

Figure 3 about here

As already hinted at, we complement the original data by assigning a latitude-longitude pair to each location associated to a patent.[20] We then allocate these places to French historical departments by plotting their coordinates over the 1830 French administrative map.[21] Figure 4 depicts the results of this process and illustrates the geographical distribution of municipalities that appear in our data at least once – each blue dot represents a different place. It can be seen that clusters are denser in the North-East and in correspondence of departments orbiting around Paris (*Seine*) and Lyon (*Rhône*). *Bretagne* and the *Massif Central* region display coarser patent activity. According to Braudel (1984, pp. 337) the "supremacy" of Paris in the French

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[19] See Table A1 in the Appendix for a fine-grained country-wise disaggregation.

[20] We automated this process through an *ad-hoc* script that searches single municipality strings within the OpenStreetMap database and geocodes them. This approach minimizes the impact of – yet minor and infrequent – spelling mistakes: slight toponym changes are easily accounted for by a system of suggestions *à la* Google Spell Checker. Unmatched municipalities have been manually double-checked so that each location could be correctly identified.

[21] The shapefile of the map we used is available at the following website: http://www.datavis.ca/gallery/guerry/maps.html. We applied an intuitive approach: a purposely coded script assigns each location to the 89 departments whose boundaries falls within. While included in the econometric analysis, all the maps in the paper exclude the following 4 departments: *Territoire de Belfort*, *Savoie*, *Haute-Savoie* and *Alpes-Maritimes* since they are not included in the 1830 shapefile.

economic life dates back to the end of the seventeenth century. Another interesting feature of the maps of Figure 4 is the concentration of patenting activity in the North-East regions of the country. This is consistent with the idea of a regional divide of the French economic and social geography along the notional line running from Rouen to Geneva suggested by Braudel (1984, pp. 337-343).

Figure 4 about here

Figure 4 only refers to the extensive margin – i.e. how many municipalities are involved in any patenting activity per department. On the contrary, Figure 5 is concerned with the intensive margin – i.e. how many patents were actually granted in each department. Overall, it makes clear that French patenting activity was concentrated around a single hub: Paris. Indeed, the *Seine* department (in red)[22] was by far the most active, since 6,363.5 (50.6%) were granted to individuals or companies residing there – excluding *Seine-Inférieure*, *Seine-et-Oise* and *Seine-et-Marne*, which all together amounted for further 4.2% of the total. Other departments display much lower numbers – e.g. *Rhône*, comes second with only 533 patents (4.2%), the *Gironde* is the 4th most active French region with 271 patents (2.2%). The geographical distribution is therefore very skewed, confirming that a distinctive feature of the French economy holds true even in terms of patenting activity: Paris and the *Seine* department play a dominant role.[23]

Figure 5 about here

Taken together, these three maps also add a valuable temporal dimension, suggesting two interesting stylized facts: on one hand, patenting activity spread around France until it progressively involved all the departments; on the other hand, there seems to be a high degree of path-dependency, meaning that departments where patenting activity was more prominent in the first period were also the most dynamic by 1844. This idea is telling, especially when

[22] Note that this department has been excluded from the computation of the scale as it would flatten the whole map out. The same applies to Figure 9.
[23] Later in the paper, in Section 5, we address this concern by excluding the *Seine* department from the main econometric specifications.

considering the fact that our data captures the very introduction of the patent system and its early development.

Additionally, we enrich the original version of the INPI data by manually standardizing the industry categorization of each patent. In particular, we assigned technological classes – 20 in total – according to the pre-1853 coeval classification reported by the institute. Figure 6 shows that patenting activity was concentrated, along the three different sub-periods, in three main fields – textiles machines and fabrics (category 4), chemical products, food and cosmetics (14), and lightning, heating and fuels (15). In all sub-periods, taken together, these industries accounted for more than one third of the total (Table A2 in the Appendix reports the complete disaggregation).

Figure 6 about here

Finally, we standardized patentee's occupations, ownership status and, indirectly, their social class. In particular, we adopted the *Historical International Classification of Occupations* (HISCO) (Van Leeuwen, Mass and Miles 2002, p. 57), which distinguishes occupations according to manual/non manual, skill level (high, medium, low and unskilled), supervision (yes or no) and sector (primary or other). Since, the original source contains appellations such as *proprietaire*, *negociant*, *fabricant* and so on, we complemented the original 11 classes by adding a marker for ownership, distinguishing between small (0_1) and large proprietors (0_2).[24] Figure 7 shows that four occupations account for more than three-quarters of the total in all sub-periods. The most represented class is always that of the 'large proprietor' (0_2), while the others are: 'higher professional' (2) which includes engineers and other highly skilled individuals, foremen (artisans) (6), which comprises skilled workers for key technologies in the 18th-19th centuries, and 'medium skilled workers' (see Table A3 in the Appendix for a list of the most represented professions within each class). Remarkably, the share of artisans and low skilled/unskilled workers amounted for 34.8% of the total number of patents. This value is large and much

[24] We distinguished between 'small' and 'large' proprietors considering the most likely size of the activity. For instance, the string *negociant* has been classified as 'small proprietor', *fabricant* as 'large proprietor'.

higher than the 18.8% estimated by Khan (2020, p. 165) for artisans only on a sample of 849 patents for the period 1791-1855.

Figure 7 about here

In the case of the United States, Sokoloff and Khan (1990) interpreted the share of patentees with only one career patent as an indicator of the accessibility ("democratization") of the patent system. The intuition being that a system largely opened to 'one off' patentees did not have significant barriers to entry. In Figure 8, we compare the shares of patentees with only one career patent for France, England and the United States using the same sub-periods of Sokoloff and Khan (see Table A4 in the Appendix for the full comparative data). Considering this indicator of accessibility, it turns out that, remarkably, that France was very similar to the United States in all the sub-periods considered.[25]

Figure 8 about here

Overall, both these results on the occupations of patentees and their long term commitment to patenting suggest that the accessibility of the French patent system was significantly broader than the one suggested by Khan (2005, 2020).

4. Measuring patent quality

Notwithstanding the large success of patents as a measure of inventive activities, one of their most notable shortcomings, following Griliches (1990), is that "… the inventions that are patented differ greatly in quality".[26]

Recently, economic historians have constructed patent quality indicators by implementing two main strategies (for a survey, Streb 2016). Largely inspired by American system which prescribed the documentation of prior art by means of citations, the first approach adopts the number of citations received by a patent as a measure of its relative

[25] The results for England are based on the total number of patents granted. Despite this, the results are consistent with those obtained by Khan who used a sample of 319 patentees (2005, table 4.1).
[26] This issue has been extensively tackled by the modern literature on innovation (Nagaoka, Motahashi and Goto 2010, Higham, de Rassenfosse and Jaffe 2020).

significance: important inventions attract the interest of many, especially follow-up inventors (Nicholas 2011).[27] The second approach exploits renewal data and draws from the idea that inventors will pay renewal fees only as long as the economic returns of the patent exceed the cost of maintaining it in force (Streb, Baten and Yin 2006). In our context, neither approaches are feasible: French patents were not yet systematically cited in the United States and, as mentioned above, renewals were not contemplated by the law. However, following Nuvolari and Vasta (2015, 2017), we maintain that patent duration could be used as a proxy for its value. The intuition is straightforward: ground-breaking inventions are more likely to be associated with longer patents than more limited contributions.

4.1 Patent quality: constructing the indicators

As touched upon in Section 2, each patentee – or team of patentees – was required to declare upfront how long they wished to secure the legal protection related to the patenting of their inventions. According to the legal framework, they could only choose among three patent durations: 5, 10 or 15 years. We therefore argue that patent duration is a good approximation of its quality and develop three measures based on it – considering also improvements introduced by the inventors and withdrawals.

First, we simply classify patents with respect to their nominal duration and assign a progressive quality score from 1 to 3 to each observation, proportional to patent duration: 5, 10 and 15 years. Table 1, panel on the left, summarizes the distribution of this variable: more than half of all the patents were originally taken for 5 years, 27.2% were filed for 10 years, while the remaining one fifth (20.8%) was supposed to last 15 years.

Table 1 about here

Second, we exploit the very steep fee structure of the French patent system and introduce a monetary measure of patent quality. As already noticed, patentees who wished to deposit 5-, 10- or 15-year patents incurred, in an initial cost of, respectively, 300, 800 or 1500

[27] A related approach is based on the use of information relative to patent visibility in the relevant engineering and legal literatures. See Nuvolari and Tartari (2011) for an example focused on English patents.

francs. After the initial deposit (handled by the patent administration for 50 francs), inventors were granted the possibility of filing additions against the payment of a moderate fee (24 francs) – the majority of patents do not have any addition (the median is 0, the mean 0.42 and the maximum 23). Taken together, these pieces of information allow us to assign a precise monetary value to each patent: for example, a 5-year patent with 5 additions would have a monetary value of 470 francs (50 + 300 + 24 * 5); a 10-year patent with only one addition would have a monetary value of 874 francs (50 + 800 + 24). Table 1, panel on the center, bins observations into 4 classes: 0-350 francs, capturing 5-year patents with no additions; 351-849 francs, capturing 5-year patents with additions up to (but excluding) 10-year patents with no additions; 850-1,549 francs, capturing 10-year patents with additions up to (but excluding) 15-year patents with no additions; 1,550-2,102 francs, capturing 15-year patents with additions. The distribution of this variable largely retraces the one seen in the left panel and confirms that 5-year patents, with or without additions, accounted for about half the total.

Third, we consider the number of days in which each patent was actually in force considering withdrawals.[28] For example, a 5-year patent would be associated with a value of 1,825 days;[29] should the same 5-year patent be withdrawn after a year from its granted date, its value would then become 365. Following Nuvolari and Vasta (2015, 2017), this indicator, can be thought as capturing the 'real' duration of a patent since it takes into account its entire life-time, defined as the temporal difference between the granting date and the precise moment in which it expired. This indicator provides a more precise value assessment and it is therefore our favorite measure – i.e. the baseline of our econometric exercise.

Table 1, panel on the right, gathers observations into 4 bins by their duration measured in days. When contrasted to the other panels, it reveals that taking into account withdrawn patents considerably increases variability contributing to providing a more nuanced view of patent value as patents could be withdrawn independently of their initial duration.

[28] The dataset contains 2,875 withdrawn patents – over a grand total of 12,575 – but we cannot, unfortunately, disentangle the motivations of each individual withdrawal.
[29] While not mentioned in this example, we do take into account leap years.

Figure 9 better clarifies this point by showing three panels where we plot the frequency of actual patent durations within each patent class.[30] The highest bars are in correspondence with the natural expiration date of each patent – respectively, 1,825, 3,650 and 5,475 days. Shorter bars in the leftmost part of the figure show the distribution of withdrawn patents: while being most represented in the 5-year class, withdrawals are not uncommon among 10- and 15-year patents either.

Figure 9 about here

Figure 10 maps the geographical distribution of high quality patents, defined as those having been active for more than 4,000 days. Aside from confirming the stylized facts already noted in Figure 5 – i.e. the *Seine* department being a clear hub and path-dependency being relevant –, these maps also reveal that better patents were deposited in more active departments. While the number of departments without high quality patents decreases over time, not all of France was covered by 1844, suggesting that certain regions experienced agglomeration in terms of both quantity and quality. In the following subsection, we gather further evidence to corroborate our quality measures.

Figure 10 about here

4.2 Patent quality: robustness checks

Our approach is dependent on the idea that, while not as cheap as in the United States (see Figure 2), the French patent system did not prevent lower social classes from registering inventions for long(er) periods – i.e. 10- and 15-year patents. In other words, we need to make sure that the system was overall accessible and that worse-off individuals who wished to patent high-quality inventions – hence longer and more expensive – were not systematically prevented from doing so as a result of binding credit constraints.[31] Figure 11 substantiates our claim by depicting the duration-wise patent distribution across the whole population and the sample of high social class individuals (identified as classes 0_1-5 of the HISCO classification, see Figure

[30] Frequency, on the y-axis, is reported in logs because it helps visualizing the distribution.
[31] For a discussion of this issue for the British case, see MacLeod et al. (2003).

7).[32] The similar heights of each column pair makes clear that patentees with higher social background were not overrepresented in any patent class and neither were they when considering withdrawn patents.

