Online Appendix

Technology Adoption and Productivity Growth: Evidence from Industrialization in France

Réka Juhász Mara P. Squicciarini Nico Voigtländer

A Historical Background: Additional Detail

This section provides additional information about industrialization in France in the first half of the 19th century, followed by further detail on the three sectors that we examine: mechanized cotton spinning as well as metallurgy and paper milling.

A.1 The Industrial Revolution in France

This appendix provides further detail on the Industrial Revolution in France, complementing Section 2.1 in the paper. An earlier literature "derogated the economic development of France as a story of retardation or relative backwardness" (O'Brien and Keyder, 1978, p. 194). This view has been largely revised in recent decades, leading to a new consensus that – similar to Britain – economic growth also accelerated in France in the mid-18th century (Rostow, 1975). The "retardation view" of French industrialization was defended by traditionalists who criticized the emerging cliometric approach and its quantitative methods and data. Numerous studies following the work of French historian Jan Marczewski gave credence to the cliometric approach (most prominently Maddison, 2001). These studies weakened – and eventually eliminated – the idea that French economic growth had stagnated in the 19th century. The consensus view that emerged holds that French growth had in fact been substantial (Crouzet, 2003). Illustrative of the similarities across the two countries, Horn (2006, p.10) writes that "[i]n an astonishing number of sectors, French entrepreneurs of the 1780s competed successfully with their English counterparts."

As we note in the main text, during the early stages of industrialization, France largely depended on the adoption of major British technological breakthroughs. Industrial espionage became widespread and, despite the attempts of the British government to block it, detailed reports and descriptions of English technology were sent across the Channel (Harris, 1998; Bradley, 2010). Additionally, "industrially minded" people in Britain and France entertained an intense correspondence on scientific and technological advances (Mokyr, 2005). Correspondingly, upper-tail human capital played an important role in industrialization (Squicciarini and Voigtländer, 2015). The fact that France *adopted* the major new technologies from Britain in this period renders the setting well-suited to examine technology adoption.

The adoption of new technologies from Britain was the primary source of innovation in the early 19th century. However, as French industrialization proceeded, "technological progress became indigenous, built in to the economy, so that ... France became at mid-[19th]century a centre of invention and diffusion for modern technologies" (Crouzet, 2003, p.234).

A.2 Mechanized Cotton Spinning

In Section 2.2, we discussed the development of mechanized cotton spinning in Britain as well as its adoption in France. Figure A.1 provides an illustration of how cotton spinning was traditionally performed, mostly by women in their homes, using a simple spinning wheel. With this technology, each spinner was able to spin only one thread of yarn at a time. The invention of the spinning jenny by James Hargreaves in 1765 made it possible to spin multiple threads simultaneously, as twist was imparted to the fibre by using spindles rather than by the workers' hands. Throughout the 1760s – 70s, Richard Arkwright and Samuel Crompton developed two subsequent vintages: the water frame and the water-powered spinning mule, respectively (see Figure A.2, left panel). The mechanization of preparatory processes was also well-underway prior to the 19th century. These new technologies entailed a move from home-based to factory-based production (right panel in Figure A.2). This was partly due to the machines' reliance on inanimate power sources, and partly to an increased need to monitor workers more closely (Williamson, 1980; Szostak, 1989).[1]

The Spinning Wheel　　　　Home Spinning

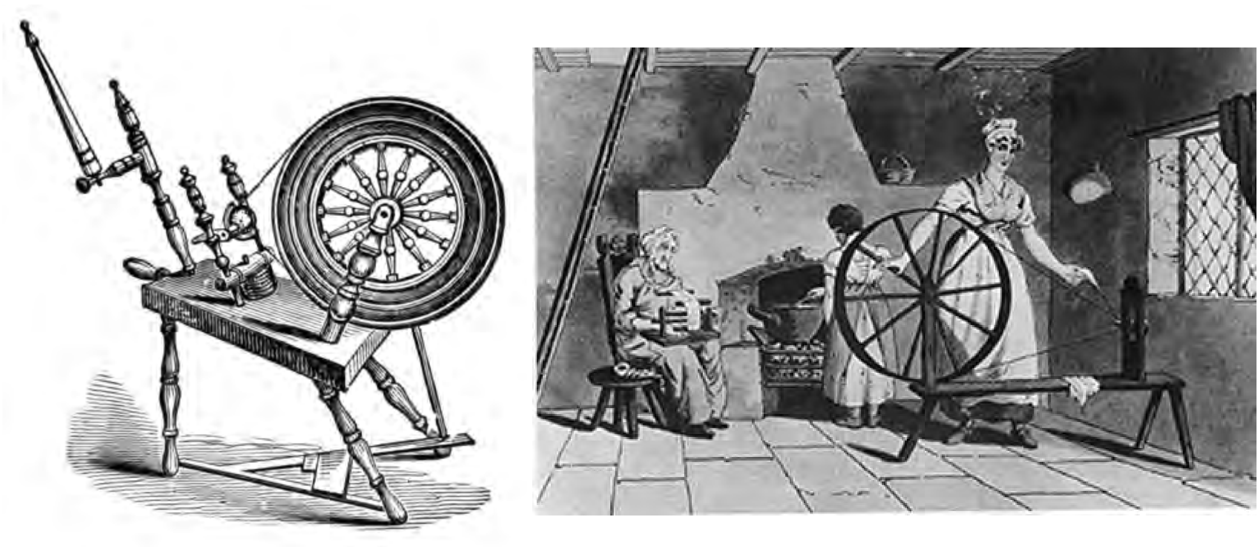


Figure A.1: Old Handspinning Technology

Source: https://etc.usf.edu/clipart/7700/7797/wheel_7797.htm (left panel) and https://digitalcollections.nypl.org/items/510d47dc-dcb3-a3d9-e040-e00a18064a99 (right panel).

These innovations had enormous productivity effects. The first vintage of the spinning jenny alone led to a threefold improvement in labor productivity (Allen, 2009). As a consequence, the

[1]The spinning jenny was typically hand-powered.

Water-Powered Spinning Mule — Spinning Mule Operated in a Mill

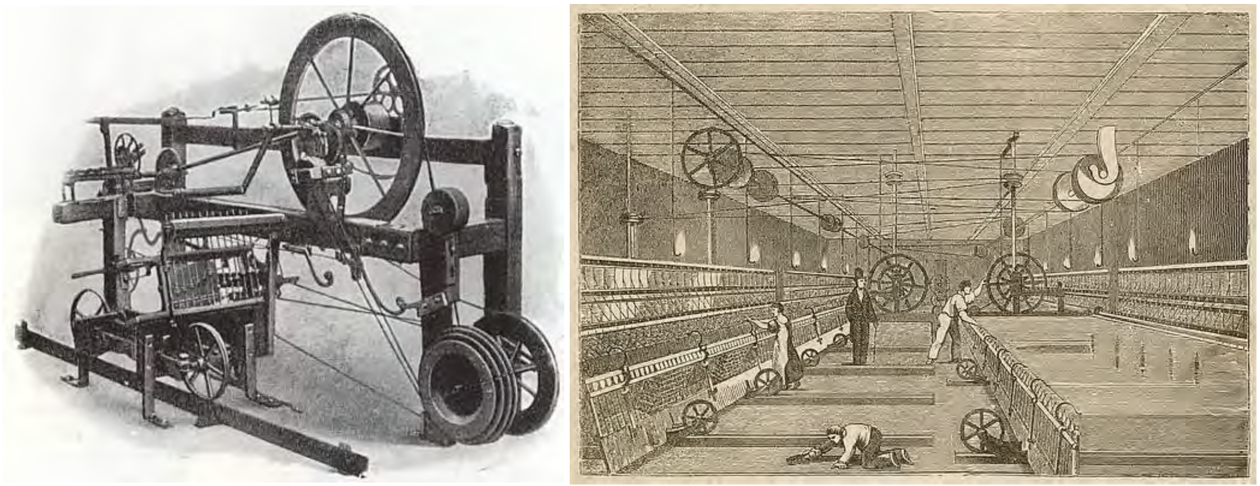


Figure A.2: New Mechanized Technology in Cotton Spinning

Source: https://powerloom.weebly.com/uploads/3/3/4/7/3347452/1722116.jpg?270 (left panel) and https://commons.wikimedia.org/wiki/File:Cotton_Mule_Spinning,_1835.jpg (right panel).

price of yarn declined in the late 18th century, especially for the highest-quality yarn. This can be seen in Figure A.3, which shows price data for three different qualities of yarn: 18, 40 and 100 count yarn.[2] While all counts saw striking price declines, this trend was most pronounced for the finest, highest-quality varieties, where prices dropped from 1,091 pence per pound to 76 pence per pound in real terms between 1785 and 1800. Machine spinning had the largest impact on the fine high-quality yarn, which British hand-spinners had not been able to effectively produce and to which the mule-jenny (a subsequent vintage of the machine introduced in the late 18th century) was well-suited (Riello, 2013). Note that our data on French cotton spinning include information on the type of yarn produced, allowing us to account for quality differences across plants.

Historical evidence about machinery producers. As we discussed in Section 2, machines were mainly produced domestically in France. Importantly, master mechanics and builders were typically not employees of the firm – they were paid by the factories to install, maintain and repair equipment (Cookson, 1997). Technologically complex tasks were 'outsourced' to engineers (Mokyr, 2010). This suggests that plants had access to broadly similar markets for the capital equipment within the same regions.

No large-scale switch to steam power. In contrast to Britain, mechanized cotton spinners in France

[2] Harley (1998) collected price data for three different qualities of yarn from British sources: 18, 40 and 100 count yarn. The count is an industry-wide standard that refers to the length per unit mass, implying that higher counts are finer. Finer count yarns are used to produce higher-quality cloth, while lower counts are used to produce heavier, cheaper cloth.

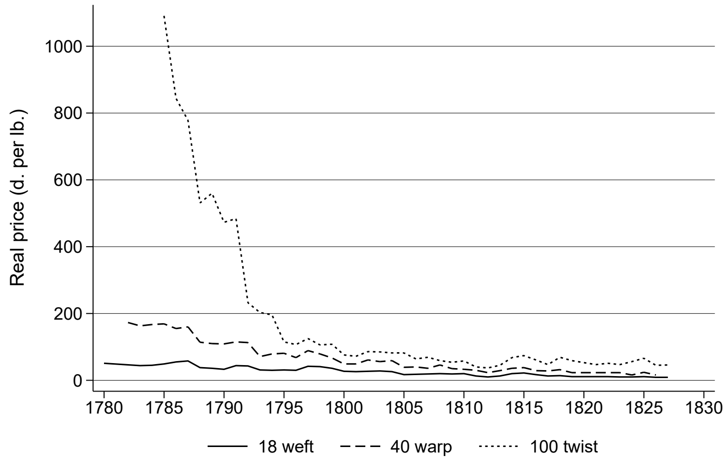


Figure A.3: Price of Different Counts of Yarn in Britain

Notes: Data are from Harley (1998), who collected prices for three different qualities of yarn: 18, 40 and 100 count yarn. The count is an industry-wide standard that refers to the length per unit mass (implying that higher counts are finer). Machine spinning had the largest impact on the fine high-quality yarn, which British hand-spinners had not been able to effectively produce.

did not switch from water to steam power to a large extent, owing to the fact that France was not particularly well-endowed with coal (Cameron, 1985).[3] Thus, we can think of the power source used as remaining mostly constant over the time period. Moreover, improvements to the technology used to operate water wheels should have a similar effect on productivity growth in paper milling, one of our comparison sectors, as this sector was also reliant on water power.

A.3 The Challenging Transition to Factory-Based Production in Mechanized Cotton Spinning: Additional Details

This appendix complements Section 2.2 in the paper, where we discussed some of the key challenges regarding the move to factory-based production in mechanized cotton spinning. Here, we provide additional evidence and examples.

Building design challenges. We illustrate the trial and error process of overcoming building design challenges using the example of constructing buildings better able to withstand fires. Cotton textile mills introduced the so-called “fire-proof building” in Britain in the late 18th century, which entailed leaving no timber surfaces exposed by using cast-iron columns instead of wood (Johnson and Skempton, 1955). However, it quickly became apparent that fireproof mills were not actually fireproof, because “steel or wrought iron, when heated, will fail by buckling or bending very much sooner than the equivalent beam of post or wood” (Boston Mutual Fire, 1908, p. 3). US

[3] This is confirmed in our data for 1840, showing that the majority of cotton spinning plants were still using water power (see Table A.2).

textile mills developed what became known as "slow-burning mills" in the 1820s, recognizing that fires could not be prevented, but their effects could be curtailed by better mill design. Partly, this entailed moving back to using wood: "Timber posts offer more resistance to fire than either wrought-iron, steel, or cast iron pillars, and in mill construction are preferable in many respects (Boston Mutual Fire, 1908, p. 3). Chassagne (1991, p. 340) posits that early 19th century French mills consisted of multiple buildings and covered vast spaces (as opposed to building vertically), partly in order to minimize the fire hazard.

Labor management challenges. Cotton spinning plants needed to develop organizational and management practices for running spinning mills at a scale not seen elsewhere in the economy. Here, we provide additional evidence regarding labor management challenges.[4] There were three salient aspects of this for cotton spinning mills as described in the main text; i) how to get workers to adapt to the rhythm of factory work, ii) how to coordinate labor in a factory setting and, iii) how to solve monitoring problems.

First, from the workers' side, the move to factory-based production fundamentally altered both the location and the nature of work (Clark, 1994). Under the factory system, the employer "dictated when workers worked, their conduct on the job and that they steadily attend to their assigned tasks." (Clark, 1994, p. 128). Following instructions, showing up to work on time, or getting along with other employees was a challenge for the first generation of factory workers, who had been used to the high degree of independence in the domestic spinning system (Pollard, 1965). As Pollard (1965, p. 181) writes, "What was needed was regularity and steady intensity in place of irregular spurts of work; accuracy and standardization in place of individual design; and care of equipment and material in place of pride in one's tools." Simply put, an industrial labor force needed to be created where none had existed before (Mokyr, 2010).

Second, as we noted in the main text, coordination of labor was crucial, as flow production meant that one worker could hold up the entire production line. This is illustrated by the Karl Marx quote in Section 2.1.

Third, monitoring worker effort, much of which was hard to observe (Huberman, 1996), was another novel aspect of factory work. Huberman (1996, p. 11) describes the need for monitoring in mechanized cotton spinning: "If there were multiple breakages of yarn on the larger machines, the mule had to come to a complete stop to piece the broken threads. There was also doffing, when the reels were full of spun cotton, the mule had to be stopped and the reels removed. Finally, there was cleaning. At all times, the spinners could expend effort as they were motivated to, and without proper supervision or incentives they could disguise how hard they could in fact work." This created a strong need for monitoring, so that even early hand-powered machines (a particular vintage

[4] Pollard (1965) and Mokyr (2010) provide more general discussions of other management challenges facing firms at the time.

of spinning machinery) were housed in the "garrets of cottages and later in sheds" (Huberman, 1996, p. 11) in order to enable a direct supervision of workers.

As we discuss in the main text, overcoming these challenges proceeded via a slow process of trial and error. The industry eventually settled on efficiency wages in the 1830s in Britain (Huberman, 1996).

A.4 Comparison Sectors: Metallurgy and Paper Milling

This appendix complements Section 2.3; it discusses our two comparison sectors during the First Industrial Revolution in France in more detail. We give an overview of the production processes in each, and discuss new technologies developed during our sample period and how they were adopted into the existing organization of production.

Metallurgy

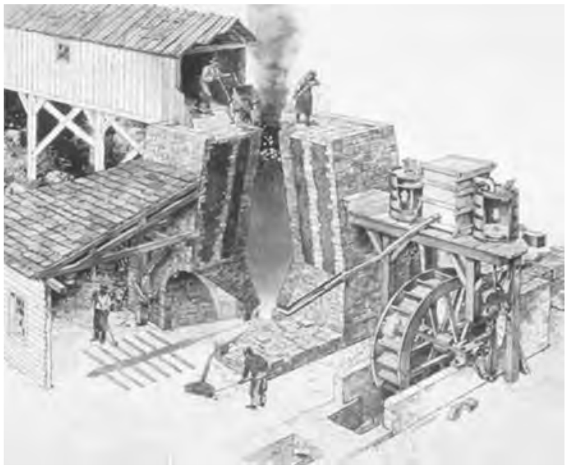
Iron was a flagship product of the Industrial Revolution. It was used for railways, steamships, and for machines. The fundamental process of producing iron has remained the same over centuries. Despite large productivity improvements achieved during the Industrial Revolution (Allen, 2009), the actual changes to methods of production were modest.

Historical production process. Iron is extracted from iron ore in a process called 'smelting' – freeing the iron by combining carbon with the oxygen of the ore under heat. The difficulty comes from the fact that the iron also needs to be separated from other metallic substances in iron ore. This is achieved by controlling the heat of the furnace so that most of the foreign matter separates out with the lowest-possible expenditure of fuel. In the Medieval period, the production process of iron used 'direct' technology. Smelting with this technology produced malleable iron directly from iron ore in a bloomery (a type of furnace) where the temperature was low enough for the iron not to melt. The product of this technology is wrought iron. This process is referred to as 'direct' because iron was produced in a near-finished condition in a single process. One vintage of this technology, the Catalan forge, survived into our study period and beyond in certain parts of France (Pounds and Parker, 1957).

Starting in the late Middle Ages, the direct technology began to be gradually replaced by an 'indirect' technology, which consists of two steps: smelting and refining. Smelting is similar to the direct technology. A blast furnace – with temperatures high enough for the complete fusion of the metal – is used to produce an intermediate product – pig iron. However, as pig iron is too brittle to be used in many applications, it needs to be refined one more time on a hearth. This second stage is known as refining. The blast furnace first appeared in Europe in the 15th century, but it was not widely adopted until the 17th or 18th century (Pounds and Parker, 1957). Figure A.4 illustrates the blast furnace and the organization of an 18th century metallurgy plant (foundry).

New technologies developed in Britain during the Industrial Revolution. Prior to the Industrial Rev-

18C Charcoal Iron Blast Furnace



Organization of 18C Metallurgy Plant

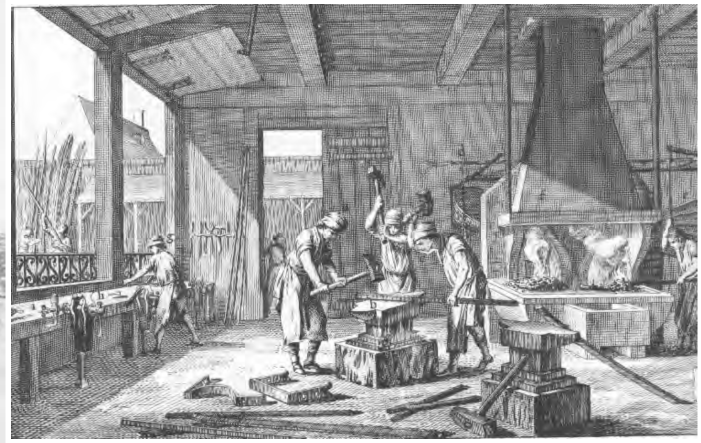


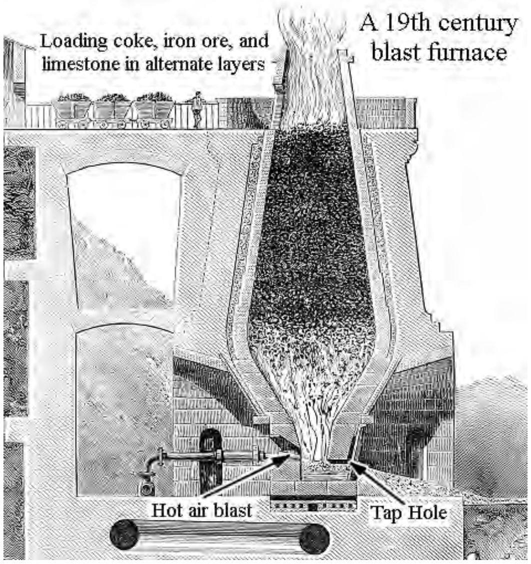
Figure A.4: 'Old' 18th Century Charcoal-Based Technology in Metallurgy

Source: https://www.nps.gov/articles/hopewell-furnace-a-pennsylvania-iron-making-plantation-teaching-with-historic-places.htm (left panel) and https://artflsrv04.uchicago.edu/images/encyclopedie/V26/plate_26_4_1.jpeg (right panel).

olution, both stages of the indirect process relied on charcoal as the source of fuel. The key innovation during the Industrial Revolution was the switch from charcoal to coal, through a series of gradual improvements in the period 1700-1850. The change in the type of fuel required modifications to the blast furnace, but the new technology "merely replaced earlier, recognizably similar, though less 'efficient' methods" (Pollard, 1965, p. 101). In particular, a coal-based blast furnace required larger furnace sizes and a switch from water to steam power. Such modifications could be made to existing blast furnaces (Pounds and Parker, 1957). Allen (2009) estimates that the cost of producing pig iron using coal decreased by 75% during this period in Britain. Figure A.5 presents illustrations of the 'new' coal-based technology. A comparison with Figure A.4 shows that the organization of metallurgy plants remained practically unchanged.

In refining, the move from charcoal to coal was achieved by the puddling process. Pig iron was melted in a reverbatory furnace fueled by coal while stirring, or 'puddling' the molten mass until the free carbon in pig iron was oxidized and the mass reduced to malleable form as bar iron. Similar to smelting, the development of puddling proceeded gradually, and the technologies were not meaningfully different to others already in use. Pounds and Parker (1957, p. 35) characterize the development of puddling in the following way: "Cort's [the inventor] invention was less the introduction of entirely new processes than a synthesis of practices that were already familiar. The reverberatory furnace, burning any fuel that might be available, had long been known. [...] Rolling mills were also known [...]. The lawsuits with which Cort was faced served to emphasize that some of his contemporaries regarded his claim to be an inventor as remarkably thin."

19th Century Coal Blast Furnace



Organization of 19C Metallurgy Plant

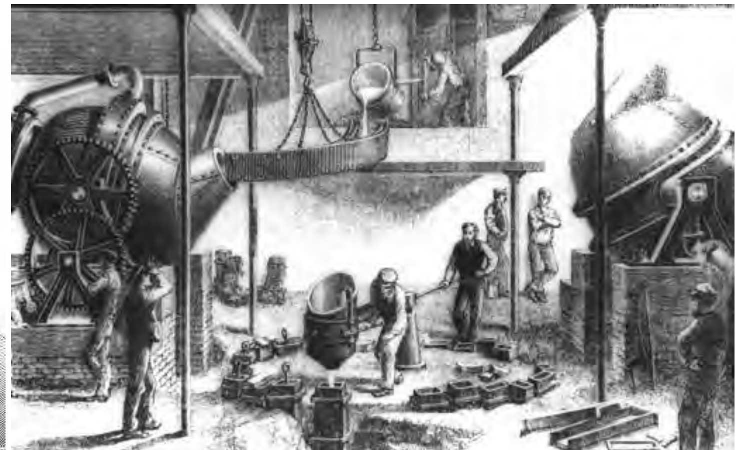


Figure A.5: 'New' 19th Century Coal-Based Technology in Metallurgy

Source: http://www.historywebsite.co.uk/articles/DarlastonIE/heavyindustry.htm (left panel) and https://www.sciencephoto.com/media/1288706/view (right panel).

Of course, adopting the new technology also entailed difficulties. Switching to coal as a source of fuel required changing or adapting machines, training workers, and modifying buildings (Gille, 1968). This is an important aspect of our setting, as in this regard the metallurgy sector is comparable to that of cotton spinning, where we also see dynamic innovation. We turn to this point after reviewing the process of adopting the new technologies in France.

Technology adoption in France. The switch from charcoal to coal as a source of fuel took place gradually throughout our sample period in France. However, a modernized metallurgy sector, characterized by large establishments producing for national markets, did not emerge until well after our sample period (Gille, 1968). By the end of our sample period, smelting had seen relatively little change; pig iron was still produced predominantly with charcoal using the old technology. In refining, technology adoption was more rapid, and the use of coal dominated charcoal three-to-one by 1847 (Gille, 1968).

The literature has put forward a number of explanations for the slow adoption of new technologies in smelting. One important factor was that, in contrast to Britain, iron ore and coal were not located in close proximity, making access to the necessary inputs expensive, particularly before the national rail network was established (Gille, 1968, p. 91). However, it was much easier to install puddling furnaces, which required less coal, and could use traditional water wheels to power the rolling mills (Gille, 1968).

In light of these constraints in France, a dual system began to emerge during our sample period. New technologies were adopted in existing forges. At the same time, new firms were set up near coal deposits. Our empirical findings confirm this. We see both an expansion of the industry near coal deposits (see Figure A.14 below) alongside relatively high survival rates of existing plants (Table 2 in the paper).

Re-organization of production in metallurgy. The organizational changes necessary to adopt new technologies in metallurgy were more modest relative to those described in the move to factory-based production in cotton spinning. This can be seen by comparing the before-vs. after illustrations for metallurgy (Figures A.4 and A.5) with those for spinning (Figures A.1 and A.2). One reason for the small changes in metallurgy is that plant-based production in this sector was already well-established historically in France. Data from the *Encyclopédie* (see Section A.5) confirms that the industry had well-established best practices regarding building layouts and the organization of production more generally.

Given that many of the new technologies were adopted within existing plants, major changes to structures or organizational practices were not required. To install a large English-style puddling furnace (which was the main margin of technology adoption during our sample period), the plant could continue to rely on water power, and only limited investments were necessary (Gille, 1968, p. 47). Where technology adoption relied on setting up new plants (as was often the case in refining), the primary impetus to do so was to locate close to coal deposits.

Paper Milling

In contrast to metallurgy and cotton spinning, paper milling was not a flagship industry of the Industrial Revolution, and its output was not particularly important for other sectors. However, paper making was one of the few manufacturing activities that was organized as plant-based production from well before the Industrial Revolution because of its reliance on water power. Moreover, it too underwent mechanization during our study period. For these reasons, paper making serves as a useful second comparison sector to cotton spinning.

Historical production process. In Europe, paper making had traditionally taken place in mills. Production consisted of several stages. First, the vegetable matter (the raw material) was broken down into cellulose fiber, which involved a water-powered stamping machine (see Figure A.6, left panel). Next, it was formed into thin, wet sheets by a skilled worker, called a vatman (Figure A.6, right panel). It was then dried and – depending on its intended use – finished in different ways. Each of these steps was performed in a different section or room of the mill with a marked division of labor by function and gender. The only step of the production process that required water power was the washing, breaking, and beating (stamping) down of rags into fiber. The machine that performed all of these tasks (known as the washing, breaking or stamping engine) consisted of an oval, wooden tub containing a water-powered revolving roll and was operated by a skilled workman or an engineer. This stage of the production process and the work of the engineer determined to a large extent the quality of the paper that could be produced. Moreover, it was because of this technology that production was located in mills from very early on (McGaw, 1987).

New technologies developed during the Industrial Revolution. The important innovation that took place during our study period was mechanization of the forming of the paper, eventually fully replacing the tasks performed by the vatman with the Fourdrinier machine (Figure A.7). This technology is still at the core of modern-day paper production. The Fourdrinier machine was important not only because of the productivity improvements that it yielded, but also because it enabled the production of continuous rolls – something that had not been possible with the hand-based technology. The first vintage of the machine was patented in France in 1799 by Nicholas Louis Robert. In the 1800s, the idea behind the original machine was developed further by a British mechanic, Bryan Donkin, who developed a commercially viable machine with financing from the Fourdrinier brothers (André, 1996; McGaw, 1987).

Technology adoption in paper milling in France. The Foudrinier machine was gradually adopted during our sample period in France. André (1996, p. 253) claims that all large paper mills were mechanized by 1840, but the full assimilation of the new technologies in the industry was not completed until the 1850s and 1860s, after our sample period (André, 1996, p. 389).

Re-organization of production in paper milling. The organizational changes necessary to adopt the Foudrinier machine were minimal. One important point to note is that, different to mechanized cotton spinning, paper milling in this period never developed a standardized building layout. André (1996, p. 182) describes this explicitly: “In this [paper milling] industry, there are no stereotypical buildings that are easily identifiable like those of the large multi-story textile mills...” As we discuss in the main text, modifications of existing plants were often undertaken without having to substantially change other parts of the production process, and different parts of the paper milling process could be hosted in different buildings. For example, when plants adopted the Fourdrinier machine, they typically merely reconstructed the two sections hosting the cylinders and the machine, while re-using the buildings previously devoted to the other operations (André, 1996, p. 178).

Water-Powered Stamping Handling by Vatman, Coucher, and Layer

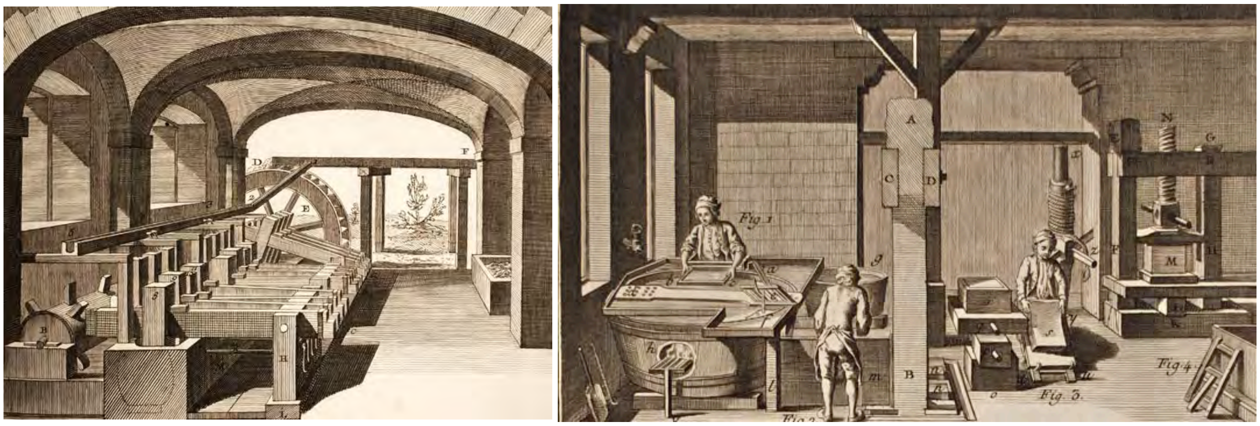


Figure A.6: Old Technology in a Paper Milling Plant

Source: http://paper.lib.uiowa.edu/european.php (both panels).

Sketch of Fourdrinier Machine Fourdrinier Machine in a Plant

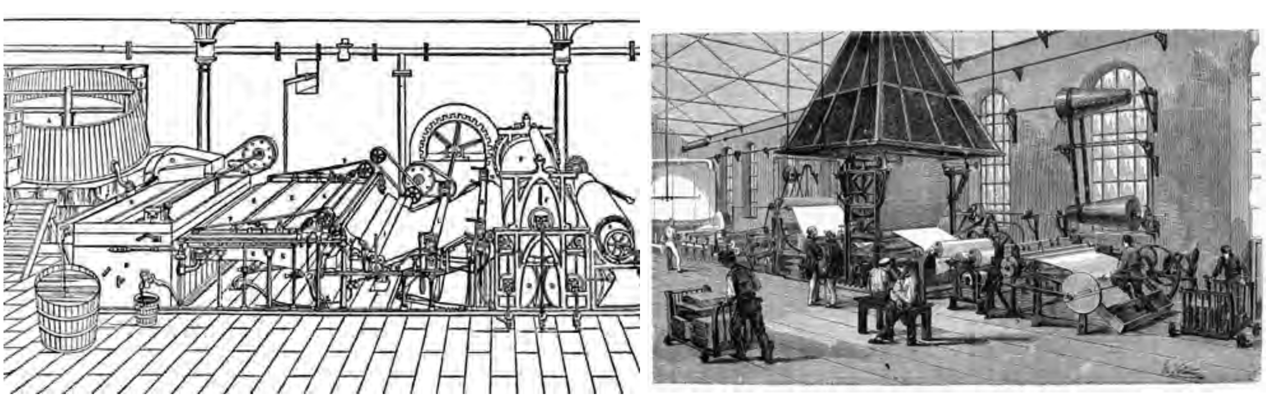


Figure A.7: New Technology in Paper Milling Plants: The Foudrinier Machine

Source: https://www.researchgate.net/figure/The-traditional-Fourdrinier-paper-making-machine-of-the-type-built-by-Bryan-Donkin_fig2_322872610 (left panel) and
https://www.granger.com/results.asp?image=0079612&screenwidth=1024 (right panel).

A.5 18th Century Encyclopédie Plates for the Three Sectors

This appendix complements the discussion of *differences* between our comparison sectors and mechanized cotton spinning in Section 2.3. Here, we examine illustrations from the 18th century on plant organization and production technology in the three sectors. These provide evidence that while standardized knowledge on plant organization and production technology existed for our two comparison sectors, it did not exist for mechanized cotton spinning. In particular, we use data on plates contained in the late 18th-century *Encyclopédie* of Diderot and d'Alembert from *the Encyclopedia of Diderot and d'Alembert: collaborative translation project*.[5] These plates were used to illustrate crafts, processes, and inventions from the time. They represent a unique source of information to study the amount and type of existing knowledge on manufacturing at the time. In total, there are 2,575 plates, accompanying 326 entries. Approximately half of them describe manufacturing technologies (Squicciarini and Voigtländer, 2015).

We identify all plates that illustrate plant organization or production technology for our three sectors. Overall, there are 28 such plates. Figure A.8 below provides two examples for plates on plant organization in metallurgy and paper milling. For cotton spinning, we further distinguish between home production and mechanized production.[6] Figure A.9 shows that for paper milling and metallurgy (and to a lesser extent for home spinning), there was a significant number of *Encyclopédie* plates specifically illustrating plant organization and production technology. In contrast, this type of codified knowledge was completely absent for mechanized cotton spinning, where we observe zero plates on technology or organization. This is in line with the historical evidence discussed in Section 2.2, suggesting that best-practice methods for mechanized cotton spinning did not yet exist in the late half of the 18th century. This absence of plates on mechanized cotton spinning is not surprising, as the technology had just been invented. Nevertheless, the *Encyclopédie* plates illustrate that codified knowledge was indeed available for our two comparison sectors in the late 18th century.

[5] This is available at http://quod.lib.umich.edu/d/did/index.html.

[6] We do not count other plates related to our three sectors that do not illustrate production technologies or plant organization. These include, for example, plates that describe products (e.g., metal products).

Metallurgy Paper Milling

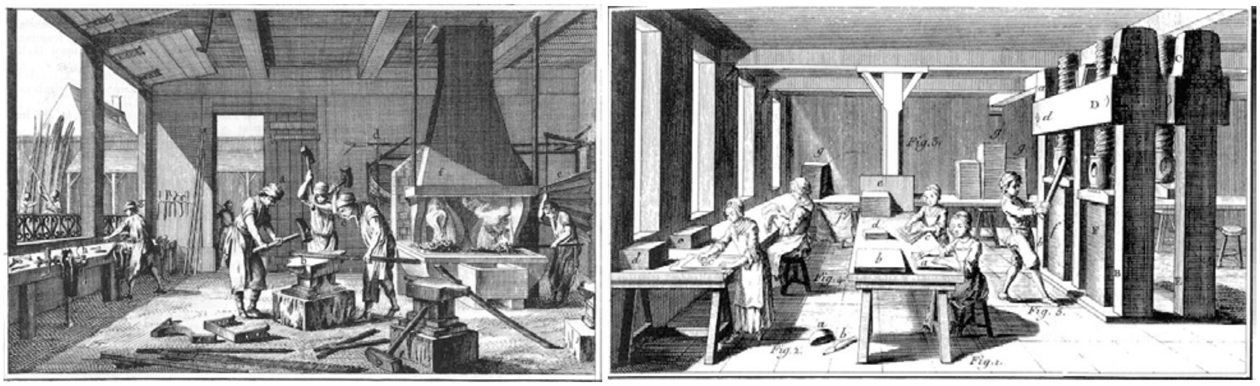
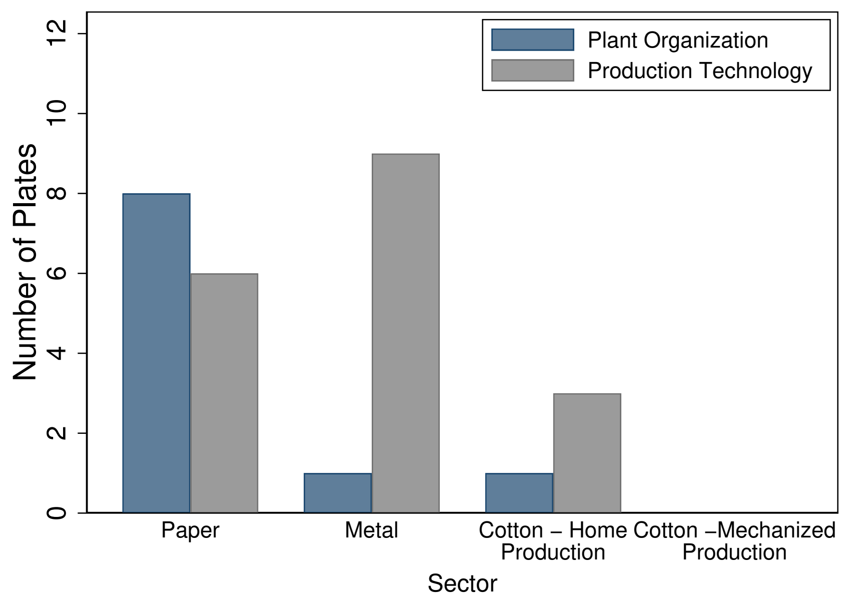


Figure A.8: *Encyclopédie* Plates on Plant Organization

Source: http://quod.lib.umich.edu/d/did/index.html.

Figure A.9: Number of Encyclopédie Plates about Plant Organization and Production Technology in the Three Sectors



Notes: Source: *Encyclopédie, ou Dictionnaire raisonné des sciences, des arts et des métiers* (1765). Available at https://quod.lib.umich.edu/d/did/ "Plant organization" refers to plates on plant layout/organization. "Production Technology" refers to plates on machinery and techniques for production. Plates relating to products are excluded.

A.6 Evidence on Innovation Across the Three Sectors Using British Patent Data

This appendix complements the discussion of *similarities* between our comparison sectors and mechanized cotton spinning in Section 2.3. Here, we provide evidence that all three sectors that we study were innovative during our sample period. In Figure A.10, we show that patenting activity was consistently high throughout the 1800-1840 period, using data on the number of British patents by category (as classified in the original source). Spinning was the third-most patent intensive industry among 146 categories, while metallurgy and paper milling were ninth and twenty-first respectively. These data were kindly shared by Walker Hanlon (2020), who digitized the data from Bennet Woodcroft's (1854) *Subject Matter Index of Patents of Invention*.

Figure A.10: Number of British Patents, 1800-1840

Notes: 'Spinning' refers to the patents related to all textile fibers, not just cotton. Data were kindly shared by Walker Hanlon based on work on patenting in Hanlon (2020).

Moreover, Table A.1 shows that in all three sectors, innovations were broad-based in the sense that they covered different parts of the production process. This is shown by the large number of patents in both 'core' (main part of the production process) and 'other' innovations in preparatory or finishing stages. In combination with the historical evidence on the nature of innovations, we conclude that the three sectors were undergoing technological change of a similar type *after* the adoption of mechanized cotton spinning. None of the sectors experienced major innovation that required reorganization of production.

Table A.1: Patents, 1800-1847

Sector	'Core'	Other	Total
Spinning	176	313	489
Metallurgy	100	143	243
Paper	89	33	122

Notes: The table reports the number of patents divided between different stages of the production process. 'Core' patents refer to innovations in the main part of the production process, while 'Other' refers to innovations in preparatory or finishing stages. Data were kindly shared by Walker Hanlon based on work on patenting in Hanlon (2020). Note that spinning patents include those for all textile fibers, not just cotton.

B Main Data: Surveys and Census of the Three Industries

This appendix complements Section 3 in the paper, where we introduced each of the four industrial surveys that we use. Here, we describe the data cleaning and construction steps and assess data quality. For each survey, we define the variables used in the paper and describe how they were constructed. We also provide further details on linking plants over time and define all control variables used in the analysis.

B.1 Mechanized Cotton Spinning, 1806

Primary data sources.