Figure 11 about here

In order to further validate our quality indicators, we cross-matched our data with four recently compiled datasets that seek to identify the most relevant figures in human history, including inventors.[33] Pioneered by Khan and Sokoloff (1993, 2006) in the context of 18th century US patents, this approach tests patent quality indicators through independent measures based on external lists of famous inventors. In order to do so, we use the following sources: *Pantheon* (Yu et al. 2016), *Notable people* dataset (Gergaud, Louenan and Wasmer 2016), the *Human accomplishment* dataset (Murray 2003) and the *Notable individuals* dataset (Schich et al. 2014).[34] In Table 2, we summarize the most important characteristics of these sources.

Table 2 about here

More specifically, we signal out particularly successful patentees in our data and order them according to a 0 to 4 scale, depending on how many times they are matched in the previously mentioned sources. We then evaluate whether or not their patents were of higher quality – in terms of our own measures – with respect to the rest of the sample.

Table 3 shows comforting results. The leftmost column specifies how many external datasets contain information on a given patentee. The average and median duration of patents deposited by 'historically significant' individuals are much higher, suggesting that our approach captures patent quality reasonably well. In general, with an exception of a handful of patents

[32] Table A5 in the Appendix reports the numbers used to plot this figure. Table A6 in the Appendix presents the same comparison by using the quality measure in years, showing largely similar results.
[33] The matching is mostly based on a string consisting of names and surnames. In order to minimise false positives, we have restricted the timeframe of reference to individuals born or active after 1750, depending on what information was available. We also limited the geographical scope of the search.
[34] This latter dataset has been recently used by Serafinelli and Tabellini (2020).

having value 3, the ordinal fame index grows hand in hand with average and median patent duration.

Table 3 about here

Lastly, following Moser (2012) who used prizes as quality indicators, we digitized the *Annuarie de la Société d'encouragement pour l'Industrie Nationale* (1852) in order to perform an additional test of patent quality.[35] This publication contains detailed information on all the French inventors that were granted a monetary prize or a medal (bronze, silver and gold) for a particularly ground-breaking invention.

We cross-matched our data with this information too. In the bottom part of Table 2, we split the sample according to whether or not a patentee received any sort of prizes and compute the same statistics as before. The results of this exercise are again in line with our expectations: whenever patents were filed by (*a posteriori*) more successful inventors, the average and median patent duration was definitively higher.

5. Technology transfer and patent quality

Our dataset represents a unique opportunity to provide a quantitative appraisal of the relevance of technology transfer as driving forces of French industrialization. To the best of our knowledge, we provide the first detailed account of technology transfer from Britain to France by identifying all the British patents granted in France, evaluating their quality and looking at how involvement with British inventors impacted on the quality of French patents themselves.

In doing so, we complement qualitative accounts and offer a new perspective on the diffusion and key role of British techniques in France during this period (Cotte 2010a, 2010b).

[35] The *Société* was founded in 1801 with the aim to promote the modernization of French industry by supporting inventors with prizes and fostering the diffusion of technical knowledge. Jean-Antoine Chaptal (1756-1832), the most influential actor of French industrial policies of the time, played a crucial role in the formation of the *Société*. According to Horn (2006, p. 203): "The Society contributed to a number of French technological advances and improved techniques with signal successes in the perfection of the Jacquard loom for silks in 1808 and the naturalization of the sugar beet". For a significantly less positive view on the role of the *Société*, see Khan (2020, pp. 152-158). For further discussion of the use of prizes in historical research on innovation, see Brunt, Lerner and Nicholas (2012) and Khan (2020).

As already mentioned, when gauging the size and scope of technology transfer in this period, it is important to consider the prohibitive legislation forbidding the exports of machinery and the emigration of skilled workers from Britain. Even if only partially effective, it is likely that this ban acted as a constraint on technology-transfer between Britain and France until 1843, when the legislation was repealed (Jeremy 1977).

Our empirical analysis is based on a set of regressions that assess how different factors contribute to the determination of patent quality. We estimate the following type of specifications:

$$q_i = \alpha + \beta \cdot BO_i + \gamma \cdot BC_i + \delta \cdot X_i + \varepsilon_i$$

where q_i is the quality of patent *i* measured using the real duration, BO_i indicates a patent of British origin, BC_i indicates a patent granted to a French inventor with British contacts, X_i is a vector of control variables, ε_i is the error term. We include period and technological class fixed effects in all specifications and present results that both include and exclude department fixed effects. It is worth presenting in detail the construction of the model covariates:[36]

i) **British Origins (BO)**: this variable is a dummy indicating either that the patentee has British residence or that the patentee (whatever his or her nationality) had taken an English patent over the period 1791-1852, before or within five years of the granting of the French patent in question; we do so in order to identify those inventors that were more likely to be in close contact with techniques developed in Britain.[37] It is worth giving some specific examples to clarify the patents that we classify as BO. The first example, the case of a British inventor patenting in France, is represented by the patent for "*perfectionnements apportés dans la construction des locomotives"* granted (via the patent agent Antoine Perpigna) on the 5th of

[36] The summary statistics of the variables are presented in Table A7 in the Appendix.

[37] In order to establish whether the inventor in question had taken in English patent in the period 1791-1852, we have carried out a comprehensive matching between all the patentees in our French sample and Woodcroft's *Alphabetical Index* (1854).

October 1843 to James Nasmyth, the Scottish inventor of the steam hammer.[38] The second example, concerning the case of a foreign inventor patenting both in Britain and in France, is epitomized by the patent granted to the American Robert Fulton, the inventor of the steam boat, on the 17th of February 1798 for a "*canaux navigables sans écluses, au moyen de plans inclinés et de petits bateaux de forme nouvelle*", because this inventor was granted an English patent (in this case for an analogous invention) in 1794. Fulton actually worked in England in the period 1786-1797 and in France in the period 1797-1804.

ii) **British connection (BC)**: this variable is a dummy indicating, in the case of all patents not of British origins, that the patentee is a French resident that had already been involved in a patent with British origins either collaborating with the inventors of the BO patent or via a patent agent involved in a BO patent. Considering the patent agent as possible channel of transmission of technology flows is indeed fully in line with accounts of French industrialization that have stressed their critical role as brokers of technologies in this period.[39] For example, the variable includes the patent granted on the 12th May 1842 for "*perfectionnements apportés aux machines à vapeur fixes ou locomotives*" granted to Benoit Fourneyron, the famous inventor of a successful hydraulic turbine, because Fourneyron, by that time, had already taken several patents via the mediation of the patent agent Antoine Perpigna who, in turn, had been involved in several BO patents. Vice versa, the famous patent on the hydraulic turbine *("roue à pression universelle et continue, ou turbine hydraulique de Fourneyron")* granted to Fourneyron on the 24th October 1832 is not considered as a BC patent, because it was taken before the contact of this inventor with Antoine Perpigna.

iii) **Encyclopédie subscriptions**: this variable is constructed as the number of subscriptions per capita of the first quarto edition of the *Encyclopédie* in the location of the patentee (in case of patents taken by inventors with different residences, it takes the value of the location with

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[38] In his autobiography, Nasmyth (1883) describes a number of travels and contacts with the French business world (in particular with the ironworks of *La Creusot*).

[39] The most important patent agents involved in the importation of foreign technologies in this period were Charles and Jacques-Eugène Armengaud, Antoine Perpigna and Louis H.J. Truffaut. For a compact description of their activities, see Peyre (1994). On the role of patent agents see also Cotte (2010b). In 1839, Perpigna (1839) published a volume devoted to the illustration of the most important inventions patented abroad.

the largest number of subscriptions).[40] The *Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des métiers*, edited by Denis Diderot and Jean le Rond D'Alembert was without doubt the publishing triumph of the Enlightenment. The aim of the authors was to provide an effective 'search engine' to the existing stock of useful knowledge (Mokyr 2005, p. 307). The publication of the first edition run between 1751 and 1765. Several republications followed suit, allowing a relatively widespread circulation of this monumental work (Darnton 1979). Squcciarini and Voigtlander (2015) have used the number of subscribers of the *Encyclopédie* as an indicator of the upper-tail human capital, which means the presence of knowledge elites and, more broadly, of the density of the "enlightenment culture" in the location in question. This variable is of particular interest in the context of this paper since Squicciarini and Voigtlander (2015) argue that one distinguishing feature of the *Encyclopédie* was to provide a detailed illustration of technical advances taking place in Britain.

iv) **Number of patentees**: this variable denotes the number of patentees who have registered a single patent. The aim is to capture the possible influence of scale effects of the inventors' team.

v) **Experience**: this variable measures the number of patents taken by the patentee before the patent in question. In case of multiple patentees, this variable takes the value of the patentee with the maximum experience.

vi) **Famous inventor**: this variable measures the 'historical significance' of the patentee, ranging between 0 to 4 as explained in the previous section. Again, in case of multiple patentees, the variable considers the highest score.

vii) **Award**: this variable is a dummy that considers whether the patentee in question received an award from the *Societe d'Encouragement pour l'Industrie Nationale*.

viii) **Engineer/Scientist**: this is a dummy variable that indicates whether the occupation of one of the patentees was that of engineer or a similar professional (HISCO class 2). In this period, in France the profession of engineer was already characterized by a formalized educational qualification. There were two main type of engineering education: the famous

[40] We would like to thank Mara Squicciarini and Nico Voigtlander for providing us with the data on the *Encyclopédie* subscribers.

grand ecoles that provided engineers mostly for the army and other state departments, and the *ecoles d'arts et métiers* (introduced in 1803) that were more focused on the formation of engineers for the private sectors (Day, 1978). [41] In both schools, the curricula were closely supervised by the State and featured a highly intensive theoretical training. In contrast, in Britain there was not a formalized national system of engineering education and the training took place mainly by means of on-the-job apprenticeships (Hanlon 2020).

ix) **Skilled worker**: this is a dummy variable that indicates whether a patentee was a foreman, an artisan or a similarly skilled worker (HISCO class 6). In the English context, a significant stream of literature has emphasized the critical role played by artisans in developing incremental inventions with large productivity impact (Kelly, Mokyr and O'Grada 2020). In contrast, for the French case, there are no quantitative analysis of the contribution of skilled workers to inventive activities.

x) **High tech sector**: is a dummy that indicates whether the patent belong to what can be regarded, in the period in question, as sectors characterized by rapid rates of technical progress, namely steam engines and engines (class 3), textile machines and fabrics (class 4), navigation (class 6) and metallurgy (class 8).

xi) **Rouen-Geneva line**: this variable, possibly capturing the effect of geographical proximity to England, takes value 1 when at least one of the patentees was resident North of the Rouen-Geneva line.

Table 4 presents a number of regressions in which the dependent variable is the real duration (measured in days) of a patent. Column (5) contains a regression which does not consider withdrawn patents (in this case the sample amounts to 9,698 patents, instead of 12,573 of the total sample). Columns (6), (7) and (8) contain specifications controlling for department fixed effects absorbing all unobserved characteristics that do not vary over time.

Table 4 about here

We find that in the variable **British origins (BO)** is significant and positive in all specifications. The estimated effect ranges between 747 and 1,204 days. It is worth noting that

[41] For a useful overview of the development of technical education in France, see Kindelberger (1973).

this intensive technology transfer took place by virtue of the activities of patent agents: 80% of the patents with **British Origins** featured the active involvement of a patent agent. The coefficient of the variable **British connection (BC)**, among the largest, is also positive and significant in all the specifications. In this latter case the estimated effect ranges between 354 and 530 days, pointing towards a very sizeable impact of British connections on patent quality – albeit lower than in the BO case. The coefficient of the variable **Encyclopédie subscriptions** is negative, even if the effect is tiny (the order of magnitude is between 2 to 3 additional days of duration for a variation of 10 subscriptions per capita). Curiously, the coefficient – still approaching zero – turns positive (2 additional days) in the regressions estimated for the sample without withdrawn patents (columns 5 and 8). A possible interpretation of this result is that locations with higher density of subscriptions were also characterized by a more intense economic activity and/or abundance of legal professionals leading to more forceful patent litigation and opposition. In the context of our data, it is likely that the notion of "upper-tail" human capital is better captured by the variable **Engineer/scientist**, rather than the density of Encyclopédie subscriptions. These findings are robust to the inclusion of department/period fixed effects and sectoral dummies.

Concerning the other co-variates, we find that the size of the team that registered a patent (**number of patentees**) is generally not a significant predictor of patent quality. This result is in line with the findings of Nuvolari and Tartari (2011) on English patents in the same period. The coefficient of the variable **experience** is positive and significant, although this result does not seem very robust, and the effect is relatively small. The coefficients of the variables **famous inventor** and **award** are both positive and significant and they have a sizable effect: being between 289 and 348 days for the former and between 403 and 470 days for the latter. These results show that the findings reported in Table 2 carry on within a multivariate regression setting, further corroborating our indicator of patent quality. The coefficient of the variable **engineer/scientist** is positive and significant, indicating an important role of relatively sophisticated engineering competences for the development of high quality innovations. On the other hand, the coefficient of the variable **skilled worker** is negative and significant at the 5% level, which may suggest a scarcity of skilled workers acquainted with the implementation of modern industrial machineries as also testified by the intense migration flow from Britain to France of high quality craftsmen (Kelly, Mokyr and O'Grada 2014).[42] This picture is also consistent with the view that the crucial needs of modern manufacturing, even before the rise of the science-based sectors in the second half of the 19th century, were met more by a growing science-oriented and highly educated elite than through more traditional models of apprenticeship (Fox 2012).

The coefficient of the variable **high tech sectors** is positive and significant, as one would have expected. Finally, it is interesting to note that the coefficient of the variable **Rouen-Geneva** is not significant. This can be interpreted as an indication of the relative importance of direct social contacts, measured by the variable **British Connection (BC)**, rather than the mere geographical proximity to England for technology transfer.[43]

As a general robustness check of our analysis, Table 5 presents a number of regressions that use alternative indicators of patent quality as dependent variables. In particular, we consider the total cost of the patent in French francs, both without additions (columns 1 and 5) and with additions (columns 2 and 6). Furthermore, we also validate our findings by using the simpler indicator of patent value constructed as a simple score of 1 when the patent has a duration of 5 years, of 2 when the patent as a duration of 10 years and of 3 when the patent has a duration of 15 years (columns 3, 4, 7 and 8). This exercise is useful in order to rule out that our findings are a spurious outcome of the noise which most likely affects our indicators of patent quality constructed in terms of days or monetary value. In this case, we estimate an ordered logit regression model.

Table 5 about here

Table 5 confirms the results of Table 4. The significance and magnitude of the estimated effects, in particular of the two key variables of interest **British Origins (BO)** and **British**

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[42] As noted by Kelly, Mokyr and O'Grada (2014, p. 376), French workers, thanks to the direct contact with British immigrants, were quickly to develop the skills to manage modern technologies.
[43] In Table A8 in the Appendix, we run the same regressions excluding the *Seine* department. Results hold, mostly unchanged in their substance.

Connection (BC), are fully confirmed. Again, these results are robust to the inclusion in the specification of department fixed effects, sectoral dummies and time effects.

The literature on French industrialization (Crouzet 1996) has pointed out that before being adopted to the French economic context, British technologies had to be tailored and non-trivially modified because the factor endowments of the two countries differed. In this paper, we provide new insights on this issue by studying the relationship between the distribution of patents across technologies in the 'exporting' country (Britain) and that in the 'receiving' country (France). We use the indicator of technological distance suggested by Bar and Leiponen (2012). The aim of this indicator is to provide a measure of the distance between two patent 'portfolios' distributed over K different industries. The indicator is computed as follows:

$$TD_{ij} = 1 - \sum_{k=1}^{K} \min(p_{i,k} \, p_{j,k})$$

where TD_{ij} denotes the technological distance between the patent portfolios *i* and *j* while $p_{i,k}$ and $p_{j,k}$ indicate the share of patents in industry k in portfolio *i* and *j* respectively. The indicator is equal to 0 when the sectoral distribution of the patent portfolio is perfectly equal, while it is equal to 1 (which is the maximum distance) when there is no overlap in the sectoral distribution of the two patent portfolios.

Table 6 reports our findings on the technological distance of patents of different origins.

Table 6 about here

In the upper panel of Table 6, we use a 17-industry classification which allows to integrate the 21-industry classification for English patents constructed by Nuvolari and Tartari (2011) with the 20 industry classification for French patents adopted in this paper. The matching is not perfect, since the criteria used to allocate patents in the different classes reflect the features of the original sources.[44] Even with this caveat, the results are insightful. Indeed,

[44] The 1853 French technological classification is mainly based on a sector of use approach, while the English classification adopts a combination of sector of use and industry of manufacture approach. For a discussion of this issue, see Nuvolari and Vasta (2020).

the technological distance is minimal between the English technological frontier (represented by all English patents) and British origins patents in France; it is intermediate between the English technological frontier and the British connections patents; and it is maximum between the English technological frontier and the entire distribution of patents granted in France. The lower panel of Table 6 contains a study of technological distance using only the French patent sample (structured in 20 patent classes). In this case, the criteria for allocating patents in different classes are homogeneous and, for this reason, the results are probably to be regarded as more accurate. The reference point from which the distance is computed is the entire French patent sample. Reassuringly, the results of the upper and lower panels of Table 6 are fully consistent. Indeed, the lower panel shows that the distance between the entire French patent sample and British connection patents is minimal and that between the entire French patent sample and British origins patents is much higher.

A possible interpretation of Table 6 is that British origins patents mirrored the sectoral distribution of the English technological frontier and, for this reason, they were probably an attempt to transfer directly British inventions in France. Instead, British connection patents, in terms of sectoral distribution, had an intermediate position between the English technological frontier and overall French patenting. Intriguingly, a possible explanation of this results is that British connected inventors were actually involved in attempts to adapt British technologies to French local conditions. For example, several French inventors focused on the improvements and development of water-power technologies, expanding on the work carried out by John Smeaton and John Rennie in England during the 18th century. These efforts culminated in the development of the water-turbine by Benoit Fourneyron in 1837, which provided an effective alternative solution to steam power in coal expensive regions such as France and New England (Mokyr 1990, pp. 90-92). Even, in the case of an iconic British technology, such as the steam engine, French inventors were capable of introducing significant improvements that enhanced the fit of the technology to the French context. In the first half of the 19th century, the most common engine in French mills was the high-pressure Woolf compound engine, which have been imported from England by Humphrey Edwards by means of a French patent of importation granted on the 17th of May 1815. In comparison with the Watt-low pressure engine

– which remained the standard technology in British manufacturing districts until the 1840s –, the Woolf engine permitted substantial fuel savings. By 1824, some 300 engines of the Edwards-Woolf design had already been installed in France. Additionally, this design was further improved during the 1820s and 1830s in France (Nuvolari 2010). It is also interesting to notice that, according to Fox (1986), the adaptation of British technology to the French context had the effect to stimulate major scientific development such as the formulation of the Carnot's theorem of thermodynamics. A similar pattern of rapid introduction followed by streams of domestic improvements characterized the importation of steel making technologies using coke in France. In this case, the patent of importation granted to James Jackson on the 26th of January 1819 was complemented by a special grant of the government. According to Horn (2006, p. 256), the investment "paid impressive dividends for national industrial performance and international competitiveness".

6. Conclusions

In this paper we have provided a thorough quantitative assessment of the French patenting activities from the Revolution to 1844, when a new law substantially changed the patent system. Although the cost of patenting in France was between two extremes – the very cheap American system and the very expensive British one –, patenting activity was intense and relatively accessible to lower social classes, such as artisans and medium skilled workers. Furthermore, the high share of 'one-off' patentees seems to indicate a degree of openness similar to that of the "democratic" United States patent system. This characterization seems to be in contrast with Khan (2020) who painted an elitist picture of the French patent system claiming that it was only accessible to the wealthy classes. In this respect, our findings cast the functioning of the French patent system in a much more favorable light than previously thought.

Considering technology transfer, in the case of the early industrialization of the United States, several contributions have emphasized the role of discriminatory clauses against foreign inventors, with American inventors incentivized to patent small adaptations and modifications of British technologies (Mowery 2010).[45] Interestingly, rather than adopting discriminatory clauses, the French policy tried to foster technology inflows by granting complete access to the patent system to foreign inventors. Our results indicate that France was able to import high-quality technologies from Britain, by means of this non-discriminatory approach. This is not a trivial finding: in the same period, foreign technologies imported into Britain, where the access to the patent system was much more expensive and selective, were of lower quality than domestic inventions (Nuvolari and Tartari 2011). This evidence also suggests a general attractiveness of the French context characterized by both the crucial role of patent agents – able to select valuable technologies and to help foreign inventors to navigate effectively into the patent system – and the ability of French engineers and skilled workers to implement foreign technologies. Moreover, our finding shows that French inventors involved in technology transfer were capable of developing valuable inventions and adapt them to the local context, possibly as a direct result of personal contacts with their British counterparts.

Our results also offer a positive assessment of French investments in engineering education (Fox 2012). Indeed, we show that inventors with this type of educational background were more likely to produce valuable patents than artisans or workers. In this perspective, we can speculate that the French set of institutions impinging on scientific and technological activities (the national innovation system) was characterized by significant complementarities that enhanced its overall effectiveness. These findings seem to be in line with the results of Squicciarini and Voigtlander (2016) who suggested that upper-tail human capital played a critical role in fostering French industrial growth during a period of rapid expansion of the technological frontier.

In this way, our paper is consistent with a representation of France as close to the Britain leadership in terms of major technological discoveries and inventions for the whole 19th century as already shown in Figure 1. Further evidence of a creditable French technological performance is also provided by Moser (2002), who shows that France was by far the first

[45] Another interesting case of the use of discriminatory measures against foreign inventors for improving technological competitiveness in the first half of the 19th century is the German state of Wuerttemberg (Lehmann-Hasemeyer and Streb 2021).

visiting country in the ranking of number of medals per capita at the Crystal Palace Exhibition in 1851. At the same Exhibition, as far as the high-tech industry of scientific instruments is concerned, France was the leading country after Britain (Brenni 2010). Trade data indicate that France was the largest importer of machinery from Britain in the early 1840s, confirming that by that period, France had attained significant capability in adopting and using sophisticated industrial technologies (Bruland 1989, p. 149).

Despite our findings provide innovative elements that corroborate a more optimist view of the French industrialization, further research is needed to reassess this issue. First, a comprehensive investigation of the effectiveness of interventionist policies a là Chaptal adopted by the French state is still missing. Second, a quantitative analysis of the French patent system in the second half of the 19th century could lead a broader understanding of French technological performance in the long run.

References

Adams, D. (1968), 'Wage rate in the early national period: Philadelphia, 1785-1830', *Journal of Economic History,* 28(3), pp. 404-426.

Allen, R.C. (2009), 'The industrial revolution in miniature: the spinning jenny in Britain, France and India', *Journal of Economic History,* 69(4), pp. 901-927.

Allen, R.C. (2011), 'The spinning jenny: a fresh look', *Journal of Economic History,* 71(2), pp. 461-464.

Bar, T. and Leiponen, A. (2012), 'A measure of technological distance', *Economics Letters*, 116, pp. 457-459.

Baudry, J. (2019), 'Examining inventions, shaping property: the savants and the French patent system', *History of Science,* 57(1), pp. 62-80.

Baudry, J. (2020), 'A politics of intellectual property: the French Revolution and the creation of a patent system', *Technology and Culture,* forthcoming.

Bottomley, S. (2014), *The British Patent System during the Industrial Revolution, 1700-1852*, Cambridge: Cambridge University Press.

Braudel, F. (1984), *The Perspective of the World. Civilization and Capitalism 15th-18th Century*, London: Phoenix Press.

Brenni, P. (2010), "La science française au Crystal Palace", *Documents pour l'histoire des techniques,* 19(2), pp. 255-265.

Bruland, K. (1989), *British Technology and European Industrialization. The Norwegian textile industry in the mid nineteenth century*, Cambridge: Cambridge University Press.

Brunt, L., Lerner, J. and Nicholas, T. (2012), 'Inducement Prizes and Innovation', *Journal of Industrial Economics*, 60(4), pp. 657-696.

Clapham, J.H. (1921), *The Economic Development of France and Germany, 1815-1914*, Cambridge: Cambridge University Press.

Cotte, M. (2010a), 'Le role des ouvriers et entrepreneurs britanniques dans le décollage industriel francais des années 1820', *Documents pour l'histoire des techniques,* 19(2), pp. 119-130.

Cotte, M. (2010b), 'La diffusion des techniques pendant la «revolution industrielle». Les comportements de veille et le role des échanges intenatiounaux', *Traverse: Zeitschrift fur Geschichte*, 17, pp. 21-36.

Crafts, N. (1984), 'Economic growth in France and Britain, 1830-1910. A review of the evidence', *Journal of Economic History,* 44(1), pp. 49-67.

Crawford, S. (1996), "The making of the French Engineer", in P. Meiskins and C. Smith (eds), *Engineering Labour*. *Technical workers in comparative perspective*, London: Verso, pp. 98-131.

Crouzet, F. (1996), 'France' in M. Teich and R. Porter (eds.), *The Industrial Revolution in National Context*, Cambridge: Cambridge University Press.