- J.-B. de Nompère de Champagny's survey of the cotton textile industry (1805/06).[7] *Archives Nationales, Series F12/1562-1564.*

- Price schedule by count of cotton yarn (price per kilogram in francs, 1806-07). *Archives Nationales, Series F12/533.*

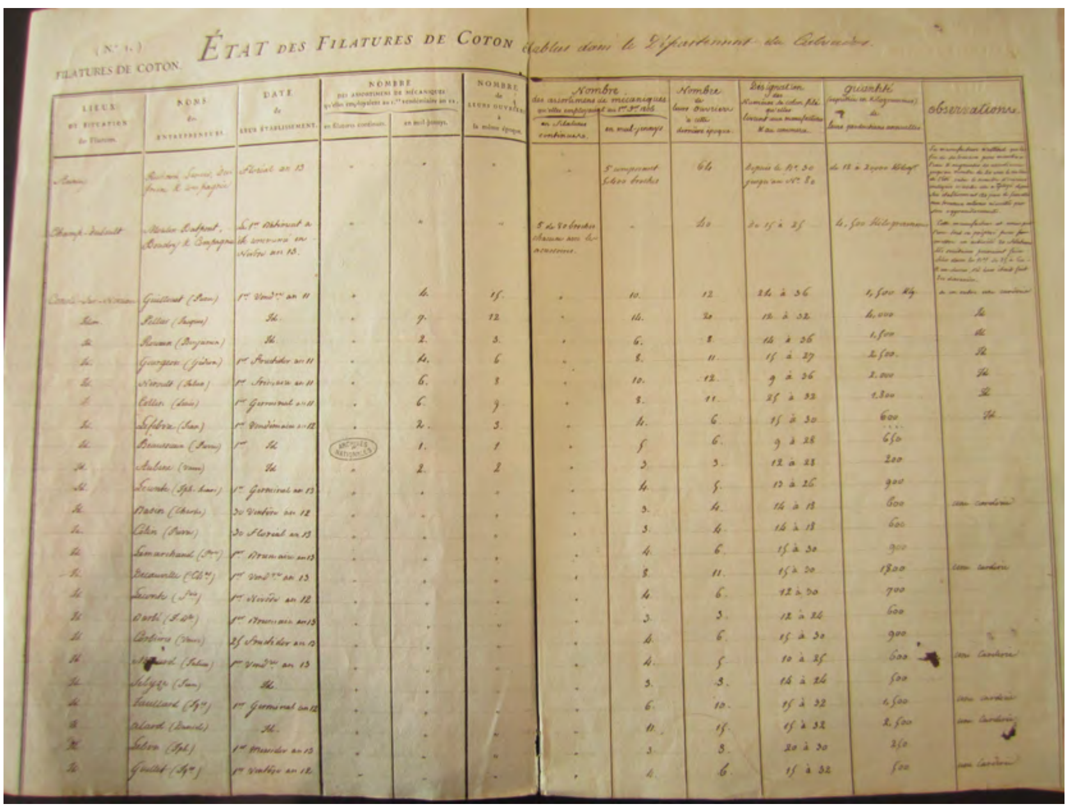

(N° 1.)
FILATURES DE COTON.
ÉTAT DES FILATURES DE COTON

Figure A.11: Sample Page from the Cotton Spinning Survey, 1806

[7] Champagny was the minister in charge of conducting the survey.

Source used in the paper. The data covering mechanized cotton spinning establishments were digitized and cleaned by Juhász (2018). We use the plant-level version of these data (which was not made public, but all cleaning procedures are as described in Juhász, 2018).

How was the survey administered? A standardized questionnaire was sent to each *département* (see Figure A.11). Returns were filled in by the *préfets*, the highest public official at the *département* level. For an extensive discussion and evaluation of the survey see Chassagne (1976).

Response rate. 107 of the 109 *départements* that were surveyed submitted a response.[8]

Missing data pattern. Of the 389 plants in the dataset, we are missing data on output for 37 (9.5%) plants, and on employment for 12 (3.1%) plants. In total, we are missing data on labor productivity for 49 (12.6%) plants in the dataset.[9] This leaves 340 cotton spinning plants with observed labor productivity in our sample. We refer to the latter as the baseline sample in our dataset.

Assessment of data quality. Beyond the high response rate, there are two further factors that suggest this survey was of a high quality. First, given the survey was administered five years after a previous inquiry into economic activity, *La Statistique des Préfets*, officials needed to update their existing knowledge, as opposed to starting from scratch (Chassagne, 1976). Second, these data have been used in qualitative work (e.g. Chassagne, 1991) as well as in recent empirical work Juhász (2018). In the latter case, mechanized cotton spinning capacity at the *département* level was compared to data on cotton textile manufacturing activity from around 1790 (using the *Tableaux du Maximum*) and from an industrial survey conducted in 1812 (which was typically submitted at the level of *départements* as opposed to individual plants). While there are some differences in the location of mechanized cotton spinning capacity, overall the data do line up fairly closely, suggesting that the 1806 survey of mechanized cotton spinning plants is of a high quality.

Plant locations. To geocode plant locations, we use information from the survey on the 'commune' in which the plant was located. We assign geocodes using a combination of automated packages and manual assignment.[10] Using the geocodes, we then assign each plant the present-day commune, *dèpartement* and region to which the commune belongs.

Variables directly reported in the 1806 cotton spinning survey.

- Number of employees
- Vintage of physical capital used and the number of machines[11]
- Location of the plant (up to the commune level)

[8]This number includes *départements* annexed to the French Empire during Napoleon's reign and is thus different from the modern-day number of *départements*, which we use for our analysis.

[9]In many instances where we are missing data on employment and/or output, it seems likely that the plant had shut down, or had temporarily ceased production at the time of the survey.

[10]For 19 plants out of the 340 for which we have labor productivity data, we could not identify a location because either there was no commune reported, or the historical name of the commune could not be located.

[11]The survey asked for throstles (water-frame) and mule-jennies, but many plants also reported spinning jennies. Juhász (2018) thus constructed a third, separate category to capture these.

- Name of the owner
- Output (reported in kilograms)
- Quality of yarn spun (measured by the count of the yarn)
- Date of foundation
- Number of spindles (including those imputed by Juhász, 2018)[12]

Constructed variables for cotton spinning plants in 1806.

- **Plant labor productivity**: This is defined as log(revenue per worker), where revenues are deflated as described in Appendix B.6. The survey reports the quantity of yarn spun in kilograms, as well as the minimum and maximum count of yarn spun. We use the (unweighted) average of the minimum and maximum count of the yarn produced by the plant as a proxy for its average output quality. We construct plant-level revenue by multiplying the quantity of plant-level output by the price of the average quality of yarn produced by the plant. We use a schedule of prices for different counts of yarn reported by the French government (see primary data sources above, at the beginning of this appendix section). We deflate revenues using the wholesale price index reported for 1806 in Mitchell (2003). See Appendix B.6 for detail.

  We also construct an alternative measure of labor productivity that does not adjust for the quality of yarn spun by the plant. In this case, we construct plant-level revenues by multiplying physical output at the plant level with the price of the (unweighted) average quality of yarn reported across *all* plants in 1806.
- **Capital:** We define capital as the log of the number of spindles at the plant level. Spindles are the standard measure of capital in the industry. Though these data were not explicitly asked for in the survey, many plants reported them, and Juhász (2018, Online Appendix pp. 22-24) imputed the remainder.
- **log(Employment)** This is defined as the log of the total number of workers. The 1806 cotton spinning survey does not provide a breakdown of male, female, and child labor. We interpret this measure as the sum of all forms of labor.
- **Plant total factor productivity:** TFP at the plant level is computed as the residual from regressing plant-level deflated log(total revenue) on log(total workers) and log(capital), as defined above.
- **Plant age:** This is defined as the number of years since the plant was established. We use log(plant age) in our regressions.
- **Vintage machine (Spinning jenny, Throstle, Mule jenny:** These are defined as binary indicators that take on value one when the plant has at least one machine of that vintage. The categories are not mutually exclusive.

[12] As discussed in Juhász (2018, Online Appendix p. 22–24), only a subset of plants reported the spindles used. The remainder were imputed using other plant-level information.

- **Log(Spindles per worker):** This measure of capital intensity calculates the log number of spindles per worker in the plant.
- **Young plant:** This binary indicator takes the value of one if the plant is younger than the median mechanized cotton spinning plant in 1806 (3 years).
- **Exit dummy:** This is a variable equal to one for plants that existed in 1806 and that had exited the market by 1840. This is defined using our baseline measure of survival (see Appendix B.5). Any plant that we cannot match by owner name or by single-plant communes is classified as an exiting plant.

Identifying cotton spinning from other parts of the production process. In France, cotton spinning and weaving were generally not vertically integrated during this time period. Weaving, particularly in the early 19th century, was rurally organized. This implies less of an incentive to locate the workers in a common location, i.e, in a plant. Nevertheless, our dataset contains a few examples of vertically integrated spinning and weaving plants. We deal with these integrated plants in the following way. In the 1806 survey, enumerators were instructed to separately collect data for spinning and weaving activities (which is indicative of the lack of integration across these sectors in general). In the few cases where both took place under the same roof, we observe labor and output reported *by activity* and can thus estimate productivity separately for the spinning activities.

B.2 Metallurgy, 1811

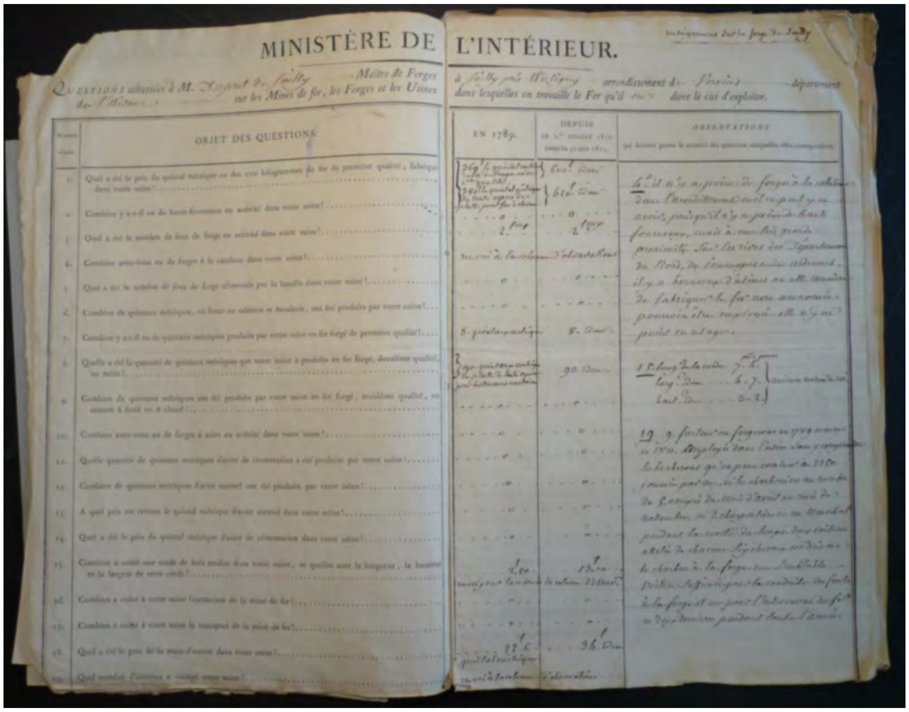
Primary data source. "Enquête sur les usines á fer de L'Empire (1811)" – Survey of iron manufacturers (1811). *Archives Nationales, Series F12/1603-1610.*

Source used in the paper. Primary data collected, digitized, and cleaned for this project.

How was the survey administered? A standardized questionnaire (see Figure A.12) consisting of 39 questions (8 pages in length) was sent to the *préfet* of each *département*. The officials were tasked with passing on the survey to owners (the *maîtres de forge* – forge masters), who needed to provide the necessary information. The *préfets* were also tasked with verifying that the data provided by the plants were accurate (Woronoff, 1984, p. 64).

Response rate. The response rate across *départements* was complete (Perrot and Woolf, 1984). In the case of metallurgy, we are able to assess not only compliance across *départements*, but also survey responses within them. As we describe in more detail below, this is because metallurgy plants had been surveyed multiple times since the 1770s, which meant that there was detailed knowledge about plant owners.

Woronoff (1984, p. 69) estimates that over two-thirds of the owners of active plants complied with the request for information. He suggests that compliance rates were inversely proportional to the number of establishments in metallurgy in the *département*. In the 20 or so *départements* with 1-5 plants, response rates were practically complete, whereas in regions with higher levels of


MINISTÈRE DE L'INTÉRIEUR.

OBJET DES QUESTIONS

EN 1789.

OBSERVATIONS

Figure A.12: Sample Page from the Metallurgy Survey, 1811

activity in the sector, the response rate was lower. This suggests that time constraints on officials were the main reason for non-compliance by plants.

Missing data pattern. Of the 576 plants surveyed, 44 reported no labor, 20 reported no output, and 34 plants reported neither of these variables. In many of these cases, the notes make it clear that the plant had shut down production. In total, labor productivity cannot be estimated for 98 (17%) of plants in the survey.[13]

Assessment of data quality. The survey covering metallurgy is a prime example of the 'statistical boom' that characterized the later empire between 1811-14 (Perrot and Woolf, 1984, p. 140). Beyond the high response rates at the *département* and plant level, other factors also contributed to this survey being of a particularly high quality. First, the level of existing knowledge about this industry was already high, given the information with which *préfets* could cross-check the returns. While the survey was addressed to the forge masters, it was cross-checked by *préfets* as well as by engineers of the mining agency. Second, Perrot and Woolf (1984, p. 161) note that the detailed questionnaire was designed so that it would be difficult for forge masters to manipulate their figures.

[13]It should be noted that as administrators had existing detailed information on forge masters from previous data collection efforts, it is likely that many of the plants with 'missing' data based on this definition had in fact been shut down for years. In this sense, we are likely overestimating the extent of missing data.

Variables directly reported in the 1811 metallurgy survey.

- Location of the plant (up to the commune level)
- Name of the owner (here: 'forge master')
- Quantity of output produced in metric quintals, by type (iron of first quality, iron of second quality, iron of third quality, steel using the cementation process, natural steel, and pig iron)
- Price of output produced (can be missing)
- Labor employed (does not always distinguish internal and external workers)
- Capital (number of blast furnaces, forges, catalan forges)
- Indicator variable if the firm was already in the market in 1788.

Data processing steps. In processing and cleaning the raw data, we performed the following steps:

1. **Data cleaning for numerical variables.** We cleaned strings (e.g., production reported as an interval) and converted observations where the unit of measurement was different (e.g., observation reported as "poids de mar" instead of reporting in quintals).
2. **Clean capital variables.** The number of machines reported under different categories (enumerated above) should add up to the total number of machines that the plant used; but in a small number of cases, it is likely that there is double-counting across categories. We manually correct these where possible.[14] Measurement error in the number of machines should not affect our results too much, as we only use capital in metallurgy for imputing internal labor (see next point).
3. **Harmonize labor variables.** Plants reported labor in various forms. Some reported labor by occupation. Others gave total by 'internal' and sometimes also 'external' labor[15]; or by male, female and child labor. We create a set of mutually exclusive categories based on whether the worker was an internal worker, an external worker, or of an unknown status. We classify occupations into internal and external categories based on a historical technical manual that describes the type of tasks performed by a particular occupation.[16]
4. **Impute internal labor.** As we mentioned in the text (Section 3.2), about 40% of the metallurgy plants reported either 'internal' labor only, or both 'internal' and 'external' labor, separately. The remainder of plants reported only total labor, with no indication of whether this includes external labor. To construct a consistent measure of 'internal' labor for all

[14]For example, plants were asked to report the number of forges and the number of Catalan forges (both are types of capital). Some plants report capital under each, which is unlikely, as these are two very different vintages of technology.

[15]Woronoff (1984, p. 138) describes external labor as only having very loose ties to the plant, performing tasks such as driving or collecting charcoal for the plant. Thus, external workers were unlikely to be considered formal salaried employees of the plant in the 1840 census.

[16]Le Blanc, V., Auguste, C., Walter de Saint-Ange, J. (1835). *Métallurgie pratique du fer, ou, Description méthodique des procédés de la fabrication de la fonte et du fer: accompagné de documents relatifs à l'établissement des usines, à la conduite et aux résultats des opérations.* Librairie Scientifique et Industrielle de L. Mathias, France.

plants, we estimate the size of the internal labor force for the 60% of plants that reported only total labor. We use a nearest neighbor matching algorithm to determine whether plants that only report total labor are more likely to be reporting internal labor only or the sum of internal and external labor. We match each plant that reports only total labor to its nearest neighbor that reports internal and external labor, where matching is based on capital, output, and the stage of production (see below, under *'Constructed variables for metallurgy plants in 1811'*, for the definition of this variable) the plant is involved in. We then classify a plant as "reporting only internal labor" if its reported total labor is closer to the matched plant's internal labor force. Likewise, we define a plant as "reporting total labor" when it is closer to the internal plus external labor force of the matched plant. When our algorithm suggests that the plant is reporting internal and external labor together, we estimate the number of internal workers by using the mean proportion of internal labor from all plants that report both types (the average internal labor share is 20%).

5. **Clean owner names.** In a small number of cases, the notes from the survey make it clear that the name entered under 'forge master' was the manager, not the owner. In these cases, we code the owner name as 'missing.'
6. **Drop plants outside of mainland present-day France** We drop 8 plants located on the island of Corsica. We do so because our spatial diffusion analysis does not apply to areas that were isolated from other plants. Thus, our baseline sample is restricted to plants within mainland France in its current borders. With this restriction, we are left with 470 metallurgy plants that have labor productivity data (478 out of 576 plants have the information needed to compute labor productivity).
7. **Plant locations.** To assign plant location geocodes, we use information provided in the survey on the 'commune' in which the plant was located, using a combination of automated packages and manual assignment. Using the geocodes, we then assign each plant the present day *dèpartement* and region to which the commune belongs. Using this procedure, only 44 (9.4%) of the 470 plants for which we have labor productivity data could not be geocoded.

Constructed variables for metallurgy plants in 1811.

- **Plant labor productivity**: This is defined as log(revenue per worker), where revenues are deflated as described in Appendix B.6. For all plants, the survey reports the quantity of output produced by product type: iron of first quality, iron of second quality, iron of third quality, steel using the cementation process, natural steel, and pig iron. In addition, some plants report also the prices by product type. To construct plant-level revenue, we multiply the quantity of each product type that the plant produced by the average price of this product, and then sum across all of the plant's products. We compute these average prices for each product type using the information from those plants that reported prices for the corresponding product.[17] We deflate revenues using the wholesale price index reported for 1811 in Mitchell (2003), as described in Appendix B.6.

We also construct an alternative measure of labor productivity that uses the plant-specific output prices for those plants that report this information, and the average product-specific price (as described above) for those plants that do not report output prices.

- **log(Employment):** This is defined as the log of the total number of internal workers.
- **Stage of production:** We assign plants to mutually exclusive stages of production based on the capital they use and the type of output they produce. Upstream plants produce only pig iron with a blast furnance. Downstream plants produce wrought iron or steel with a forge and have no catalan forge (old technology used for indirect production). Integrated plants do both upstream and downstream stages. Indirect producers use a catalan forge to produce wrought iron. These binary variables are only used for the matching algorithm used to impute internal labor.
- **Young plant:** Indicator variable that takes the value of one if the plant was not active in 1788 (and we consider it an 'entrant' in 1811).
- **Exit dummy:** This is a variable equal to one for plants that existed in 1811 and that had exited the market by 1840. This is defined using our baseline measure of survival. Any plant that we cannot match by owner-name or by single-plant communes will be classified as an exiting plant.

B.3 Paper Milling, 1794

Primary data sources.

- *"Enquêtes sur les papeteries en France, an II."* – Survey of the paper milling industry in Frnace, 1794 (year 2 according the the Revolutionary calendar). *Archives Nationales, Series F12/1482– 1485*.
- Price data for paper milling products from the *Tableaux du Maximum*. Images from the *Tableaux* for paper milling were kindly shared by Guillaume Daudin. Original source: *Archives Nationales, Series F12/1516–1544*. See Daudin (2010) for further details.

Source used in the paper. Primary data collected, digitized, and cleaned for this project.

How was the survey administered? The survey was administered by the Jacobin government using a standardized template that was given to local authorities. Given the level of detail asked for by the survey (name, birthplace, age, tenure and occupation of workers), it is likely that plants themselves had to provide this information. In some cases, the information is certified by the mayor or other local public officials.

[17] Overall, 308 out of 470 plants reported at least one price for their products. We show in Appendix E.2 that our results hold when we use the product-specific prices for those plants that reported them, while dropping the remaining metallurgy plants in 1811.