Crouzet, F. (2003), ‘The historiography of French economic growth in the nineteenth century’, *Economic History Review,* 56(2), pp. 215-242.

Darnton, R. (1979), *The Business of the Enlightenment: A Publishing History of the Encyclopedie, 1775-1800*, Cambridge (MA): The Belknap Press of Harvard University Press.

Day, C. R. (1978), ‘The making of mechanical engineers in France: the *Ecoles d’Arts et Métiers*, 1803-1914’, *French Historical Studies,* 10 (3), pp. 439-460.

Dutton, H. I. (1984), *The patent system and inventive activity during the industrial revolution, 1750-1852,* Manchester: Manchester University Press.

Empotz, G. and Marchal, V. (2002), *Aux sources de la propriété industrielle: guides des archives de l’Institut National de la Propriété Industrielle*, Paris.

Fox, R. (1986), ‘Introduction’, in S. Carnot, *Reflextions on the motive power of fire. A critical edition with the surviving scientific manuscripts*, Manchester, Manchester University Press, pp. 1-57.

Fox, R. (2012), *The Savant and the State. Science and cultural politics in nineteenth France*, Baltimore, John Hopkins University Press.

Galvez-Behar, G. (2019), ‘The patent system during the French Industrial Revolution: institutional change and economic effects’, *Jahrbuch fur Wirtschaftsgeschichte,* 60(1), pp. 31-56.

Gergaud, O., Louenan, M. and Wasmer, E. (2016), ‘A Brief History of Human Time. Exploring a database of “notable people” (3000BCE-2015AD) Version 1.0.1’, *Sciences Po Economics Discussion Papers*, no. 2016-03.

Gragnolati, U., Moschella, D. and Pugliese, E. (2011), ‘The spinning-jenny and the Industrial Revolution: a reappraisal’, *Journal of Economic History,* 71(2), pp. 455-460.

Grinin, L. and Korotayev A. (2015), *Great Divergence and Great Convergence. A Global Perspective*, Heidelberg, Springer.

Hanlon, W. (2020), “The Rise of the Engineer: Inventing the Professional Inventor During the Industrial Revolution”, *mimeo*.

Harris, J.R. (1998), *Industrial Espionage and Technology Transfer. Britain and France in the eighteenth century.* London: Routledge.

Henderson, W.O. (1972), *Britain and Industrial Europe, 1750-1870*, Leicester: Leicester University Press.

Higham, K.W., de Rassenfosse, G. and Jaffe, AB. (2020), ‘Patent quality: towards a systematic framework for analysis and measurement’, *NBER working paper*, no. 27598.

Hilaire-Perez, L. (1991), ‘Invention and the State in eighteenth century France’, *Technology and Culture,* 32(4), pp. 911-931.

Hilaire-Perez, L. (2000), *L’invention technique aux siècle des Lumieres*, Paris: Albin Michel.

Horn, J. (2006), *The Path not taken. French Industrialization in the Age of Revolution*, Cambridge (MA): MIT Press.

Jeremy, D.J. (1973), 'British textile technology transmission to the United States: the Philadelphia region experience, 1770-1820', *Business History,* 47(1), pp. 24-52.

Jeremy, D.J. (1977), 'Damning the flood: British government efforts to check the outflow of technicians and machinery, 1780-1843', *Business History,* 51(1), pp. 1-34.

Juhasz, R. (2018), 'Temporary protection and technology adoption: evidence from the Napoleonic Blockade', *American Economic Review,* 108(11), pp. 3339-3376.

Kelly, M., Mokyr, J. and O'Grada, C. (2014), 'Precociuos Albion: A New Interpretation of the British Industrial Revolution', *Annual Review of Economics*, 6, pp. 363-389.

Kelly, M., Mokyr, J. and O'Grada, C. (2020), "Could artisans have caused the Industrial Revolution?", in K. Bruland, A. Gerritsen, P. Hudson and G. Riello (eds), *Reinventing the Economic History of Industrialization*, Montreal: McGill-Queen's University Press, pp. 25-43.

Khan Z. (2005), *The Democratization of Invention: Patents and Copyrights in American Economic Development, 1790-1920*, Cambridge: Cambridge University Press.

Khan, Z. (2008), 'An Economic History of Patent Institutions', R. Whaples (ed.), *EH.Net Encyclopedia*, http://eh.net/encyclopedia/an-economic-history-of-patent-institutions/.

Khan, Z. (2016), 'Invisible Women: Entrepreneurship, Innovation, and Family Firms in Nineteenth France', *Journal of Economic History*, 76(1), pp. 163-195.

Khan, Z. (2020), *Inventing Ideas: Patents, Prizes and the Knowledge Economy*, New York, Oxford University Press.

Khan, Z., Sokoloff, K. (1993), 'Schemes of Practical Utility': entrepreneurship and innovation among 'Great Inventors' in the United States, 1790–1865', *Journal of Economic History*, 53(1), pp. 289-307.

Khan Z. and Sokoloff, K. (2006), 'Institutions and Technological Innovation During Early Economic Growth: Evidence from the Great Inventors of the United States, 1790-1930', in T. Eicher and C. Garcia-Penalosa (eds), *Institutions and Economic Growth*, Boston, MIT Press, pp. 123-158.

Kindleberger, C. (1973), 'Scientific education and the French entrepreneur', MIT Working Paper – Department of Economics, n. 104.

Landes, D. S. (1949), 'French entrepreneurship and industrial growth in the Nineteenth Century', *Journal of Economic History,* 9(1), pp. 45-61.

Landes, D. S. (1969), *The Unbound Prometheus. Technological Change and Industrial Development in Western Europe from 1750 to the Present,* Cambridge: Cambridge University Press.

Lehmann-Hasemeyer, S. and Streb, J. (2021), 'Discrimination against Foreigners: The Wuerttemberg Patent Law in Administrative Practice', *Journal of Economic History,* doi: 10.107/S002205072000479.

Maddison, A. (2003), *The World Economy: Historical Economics*, Paris, OECD.

MacLeod, C., Tann, J., Andrew, J and Stein, J. (2003), 'Evaluating inventive activity: the cost of nineteenth century UK patents and the fallibility of renewal data', *Economic History Review,* 56(4), pp. 537-562.

Mokyr, J. (1990), *The lever of riches. Technological creativity and economic progress*, New York-Oxford, Oxford University Press.

Mokyr, J. (2005), 'The intellectual origins of modern economic growth', *Journal of Economic History,* 65(2), pp. 285-351.

Moser, P. (2002), *The Determinants of Innovation. New Evidence from Nineteenth-Century World Fairs*, Phd thesis, University of California, Berkeley.

Moser, P. (2012), 'Innovation without patents: evidence from world's fairs', *Journal of Law and Economics*, 55(1), pp. 43-74.

Moser, P. (2016), 'Patents and innovation in economic history', *Annual Review of Economics,* 8, pp. 241-258.

Mowery, D. (2010), 'IPR and US economic catch-up' in H. Odagiri, A. Goto, A. Sunami and R. Nelson (eds), *Intellectual Property Rights, Development and Catch-Up. An International Comparative Study*, Oxford: Oxford University Press, pp. 31-62.

Murray, C. (2003), *Human Accomplishment. The pursuit of excellence in the arts and sciences, 800 B.C. to 1950*, New York: Harper and Collins.

Nagaoka, S., Motohashi, K., and Goto, A. (2010), 'Patent statistics as an innovation indicator', in B.H. Hall and N. Rosenberg (eds), *Handbook of the economics of innovation*, vol. 1, Amsterdam: North Holland, pp. 1083–1127.

Nasmyth, J. (1883), *James Nasmyth Engineer. An Autobiography*, London: John Murray.

Nuvolari, A. (2010), 'The theory and practice of steam engineering in Britain and in France, 1800-1850', *Documents pour l'histoire des techniques,* 19(2), pp. 177-185.

Nuvolari, A. and Vasta, M. (2015), 'Independent invention in Italy during the Liberal Age, 1861-1913', *The Economic History Review*, 68(3), pp. 858-886.

Nuvolari, A. and Vasta, M., (2017), 'The Geography of Innovation in Italy, 1861-1913: Evidence from Patent Data', *European Review of Economic History,* 21(3), pp. 326-356.

Nuvolari, A. and Vasta, M., (2020), *Pavitt's Taxonomy in Historical Perspective: Evidence from Italian Industrialization, 1861-1936*, mimeo.

O'Brien, P. and Keyder, C. (1978), *Economic Growth in Britain and France 1780-1914. Two Paths to the Twentieth Century.* London: Allen & Unwin.

Perpigna, A. (1832), *The French Law and Practice of Patents for Inventions, Improvements and Importations*, London: Newton & Berry.

Perpigna, A. (1839), *Repertoire de l'Industrie Etrangere ou Dessins et Descriptions des Machines le plus importantes brevetees a l'etranger*, Paris: Alphonse Monginot.

Peyre, P. (1994), 'Les Armengaud, la "petite ecole" et le developpement de l'innovation', *Les Cahiers de l'Histoire du CNAM,* 4, pp. 93-142.

Ridolfi, L. and Nuvolari, A. (2020), '*L'histoire immobile?* A reappraisal of French economic growth using the demand-side approach, 1280-1850', CEPR Discussion paper n. 14985.

Rosenberg, N. (1967), 'Anglo-American wage differences in the 1820s', *Journal of Economic History,* 27(2), pp. 221-229.

Schich, M., Song, C., Ahn, Y., Mirsky, A. Martino, M., Barabási, A., Helbing, D. (2014), 'A network framework of cultural history', *Science*, 345, pp. 558-562.

Serafinelli, M. and Tabellini, G. (2020), 'Creativity over Time and Space', CEPR, Discussion Paper, no. 12365.

Sharp, P. and Weisdorf, J. (2012), 'French revolution or industrial revolution? A note on the contrasting experiences of England and France before 1800', *Cliometrica,* 6, pp. 79-88.

Sokoloff, K. (1988), 'Inventive Activity in Early Industrial America: Evidence from Patent Records, 1791-1846', *Journal of Economic History,* 48(4), pp. 813-850.

Sokoloff, K. and Khan Z. (1990), 'The Democratization of Invention during Early industrialization: evidence from the United States, 1790-1846', *Journal of Economic History,* 50(2), pp. 363-378.

Squicciarini, M. and Voigtlander, N. (2015), 'Human capital and industrialization: evidence from the Age of the Enlightenment', *Quarterly Journal of Economics*, 130, pp. 1825-1883.

Streb, J. (2016), 'The Cliometric Study of Innovations', in Diebolt, C. and Haupert, M. (eds), *Handbook of Cliometrics*, Berlin-Heidelberg: Springer, pp. 446-468.

Streb, J., Baten, J., and Yin, S. (2006), 'Technological and geographical knowledge spillover in the German empire, 1877–1918', *Economic History Review*, 59(2), pp. 347–73.

Van Leeuwen, M., Maas, I. and Miles, A. (2002), *Hisco-Historical Standard Classification of Occupations*, Leiden: Leiden University Press.

Woodcroft, B. (1854), *Alphabetical Index of Patentees of Inventions*, London: G.E. Eyre and W. Spottiswoode.

Yu, A.Z., Ronen, S., Hu, K., Lu, T. and Hidalgo, C.A. (2016), 'Pantheon 1.0, a manually verified dataset of globally famous biographies', *Scientific data*, 3: 150075.