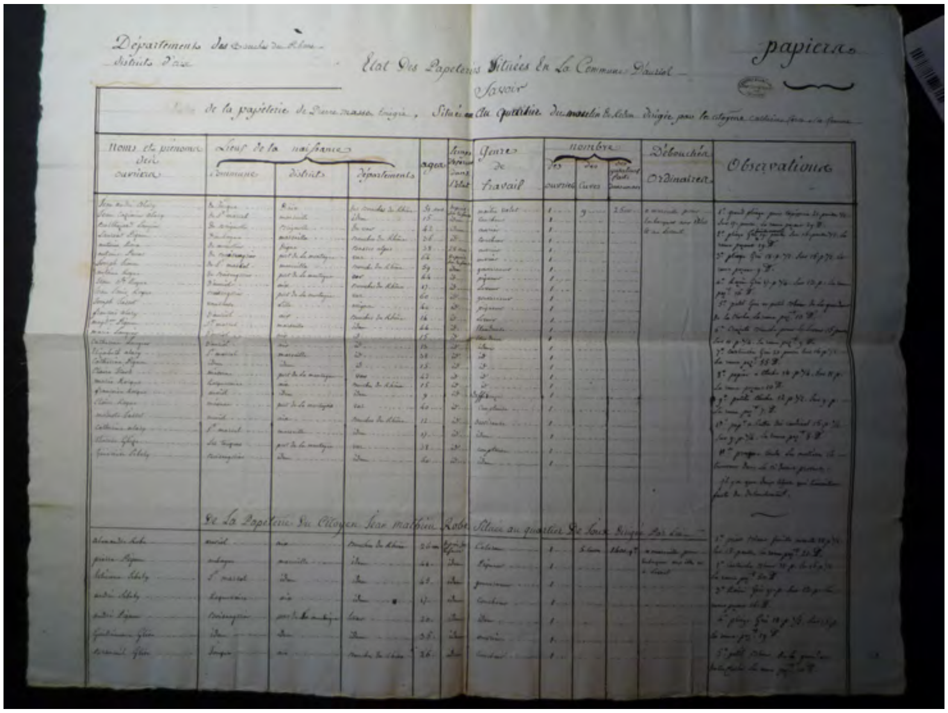

Département des Bouches du Rhône
district d'aix
Etat des Papeteries Situées En La Commune D'auriol
Savoir
papiers
Noms et prénoms des ouvriers | Lieux de la naissance: Communes, districts, départements | ages | Genre de travail | nombre: des ouvriers, des cuves | Débouchés Ordinaires | Observations

Figure A.13: Sample Page from the Paper Milling Survey, 1794

Response rate. All returns except for those from Corsica were submitted.

Missing data pattern. Of the 593 plants surveyed, 28 reported no labor, 30 reported no output, and 15 plants reported neither of these variables. In many of these cases, the notes from the survey enumerators make it clear that the plant had shut down production. In total, labor productivity cannot be estimated for 73 (12%) of plants in the survey.

Assessment of data quality. Bonin and Langlois (1987) use the data from the 1794 paper milling survey and argue that the geographic dispersion of production lines up fairly well with another survey of paper milling conducted later (in 1811, under the same Napoleonic regime that conducted the cotton spinning and metallurgy surveys).[18] This suggests that despite our survey being conducted earlier than the other two from the time period, the data quality is similar.

Variables directly reported in the 1794 paper milling survey.

- Name of the owner
- Location of the plant (up to the commune)
- Name (first and last) of workers
- Age of the worker

[18]While we collected the data from the 1811 paper milling survey, it proved to be of little use for our purposes in this paper, as 40% of plants surveyed gave no information at all on labor employed, making it infeasible to calculate labor productivity.

- Occupation of each worker
- Total number of workers employed by the plant
- Output (in quintals)[19]

Data processing steps. In processing and cleaning the raw data, we performed the following steps:

1. **Data cleaning for numerical variables:** We cleaned strings (e.g., production reported as an interval) and converted observations where the unit of measurement was reported incorrectly (e.g., observation reported as 'livres' instead of quintals). For a handful of observations, we could not convert the unit of measurement for output, when there was no obvious conversion rate (e.g. 'reams' of paper). These were dropped. For 27 observations, the output reported was so high, it suggested the unit of measurement was incorrect. For these plants, we suspect they reported output in 'livres' which is one-hundredth of a quintal. Using the original high values would lead to unrealistic labor productivity estimates. Rather than dropping these observations, we decided to keep them in the data and convert them to quintals from livres, assuming that they were erroneously reported in the latter. We note in passing that this data cleaning step is not crucial for our results: Omitting this step does not affect any of our results.
2. **Clean individual worker data:** We group workers into four categories: men, women, children and apprentices. We drop children younger than 7 years old (and only keep those between 7-10 that report an occupation). Any worker aged younger than 15 years is classified as a child worker. Apprentices are classified based on their reported occupation. Male and female workers were assigned a gender based on their first name.
3. **Create employment data:** All paper milling plants report employment in two forms. The returns list individual workers as well as total employment. We add the individual workers and compare the sum to the reported total. In 90% of the cases, the two match up perfectly, or differ by only one unit.[20] However, only male labor seems to be consistently reported across plants. Only 37% of plants report any female workers; only 38% of plants report any child labor; and only 22% of plants report employing apprentices. Given that proto-factories were characterized by family units working together, it is highly likely that the raw totals are undercounting employees in many plants. For these reasons, we use male labor as our baseline measure of employees. To construct a measure of total employment by plants that

[19] The metric system was adopted by the Revolutionary French government in 1795, *after* the paper milling survey was conducted. In processing this data, we assume that output is reported in 'old regime' quintals (which is 100 pounds (*livres*)). This is the most likely unit, given that the metric system had not yet been adopted when the paper milling survey was administered in 1794. In addition, the later cotton spinning survey in 1806 explicitly specified that output be enumerated in kilograms. Likewise, the 1811 survey in metallurgy requested that units of output should be in *metric* quintals (i.e., 100 kilograms).

[20] We create a consistent variable when there is a discrepancy between the two employment numbers by taking the larger reported number of the two.

we can compare to 1840, we impute total employment for 1794 by scaling male labor by the proportion of total labor to male labor in 1840 (2.29). As discussed in the main text, the validity of this method hinges on the assumption that the ratio of total employment to male employment remained constant over our sample period. We find that the proportions are consistent. The proportion of total employees to male employees is 2.11 in 1794 for the 18 plants that report all types of labor, while in 1840, it is 2.29 (averaged across all plants).

4. **Plant locations:** We use information provided in the survey on the 'commune' in which the plant was located to assign geocodes, using a combination of automated packages and manual assignment. Using the geocodes, we then assigned each plant the present-day *dèpartement* and region to which the commune belongs. Using this procedure, only 13 (2.5%) of the 520 plants for which we have labor productivity data could not be geocoded.

Constructed variables for paper milling plants in 1794.

- **Plant labor productivity**: This is defined as log(deflated revenue per worker). For all plants, the survey reports the quantity of output produced. We price this output using the mean price of paper products as reported in the *Tableaux du Maximum*. Employment is the total imputed employment as described above. We deflate revenues using the wholesale price index reported for 1811 in Mitchell (2003). See Appendix B.6 for detail. We also construct an alternative measure of labor productivity that uses only male employment in 1794.
- **Exit dummy:** This is a variable equal to one for plants that existed in 1794 and that had exited the market by 1840. This is defined using our baseline measure of survival. Any plant that we cannot match by owner-name or by single-plant communes is classified as an exiting plant.

B.4 The Manufacturing Census of 1839-47

Primary data source. The data are from the four-volume *Statistique de la France: Industrie* published in 1847 by the Ministry of Agriculture and Commerce. The volumes were scanned by the French National Library (BNF) and are available to view on their online catalogue (https://gallica.bnf.fr/ark:/12148/bpt6k857958?rk=64378;0).

Source used in the paper. The data were digitized by Chanut, Heffer, Mairesse, and Postel-Vinay (2000). We use this version of the data.

How was the survey administered? This was the first full industrial census conducted by the royal statistical agency, *"Statistique générale du royaume."* Its execution was similar to previous industrial surveys covering individual sectors in that the circular to collect the requested information was sent to regional officials (*préfects* and their subordinates). Plants themselves submitted the information. Local officials and technical experts were tasked with verifying the information provided by plants. However, different to the industrial surveys from the 1800s, the data were also checked, cleaned, and harmonized by the central statistical agency (Ministère de l'Agriculture et du Commerce, 1847). These data were then released by the Ministry of Agriculture and Commerce, and this publication formed the basis of the modern digitization efforts of Chanut et al. (2000).

While the timing of the census seems broad (1839-47), the data were actually collected in a relatively narrow window of time around 1845. Local administrators set to work on collecting the data in 1839, but the effort was halted after 18 months. The reason was that a concurrent survey was started by the Minister of Finance, and officials became concerned that the returns would be unreliable. Work began again in 1845, at which time *préfects* updated their records and submitted the returns (Ministère de l'Agriculture et du Commerce, 1847, pp. xxiv-xxv). The returns were centrally cleaned and organized. The results were released in 1847.

Response rate. All returns except those for Paris and Corsica were submitted.

Missing data pattern. Every observation included in the dataset for our three sectors of interest has a strictly positive value for labor and output. This is plausibly due to the fact that the released data were already cleaned.

Assessment of data quality. The census was conducted with a high degree of care. Local officials were instructed to declare to surveyed plants that the investigation had no fiscal purpose. The plant was tasked with writing a descriptive bulletin that was verified by local authorities and people with relevant technical knowledge. Figures were checked at the *département* level and centrally, by authorities with relevant technical knowledge. Where possible, figures were cross-checked against other sources (e.g., against tax records) (Ministère de l'Agriculture et du Commerce, 1847).

An important limitation is that the 1840 manufacturing census undercounted plants with fewer than 10 employees (Ministère de l'Agriculture et du Commerce, 1847, p. xviii.). We deal with this issue by conducting robustness checks where we omit plants with fewer than 10 employees from all sector-year pairs (see Appendix E.10).

Variables directly reported in the 1840 census for all three industries.

- Location of the plant (up to the commune level)
- Name of the owner
- Value of production (in francs)
- Total number of employees
- Employees by male, female and child labor
- Number of water-powered, steam-powered, animal-driven and wind-powered engines (separately).
- Spindles (including those imputed by Juhász, 2018)[21].

Data processing steps. In processing and cleaning the raw data, we performed the following steps:

[21] As discussed in Juhász (2018, Online Appendix p. 25), only a subset of plants reported the spindles used. The remainder were imputed using other plant level information.

1. **Data filtering for the three industries:** The three industries can be identified with a high level of precision. For cotton spinning we use all plants that report their main activity as cotton spinning (*CODB5000 = 5283*). For metallurgy, we classified all plants that reported metallurgy as their main activity (*CODBRAG = 3*). For paper milling, we use all plants that report paper and cardboard as their main activity (*CODB2000 = 2550*).
2. **Data cleaning:** As the raw census data were processed by the central statistical agency of France in 1847, we cannot rule out that observations with missing labor or output data were dropped in a previous cleaning step. We dropped observations where multiple establishments jointly reported their data. This issue affects 6.8% of establishments in metallurgy, 2.0% of establishments in cotton spinning, and 18% of establishments in paper milling.
3. **Plant locations:** We use information provided in the survey on the 'commune' in which the plant was located to assign geocodes, using a combination of automated packages and manual assignment. Using the geocodes, we then assigned each plant the present-day *dèpartement* and region to which the commune belongs. Using this procedure, only 9 (1.7%) of the 528 plants for which we have labor productivity data in cotton spinning could not be geocoded. In metallurgy, this number is 33 (3.7%) out of 896 plants; in paper milling it is 4 (1.1%) of 347 plants.

Constructed variables for the three sectors in 1840.

- **Plant labor productivity**: This is defined as log(revenue per worker). The census reports the value of output (in francs) and the total labor employed. We deflate output using the wholesale price index reported for 1840 in Mitchell (2003). The base year for the index is 1820; see Appendix B.6 for detail.

- **Capital (for cotton spinning only):** We define capital as the log number of spindles at the plant level. Spindles are the standard measure of capital in the industry. Some plants reported them and Juhász (2018, Online Appendix pp. 22-24) imputed the remainder.

- **log(Employment):** This is defined as the log of the total number of workers.

- **Plant total factor productivity (for cotton spinning only):** TFP at the plant level is computed as the residual from regressing plant-level deflated log revenue on log(total workers) and log(capital), as defined above.

- **Log(Spindles per worker) – for cotton spinning only:** This measure of capital intensity calculates the log number of spindles per worker in the plant.

- **Entrant:** Binary variable equal to one if the plant in 1840 did not have a name-based match in the 1800 survey wave.

B.5 Plant Linking and Plant Survival

All three surveys from around 1800 as well as the 1840 census report the name of the owner and the location of the plant up to the commune, which is the lowest administrative unit in France. In bigger cities such as Paris, the *arrondissement* is also reported. We construct a consistent measure of plant location across surveys by assigning each plant to its modern-day commune, *département*, and region as described above under the "Plant locations" bullet points for each sector.

Linking plants. We use two pieces of information to link plants over time. First, we match plants by their owner names in a given commune in the respective industry.[22] Since the name of the owner may change even if the physical structure of the plant is the same, we also match by location in a second step. We match locations that had only *one* plant in the respective sector in 1800, and at least one plant active in the same sector in 1840. This turns out to be fairly common in the data. An obvious concern is whether this 'local matching' indeed identifies the same plant. This is likely, given a fortuitous feature across all three of our industries: their reliance on water power. Only a small number of locations in a typical commune were suitable for setting up a water-powered mill, as rapid stream flow was needed to yield sufficient power. Moreover, the backwater created by one mill meant that another mill could not be located in close proximity. Consistent with this, Crafts and Wolf (2014) argue that agglomeration in the cotton textile industry was not observed until steam became the common source of power in Britain. Consequently, our 'local matching' arguably identifies plants that had the same location within communes. Whether these were owned by the same entrepreneur (or their descendants), or whether they had passed on to a different owner is not crucial for our analysis.[23]

Plant survival. Our main measure of plant survival is based on the combination of matching by owner name and 'local matching' that we described above. We define the survival rate as the percentage of plants from the initial period that survive into the later period. The numerator counts all plants that fulfill at least one of the following two conditions: i) the plant had the same owner in both periods; ii) there was only one plant in the respective sector in the location in the initial period and *at least* one plant in the same sector in 1840. The denominator is the sum of *all* plants in the given sector in the initial period. The corresponding survival rates are reported in Table 2 in

[22] We use a fuzzy string match to allow for differences in spelling as well as for different first names of owners, in cases where the plant was passed on within a family. All matches were verified by hand. Ownership data indicate that only a small fraction owned more than one plant: Among the 528 cotton spinning plants in 1840, only 30 were part of multi-establishment firms with the same owner (in almost all these cases, one owner had two plants). Throughout the text, we thus refer to plants and firms interchangeably.

[23] One way to validate the assumptions underlying our 'local matching' is to examine how frequently communes with a single plant active in the sector in 1800 show up in 1840 with multiple plants active in the same sector. If this occurred frequently in the data, it would suggest that in fact there were often multiple suitable locations for production in that sector in the same commune. This is not the case in our data. It is rare (6.9% in cotton spinning, 5.2% in metallurgy and 5.7% in paper milling) across all three surveys for single-plant communes to 'add' additional plants (despite the large increase in the overall number of plants in metallurgy and cotton spinning).

the paper.

We can verify this methodology in the metallurgy sector, where the 1811 survey asked about each plant's activities in 1788. If our strategy of 'local matching' led to too many plant matches over time, we would expect an exaggerated survival rate. The contrary is true. Among the metallurgy plants in the 1811 survey, 77% reported that they had existed in 1788. Our plant-linking procedure for 1811-40 yields that among the 896 plants in 1840, 177 (20%) existed in 1811.[24] While the later period is longer, this cannot account for the substantially smaller number of initially existing plants in our matching procedure. This suggests that it is unlikely that we systematically *overestimate* plant survival.

Note that our baseline measure of plant survival does not adjust for the fact that the number of plants located in communes that had only one plant varies across the three sectors in our sample.[25] Thus, we may mechanically find higher survival rates in a sector where single-plant communes were relatively more frequent. To address this issue, we also construct the 'restricted sample' survival rate as a robustness check. This measure is based solely on single-plant locations. The numerator of the 'restricted sample' survival rate counts the number of communes that had only one plant in the respective sector in the initial period, and at least one plant in 1840. The denominator is the set of all single-plant communes in 1800.

B.6 Variables Used to Complement the Four Industry Surveys

Price Deflators.

Source: Mitchell (2003)

Methodology of deflating output prices: For all three sectors, and both time periods, we deflate revenues using the one wholesale price index reported in (Mitchell, 2003). The base year is 1820. We use these to deflate revenues in cotton spinning (1806), in metallurgy (1811) in the corresponding exact years of the survey. For the paper milling survey from 1794, we need additional information, as the series starts in 1798. We use price data from the *Tableaux du Maximum*, which lists prices from 1790, before the Mitchell (2003) series begins.[26] We thus we need to make an assumption about how 1790 prices relate to prices we observe. Based on our reading of the literature on the timing of hyperinflation during the French Revolution and its subsequent reversion, we assume that 1790 prices were the same as prices in 1800.[27] For the census, we deflate revenues

[24] Note that we cannot compute the actual survival rate for 1788-1811 because we do not have information on the initial number of plants in 1788. We thus compare the share of plants that existed in the earlier period, conditional on existing in the later period.

[25] Among the 520 plants in paper milling in 1794, 211 (40.6%) were the only plants active in their commune in this sector. For cotton spinning in 1806, the proportion is 25.6% (87 out of the 340 plants), and in metallurgy in 1811, 69% (324 out of 470 plants).

[26] As part of the revolutionary government's fight against inflation, a survey was conducted across the country, asking French districts to submit prices of goods produced or imported from aboard, along with their price (Daudin, 2010) These are reported in the *Tableaux du Maximum*.

[27] The high inflation during the revolutionary period was accompanied by the increasing issuing of *assignats* – a type

using the value for 1840.

Variables Common to all 3 Sectors:

- **Distance to high-productivity plants:** For each sector, this is computed as the log straight-line distance (in km) to the nearest plant with productivity in the 90th percentile (in the same sector) in the initial period. Any plant in the top decile of the productivity distribution is excluded from these regressions (which is why the number of observations in these regressions falls).
- **Distance to London:** This is the log straight-line distance (in km) from each plant's location in France to the city of London (England).

Control Variables:

- **Access to high stream-flow:**
  Data sources: EURO-FRIEND (2015). *European Water Archive, River Discharge Data*
  Data construction: The source data contain information on monthly mean streamflow rates (m^3/s) for 1,279 collection points across France for the years 1863 – 2012 (with data coverage best around 1960 – 1990). For each measuring station, we calculated the 95th percentile of streamflow across all months. That is, 95% of streamflow values are greater than this number at the given measuring station. This captures the year-round minimum streamflow that can be expected. We match each plant to its closest measuring station. Generally, this should be a good proxy for the streamflow available locally. The median commune in France is located about 10km from its nearest measuring station. The commune at the 95th percentile of distance to its nearest measuring station is 46 km away. In other words, almost all plants are at a reasonable distance from their nearest measuring station.

  Access to high streamflow is a binary variable that takes the value of one if a plant's nearest data collection point for river discharge has streamflow in the top quartile of the distribution (within a sector-year).
- **Proximity to coal:**
  Data sources: For coalfields within France: Guiollard P. – C. (1993) *Les Chevalements des Houilléres Françaises*. France, (2éme éd.)

of paper money. Initially, *assignats* were linked to gold – one *louis d'or* (a gold coin) was equal to 100 *assignats* in 1791. Thereafter, the value of *assignats* depreciated: In 1794, the same *louis d'or* corresponded to about 500 *assignats*. After a period of hyperinflation (1793-1797), the *assignats* were removed from the market (White, 1991; Sargent and Velde, 1995). In 1800, Napoleon founded the *Banque de France* and then eliminated paper money (Lefebvre, 2011), while trying to increase the stock of metallic money. While there is no systematic price index linking the 1790 and 1800 prices, it seems that by 1800, prices reverted back to their 1790 level (we are grateful to Eugene White for these insights on hyperinflation during the French Revolution). Moreover, for one town (Château-Gontier), we also observe a (wheat) price index every year from 1790 to 1800: This was 202 in 1790; it increased to 336 in 1794, and went back to 209 in 1800 (Hauser, 1985). This evidence from Château-Gontier further supports our assumption that 1790 prices were approximately the same as prices in 1800.

For coalfields in Europe outside of France: Coalfields of Europe, 1910. Available online at: https://etc.usf.edu/maps/pages/7200/7264/7264.htm

Data construction: These maps were georeferenced by a Digital Cartography Specialist at the Harvard Map Collection. For each plant in our data, we then computed the distance to the nearest coalfield.

Proximity to coal is a binary indicator that takes the value of one if a location is in the bottom quartile of plant locations (within a sector-year) in terms of distance to the nearest coalfield.