Table 1. Distribution of different patent quality indicators

Duration (years)	No.	%	Total value (French francs)	No.	%	Real duration (days)	No.	%
5	6,547	52.1	**0-350**	5,545	44.1	**0-1,000**	1,275	10.1
10	3,415	27.2	**351-849**	1,002	8.0	**1,001-2,000**	6,273	49.9
15	2,611	20.8	**850-1549**	3,415	27.2	**2,001-4,000**	2,856	22.7
			1550-2102	2,611	20.8	**4,000-5,479**	2,169	17.3
Total	12,573	100.0	**Total**	12,573	100.0	**Total**	12,573	100.0
Mean	8.4		**Mean**	745.0		**Mean**	2,699	
Median	5		**Median**	374.0		**Median**	1,826	

Table 2. Sources of relevant figures in human history used to identify important patentees

Dataset	Reference	Summary	No. records	Covered period
Pantheon	Yu et al. (2016)	Based on *Freebase.com* and *Wikipedia* in 277 language editions of different individuals. It focuses on globally famous individuals and it connects occupations and place and date of birth	74,620	4000 b.c. - 2010
Notable people	Gergaud, Louenan and Wasmer (2016)	Based on *Freebase.com* and *Wikipedia*. It focuses on notable people rather than only on the "very famous" with the aim to understand their economic impact	1,243,776	3000 b.c. - 2015
Human accomplishment	Murray (2003)	Based on 183 different sources. It contains inventories of people and events most important to the story of human accomplishment in the sciences and arts	19,794	800 b.c. - 1950
Notable individuals	Schich et al. (2014)	Based on *Freebase.com*. It contains deceased creative individuals with different professions (arts, humanities and sciences, business)	120,211	XI-XIX Centuries

Table 3. Real duration (days) for patents granted to famous and awarded inventors

Famous inventors	No.	Days (average)	Days (median)
0	12,426	2,687	1,826
1	90	3,552	3,652
2	42	4,200	5,478
3	6	2,889	2,740
4	9	4,342	5,478
Awarded inventors	**No.**	**Days (average)**	**Days (median)**
0	12,457	2,694	1,826
1	116	3,264	3,652

Table 4. Determinants of patent quality in France (Dependent variable: duration in days)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
British origins (BO)	1,204*** (49.72)	1,095*** (53.51)	1,099*** (53.35)	827.2*** (109.4)	1,072*** (48.27)	914.5*** (77.41)	841.6*** (78.40)	747.2*** (73.58)
British connection (BC)	396.5*** (85.74)	381.4*** (85.67)	354.1*** (87.08)	337.3*** (87.93)	530.0*** (88.25)	411.2*** (85.73)	395.4*** (85.94)	505.6*** (88.82)
Encyclopédie subscriptions		-0.232*** (0.0496)	-0.309*** (0.0489)	-0.175*** (0.052)	0.175*** (0.0527)		0.0403 (0.115)	0.285** (0.123)
Number of patentees		20.46 (28.18)	31.35 (28.32)	29.01 (28.88)	45.78 (29.79)		8.901 (28.40)	58.34* (30.14)
Experience		7.638* (4.044)	8.061** (3.974)	56.96*** (11.46)	5.788* (3.367)		7.278* (4.101)	3.906 (3.365)
Famous inventor		320.3*** (78.09)	338.2*** (77.55)	286.5*** (92.26)	302.8*** (71.88)		348.5*** (78.78)	318.5*** (72.30)
Award		441.2*** (160.6)	468.0*** (160.2)	488.5*** (164.0)	436.1*** (161.6)		403.3** (160.7)	421.3*** (160.2)
Engineer/Scientist		264.9*** (54.89)	325.7*** (54.19)	236.0*** (60.32)	420.5*** (55.60)		267.1*** (55.28)	408.2*** (56.01)
Skilled worker		-112.0** (43.82)	-148.9*** (42.94)	-102.0** (44.23)	-102.5** (48.55)		-102.1** (43.64)	-83.62* (48.46)
Period (1791-1815)	549.3*** (51.53)	543.4*** (51.28)	541.1*** (51.52)	557.1*** (53.48)	12.73 (52.76)	533.7*** (52.06)	518.7*** (51.78)	-37.39 (53.30)
Period (1816-1829)	279.7*** (34.26)	288.8*** (34.30)	277.2*** (34.39)	295.3*** (35.61)	-70.39* (36.08)	291.9*** (34.54)	294.0*** (34.52)	-74.01** (36.18)
High-tech sectors			319.7*** (31.08)					
Rouen-Geneva line				-33.60 (31.44)				
Technological classes	YES	YES	NO	YES	YES	YES	YES	YES
Department FE	NO	NO	NO	NO	NO	YES	YES	YES
Constant	2,587*** (58.72)	2,596*** (67.53)	2,445*** (40.65)	2,586*** (71.25)	2,956*** (71.90)	2,506*** (62.80)	2,452*** (83.40)	2,970*** (89.35)
Observations	12,573	12,573	12,573	11,355	9,698	12,573	12,573	9,698
R-squared	0.092	0.099	0.082	0.065	0.115	0.107	0.112	0.133

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Model (4) comprises only French resident patents; models (5) and (8) do not include withdrawn patents.

Table 5. Determinants of patent quality in France (alternative indicators of patent quality)

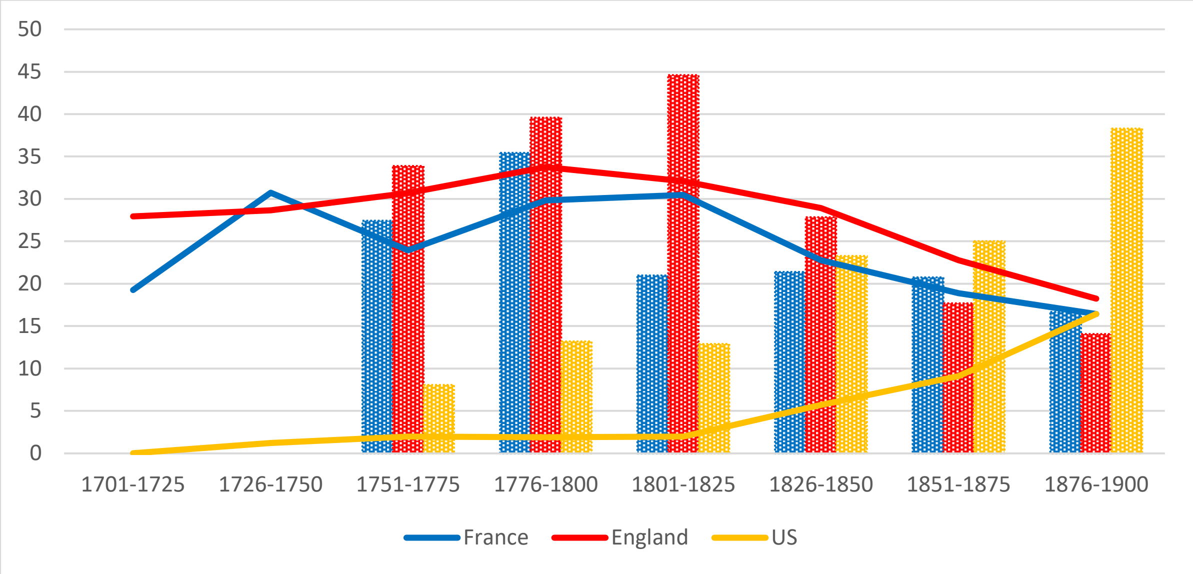
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variables	**Cost in French francs without additions**	**Cost in French francs with additions**	**Duration by class**	**Duration by class without withdrawn patents**	**Cost in French francs without additions**	**Cost in French francs with additions**	**Duration by class**	**Duration by class without withdrawn patents**
British origins (BO)	335.6*** (15.24)	332.2*** (15.41)	1.339*** (0.0584)	1.357*** (0.0635)	235.5*** (22.39)	235.9*** (22.71)	0.931*** (0.0872)	0.946*** (0.0977)
British connection (BC)	144.0*** (23.99)	145.8*** (24.46)	0.630*** (0.0979)	0.723*** (0.117)	140.2*** (24.08)	142.0*** (24.58)	0.629*** (0.0996)	0.710*** (0.119)
Encyclopédie subscriptions	0.0313** (0.0150)	0.0349** (0.0152)	8.99e-05 (6.61e-05)	0.000230*** (7.33e-05)	0.0498 (0.0341)	0.0525 (0.0345)	0.000188 (0.000154)	0.000386** (0.000182)
Number of patentees	14.86* (8.466)	13.78 (8.580)	0.0810** (0.0356)	0.0686* (0.0403)	17.66** (8.565)	16.85* (8.688)	0.0938*** (0.0364)	0.0883** (0.0413)
Experience	1.520 (1.106)	1.663 (1.132)	0.00725* (0.00390)	0.00437 (0.00387)	1.096 (1.116)	1.231 (1.140)	0.00572 (0.00396)	0.00216 (0.00386)
Famous inventor	108.4*** (23.06)	107.6*** (23.22)	0.456*** (0.120)	0.452*** (0.132)	114.5*** (23.12)	113.2*** (23.30)	0.488*** (0.121)	0.478*** (0.133)
Award	129.7*** (47.42)	141.2*** (49.18)	0.556*** (0.200)	0.635*** (0.231)	117.2** (47.18)	128.7*** (49.04)	0.498** (0.199)	0.611*** (0.229)
Engineer/Scientist	125.6*** (15.96)	129.6*** (16.31)	0.522*** (0.0646)	0.569*** (0.0741)	123.5*** (16.07)	127.3*** (16.43)	0.516*** (0.0657)	0.555*** (0.0756)
Skilled worker	-40.05*** (13.04)	-41.08*** (13.24)	-0.186*** (0.0634)	-0.144** (0.0720)	-34.32*** (13.03)	-35.40*** (13.24)	-0.167*** (0.0641)	-0.123* (0.0728)
Period (1791-1815)	58.56*** (16.57)	53.17*** (16.70)	0.206*** (0.0729)	-0.0121 (0.0765)	46.32*** (16.69)	41.04** (16.83)	0.153** (0.0741)	-0.0834 (0.0780)
Period (1816-1829)	17.59* (10.62)	15.04 (10.75)	0.0760 (0.0474)	-0.107** (0.0522)	18.05* (10.64)	15.23 (10.77)	0.0816* (0.0480)	-0.111** (0.0530)
Technological classes	YES	YES	YES	YES	YES	YES	YES	YES
Department FE	NO	NO	NO	NO	YES	YES	YES	YES
cut1			0.296*** (0.0860)	0.203** (0.0979)			0.286*** (0.109)	0.190 (0.127)
cut2			1.678*** (0.0876)	1.622*** (0.0996)			1.685*** (0.110)	1.630*** (0.128)
Constant	623.5*** (20.29)	683.0*** (20.57)			629.6*** (24.89)	690.0*** (25.21)		
Observations	12,573	12,573	12,573	9,698	12,573	12,573	12,573	9,698
R-squared	0.110	0.107			0.124	0.121		

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models 1-2 and 5-6 are OLS, models 3-4 and 7-8 are Ordered logistic regressions.

Table 6. Bar-Leiponen measure of technology distance by technological classes

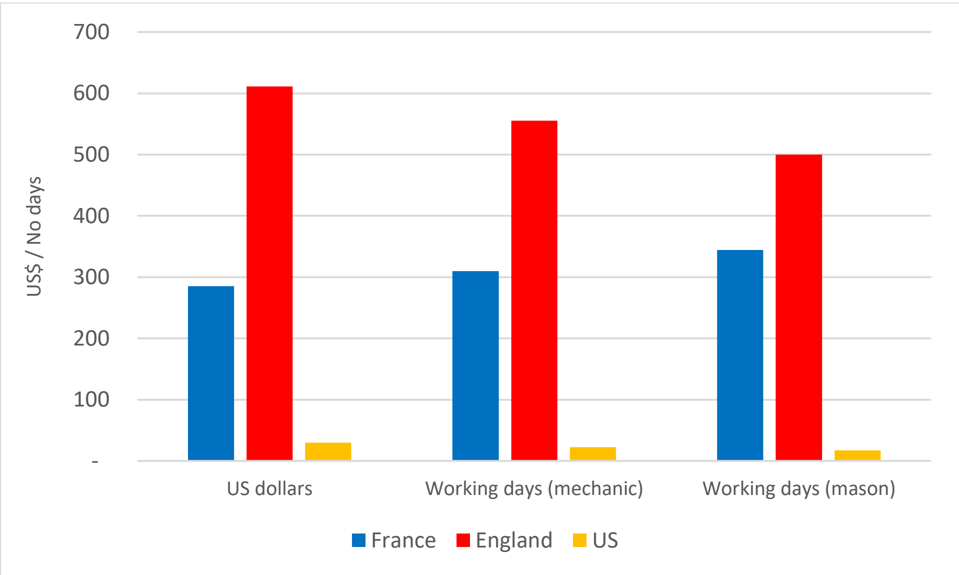
Technology distance (17 technological classes)	**Bar-Leiponen Index**
Patents in England – English patentees in France	0.133
Patents in England – French patentees with English collaborations	0.170
Patents in England – Patents in France	0.185
Technology distance (20 technological classes)	**Bar-Leiponen Index**
Patents in France – French patentees with English collaborations	0.116
Patents in France – English patentees in France	0.161

Figure 1. Share of world important scientific discoveries and inventions by countries (1700-1900)



Source: Sorokin (1947, vol. II, p. 150) lines and our own elaborations from Streit (1954, annex I, table I) bars.

Figure 2. Cost of patenting by country, about 1825-30



Source: the conversion rate in dollars is based on Rosenberg (1967). The wages of a mechanic are from Rosenberg (1967). The wage of masons in England (London) and in France (Paris) are from Allen (https://www.nuffield.ox.ac.uk/people/sites/allen-research-pages/), while for the US (Philadelphia) are from Mason (1968).

Figure 3. Number of patents granted in France by year (1791-1844)

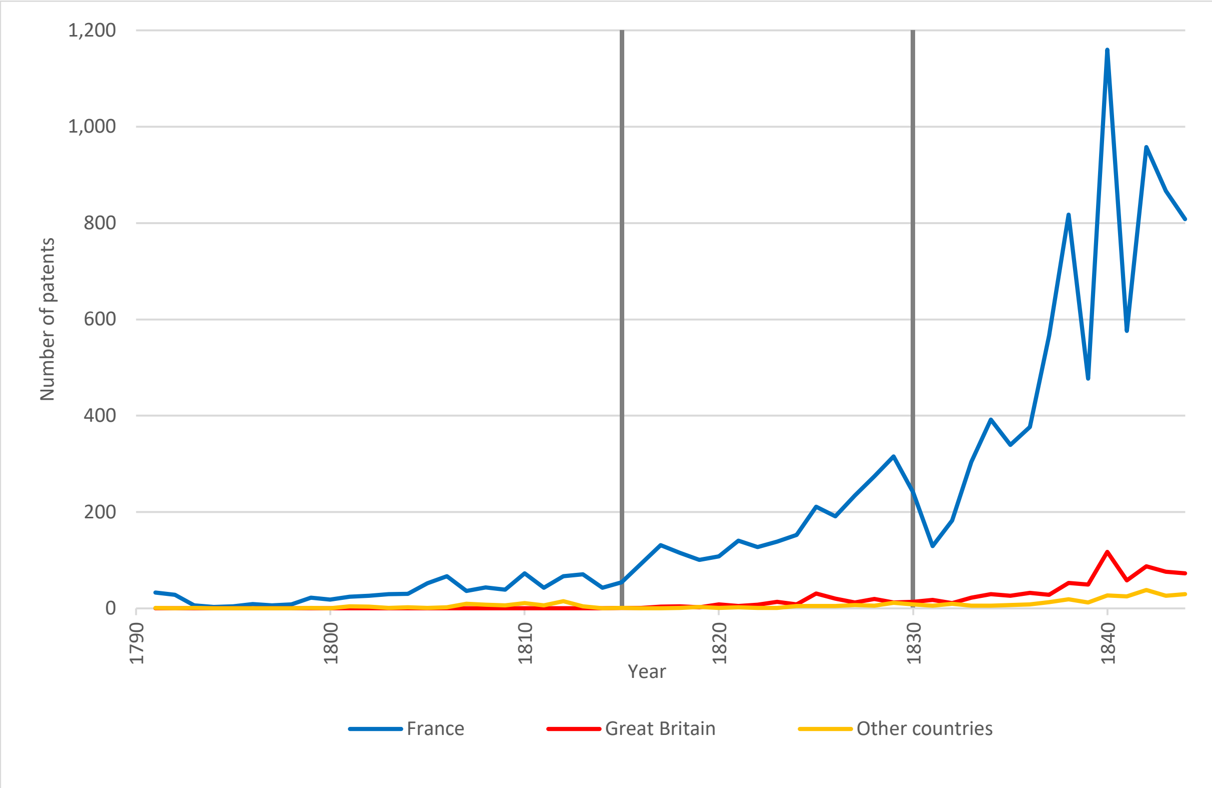


Figure 4. Geography of French patents (1791-1844)

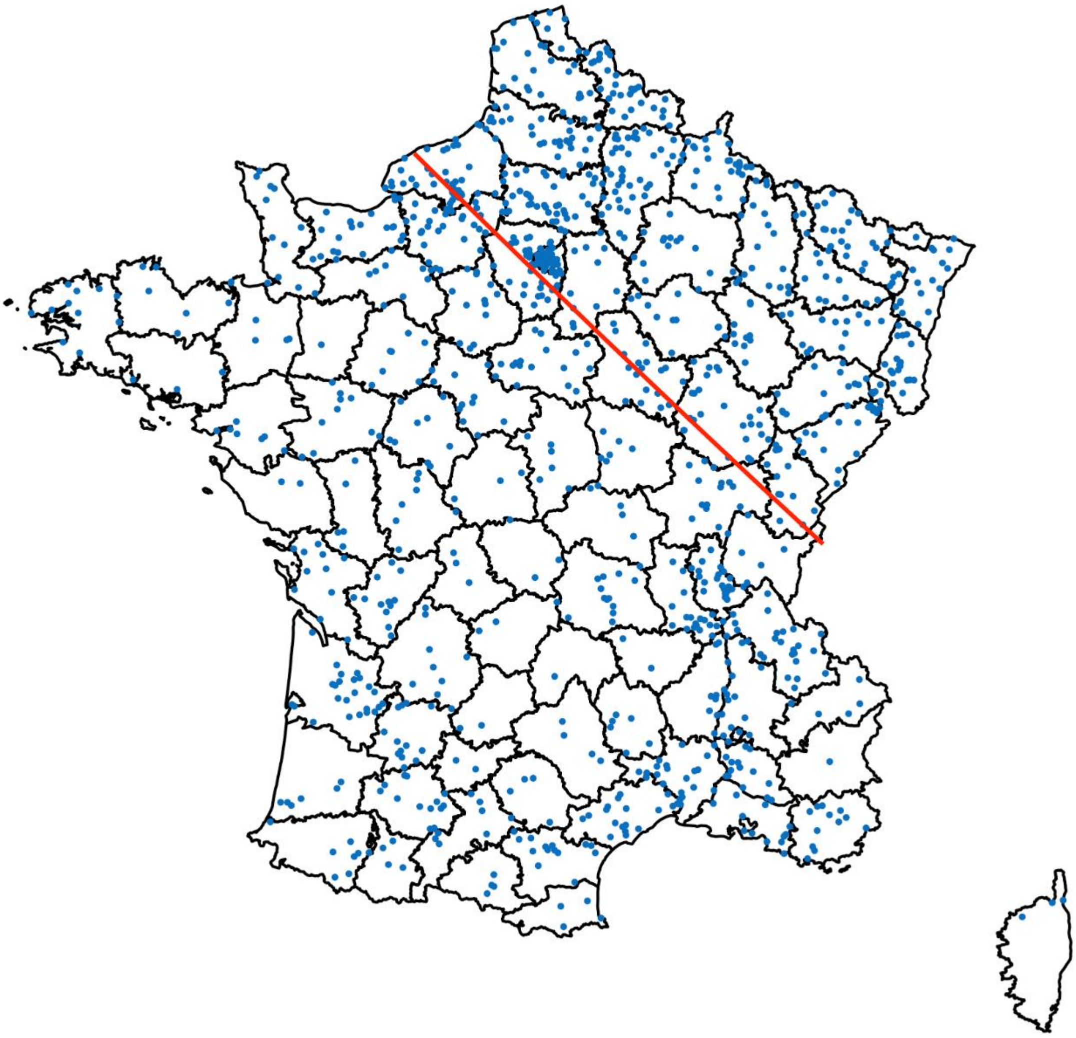


Figure 5. Number of patents granted in France by department (1791-1844)

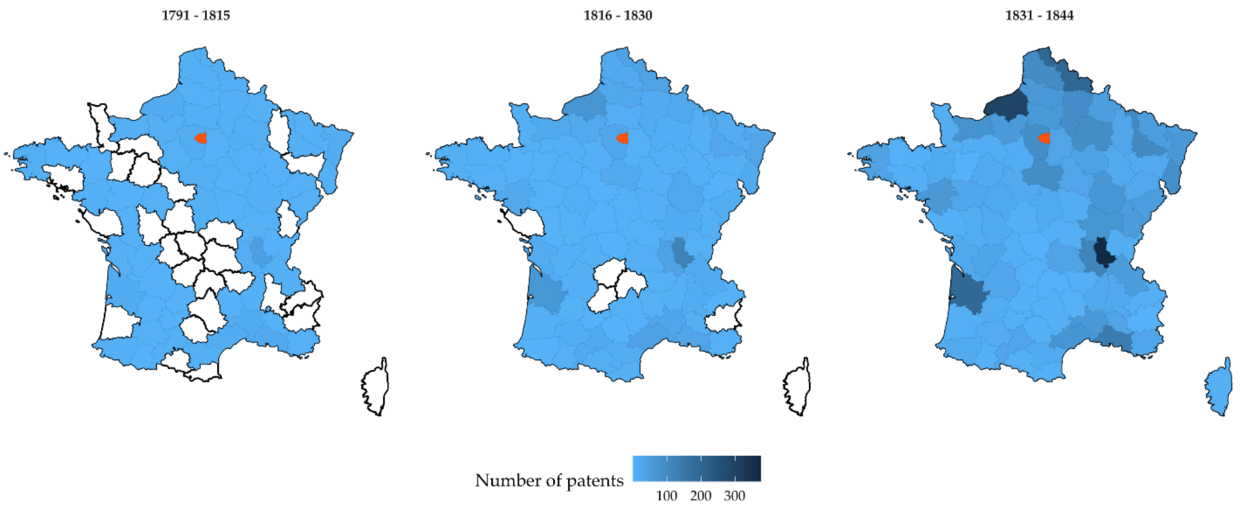
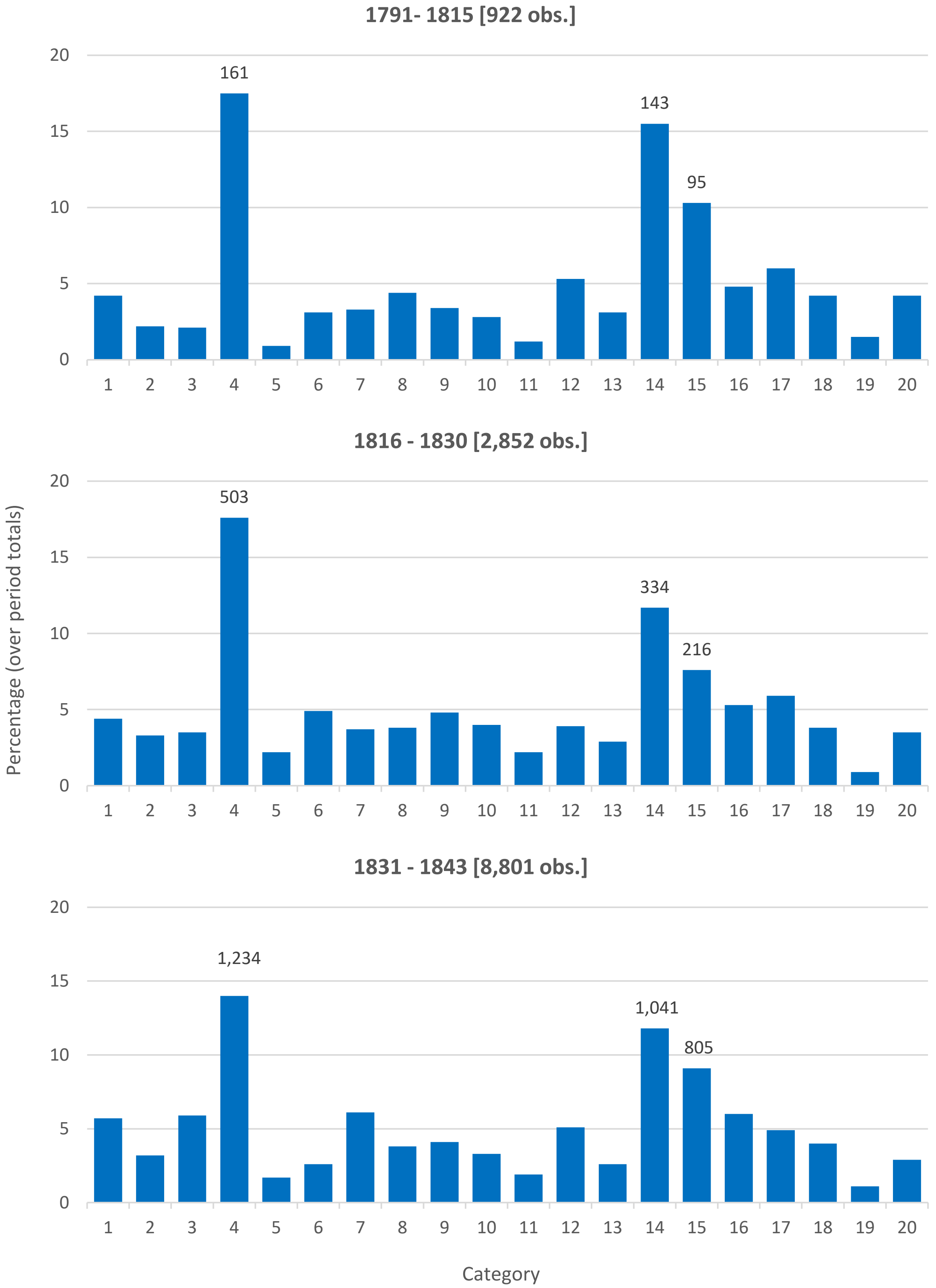
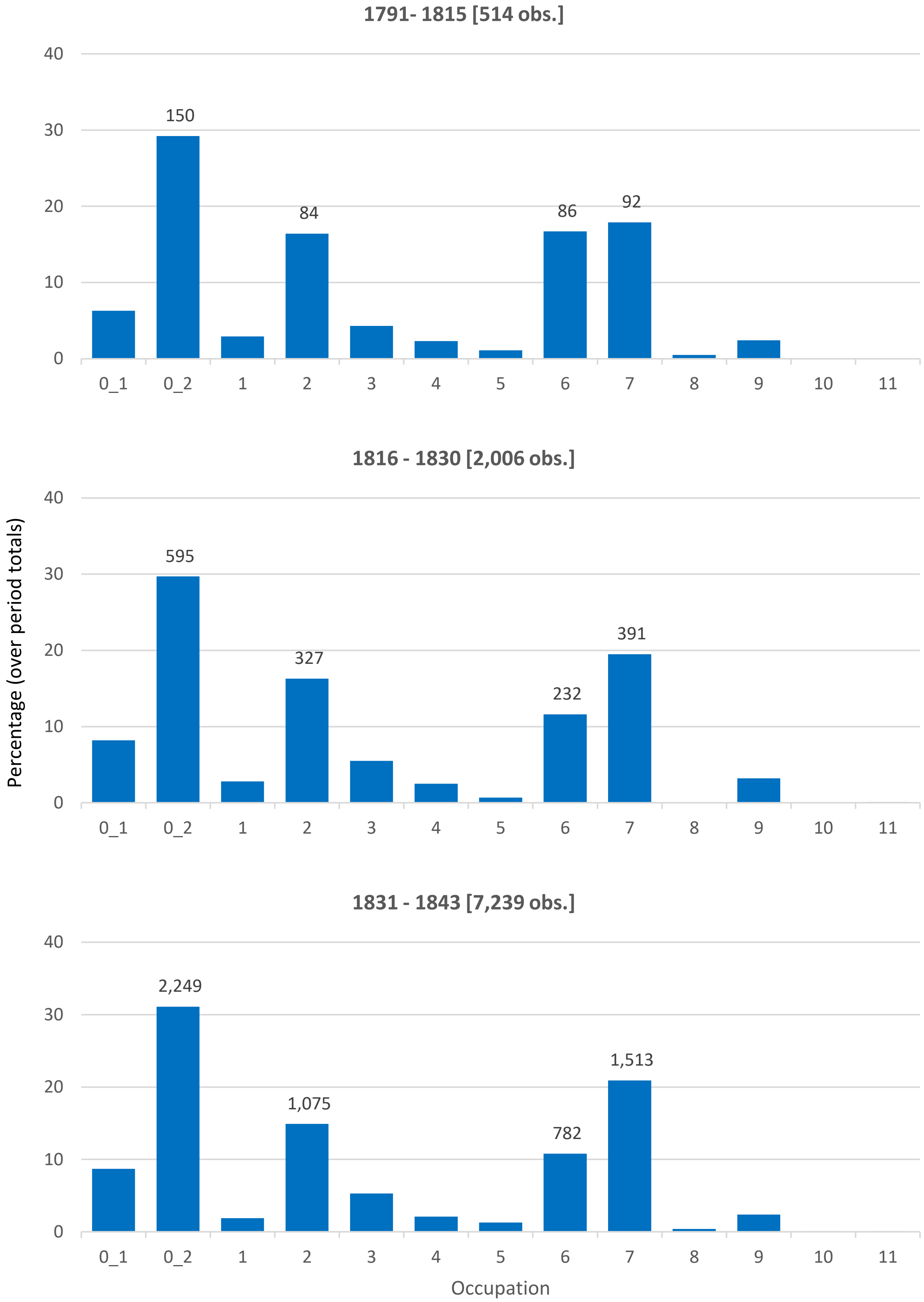