- **Share of forest area:**
  Data sources: Vallauri, Grel, Granier, and Dupouey (2012)
  Data construction: We calculate the share of each commune covered by forests as reported in the *Cassini* maps from the late 18th century. These maps were georeferenced and made available by Vallauri et al. (2012).
- **Production density:**
  Data construction: We sum the total revenue produced by commune in a sector-year net of the plant's own output. Production density is defined as log of 1 plus this sum.
- **Conscripts per capita by region:**
  Data sources: Vallée and Hargenvilliers (1936) and INSEE (https://www.insee.fr/fr/statistiques/2591293?sommaire=2591397)

  Data construction: We collected data on conscripted men from Vallée and Hargenvilliers (1936). This contains data by historical *département* on the number of men that were recruited for the years 1798-1805 (more specifically, between year 7 and year 13 according to the Republican Calendar). While this does not include recruited men for later years, it is arguably a good proxy, as recruitment rates across *départements* displayed high persistence (Forrest, 1989). We then compute the variable log(conscripts per capita), using data on population at the historical *département* level from INSEE. Since historical *département* do not map into their contemporaneous counterparts (which we use in our analysis), we aggregate the data on conscripts per capita to the regional level.
- **Proximity to battles during the Napoleonic Wars:**
  Data sources: Wikipedia
  https://en.wikipedia.org/wiki/List_of_battles_of_the_War_of_the_Sixth_Coalition (for the War of the Sixth Coalition);
  https://en.wikipedia.org/wiki/List_of_battles_of_the_Hundred_Days (for the Hundred Days War)

  Data construction: We first geocode the location of all battles that took place on French territory. These comprise the final battles of the Sixth Coalition (1813-14) and of the Hundred Days War (culminating in Napoleon's defeat at Waterloo). We then construct a dummy

(*Near Battles*) equal to one for plants located within 10km from a battlefield.

- **Market access:**

  Data sources: Özak (2018) and Nunn and Qian (2011)

  Data construction: We construct two measures of market access: i) within France and; ii) across Europe. Both measures are computed as the sum of inverse-distance-weighted urban populations j around each French commune i in 1800 (Market Access $MA_i \equiv \sum_j \frac{pop_j}{dist_{ij}}$). For commune i, we use the geocoded location (described above). We take data on cities j with a population of more than 1,000 inhabitants in 1800 from Bairoch, Batou, and Chèvre (1988), as reported in Nunn and Qian (2011), including geocodes for these cities. Then, for each plant in our data, we calculate the shortest travel time between the plant and each city, using the *Human Mobility Index with Seafaring* (Özak, 2018). This measure constructs minimum travel time (in hours) using constraints on human mobility and technological constraints from before the steam-age. Specifically, the data provides the cost of crossing each 1 x 1 km cell across the globe (land and sea). As such, the minimum travel time between any two points in space can be computed using GIS software. For the within-France measure, we only use population centers in France, whereas for the Europe-wide measure we use all European cities in the data.

C Descriptive Statistics

This appendix describes key descriptive statistics for the three industries covered in our data.

C.1 Plant Locations

Figure A.14 shows the spatial distribution of firms in the three sectors and in the two time periods.

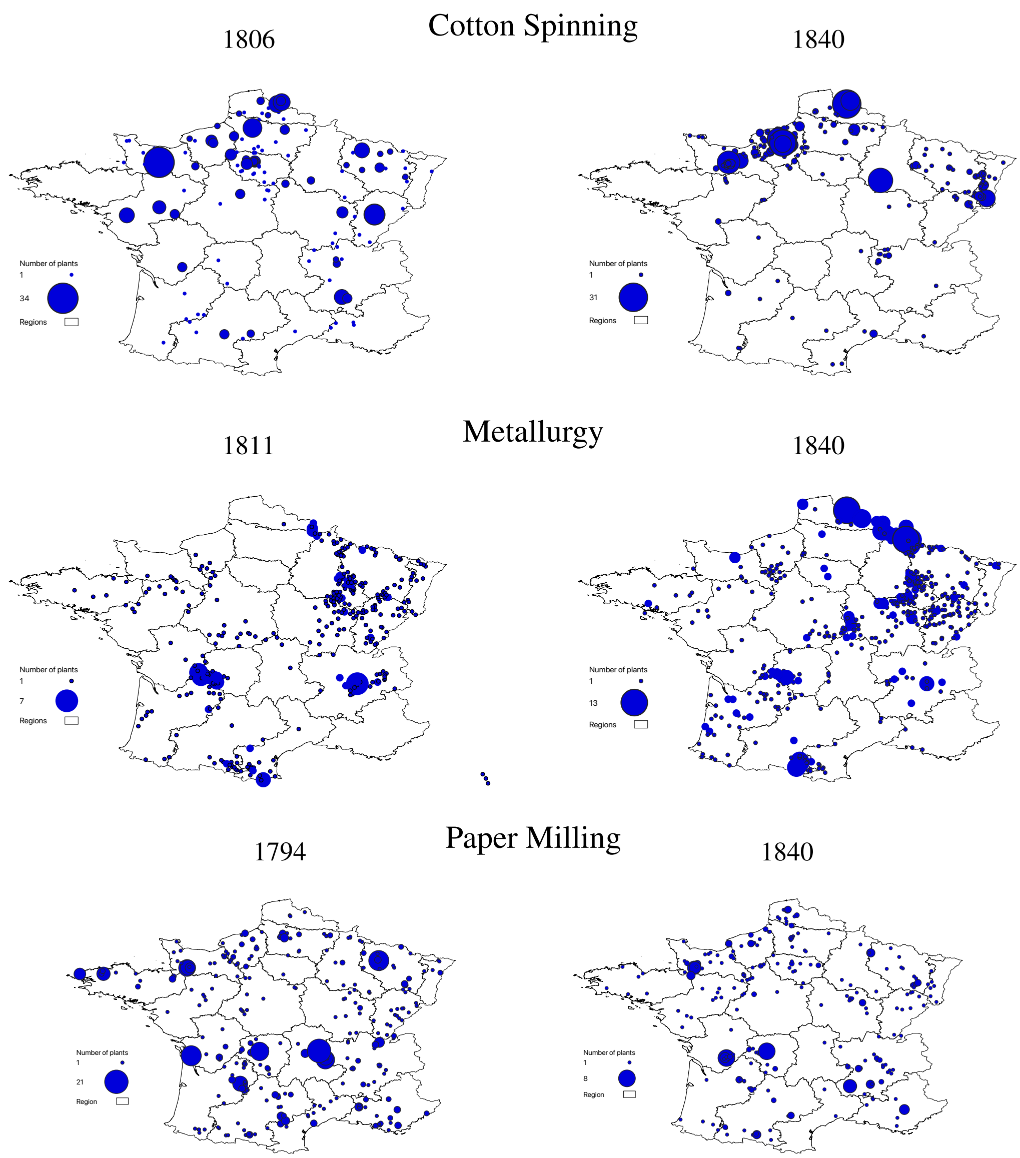


Figure A.14: Spatial Distribution of Plants Across France in the Three Sectors

Note: The figure shows the spatial distribution of plants in cotton spinning (top), metallurgy (middle), and paper milling (bottom). Dot sizes reflect the number of plants per commune.

C.2 Summary Statistics for the Three Sectors

Tables A.2, A.3, and A.4 show summary statistics for mechanized cotton spinning, metallurgy, and paper milling plants, respectively.

Table A.2: Summary Statistics – Mechanized Cotton Spinning

	Around 1800					1840					Sources
	#obs	Mean	Std. Dev.	Min	Max	#obs	Mean	Std. Dev.	Min	Max	& Detail
Firm-level characteristics											
Log (output per worker)	340	7.08	0.87	2.48	9.73	528	7.9	0.51	6.73	9.06	App. B.1
Number of workers	340	63.9	103.07	1	950	528	112	148	4	1,413	App. B.1
Plant Age	334	6.6	8.06	0	56						App. B.1
Exit dummy	340	0.95	0.22	0	1						App. B.1
Avg. quality of yarn	323	35.19	19.99	4.5	135						App. B.1
Total num. of machines	300	14.76	23.31	1	250						App. B.1
Num. spinning jennies	336	2.39	6.99	0	60						App. B.1
Num. water-frames	301	4.11	11.24	0	96						App. B.1
Num. of spinning-mules	302	7.91	19.37	0	200						App. B.1
Spindles	340	1,658	3,686	26	49,200	528	6,392	7,393	300	85,000	App. B.1
Spindles per worker	340	27.7	19.05	1.7	120	528	78.2	90.11	4.92	1,000	App. B.1
Water power						528	0.66	0.47	0	1	App. B.1
Steam power						528	0.39	0.49	0	1	App. B.1
Other power						528	0.02	0.14	0	1	App. B.1
Control Variables											
Access to high streamflow	321	0.25	0.43	0	1	519	0.22	0.41	0	1	App. B.6
Proximity to coal	321	0.25	0.43	0	1	519	0.26	0.44	0	1	App. B.6
Share of forest area	321	0.1	0.15	0	0.82	519	0.15	0.18	0	0.81	App. B.6
Production density	340	9.28	5.65	0	14.94	528	9.47	6.51	0	15.84	App. B.6
Market access, France	321	5.09	0.85	4.08	8.14	519	4.81	0.50	4.11	6.35	App. B.6
Market access, Europe	321	5.91	0.55	5.31	8.18	519	5.78	0.26	5.32	6.64	App. B.6
Access to overseas market	321	0.39	0.49	0	1	519	0.56	0.50	0	1	App. B.6
log(conscripts pc)	321	2.88	0.57	1.63	3.38	519	2.88	0.47	1.63	3.38	App. B.6
Near Battles	321	0.14	0.35	0	1	519	0.008	0.088	0	1	App. B.6
Distance Variables											
Dist to p90	290	87.80	86.17	0	428.79	467	34.84	54.82	0	287.55	App. B.6
Dist to p90 metal (1800)	321	110.02	56.97	10.8	207.63						App. B.6
Dist to p90 paper (1800)	321	61.63	33.31	0	148.34						App. B.6
Dist to London	321	433.19	202.35	191.42	952.73	519	359.80	181.57	195.32	1005.34	App. B.6

Note: The table shows the summary statistics for the variables used in the paper and appendix.

Table A.3: Summary Statistics – Metallurgy

	Around 1800					1840					Sources
	#obs	Mean	Std. Dev.	Min	Max	#obs	Mean	Std. Dev.	Min	Max	& Detail
Firm-level characteristics											
Log (output per worker)	470	8.1 2	0.93	2.09	11.04	896	8.80	0.92	4.87	11.69	App. B.2
Number of workers	470	22.64	37.35	2	500	896	56.55	112.42	1	1,400	App. B.2
Exit dummy	470	0.62	0.49	0	1	896					App. B.2
Water power						896	0.64	0.48	0	1	App. B.2
Steam power						896	0.15	0.36	0	1	App. B.2
Other power						896	0.08	0.28	0	1	App. B.2
Control Variables											
Access to high streamflow	426	0.23	0.42	0	1	863	0.25	0.43	0	1	App. B.6
Proximity to coal	426	0.25	0.43	0	1	863	0.25	0.43	0	1	App. B.6
Share of forest area	417	0.24	0.21	0	0.88	863	0.24	0.22	0	0.90	App. B.6
Production density	470	3.85	5.92	0	15.56	896	5.57	6.45	0	16.47	App. B.6
log(conscripts pc)	426	3.05	0.41	1.39	3.38	863	2.99	0.50	1.39	3.38	App. B.6
Near Battles	426	0.01	0.11	0	1	863	0.03	0.16	0	1	App. B.6
Distance Variables											
Dist to p90	385	40.59	40.20	0	236.04	863	48.25	51.5	0	273.92	App. B.6
Dist to London	427	632.25	178.83	253.90	1034.83	864	570.46	191.41	148.50	1006.98	App. B.6

Note: The table shows the summary statistics for the variables used in the paper and appendix.

C.3 Plant Scale

We examine plant scale and the number of plants in each industry. Plant size is measured by the number of workers. A few points stand out. First, as early as 1806, cotton spinning plants were strikingly large. The average spinning plant in this period had 64 employees. Despite the recent introduction of mechanized cotton spinning in France, plants were already larger than in the two comparison sectors, both of which had a longer tradition of factory-based production. Plants in metallurgy (reported in 1811) had on average 23 workers; paper milling plants had on average 13 employees.[28]

We also observe that between 1806 and 1840, the number of mechanized cotton spinning plants active in the market expanded markedly (from 340 in 1806, to 528 in 1840). This is important,

[28]One caveat with making this comparison is that the paper milling survey dates from 1794. Thus, plant size may have grown by 1806 – the year of the cotton spinning survey. In addition, we had to extrapolate the overall number of workers in paper milling in 1794 (including women and children – see Section 3.2). However, it is unlikely that the actual paper plant scale was very different in 1806. This is because even in 1840, the average plant size in paper milling was only 43 (including women and children, which are reported in this year). We can thus be confident that paper milling plants in 1806 were substantially smaller than cotton plants. Finally, as described below in Appendix B.4, there is a concern that the 1840 census did not enumerate all plants with less than 10 employees (which, however, does not affect our results – see Appendix E.10).

Table A.4: Summary Statistics – Paper Milling

	Around 1800					1840					Sources
	#obs	Mean	Std. Dev.	Min	Max	#obs	Mean	Std. Dev.	Min	Max	& Detail
Firm-level characteristics											
Log (output per worker)	520	7.28	0.77	3.55	10.52	347	7.61	0.71	4.89	11.51	App. B.3
Number of workers	520	12.56	17.80	2	317	347	42.61	58.52	1	507	App. B.3
Water power						347	0.85	0.35	0	1	App. B.3
Steam power						347	0.12	0.32	0	1	App. B.3
Other power						347	0.02	0.14	0	1	App. B.3
Control Variables											
Access to high streamflow	507	0.24	0.43	0	1	343	0.23	0.42	0	1	App. B.6
Proximity to coal	507	0.25	0.44	0	1	343	0.25	0.43	0	1	App. B.6
Share of forest area	507	0.11	0.15	0	0.76	343	0.10	0.15	0	0.76	App. B.6
Production density	520	6.62	5.56	0	13.45	347	5.46	5.77	0	14.32	App. B.6
log(conscripts pc)	507	2.96	0.44	1.39	3.38	343	2.91	0.51	1.30	3.38	App. B.6
Near Battles	507	0.004	0.06	0	1	343	0.015	0.12	0	1	App. B.6
Distance Variables											
Dist to p90	456	38.08	33.08	0	168.79	309	60.05	47.75	0	203.63	App. B.6
Dist to London	510	605.30	222.37	194.70	1036.35	343	544.31	238.52	177.63	1021.91	App. B.6

Note: The table shows the summary statistics for the variables used in the paper and appendix.

as it suggests that our results, which show a disappearance of the lower tail of the productivity distribution, were driven by more than simply the 'shake-out' of unsuccessful plants. In fact, each exiting plant was replaced on average by more than one new entrant.

D Mechanism: Stylized Framework and Evidence

This section describes a stylized theoretical framework that generates the main pattern in our data: a lower-tail bias in productivity growth in mechanized cotton spinning. For simplicity, we focus on a partial equilibrium setting where the economy-wide expenditure for spun cotton yarn is given. Spinning firms produce differentiated products, which reflects differences in output varieties as well as spatially segmented markets. Firms randomly draw their productivity, based on a combination of complementary input tasks. The complementarity across individual input tasks leads to a fat lower tail in the initial productivity distribution.

We consider three periods over a firm's lifetime. In the first period, firms either establish themselves in the market or they exit (if they cannot pay the fixed cost of production). This weeds out firms with very low productivity draws. In the innovation period, established firms can decide whether they want to invest their time in learning organizational knowledge from other producers, or whether they want to continue producing. In the spirit of Perla and Tonetti (2014), searching comes at the cost of foregone output. In the final period, firms that searched adopt the improved organizational knowledge. This leads to the disappearance of the lower tail, as relatively unproductive firms endogenously sort into improving their productivity by learning from the high-productivity firms.

D.1 Production

We choose a Leontief production function that features strong complementarity across multiple inputs (tasks). When organizing production, a firm needs to coordinate $m = 1, ..., M$ production tasks, such as feeding raw cotton into its machines, collecting output, managing fire hazards, ensuring power supply, etc. Each task is performed by task-specific production labor l_m^P, and the corresponding task-efficiency γ_m is drawn from a uniform distribution with support $[0, 1]$. Firm output q is given by:

$$q = M \cdot \min\left\{\gamma_1 l_1^P ; \gamma_2 l_2^P ; ...; \gamma_M l_M^P\right\} \tag{D.1}$$

We refer to the set of γ_m draws as "organizational knowledge." Note that the maximum efficiency (i.e., the technology frontier) is reached if all tasks are performed with $\gamma_m = 1$, reflecting a 'perfect' organization of production. The strong (Leontief) complementarity implies that any particularly low γ_m draw has a disproportionate negative effect on overall productivity, leading to a fat lower tail of the productivity distribution.

Optimal choice of task-specific labor for given organizational knowledge (γ_m draws) implies $\gamma_m l_m^P = \gamma_1 l_1^P, \forall m$. This allows us to write firm output as $q = M \cdot \gamma_1 l_1^P$. In addition, defining total production labor $l^P = \sum_{m=1}^{M} l_m^P$ and substituting $l_m^P = \frac{\gamma_1}{\gamma_m} l_1^P$, we obtain: $l^P = l_1^P \cdot \sum_{m=1}^{M} \frac{\gamma_1}{\gamma_m}$, and therefore: $l_1^P = \frac{l^P}{\sum_{m=1}^{M} \frac{\gamma_1}{\gamma_m}}$. Substituting this expression in the above equation for q yields:

$$q = \psi \cdot l^P, \quad \text{where} \quad \psi \equiv \frac{1}{\frac{1}{M}\sum_{m=1}^{M} \frac{1}{\gamma_m}} \tag{D.2}$$

Note that ψ reflects the overall productivity of a firm, which in turn is a composite of its γ_m draws. In addition to production labor, firms also incur a fixed cost f each period which – following Melitz (2003) – is paid in units of labor.

Thus, the overall labor used to produce output q is given by

$$l = f + \frac{q}{\psi} \tag{D.3}$$

The fixed cost f affects a firm's decision to operate vs. shut down (as discussed below).

D.2 Demand and Profit Maximization

We assume that each mechanized cotton spinning firm i produces a differentiated variety, q_i. Differentiated varieties can reflect differences in the type of cotton that is spun (different counts of yarn), but also spatially segmented markets due to imperfect market integration. Overall demand for output from the cotton spinning sector is given by

$$Q = \left(\sum_{i=1}^{I} q_i^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}} , \tag{D.4}$$

where $\epsilon > 1$ is the elasticity of substitution, and I is the total number of firms. We assume that there are sufficiently many firms so that each individual producer takes Q as given. We focus on a partial equilibrium setting, where the aggregate spending for cotton-spinning output, $R \equiv \sum_{i=1}^{n} p_i q_i = \mathcal{P}Q$ is given, with $\mathcal{P} \equiv \left(\sum_{i=1}^{I} p_i^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}}$ denoting the price index for cotton spinning output. The aggregate expenditure can reflect both domestic and international demand. Wages w are also given. Each firm sets its price p_i to maximize profits. In this setup, demand for individual varieties is given by

$$q_i = \left(\frac{\mathcal{P}}{p_i} \right)^{\epsilon} \cdot Q \tag{D.5}$$

Firms maximize profits, which are given by $\pi_i = p_i q_i - w \left(f + \frac{q_i}{\psi_i} \right)$. This yields the profit-maximizing price as a constant markup over firm i's marginal cost:

$$p_i = \frac{\epsilon}{\epsilon - 1} \frac{w}{\psi_i} \tag{D.6}$$

Substituting the optimal price in the profit equation, we obtain the following expression for firm i's profits:

$$\pi_i = \frac{1}{\epsilon} \cdot R \cdot \left(\frac{\epsilon - 1}{\epsilon} \cdot \mathcal{P} \cdot \frac{\psi_i}{w} \right)^{\epsilon-1} - f \tag{D.7}$$

This equation shows that firms with higher productivity draws ψ_i will make higher profits, which leads to the final step: firms' decisions to operate and innovate.

D.3 Firms' Decisions to Operate and Innovate

Following (D.7), profits depend on firm i's organizational knowledge draws $\gamma_{i,m}$, which are aggregated into ψ_i as in equation (D.2). We assume that firms receive these draws *after* committing to pay the fixed costs for the first period. For example, in order to get information about how productive they are, firms need to set up their plant and start producing. Given this setup, initially, all firms produce, and the productivity distribution exhibits a thick lower tail. Firms with low productivity draws that imply $\pi_i < 0$ exit in the first period, i.e., their revenues are not sufficient to cover their variable and fixed costs, and they go bankrupt.[29] We refer to all remaining firms (those with $\pi_i \geq 0$) as the operating firms who remain in business. We denote the productivity level that corresponds to zero profits (and thus the decision to operate) by $\bar{\psi}^O$.

Rather than examining productivity dynamics with an infinite time horizon as in Perla and Tonetti (2014), we simplify the setup by focusing on three time periods, which is sufficient to highlight the relevant productivity dynamics.

1. **Initial Period.** In the first period, entrepreneurs commit to paying the fixed cost f, receive their initial productivity draw, and start producing. Those with low productivity draws make negative profits and drop out of business at the end of the period. Thus, productivity dynamics in the first period are driven by unproductive firms exiting the market.

2. **Innovation Period.** In period 2, surviving entrepreneurs decide whether to innovate by observing and copying organizational knowledge from other firms. We follow the setup from Perla and Tonetti (2014) whereby firms that decide to search will forgo profits and encounter a randomly drawn *producing* firm, copying this firm's task-efficiency draws.[30] In equilibrium, relatively unproductive firms decide to search, while productive firms continue producing.[31] This gives rise to an endogenous productivity threshold, and firms below this threshold sample from the productivity distribution above the threshold. This process shifts mass from lower to higher productivity levels.

3. **Final Period.** Finally, in period 3, all firms are producing again: those that were searching in period 2, and those that remained in production. We compare the new productivity distribution to its counterpart in the initial period.

Assumptions. Before moving on to the simulation results, we state the implicit assumptions in our setup. First, market entry occurs only in the initial period: Firms receive their productivity draw and then decide whether or not to operate. There is no entry of new firms in the later periods. Second, only operating firms can decide to search for better organizational knowledge in period 2. Thus, only 'established' firms that survived the first period can innovate. Note that this assumption also implies that 'outsiders' who have never operated mechanized cotton technology cannot search and copy from producing firms. Third, if a searching firm i is matched to a producing firm j, it

[29] For example, think of the fixed costs per period as the payments to the bank for a loan taken out to finance the plant. If these payments cannot be met, the firm faces bankruptcy.

[30] In our setup, innovating entrepreneurs stop production and do not pay the fixed cost. They thus effectively go out of business and re-enter in the next period with their newly drawn productivity. This represents the historical findings that a large part of innovation occurred through churn, and that improvements in production facilities often meant that the old design had to be scrapped.

[31] Importantly, we simplify the structure from Perla and Tonetti (2014) by assuming that innovation (search) only occurs in the second period – as opposed to in each period. This simple structure is sufficient for our purpose – to study the productivity distribution before and after the innovation period.

copies the *full* set of organizational practices $\gamma_{j,m}, \forall m$.[32] A historical justification for this assumption is that many components of mechanized spinning plants were closely linked to each other. For example, in order to change the organization of machines within plants, buildings had to be modified or even re-built (see Section 2 in the paper). Finally, we assume that all firm activity ceases after the final period, thus abstracting from long-horizon dynamics in the decision to innovate.

D.4 Simulation Steps

To simulate the model, we use $M = 5$ production tasks with the corresponding organizational efficiency $\gamma_{it,m}$, drawn from a uniform $(0, 1)$ distribution for $I = 1,000$ firms. Using the wage rate $w = 1$, fixed cost $f = 1$, and aggregate spending $R = 10,000$, we compute firm profits using (D.7).[33] The final step in the initial period is to find the lowest-productivity firm that decides to operate. This establishes the operating threshold $\bar{\psi}^O_{ini}$, with the subscript indicating the initial period. We refer to the three periods as initial (ini), innovation ($innov$), and final ($final$).[34] All firms with $\psi_i \geq \bar{\psi}^O_{ini}$ survive the initial period and enter the innovation period.

Next, we move on to the second period, when firms decide whether to innovate (and stop production). Among all surviving firms, we compute the cutoff $\bar{\psi}^S$ above which firms produce, while those below the cutoff search for better efficiency draws. This procedure involves four steps:

1. Use an initial guess for the productivity cutoff $\bar{\psi}^S$ below which firms with $\bar{\psi}^O_{ini} \leq \psi_i < \bar{\psi}^S$ search (denoted by the set S of firms), while those with $\psi_i \geq \bar{\psi}^S$ produce and will (potentially) see their efficiency draws being copied by searching firms.[35]

2. Compute output prices $p_{i,innov}$ for the producing firms (with $\psi_i \geq \bar{\psi}^S$), the corresponding price index $\mathcal{P}_{innov}$, and profits $\pi_{i,innov}$.

3. Compute the expected productivity draw for searching firms, $E(\psi')$ for $i \in S$, where S denotes the set of searching firms. This is equal to the mean of ψ_i over all producing firms, i.e., $E(\psi') = E(\psi|\psi \geq \bar{\psi}^S)$. Based on this expected productivity draw, compute the expected profits of all firms in the next (final) period, $E(\pi_{final})$, assuming that all searching firms

[32] Without this assumption, the simple Perla and Tonetti (2014) framework cannot be applied because it builds on a productivity ranking based on overall firm productivity (ψ_i in our model), with low-productivity firms endogenously deciding to search. In our setting, even firms with a relatively high ψ_i could find it beneficial to search for better *individual* $\gamma_{i,m}$ draws, especially if just one of their $\gamma_{i,m}$ draws is particularly low, disproportionately affecting ψ_i because of the strong complementarity in (D.1).

[33] Our choice of aggregate spending R implies that about two-thirds of all firms make positive profits and thus operate.

[34] The subscript is needed because the threshold depends on the number of firms that produce output, which differs in the innovating period. Similarly, note that the price index $\mathcal{P}_{ini}$ depends on the number of firms that produce; and profits, in turn, depend on $\mathcal{P}_{ini}$. Thus, an iterative process is required to find the threshold $\bar{\psi}^O_{ini}$.

[35] The first term, $\bar{\psi}^O_{ini} \leq \psi_i$ reflects our assumption that only firms that survived the initial period can innovate by searching for better efficiency draws.

produce with productivity $\psi_{i,final} = E(\psi'), \forall i \in S$, while all producing firms continue with the same productivity as in the initial period, $\psi_{i,final} = \psi_{i,ini}, \forall i \notin S$.

4. Compute the expected overall profits (from periods 2 and 3) for a firm with initial productivity at the search cutoff $\psi_{i,ini} = \bar{\psi}^S$ for two scenarios: i) if the firm produces in the innovation period and thus keeps the same productivity in the final period: $\pi(\bar{\psi}^S|produce) = \pi_{innov}(\bar{\psi}^S) + \beta\pi_{final}(\bar{\psi}^S)$, where $\beta < 1$ is the discount rate;[36] and ii) if the firm searches in the innovation period and thus receives the expected productivity draw $\psi_{i,final} = E(\psi')$ for the final period, while foregoing profits in the innovation period: $\pi(\bar{\psi}^S|search) = 0 + \beta\pi_{final}(E(\psi'))$.[37] If $\pi(\bar{\psi}^S|\text{produce}) < \pi(\bar{\psi}^S|\text{search})$ then the initial guess for the threshold $\bar{\psi}^S$ was too low, as the threshold firm would still be better off searching instead of producing. We thus update $\bar{\psi}^S = \psi_{i+1}$, where ψ_{i+1} represents the next-higher initial productivity draw among all firms.

We order all operating firms by their productivity draws such that low i in ψ_i represent lower draws. We begin with a relatively low guess for $\bar{\psi}^S$ and repeat steps 1-4 until the firm with $\psi_i = \bar{\psi}^S$ is opting to search, while the firm with the next-higher productivity draw (ψ_{i+1}) finds it optimal to produce, rather than search. This yields the cutoff for searching in the innovation period, $\bar{\psi}^S$. Finally, we match each searching firm i (with $\bar{\psi}^O \leq \psi_i < \bar{\psi}^S$) at random to a producing firm j (with $\psi_j \geq \bar{\psi}^S$) and update i's productivity so that $\psi_{i,final} = \psi_{j,ini}$. This yields the productivity distribution in the final period.[38]

D.5 Simulation Results

The left panel in Figure A.15 illustrates the weeding-out of unproductive firms during the initial period. Because of the strong complementarity across production tasks, the original productivity distribution exhibits a fat lower tail. Firms with low productivity draws (below the cutoff $\bar{\psi}^O_{ini}$) exit the market. The remaining firms survive into the second period, where they decide between searching for better organizational knowledge and production. This leads to the productivity distribution shown in the right panel of Figure A.15. Among the surviving firms, those with productivity below the search threshold $\bar{\psi}^S$ forgo profits in the innovation period and are randomly matched to one of the producing firms, copying their efficiency draws. In the final period, searching firms proceed with their new copied productivity, whereas producing firms continue with their initial draws.

Figure A.16 illustrates the productivity dynamics that result from the search-and-innovation process, by comparing the productivity distributions before and after (i.e., in the innovation period

[36]We assume that periods 2 and 3 are of equal length and we choose $\beta = 0.6$, corresponding to cumulative discounting at a rate of 0.95 over ten years. Note also our assumption that all firm activity ceases after period 3 simplifies the setting, as we can abstract from longer-run dynamics in the decision to innovate.

[37]We assume that when searching, firms make zero profits.

[38]Matching occurs with replacement: Different searching firms can be matched to the same producing firm.

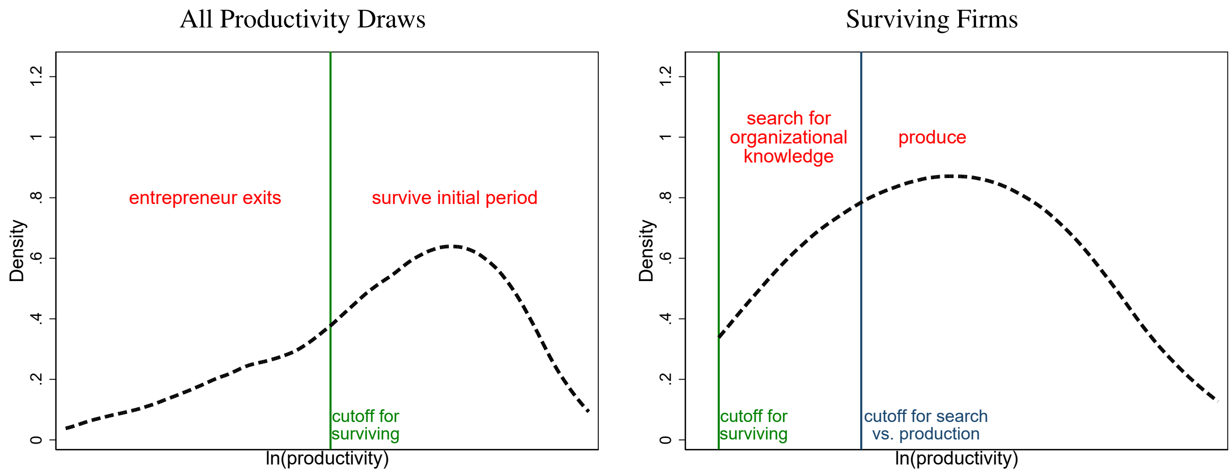


Figure A.15: Initial Period: Firm Survival

Notes: The figure illustrates two firm decisions in the model, as a function of the initial firm productivity draws (ψ_i): The left panel plots all productivity draws, showing that the distribution of ψ_i exhibits a thick lower tail due to the underlying strong complementarity across individual production tasks in equations (D.1) and (D.2). Firms with low productivity draws make negative profits and exit in the initial period. Firms with higher productivity draws decide to operate. The right panel illustrates the surviving firm' decision to produce vs. search for better organizational knowledge. Firms with relatively low productivity draws can raise their expected profits by searching for better draws among those firms that continue production. The cutoff for search vs. production is endogenously determined.

and in the final period): The lower part of the initial productivity distribution disappears, and the upper part becomes thicker. That is, productivity growth due to search exhibits a lower-tail bias. At the same time, the productivity frontier does not move out; instead, the distribution is tilted towards the frontier.

Overall, there are thus two mechanisms that lead to a lower-tail bias of productivity growth: i) the exit of unproductive firms and ii) the search of medium-productivity firms for better organizational knowledge. These features reflect the pattern that we document in the historical data for mechanized cotton spinning in France. The overall productivity dynamics that result from the three periods in combination are illustrated in Figure 3 in the paper.

D.6 Relationship to Comparison Sectors

The process described in our stylized framework (following Perla and Tonetti, 2014) eliminates the lower tail and shifts the productivity distribution closer to the frontier. The productivity distribution in cotton spinning in the final period resembles the one observed for our comparison sectors, where factory production had been adopted earlier, and the process of exit and organizational learning had already occurred around 1800. As we noted in Section 2.3, codified knowledge was already available for the two comparison sectors in the late 18th century (while it only became available after 1830 in cotton spinning – see Section 2.2).

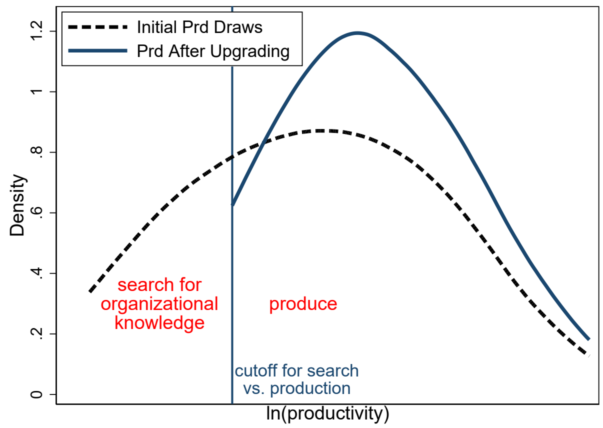


Figure A.16: Productivity Dynamics During the Search Period

Notes: The figure illustrates the productivity dynamics during the search period, focusing only on those firms that survived the initial period (see Figure A.15). Less productive firms decide to search for better organizational knowledge, and they adopt the productivity draws from more productive producing firms. Thus, the lower tail of the productivity distribution disappears, and the mass shifts towards higher productivity draws. At the same time, the technological frontier remains the same.

Why do we observe substantial variation in productivity even after best-practice knowledge became available? While there are many reasons for productivity dispersion in practice (Syverson, 2011), here we focus on one that follows from the model: The adoption of better practices is costly – it requires production to stop for one period. Thus, even if (in the model) plant owners knew where to observe the best practices, not all would adopt them (although the sudden availability of best practices would lead to a spike in plants adopting them).[39] In particular, being already closer to the frontier makes adoption less attractive, because the opportunity cost of halting production is higher. This is also in line with Bloom, Eifert, Mahajan, McKenzie, and Roberts (2013), who show that even when knowledge about standardized practices is readily available, it may not be applied.

This discussion highlights the important historical difference between cotton spinning in 1800 and i) our comparison sectors in 1800, ii) all three sectors in 1840: The former faced a lack of standardized solutions, while in i) and ii), codified knowledge was available, at least to those plants that looked for it. Consequently, only the productivity process in cotton spinning in 1800 exhibited the additional feature of experimentation that is at the heart of our stylized framework, and that leads to the elimination of the fat lower tail.

[39] Here, we refer to our model with just three periods. In the original Perla and Tonetti (2014) model with an infinite horizon, plants would continue to approach the frontier in subsequent periods, and this process would be accelerated if best-practice knowledge becomes available.

E Additional Data and Results

This appendix presents the additional empirical analyses and robustness checks referenced in the main text.

E.1 Cotton Spinning: Output Quality and TFP

In Section 4.1 of the paper we showed that the productivity gains in mechanized cotton spinning were largely concentrated in the lower tail of the productivity distribution. The lower tail disappeared over our sample period, while increases in productivity at the upper tail of mechanized spinning were modest. Panel A of Table A.5 repeats the results of our main quantile regressions from the paper, using quality-adjusted prices.[40] Panel B of Table A.5 shows that these results are robust when we do not adjust for quality differences in the count of yarn spun by individual plants, instead using the *same* sector-level output price across all plants in cotton spinning. In particular, we use the price of the yarn count that the average plant produced.[41] This reduces the productivity dispersion in 1806 because more productive plants produced higher-quality cotton.[42] As a result, the difference in productivity growth across quantiles is somewhat muted as compared to Panel A (as we would expect), but the lower-tail bias remains striking.

Panel C of Table A.5 presents results for total factor productivity (TFP) instead of output per worker in the productivity regressions of mechanized cotton spinning. To estimate (revenue-based) TFP, we use data on the labor employed by the firm (measured as number of workers) and proxy for the capital stock with the number of spindles – a standard measure of production capacity in the industry. We regress the log revenue of the firm on a constant, log labor, and the log number of spindles of the plant, separately for 1806 and 1840. This allows for the capital and labor shares to be time-varying. Log TFP for each plant i in a given year t is thus the regression constant plus the residual of the regression. We find that the lower-tail bias of productivity growth in mechanized cotton spinning is robust to using TFP instead of output per worker.

E.2 Metallurgy and Paper Milling: Robustness Checks for Imputed Variables

For metallurgy and paper milling, we had to impute labor inputs in 1811 and 1794, respectively. In this section, we check the robustness of our results to alternative data construction choices.

In metallurgy, labor inputs are not consistently reported: about 40% of the plants reported either 'internal' labor only, or both 'internal' and 'external' labor, separately. The remainder of plants reported only total labor, with no indication of whether this included external labor. As explained

[40] The output price used for each plant corresponds to the market price of the quality of yarn reported by the plant, as described in Appendix B.1 (under "Plant labor productivity").

[41] To compute the not-quality-adjusted productivity, we first construct plant-level revenues by multiplying physical output at the plant level with the price of the (unweighted) average quality of yarn reported across *all* plants in 1806.

[42] The correlation between the not-quality-adjusted productivity measure used in Panel B of Table A.5 and the plant-specific (quality-adjusted) output price (that underlies the results in Panel A) is statistically highly significant, with a p-value below 0.01.

Table A.5: Alternative Productivity Measures in Cotton Spinning

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
PANEL A: Baseline (Table 1)							
Spinning (1806-1840)	2.420***	3.917***	3.293***	2.234***	1.651***	1.014***	868
	(0.154)	(0.204)	(0.229)	(0.151)	(0.167)	(0.297)	
PANEL B: Using prices not quality-adjusted							
Spinning (1806-1840)	2.373***	3.381***	2.828***	2.105***	1.829***	1.628***	868
	(0.138)	(0.285)	(0.199)	(0.193)	(0.160)	(0.188)	
PANEL C: Using TFP							
Spinning (1806-1840)	2.845***	3.233***	3.107***	2.834***	2.647***	2.317***	868
	(0.050)	(0.080)	(0.072)	(0.056)	(0.083)	(0.072)	

Notes: Panel A reproduces the specification in Table 1. In Panel B, the dependent variable is log(output per worker) computed using prices that are *not* adjusted for plant-specific output quality. In Panel C, the dependent variable is total factor productivity. Column 7 reports the number of observations. Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

in Section 3.2 in our main analysis, we imputed internal labor for those plants not reporting it (60% of the total number of plants in 1811), because internal labor is more consistent with the 1840 data. In Panel B of Table A.6, we check whether our results are driven by this imputation: We drop all plants for which we imputed labor. Despite the fact that this drops 292 out of 470 plants in 1811 (so that the overall observations decrease from 1366 to 1074), the results remain very similar to our baseline specification. If anything, productivity growth in metallurgy skews more in the direction of an *upper*-tail bias than in the baseline.

As described in Appendix B.2, to compute plant-level labor productivity in metallurgy in 1811, we computed average prices for each product type, by using the information from those plants that reported prices for the corresponding product. Overall, 308 out of 470 plants reported these product-specific prices. In Panel C of Table A.6 we show that our results hold when we use the product-specific prices for those plants that reported them, while dropping the remaining metallurgy plants in 1811.

In paper milling, many plants reported only male labor in 1794, while the 1840 survey reports both male and total labor for all plants. We thus imputed total labor in 1794 using a scaling factor between male and total employees as described in Section 3.2 (under "Constructing Consistent Labor Variables"). As our baseline variable, we used (imputed) total labor in 1794 and the reported total labor in 1840 (reported again in Panel A of Table A.7). Panel B shows that the productivity growth pattern in paper milling is robust to using only male labor in both periods to construct

Table A.6: Alternative Productivity Measures in Metallurgy

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
PANEL A: Baseline (Table 1)							
Metallurgy (1811-1840)	2.351***	2.205***	2.068***	2.016***	2.355***	3.012***	1,366
	(0.182)	(0.526)	(0.317)	(0.243)	(0.189)	(0.217)	
PANEL B: Using plants in 1800 with non-imputed labor							
Metallurgy (1811-1840)	1.744***	0.974	1.383***	1.460***	1.998***	2.791***	1,074
	(0.259)	(0.634)	(0.342)	(0.292)	(0.288)	(0.265)	
PANEL C: Using plants in 1800 with plant-specific prices							
Metallurgy (1811-1840)	2.712***	2.687***	2.574***	2.543***	2.552***	3.286***	1,204
	(0.204)	(0.496)	(0.412)	(0.250)	(0.205)	(0.207)	

Notes: Panel A reproduces the specification of Table 1. In Panel B, the dependent variable is log(output per worker), using only plants with non-imputed labor. In Panel C, the dependent variable is log(output per worker), using only plants reporting plant-specific output prices. Column 7 reports the number of observations. Robust standard errors in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

productivity: There is no clear pattern across the productivity distribution, and if anything, growth is concentrated in the mid-area. Note that the number of observations in this check (Panel B) remains the same as in our baseline results (Panel A) because all plants reported male labor in 1794.