Figure 6. Number of patents granted in France by technology class (1791-1844)



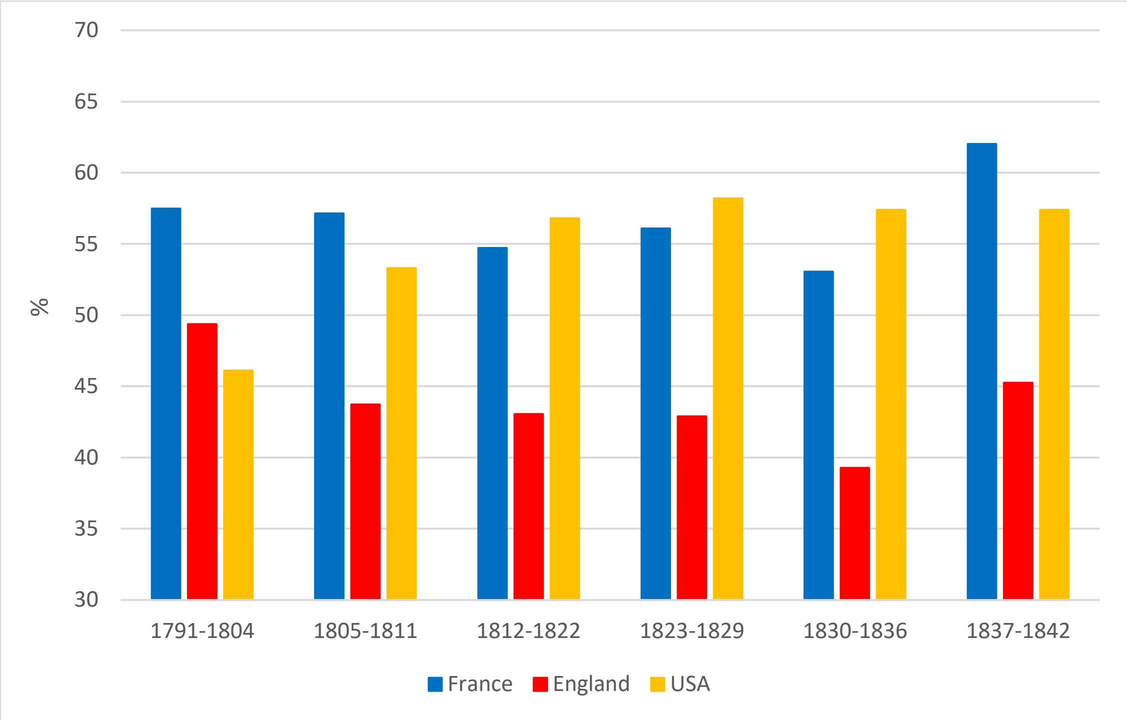
Note: the technology classes are: 1 = agriculture; 2 = hydraulic; 3 = steam engines and engines; 4 = textile machines and fabrics; 5 = other machines, devices and tools; 6 = navigation; 7 = construction; 8 = metallurgy; 9 = hardware (lock and cutlery); 10 = bodywork, saddlery, ropes and brushwork; 11 = weapons; 12 = precision and surgical instruments; 13 = mineral substances and ceramic; 14 = chemical products, food and cosmetics; 15 = lighting, heating and fuels; 16 = clothing and shoes; 17 = fine arts and musical instruments; 18 = stationery; 19 = leather; 20 = miscellaneous products.

Figure 7. Number of patents granted in France by patentees' occupation (1791-1844)



Note: the occupational HISCO categories and ownership status are the following: 0_1 = small proprietor; 0_2 = large proprietor; 1 = higher manager; 2 = higher professionals; 3 = lower manager; 4 = lower professionals, and clerical and sales personnel; 5 = lower clerical and sales personnel; 6 = foremen (artisans); 7 = medium skilled workers; 8 = farmers and fishermen; 9 = lower skilled workers; 10 = lower skilled farm workers; 11 = unskilled workers.

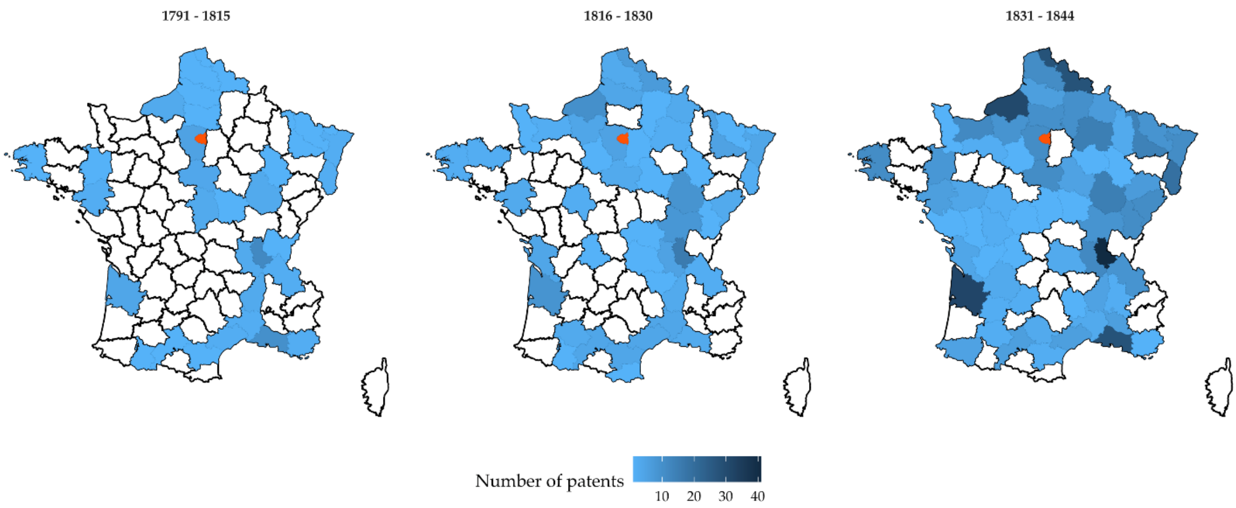
Figure 8. Share of 'one-off' patentees on total patents by countries (1791-1842)



Note: data for France and England consist of the total number of patents granted in the period 1791-1844. Instead, data for the United States consist of patents granted from 1790 to 1846.
Source: our own elaboration on our dataset for France and on Woodcroft (1854) for England. Sokoloff and Khan (1990, Table 1) for the United States.

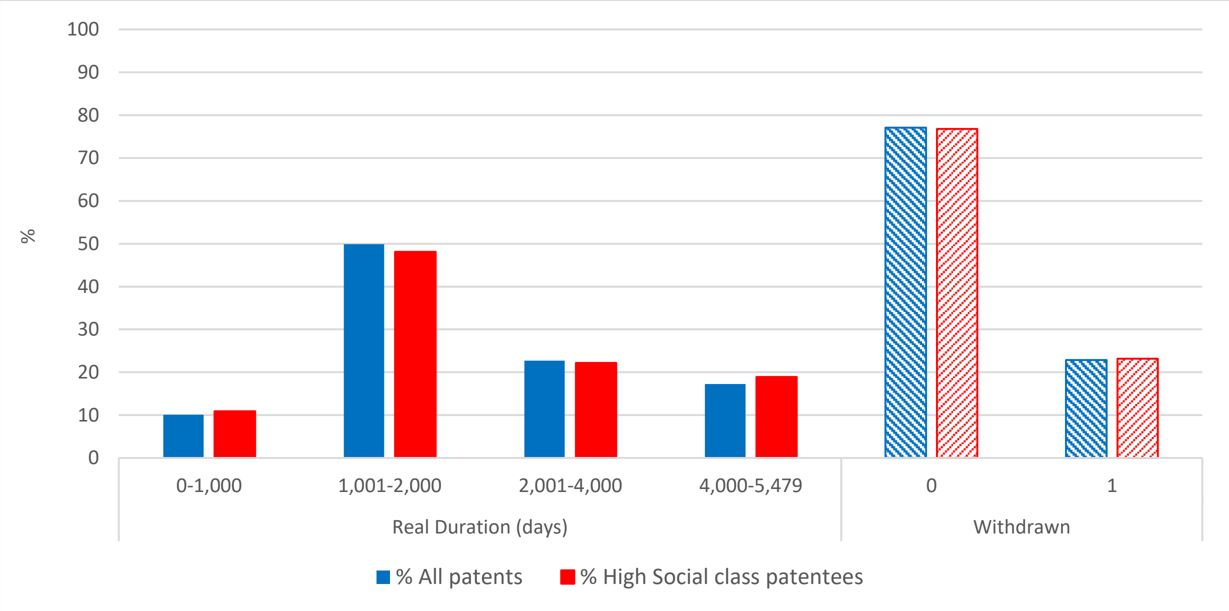
Figure 9. Real duration (days) for different types of patents (5, 10, 15)

Figure 10. Number of "high quality" patents granted in France by department (1791-1844)



Note: 'high quality' patents are those with real duration (days) greater than 4,000.

Figure 11. Distribution of real duration (days) and withdrawn patents by patentees' social class



Note: 'high social class' patentees are defined as those belong to 0_1-5 of the HISCO classification: 0_1 = small proprietor; 0_2 = large proprietor; 1 = higher manager; 2 = higher professionals; 3 = lower manager; 4 = lower professionals, and clerical and sales personnel; 5 = lower clerical and sales personnel.

Appendix

Table A1. Distribution of patents by country

Country	1791-1815	1816-1830	1831-1844
France	**836.6**	**2,574.1**	**7,952.3**
Algeria			2.0
Austria		9.0	24.5
Belgium	26.5	8.0	76.5
Denmark			3.0
Germany	15.5	10.0	31.8
India			2.0
Ireland		0.5	3.5
Italy	7.3	1.5	12.5
Luxembourg	1.0	0.7	
The Netherlands	6.0	3.0	3.0
Overseas territories		1.0	4.5
Poland			1.0
Russia			4.0
Spain		1.0	3.0
Sweden			2.0
Switzerland	10.8	7.0	11.5
UK	2.0	161.8	679.8
USA	9.0	14.0	34.0
Not specified	1.2	1.4	12.6
Total	**916.0**	**2,793.0**	**8,864.0**

Table A2. Number of patents granted in France by technology class (1791-1844)

Category	Description	1791- 1815		1816 - 1830		1831 - 1843	
		n	%	n	%	n	%
1	Agriculture	39	4.2	126	4.4	500	5.7
2	Hydraulic	20	2.2	93	3.3	286	3.2
3	Steam engines and engines	19	2.1	101	3.5	517	5.9
4	Textile machines and fabrics	161	17.5	503	17.6	1,234	14
5	Other machines, devices and tools	8	0.9	63	2.2	150	1.7
6	Navigation	29	3.1	139	4.9	233	2.6
7	Construction	30	3.3	105	3.7	540	6.1
8	Metallurgy	41	4.4	108	3.8	336	3.8
9	Hardware (lock and cutlery)	31	3.4	137	4.8	364	4.1
10	Bodywork, saddlery, ropes and brushwork	26	2.8	114	4	294	3.3
11	Weapons	11	1.2	64	2.2	171	1.9
12	Precision and surgical instruments	49	5.3	111	3.9	445	5.1
13	Mineral substances and ceramic	29	3.1	84	2.9	225	2.6
14	Chemical products, food and cosmetics	143	15.5	334	11.7	1,041	11.8
15	Lighting, heating and fuels	95	10.3	216	7.6	805	9.1
16	Clothing and shoes	44	4.8	152	5.3	524	6
17	Fine arts and musical instruments	55	6	168	5.9	435	4.9
18	Stationery	39	4.2	108	3.8	353	4
19	Leather	14	1.5	25	0.9	93	1.1
20	Miscellaneous products	39	4.2	101	3.5	255	2.9

Table A3. Most representative occupations by HISCO category

Category	Category label	Most represented professions	English translation
0_1	Small proprietor	*Négociant* *Parfumeur* *Bijoutier*	Trader/Storekeeper Perfumer Jeweller
0_2	Large proprietor	*Propriétaire* *Fabricant* *Manufacturier* *Rentier*	Owner Manufacturer/Producer Manufacturer/Producer Rentier
1	Higher manager	*Banquier* *Chef des ateliers [...]* *Colonel*	Banker Factory manager Colonel
2	Higher professionals	*Ingénieur mécanicien* *Ingénieur civil* *Ingénieur* *Docteur en médecine* *Architecte*	Mechanical engineer Civil engineer Engineer Doctor (medical) Architect
3	Lower manager	*Pharmacien* *Dessinateur* *Capitaine d'artillerie* *Capitaine au long cours*	Pharmacist Draftsman Artillery captain Long-haul captain
4	Lower professionals, and clerical and sales personnel	*Chimiste* *Distillateur* *Géomètre*	Chemist Spirit maker Surveyor
5	Lower clerical and sales personnel	*Employé* *Commis négociant*	Clerk Shop assistant
6	Foremen (artisans)	*Horloger* *Horloger mécanicien* *Menuisier* *Maître de forges* *Facteur de pianos*	Clock maker Mechanic clock maker Carpenter Smith Piano maker
7	Medium skilled workers	*Mécanicien* *Serrurier mécanicien* *Serrurier* *Filateur*	Mechanic Mechanic locksmith Locksmith Spinner
8	Farmers and fishermen	*Cultivateur*	Farmer
9	Lower skilled workers	*Arquebusier* *Lampiste*	Armed soldier Lamp attendant
10	Lower skilled farm workers	*Hacheur de bois* *Jardinier* *Marinier*	woodcutter Gardener Sailor
11	Unskilled workers	*Sans profession*	Not specified worker

Table A4. Distribution of patents by total patentee career by countries (1791-1842)

Period	1 Patent		2 Patents		3 Patents		4+ Patents	
	n	row %	n	row %	n	row %	n	row %
1791-1804								
France	196	57.5	83	24.3	18	5.3	44	12.9
England	576	49.4	213	18.3	106	9.1	272	23.3
USA	77	46.1	35	21.0	12	7.2	43	25.7
1805-1811								
France	276	57.1	95	19.7	38	7.9	74	15.3
England	338	43.7	123	15.9	98	12.7	214	27.7
USA	186	53.3	63	18.1	50	14.3	50	14.3
1812-1822								
France	735	54.7	300	22.3	107	8.0	201	15.0
England	579	43.0	201	14.9	138	10.3	427	31.7
USA	388	56.8	117	17.1	50	7.3	128	18.7
1823-1829								
France	1,128	56.1	370	18.4	176	8.8	337	16.8
England	547	42.9	228	17.9	115	9.0	385	30.2
USA	435	58.2	132	17.6	52	7.0	129	17.2
1830-1836								
France	1,747	53.1	693	21.0	314	9.5	539	16.4
England	728	39.3	275	14.8	213	11.5	638	34.4
USA	686	57.4	190	15.9	95	7.9	225	18.8
1837-1842								
France	4,692	62.0	1,385	18.3	547	7.2	941	12.4
England	1,486	45.2	590	18.0	335	10.2	873	26.6
USA	416	57.4	127	17.5	61	8.4	121	16.7

Note: data for France and England consist of the total number of patents granted in the period 1791-1844. Instead, data for the United States consist of patents granted from 1790 to 1846.
Source: our own elaboration on our dataset for France and on Woodcroft (1854) for England. Sokoloff and Khan (1990, Table 1) for the United States.

Table A5. Distribution of patent quality (days) and withdrawn patents by patentees' social class

	All patents		**High Social class patentees**	
Real Duration (days)	**No.**	**%**	**No.**	**%**
0-1,000	1,275	10.1	705	10.9
1,001-2,000	6,273	49.9	3,118	48.1
2,001-4,000	2,856	22.7	1,437	22.2
4,000-5,479	2,169	17.3	1,226	18.9
Total	12,573	100.0	6,486	100.0
	All patents		**High Social class patentees**	
Withdrawn	**No.**	**%**	**No.**	**%**
0	9,700	77.1	4,979	76.8
1	2,875	22.9	1,508	23.2
Total	12,575	100.0	6,487	100.0

Table A6. Distribution of patent quality (years) and withdrawn patents by patentees' social class

	All patents		**High Social class patentees**	
Duration (years)	**No.**	**%**	**No.**	**%**
5	6,547	52.1	3,271	50.4
10	3,415	27.2	1,751	27.0
15	2,611	20.8	1,464	22.6
Total	12,573	100.0	6,486	100.0

Table A7. Summary statistics

Variables	Mean	Median	Standard Deviation	Minimum	Maximum
Dependent Variables					
Quality class (5; 10; 15 years)	1.69	1	0.79	1	3
Quality class (300; 800; 1500 Francs)	685.01	300	467.69	300	1,500
Patent duration in days	2,699.38	1,826	1,555.34	18	5,479
Independent Variables					
British origins (BO)	0.09	0	0.28	0	1
British connection (BC)	0.03	0	0.18	0	1
Famous inventor*	0.02	0	0.19	0	4
Engineer/Scientist	0.08	0	0.27	0	1
Skilled worker	0.09	0	0.29	0	1
Award	0.01	0	0.1	0	1
Number of patentees per patent	1.2	1	0.49	1	6
Maximum experience in the applying group (based on name and location)	0.69	0	3	0	63
Maximum number of Encyclopédie subscriptions in the applying group	430.23	487	229.9	1	1,078
Rouen-Geneva line	0.72	1	0.45	0	1

Note: * Based on our own matching with the following data sets: Pantheon (retrieved in 2020), Murray (2003), Gergaud, Laouenan and Wasmer (2017), Serafinelli and Tabellini (2020).

Table A8. Determinants of patent quality in France excluding Seine Department (Paris) (Dependent variable: duration in days)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
British origins (BO)	1,196*** (55.46)	1,153*** (59.68)	1,155*** (59.25)	768.7*** (220.5)	1,183*** (53.57)	860.5*** (96.61)	839.3*** (98.31)	778.2*** (93.42)
British connection (BC)	666.3*** (147.7)	638.5*** (147.2)	641.0*** (147.0)	506.0*** (162.6)	823.1*** (137.6)	663.8*** (149.4)	650.5*** (148.9)	808.6*** (137.6)
Encyclopédie subscriptions		-0.122** (0.0620)	-0.168*** (0.0617)	-0.0483 (0.0663)	-0.00292 (0.0663)		0.137 (0.171)	0.0854 (0.184)
Number of patentees		38.68 (39.14)	44.69 (39.43)	36.52 (41.46)	30.24 (40.04)		38.02 (39.88)	18.71 (40.75)
Experience		-0.459 (3.906)	-0.340 (3.744)	76.10*** (24.11)	-4.918* (2.842)		-1.251 (3.917)	-6.003** (2.846)
Famous inventor		351.6** (144.5)	377.6*** (140.5)	184.9 (247.5)	384.6*** (110.2)		328.7** (137.9)	353.3*** (103.4)
Award		430.8* (234.2)	475.4** (235.8)	521.0** (242.6)	413.8* (235.9)		336.7 (236.1)	376.8 (233.6)
Engineer/Scientist		300.2*** (78.38)	351.8*** (77.60)	301.0*** (95.56)	402.0*** (75.42)		294.7*** (79.35)	398.9*** (76.22)
Skilled worker		-67.77 (63.87)	-82.63 (63.61)	-45.27 (65.51)	-103.0 (66.96)		-56.09 (63.27)	-95.31 (66.70)
Period (1791-1815)	524.8*** (79.38)	517.8*** (78.58)	533.1*** (78.97)	517.6*** (88.01)	169.9** (80.95)	450.2*** (81.19)	441.8*** (80.70)	74.61 (83.04)
Period (1816-1829)	222.3*** (49.74)	219.9*** (49.81)	213.3*** (49.87)	212.3*** (54.10)	-17.66 (50.27)	227.1*** (50.14)	221.9*** (50.14)	-8.334 (50.33)
High-tech sectors			196.2*** (39.25)					
Rouen-Geneva line				65.93 (45.35)				
Technological classes	YES	YES	NO	YES	YES	YES	YES	YES
Department FE	NO	NO	NO	NO	NO	YES	YES	YES
Constant	2,564*** (69.46)	2,518*** (82.60)	2,490*** (54.07)	2,481*** (88.39)	2,859*** (86.79)	2,453*** (196.0)	2,440*** (198.0)	2,530*** (199.3)
Observations	6,083	6,083	6,083	4,865	5,151	6,083	6,083	5,151
R-squared	0.107	0.113	0.098	0.052	0.144	0.134	0.139	0.175

Note: Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Model (4) comprises only French resident patents; model (5) and (8) do not include withdrawn patents.