Table A.7: Alternative Productivity Measures in Paper Milling

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
PANEL A: Baseline (Table 1)							
Paper milling (1794-1840)	0.719***	0.697***	0.717***	0.829***	0.691***	0.542**	867
	(0.111)	(0.145)	(0.139)	(0.092)	(0.130)	(0.258)	
PANEL B: Using only male labor							
Paper milling (1794-1840)	0.791***	0.522***	0.569***	0.728***	1.157***	0.884***	867
	(0.115)	(0.161)	(0.164)	(0.131)	(0.133)	(0.229)	

Notes: Panel A reproduces the specification of Table 1. In Panel B, the dependent variable is log(output per worker) computed using male labor only. Column 7 reports the number of observations. Robust standard errors in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

E.3 Evidence for Proposed Mechanism: Building Layout in Mechanized Cotton Spinning

Data. Our data on the layout of French cotton spinning mills are from Chassagne (1991), who provides details on building dimensions for 59 cotton spinning mills constructed across France between 1789-1845. While Chassagne does not give details for how these mills were chosen, we have been able to trace the source for some. In all cases, they come from notarial archives across different French *départements*. A note of caution is due here: Chassagne's sample of cotton mills is likely biased towards important, large plants for which design records have survived. We discuss how this type of bias may effect our results in footnote 15 in the paper.

We observe the number of floors as well as the dimensions of the factory floor (length and width). A limitation of these data is that they do not contain variables that would allow us to estimate productivity. As a second-best proxy, we examine plant survival. We match the plants to the 1840 census using the name of the owner and the location of the plant.[43] We construct a binary indicator that takes the value 1 if the plant shows up in the 1840 census (which collected plant data in 1839-47).

Results. We regress a binary indicator for plant survival on the number of floors and the squareness of the building (up to a quadratic term). Table A.8 presents the results of this exploratory exercise. The coefficients point to a statistically and economically meaningful relationship between survival and both dimensions of plant layout. Taking the estimated coefficients, the predicted optimal number of floors is 3.76, and the predicted optimal squareness is $S = 0.51$. Comparing these numbers to Figure 4 in the paper shows that both are close to what the industry converged to after 1820.[44]

[43] Chassagne (1991) reports the owner name for each of the 59 plants in his sample, making it straightforward to match this information with the 1840 census.

[44] One potential concern with these results is that plant age may be correlated with both design and the odds to

These results on building design suggest that plants were initially experimenting with a wide range of organizational practices, and as the industry matured, they converged to best-practice designs.

Table A.8: Survival and Building Layout

Dependent variable: Survival		
	(1)	(2)
Number of floors	0.154***	
	(0.056)	
Num. floors squared	-0.021**	
	(0.009)	
Percent of encompassing square		1.343**
		(0.624)
Squareness squared		-1.314**
		(0.565)
Predicted optimal	3.76	0.51
R^2	0.06	0.05
N	46	55

Notes: Robust standard errors in parentheses. Number of floors represents the number of floors a building had. 'Squareness' is defined as $S \equiv \frac{length*width}{max\{length,width\}^2}$. Data on the length, width, and number of floors of each building are from Chassagne (1991). Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

E.4 Evidence for the Proposed Mechanism: Strikes in the Three Industries

Data. Our data on strikes are from Shorter and Tilly (1874). They provide information on the strikes occurring in France from 1830 until 1968, including details on the location and industrial sector. In particular, we focus on all strikes that took place until 1847 (the last year of the data collection of our 1840s census) in textile (*industrie textile*), paper (*papiers, cartons, industrie polygraphiques*), and metallurgy (*travail des métaux fins et ordinaires* and *métallurgie*). In total, there are 14 macro-sectors. Textile is one of them, but we do not have more detailed information on whether strikes occurred in cotton spinning or in other textile sectors. The data by Shorter and Tilly (1874) for the 1830-1847 period had originally been digitized by Jean-Pierre Aguet from archival sources of the Interior and Justice Ministries in Paris. He found information on almost 400 strikes, but these represent only part of all strikes taking place in the country in this period (likely the

survive until 1840. To address this (at least partially, given the limited sample size), we include a second-degree polynomial in plant age. For squareness, the results are robust: we retain statistical significance, and the predicted optimal squareness is virtually unchanged. For the number of floors, we lose statistical significance – although the coefficients for age and age^2 are themselves statistically insignificant.

larger and most important ones).[45] This notwithstanding, "the Aguet data should reveal accurately the movement of strikes over time and give information on basic structural characteristics of these early conflicts." (Shorter and Tilly, 1874, p.354)

Results. Over the period 1830-47, strikes were more frequent in textile than in the other two sectors: there were 116 strikes in textile, 29 in metallurgy, and 24 in paper. Table A.9 examines this pattern more systematically: we regress log(1+number of strikes) on a dummy for the textile sector. We add the value 1 so that the outcome variable is defined for *département*-industry observations with zero strikes. The result in columns 1 and 2 suggest that, in an average *département*, strikes were 0.38 log points more frequent in textile than in metallurgy or paper milling, even when accounting for *département* fixed effects. An obvious concern is that the larger size of the textile sector is driving these results. In column 3 we thus control for male employment at the sector-*département* level. While the coefficient on textile becomes somewhat smaller in magnitude, it remains statistically highly significant: strikes (per worker) in textiles were approximately 0.30 log points higher than in the two comparison sectors. Finally, in column 4 we also include total manufacturing employment across all sectors in a given *département*, which accounts for possible scale effects (note that we have to drop *département* fixed effects for this coefficient to be identified). Again, we confirm the magnitude and significance of the coefficient on textiles. Overall, this evidence suggests that strike activity in textiles was higher than what one would expect based on the number of workers and *département* characteristics.

[45]The Justice Ministry counted 1,049 prosecutions for *coalition ouvriére* (worker coalitions, which were illegal until 1864). However, many of these were either not officially reported or subsequently considered benign (Shorter and Tilly, 1874).

Table A.9: Strikes in Textile vs. Comparison Sectors

Dependent variable: log(Strikes)

	(1)	(2)	(3)	(4)
Textile	0.377***	0.377***	0.301***	0.305***
	(0.064)	(0.079)	(0.068)	(0.064)
Log(Workers)			0.029**	0.027**
			(0.014)	(0.013)
Log(Total workers – dept)				0.168***
				(0.037)
Department FE		✓	✓	
R^2	0.10	0.68	0.69	0.26
N	258	258	258	258

Notes: Dependent variable is the log number of strikes in each of the three sectors (textile, metallurgy, paper), at the *département* level. There are overall 86 *départements*, but not all report strike data for each sector. 'Textile' is a dummy equal to one for the textile sector. 'Workers' include all workers in the respective sector and *département*. "Total workers - dept' include all workers in the *départements* (including from sectors other than the three used in our analysis). Standard errors (clustered at the *département* level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

E.5 Robustness: Spatial Diffusion of Knowledge

This appendix provides robustness checks for the results on spatial diffusion in Section 5.3 in the paper. There, we asked how information about best practice organizational methods diffused through the economy. We suggested that plants copied from successful experimenters and provided evidence supporting the spatial diffusion of knowledge. Figure 5 in the paper plots the estimated coefficients that show that proximity to high-productivity plants mattered in cotton spinning in 1800, while this pattern was much weaker for the later period and for the two comparison sectors. Table A.10 reports the corresponding regressions. Figure A.17 displays the spatial distribution of plants in mechanized cotton spinning, metallurgy, and paper milling, distinguishing those in the 90th percentile of the productivity distribution.

Table A.10: Proximity to High-Productivity Plants

Dependent variable: log(Output per worker)

	(1)	(2)	(3)	(4)	(5)	(6)
	Spinning		Metallurgy		Paper milling	
	1806	1840	1811	1840	1794	1840
$lnDist^{p90}$ (1800)	-0.841***		-0.291***		-0.232*	
	(0.135)		(0.083)		(0.130)	
$lnDist^{p90}$ (1840)		-0.174*		-0.065		-0.183
		(0.101)		(0.079)		(0.130)
Department FE	✓	✓	✓	✓	✓	✓
R^2	0.56	0.15	0.38	0.29	0.27	0.46
N	290	467	385	779	456	309

Notes: The table reports the regression results that are underlying Figure 5 in the paper. For each specification, we report the standardized beta coefficients on $lnDist^{p90}$, which measures the log distance to the closest plant with productivity in the 90th percentile (in the same sector and in the same period – 1800 and in 1840, respectively). The number of observations in these specifications is smaller than the full sample as plants that belong to the 90th percentile are excluded. Standard errors (clustered at the *département* level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Next, we show that our evidence on the spatial diffusion of knowledge is robust to a series of potentially confounding explanations. While our inclusion of *département* fixed effects across all specifications already captures *département*-level unobserved characteristics, it does not account for unobserved differences at a more disaggregated level. In what follows, we examine potential confounders at the local (e.g., commune) level.

Controlling for location fundamentals. Table A.11 controls directly for some key location fundamentals at the commune level: the availability of fast-flowing streams (as a source of water power), proximity to coal (which mattered for steam power), and the share of forest cover (which mattered

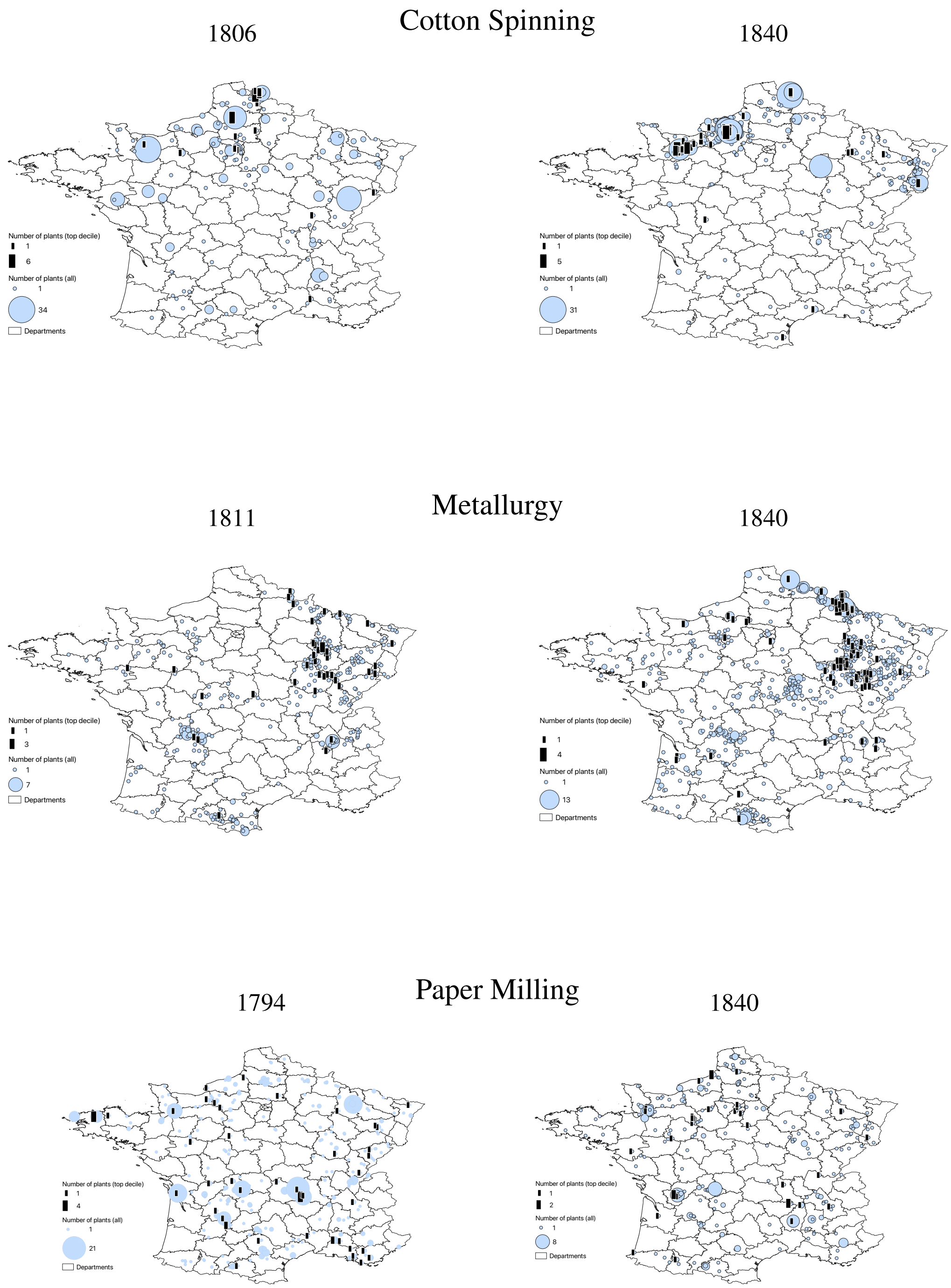


Figure A.17: Spatial Distribution of (High-Productivity) Plants Across France

Note: The figure shows the spatial distribution of plants in cotton spinning (top), metallurgy (middle), and paper milling (bottom). The figure distinguishes plants in the 90th percentile of the productivity distribution (black columns) from all other plants in a commune (light circles).

for access to charcoal – a major input in metallurgy).[46] The results in Table A.11 show that controlling for these location fundamentals does not affect the pattern of the coefficients of interest. The estimated magnitudes remain very similar to those in Table A.10. Moreover, the location fundamentals themselves are mostly small and statistically insignificant. This is probably driven by the fact that the *département* fixed effects already account for the most important spatial differences in location characteristics.

Table A.11: Proximity to High-Productivity Plants – Controlling for Location Fundamentals

Dependent variable: log(Output per worker)

	(1)	(2)	(3)	(4)	(5)	(6)
	Spinning		Metallurgy		Paper milling	
	1806	1840	1811	1840	1794	1840
$lnDist^{p90}$ (1800)	-0.882***		-0.293***		-0.214	
	(0.116)		(0.071)		(0.136)	
$lnDist^{p90}$ (1840)		-0.186*		-0.066		-0.194
		(0.105)		(0.077)		(0.118)
Access to high streamflow	-0.115	0.281**	-0.039	0.181	-0.142	-0.176
	(0.283)	(0.113)	(0.151)	(0.197)	(0.271)	(0.210)
Proximity to coal	-0.011	-0.069	-0.324	0.036	0.151	-0.213
	(0.201)	(0.330)	(0.200)	(0.156)	(0.406)	(0.259)
Share of forest area	-1.337***	0.356	-0.156	-0.057	0.541	0.330
	(0.484)	(0.337)	(0.272)	(0.334)	(0.516)	(0.892)
Department FE	✓	✓	✓	✓	✓	✓
R^2	0.58	0.16	0.39	0.29	0.28	0.47
N	290	467	376	779	456	309

Notes: The table reports robustness checks of the results in Table A.10. For each specification, we report the standardized beta coefficients on $lnDist^{p90}$, which measures the log distance to the closest plant with productivity in the 90th percentile (in the same sector and in the same period – 1800 and in 1840, respectively). Access to high streamflow is a binary variable that takes the value of one if a plant's nearest data collection point for river discharge has streamflow in the top quartile of the distribution. Proximity to coal is a binary indicator that takes the value of one if a location is within the bottom quartile of plant locations in terms of distance to the nearest coalfield. Share forest area measures the forest area over the total area of the commune where the plant is located (using data on forest cover from the late 18th century). Standard errors (clustered at the *département* level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Controlling for agglomeration. Another possible concern is that our results may be affected by more general agglomeration externalities, as opposed to learning. In particular, our findings could be driven by high-productivity plants emerging (within *départements*) where the density of produc-

[46]Data sources and the construction of each variable are described in Appendix B.6.

tion was large due to agglomeration forces. To address this possibility, we control for the density of production at the commune level. This is measured as the log of total output in the sector, excluding a plant's own output. Table A.12 shows that controlling for the local density of production barely affects our results. The estimated coefficient on distance to high-productivity plants in cotton spinning in 1800 remains large and highly significant, and also the distance coefficients in the other sectors and in 1840 are essentially the same as in our baseline specification in Table A.10. The coefficient on local production density itself is generally small, positive, and never statistically different from zero.

Table A.12: Proximity to High-Productivity Plants – Controlling for Local Production Density

Dependent variable: log(Output per worker)

	(1)	(2)	(3)	(4)	(5)	(6)
	Spinning		Metallurgy		Paper milling	
	1806	1840	1811	1840	1794	1840
$lnDist^{p90}$ (1800)	-0.771***		-0.307***		-0.203	
	(0.175)		(0.080)		(0.139)	
$lnDist^{p90}$ (1840)		-0.144		-0.083		-0.179
		(0.113)		(0.073)		(0.136)
Production density	0.019	0.007	-0.008	-0.006	0.016	0.003
	(0.021)	(0.013)	(0.013)	(0.008)	(0.015)	(0.019)
Department FE	✓	✓	✓	✓	✓	✓
R^2	0.57	0.15	0.38	0.29	0.28	0.46
N	290	467	385	779	456	309

Notes: The table reports robustness checks of the results in Table A.10. For each specification, we report the standardized beta coefficients on $lnDist^{p90}$, which measures the log distance to the closest plant with productivity in the 90th percentile (in the same sector and in the same period – 1800 and in 1840, respectively). Production density is the log of total output in the sector in a given commune, excluding a plant's own output. Standard errors (clustered at the *département* level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Persistent unobservables? A placebo check. Next, Table A.13 performs a placebo exercise and examines whether plant productivity around 1800 was also related to the distance to high-productivity plants in the top-90th percentile of productivity in 1840 in the same sector. The estimated coefficient in cotton spinning is close to zero and statistically insignificant, implying that productivity in cotton spinning in 1806 was not related to high-productivity locations more than three decades later. This suggests that our results are not driven by persistent location fundamentals within *départements*. Our results in Table A.13 also imply that it is unlikely that our findings are driven by plant selection into (persistent) high-productivity locations.

Plant selection into the proximity of high-productivity plants? Next, we examine the extent to which

Table A.13: Proximity to High-Productivity Plants – Distance Placebo in 1840

Dependent variable: log(Output per worker)

	Spinning 1806 (1)	Metallurgy 1811 (2)	Paper milling 1794 (3)
$lnDist^{p90}$ (1840)	-0.053	-0.232**	0.173
	(0.235)	(0.098)	(0.151)
Department FE	✓	✓	✓
R^2	0.55	0.34	0.21
N	321	426	507

Notes: The table reports a placebo check of the results in Table A.10. $lnDist^{p90}$ (1840) measures the log distance to the closest plant in the same sector with productivity in the 90th percentile in 1840. Dependent variable is log output per worker in the earlier period (around 1800). We report the standardized beta coefficients on the distance variables. Standard errors (clustered at the *département* level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

the estimated distance coefficient in cotton spinning in 1800 may be driven by plant selection. It is possible that we estimate a large (negative) coefficient in cotton spinning not because plants were learning from their high-productivity neighbors but rather because *ex-ante* high-productivity plants selected into locations near existing high-productivity plants. Given that we observe plant age in cotton spinning in 1806, we can examine this potential selection pattern. In Table A.14, we first report our baseline result in column 1 and then compare it to the restricted sample of plants that entered *before* the nearest high-productivity plant. In this subsample (column 2), the coefficient on distance to high-productivity plants remains statistically highly significant, although it is somewhat smaller than in the baseline sample (-0.425, se 0.144).[47] The timing of entry of the plants in this subsample rules out the type of selection described above: Our results cannot be entirely driven by selection of entering plants into locations that already featured high-productivity plants – simply because the latter were not there yet.

In combination, the results in Tables A.13 and A.14 address the possibility of selection both based on persistent location fundamentals and features that may have made locations more attrac-

[47] Note that it is not surprising that the coefficient on distance declines (in absolute value). In order to perform this check, the particularly restrictive subsample in column 2 also excludes plants that are in line with our mechanism: 'younger' plants that did *not* have high ex-ante productivity but instead learned about optimal mill design from nearby high-productivity plants during their construction phase. Since these plants entered after the nearby high-productivity plants, such cases are excluded from the subsample in column 2. Since the restrictive subsample excludes cases that are in line with our mechanism, it arguably biases the distance coefficient downward.

tive over time (i.e., the entrance of a high-productivity plant).

Table A.14: Testing for Spatial Selection in Cotton Spinning in 1806

Dependent variable: log(Output per worker)		
	(1)	(2)
	Baseline	Subsample‡
$lnDist^{p90}$ (1800)	-0.841***	-0.425***
	(0.135)	(0.144)
Department FE	✓	✓
R^2	0.56	0.66
N	290	175

Notes: The table shows that our results for proximity to high-productivity plants (see Figure 5) are not entirely driven by selection of entering plants into the proximity of high-productivity plants. $lnDist^{p90}$ (1800) is the log distance to the nearest plant in cotton spinning with productivity in the 90th percentile in 1800. We report standardized beta coefficients for all variables. Standard errors (clustered at the *département* level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.
‡ Subsample includes only plants that entered before the nearest high-productivity plant.

Learning across sectors? We examine whether there is evidence consistent with learning across sectors. In particular, we check whether proximity to high-productivity plants in the comparison sectors also mattered for mechanized cotton plants in 1800. Table A.15 shows that there is no consistent pattern in the data. The coefficient on distance to high-productivity metallurgy plants (column 1) is not statistically different from zero and noisily estimated.[48] For paper milling, on the other hand, the distance coefficient is actually positive and also insignificant. These cross-sector results are consistent with the historical record, showing no indication that early cotton spinning mills were able to learn from high-productivity plants in the more mature comparison sectors.

Spillovers from England. Finally, as many innovations in all three sectors (and the spinning machinery per se) were invented in England, it may have been easier to observe and adopt the best organizational practices for firms closer to the channel. This concern is partly addressed by the inclusion of *département* fixed effects in our regressions. Table A.16 also controls for log distance to London. Our results on distance to high-productivity plants are essentially unaffected, and the coefficients on distance to London are mixed – which is unsurprising, given that these are added on top of *département* fixed effects.

[48] A likely reason for the noisy results is that metallurgy and cotton spinning mills were located relatively far from each other (see the maps in Figure A.17). The median cotton spinning mill was located 130 km from its nearest high-productivity peer in metallurgy, but only 57 km (73km) from the nearest high-productivity plant in paper milling (cotton spinning).

Table A.15: Proximity of Cotton Spinning Plants to High-Productivity Plants in Metallurgy and Paper Milling in 1800

Dependent variable: log(Output per worker)

	Spinning-Metallurgy	Spinning-Paper
	(1)	(2)
$lnDist^{p90}$ metal (1800)	-0.410	
	(0.403)	
$lnDist^{p90}$ paper (1800)		0.169
		(0.106)
Department FE	✓	✓
R^2	0.55	0.56
N	321	321

Notes: $lnDist^{p90}$ (1800) measures the log distance of cotton spinning plants to the closest plant in metallurgy (col. 1) and in paper milling (col. 2) with productivity in the 90th percentile in 1800. We report the standardized beta coefficients on the distance variables. Standard errors (clustered at the *département* level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Table A.16: Proximity to High-Productivity Plants – Controlling for Distance to London

Dependent variable: log(Output per worker)

	(1)	(2)	(3)	(4)	(5)	(6)
	Spinning		Metallurgy		Paper milling	
	1806	1840	1811	1840	1794	1840
$lnDist^{p90}$ (1800)	-0.812***		-0.285***		-0.165	
	(0.122)		(0.083)		(0.105)	
$lnDist^{p90}$ (1840)		-0.229**		-0.073		-0.208*
		(0.102)		(0.080)		(0.123)
Distance to London	0.468	-1.829**	-0.758	0.895	4.224*	-1.144
	(1.959)	(0.756)	(1.002)	(0.840)	(2.293)	(0.921)
Department FE	✓	✓	✓	✓	✓	✓
R^2	0.56	0.15	0.38	0.29	0.30	0.47
N	290	467	385	779	456	309

Notes: The table reports a robustness check of the results in Table A.10. $lnDist^{p90}$ ($\sim$ 1800) and $lnDist^{p90}$ (1840) measure the log distance to the closest plant in the same sector with productivity in the 90th percentile in 1800 and in 1840, respectively. We report the standardized beta coefficients on $lnDist^{p90}$. Distance to London is the log distance to London (UK). Standard errors (clustered at the *département* level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

E.6 Plant Survival, Exit, Age Profile, and Productivity

This appendix complements Section 5.4 in the paper, where we compared plant survival rates in the three sectors in order to distinguish learning about the new technology itself from learning about optimal plant design. Here, we examine alternative drivers of the differential survival rates, and we provide additional complimentary evidence for building design challenges as a mechanism.

Power sources in the three sectors as a confounding factor? In the main text, we showed that the survival rate in spinning was lower than in the comparison sectors. This is consistent with a mechanism in which entrepreneurs who invested in cotton spinning mills with poor layout had to exit the market, and the mill was not subsequently used by other cotton spinning entrepreneurs. However, it could also be driven by the cotton industry adopting steam power (and moving away from water power) more than the other sectors. The summary statistics (Tables A.2-A.4) suggest that this was not the case: Even in spinning, water remained the prominent source of power until the end of our sample period in 1840: 66% of cotton spinning plants still used water power, as compared to 64% in metallurgy and 85% in paper milling. The enduring dependence on water power is a well-known aspect of the French setting (see Cameron, 1985, for a discussion). Moreover, Table A.17 shows a *negative* association between labor productivity and the use of steam power in all three sectors. This confirms that in France, plants did not face a strong profit incentive to move away from water power (Cameron, 1985).

Table A.17: Productivity and the Use of Steam Power in Cotton Spinning (1840)

Dependent variable: log(Output per worker)

	(1)	(2)	(3)	(4)
Steam power	-0.090**		-0.082*	-0.087*
	(0.046)		(0.048)	(0.046)
Water power		0.060	0.017	
		(0.050)	(0.053)	
Other power				0.144
				(0.142)
R^2	0.01	0.00	0.01	0.01
N	528	528	528	528

Notes: Water power, steam power, and other (wind or animal) power are binary indicators equal to one for plants using the respective source of power. Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Productivity handicap of exiting plants. Did plants that exit indeed have particularly low productivity? Table A.18 examines whether plants that eventually exited the market by 1840 had lower initial productivity around 1800, as compared to surviving plants. This pattern is particularly strong in cotton spinning, consistent with the large exit rates in the sector that we documented in Section 5.4. Exiting cotton plants were 46% less productive than survivors, and this difference is statistically significant. This pattern is much less pronounced in the comparison sectors: Exiting plants were about 15% less productive in metallurgy, and 6% less productive in paper milling.

Table A.18: Productivity of Exiting Relative to Surviving Plants

Dependent variable: log(Output per worker) around 1800			
	(1)	(2)	(3)
	Spinning 1806	Metallurgy 1811	Paper Milling 1794
Exit dummy	-0.458**	-0.145*	-0.055
	(0.205)	(0.085)	(0.137)
R^2	0.003	0.001	0.001
N	340	470	520

Notes: Exit is a dummy variable equal to one for plants that existed in the initial period and that had exited the market by 1840 (based on the baseline survival rate – see Section 3.2 and Appendix B.5). In cotton spinning, there were 340 plants in 1806 with information on output and labor, and 317 of these had exited by 1840. In metallurgy, there were 470 plants with data to compute productivity in 1811, and 293 had exited by 1840. In paper milling, there were 520 plants with information on output and labor in 1794, 464 of which had exited by 1840. Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Plant age and productivity. In Section 5.4 in the paper we also examined productivity over the plant age profile as a second piece of evidence that points to organizational methods as a mechanism behind the lower-tail bias of productivity. We documented that younger plants in mechanized cotton spinning were significantly more productive in 1806. Here, we investigate the productivity-age pattern in 1840. While the data for this second period are generally more comprehensive, we do not observe plant age. However, we can perform a similar – albeit weaker – test based on the comparison of surviving and entrant plants: In Table A.19 we regress log output per worker on an indicator for whether the plant was an 'entrant' in 1840 (as opposed to a surviving plant by our definition from Section B.5). The coefficient on the 'entrant' dummy thus reflects the average productivity differential for plants that entered between the initial survey year (1806) and 1840. Best-practice mill design evolved over this period, and it had largely converged by 1840 (Pollard, 1965). Correspondingly, we find that 'young' plants were not more productive; the coefficient is small and statistically insignificant. Columns 2-5 show that this holds also when we control for the use of water power, steam power, any other power source (wind or animal power used by a small subset of plants), and for the number of workers.

Next, we investigate whether a similar pattern holds in metallurgy. Tables A.20 and A.21 examine the relationship between age profile and productivity for metallurgy plants. For this sector,

Table A.19: Cotton Spinning in 1840: Productivity and Plants' Age Profile

Dependent variable: log(Output per worker) in 1840

	(1)	(2)	(3)	(4)	(5)
Entrant 1840	0.039	0.029	0.029	0.036	0.013
	(0.201)	(0.206)	(0.199)	(0.201)	(0.201)
Water power		0.060			
		(0.050)			
Steam power			-0.090*		
			(0.046)		
Other power				0.168	
				(0.140)	
log(Workers)					-0.153***
					(0.027)
R^2	0.00	0.00	0.01	0.00	0.06
N	528	528	528	528	528

Notes: The table shows that in 1840, when mechanized cotton spinning technology had reached maturity, new entrant plants did not have a productivity advantage over existing plants anymore. Entrant 1840 is a binary indicator equal to one for plants that entered the market after 1806. For this definition, we only use surviving plants that are linked based on commune and owner name (as this is almost always a one-to-one match). Water power, steam power, and other (wind or animal) power are binary indicators equal to one for plants using the respective source of power. Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

in both periods, the best measure of plant age that we observe is a binary indicator of plant survival from 1788 to 1811, and from 1811 to 1840 (the latter being the same procedure as for cotton spinning in Table A.19). Thus, in 1811, we define a plant as 'young' if the survey's recall data do not report existence in 1788. The results do not point to younger plants in metallurgy having a strong productivity advantage. While column 1 in Table A.20 shows a positive raw correlation between 'young' metallurgy plants in 1811 and labor productivity, the coefficient becomes smaller in magnitude and statistically insignificant once we control for plant size (column 2).[49] For our second comparison sector, paper milling, information on plant age or recent entry is not available for the early period. We thus cannot perform the comparison for this sector.

Table A.20: Metallurgy in 1811: Productivity and Plants' Age Profile

Dep. variable: log(Output per worker) in 1811

	(1)	(2)
Young 1811	0.190*	0.076
	(0.115)	(0.115)
log(Workers)		-0.291***
		(0.044)
R^2	0.01	0.09
N	470	470

Notes: Young 1811 is a binary indicator equal to one for plants that entered the market after 1788. Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Finally, Table A.21 examines 'young' (entrant) metallurgy plants in 1840. In this later period, 'young' plants actually had a somewhat *lower* productivity, although this difference is not statistically significant.

[49]Note that the metallurgy survey has sparser information on this dimension; plant size is the only control that can be added in 1811.

Table A.21: Metallurgy in 1840: Productivity and Plants' Age Profile

Dependent variable: log(Output per worker) in 1840

	(1)	(2)	(3)	(4)	(5)
Entrant 1840	-0.109	-0.018	-0.106	-0.123	-0.025
	(0.119)	(0.120)	(0.120)	(0.118)	(0.106)
Water power		0.324***			
		(0.063)			
Steam power			-0.072		
			(0.077)		
Other power				-0.239***	
				(0.091)	
log(Workers)					-0.351***
					(0.028)
R^2	0.00	0.03	0.00	0.01	0.20
N	896	896	896	896	896

Notes: Entrant 1840 is a binary indicator equal to one for plants that entered the market after 1811. For this definition, we only use surviving plants that are linked based on commune and owner name (as this is almost always a one-to-one match). Water power, steam power, and other (wind or animal) power are binary indicators equal to one for plants using the respective source of power. Robust standard errors in parentheses. Notation for statistical significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

E.7 Robustness: Region Fixed Effects

In Section 5.5, we examined a set of alternative explanations that may account for the lower-tail bias observed in mechanized cotton spinning. One key robustness check studies the extent to which our main result holds *within* regions. Table A.22 shows that the lower-tail bias, while more muted, remains striking when we add fixed effects for 22 regions in France. This suggests that regional fundamentals, institutions, market access, or differential access to input markets do not account for our results.

Table A.22: Productivity Growth by Quantiles – Controlling for Region FE

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
Spinning (1806-1840)	2.029***	2.941***	2.352***	1.987***	1.943***	1.668***	840
	(0.158)	(0.455)	(0.207)	(0.168)	(0.214)	(0.191)	
Region FE	✓	✓	✓	✓	✓	✓	
Metallurgy (1811-1840)	2.020***	1.955***	1.730***	1.879***	2.010***	2.145***	1,289
	(0.178)	(0.204)	(0.237)	(0.154)	(0.137)	(0.191)	
Region FE	✓	✓	✓	✓	✓	✓	
Paper milling (1794-1840)	0.775***	1.009***	0.746***	0.731***	0.616***	0.731***	850
	(0.118)	(0.137)	(0.122)	(0.099)	(0.127)	(0.213)	
Region FE	✓	✓	✓	✓	✓	✓	

Notes: The table reports the average annual productivity growth (in %) between the initial sample period (around 1800) and 1840 for the three sectors, as well as annual productivity growth estimated at various quantiles. Column 7 reports the number of observations. Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

E.8 Robustness: Market Integration

Can market integration explain the disappearance of the lower tail in cotton spinning after 1800? In the previous appendix section, we already showed that our main finding is robust to the inclusion of region fixed effects. This also addresses – at least to some extent – the concern that market integration could confound our results. Here, we present several additional pieces of evidence. In particular, for market integration to be the main driver of the lower-tail bias in cotton spinning, market access would have had to increase *disproportionately* in this sector between 1800 and 1840, relative to the comparison sectors. We present data that suggest the opposite. Figure A.18 uses data in 1794 from Daudin (2010) on within-country trade linkages across French districts by industry.[50] For each *département*, we sum the number of districts across France that reported consuming

[50] Districts were administrative units that stayed in place only for a short period between the French Revolution and 1800, when they were replaced by *arrondissements*. Each *département* included from a minimum of 3 to a maximum of 10 districts.

products (e.g., cotton textiles) produced in that *département*. The numbers in Figure A.18 show the count of districts that reported consuming a given product from the *département*.

Intuitively, higher market integration means lower price differentials across *départements*, which in turn implies that highly productive areas could dominate the market throughout France. Consequently, we can infer high market integration from the data if we observe that a few (presumably highly productive) *départements* sold to many other *départements*, while the majority of *départements* produced no output, or did so only for local consumption. Figure A.18 shows that this pattern is particularly strong in cotton textiles. Many *départements* produced mostly for themselves if at all (these are the zeros and small, positive numbers), while a few *départements* supplied cotton textiles to a large number of districts. The top tercile of *départements* exported cotton textiles to 30 or more districts. In the two comparison sectors, there is less specialization and less evidence for market integration: Fewer *départements* report not supplying to anyone (particularly in paper), and the top decile of *départements* supplied only to 6 (paper) and 7 (iron) districts in total. This suggests that cotton textile plants were already competing in a bigger market than the comparison sectors around 1800.

Given that cotton spinning already started off with more integrated markets, we would expect – if anything – that further market integration after 1800 played a *smaller* role than in our comparison sectors. This renders it unlikely that relatively tougher competition in cotton led to the disappearance of the lower tail.

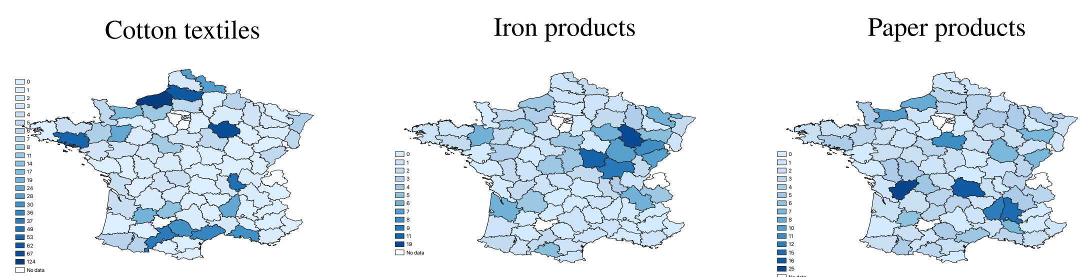


Figure A.18: Market Integration for the Three Sectors in 1794

Notes: Data source: Daudin (2010). The figure shows the extent of market integration in cotton textiles (left), iron (middle), and paper products (right). Market integration is measured as the number of districts (see footnote 50) across France that reported consuming cotton textiles, iron, or paper products from districts in the given *département*. A higher number for a *département* indicates that firms from that *département* sold their products to many distinct locations across France. Data are from Daudin (2010).

Next, in Table A.23 we control directly for market access. We construct two measures of market access: i) within France and ii) across Europe. Both measures are computed as the inverse distance-weighted sum of urban populations in 1800 (see Appendix B.6 for detail). We begin in

Panel A of Table A.23 by controlling for the log of market access within France. While we find that market access in France is correlated with productivity in cotton spinning, this relationship is relatively stable across the productivity distribution: Plants in the lowest decile of the productivity distribution benefited just as much from market access as those in the top decile. Thus, market access in France is unlikely to have had differential effects on low- vs. high-productivity plants. In addition, when adding market access as a control variable, the lower tail-bias in cotton spinning remains very similar, confirming that market integration does not confound our results.[51]

To account for access to *foreign* markets, we perform two additional exercises. First, Panel B in Table A.23 controls for market access across Europe. Second, Panel C in Table A.23 includes a dummy for *départements* located on the coast (either the Channel, Mediterranean or Atlantic) as a proxy for access to foreign markets. In both Panels B and C we find very similar results as in Panel A: While foreign market access is also associated with higher productivity in cotton spinning, this relationship is relatively flat over the productivity distribution, and the inclusion of market access does not change our main result: The lower-tail bias remains substantial. In addition, in unreported results we also confirmed that the productivity growth patterns in our comparison sectors are robust to controlling for the three measures of market access.

[51] As an alternative to controlling for market access directly in the quantile regressions, we also implemented a two-step, OLS-based approach. As a first step, we residualize productivity with respect to market access separately in 1806 and 1840 (thus allowing for differential effects of market access in the two periods). Then, we use the residual plant productivity in the quantile regressions. Again, the results (available upon request) are very similar to our baseline, showing a strong lower-tail bias in productivity growth for cotton spinning.

Table A.23: Productivity Growth by Quantiles – Controlling for Market Access

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
PANEL A: Controlling for Market Access in France							
Spinning (1806-1840)	2.569***	3.973***	3.126***	2.317***	1.996***	1.533***	840
	(0.157)	(0.266)	(0.208)	(0.176)	(0.155)	(0.305)	
Market Access, France	0.718***	0.774***	0.760***	0.587***	0.664***	0.838***	
	(0.116)	(0.199)	(0.113)	(0.129)	(0.105)	(0.189)	
PANEL B: Controlling for Market Access in Europe							
Spinning (1806-1840)	2.535***	3.825***	3.073***	2.333***	1.863***	1.357***	840
	(0.154)	(0.232)	(0.219)	(0.154)	(0.144)	(0.276)	
Market Access, Europe	1.252***	1.335***	1.321***	0.966***	1.040***	1.623***	
	(0.205)	(0.223)	(0.211)	(0.204)	(0.206)	(0.194)	
PANEL C: Controlling for Coastal *Départements*							
Spinning (1806-1840)	2.225***	3.699***	2.965***	2.315***	1.419***	0.809***	840
	(0.149)	(0.237)	(0.201)	(0.127)	(0.197)	(0.232)	
Access to overseas markets	0.810***	0.975***	1.010***	0.520***	0.736***	0.909***	
	(0.129)	(0.216)	(0.138)	(0.120)	(0.154)	(0.214)	

Notes: The table reports the average annual productivity growth (in %) between the initial sample period (around 1800) and 1840 for cotton spinning, as well as annual productivity growth estimated at various quantiles. Market access in France and Europe are computed as described in Appendix B.6. Access to overseas markets is a dummy equal to one for *départements* located on the coast. Column 7 reports the number of observations. Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

E.9 Robustness: Napoleonic Blockade and Napoleonic Wars

The period of our analysis coincides with the French Revolutionary and Napoleonic Wars (1792-1815). Here, we discuss potential channels through which these events may affect our results.

Productivity. By disrupting trade between Britain and France, the Napoleonic Blockade (1806-14) affected the spatial composition of economic activity in France (Juhász, 2018). This in turn may have affected plant-level productivity. While our robustness checks using region fixed effects partially addressed this concern, we now examine it in more detail. First, Figure A.19 splits the sample into plants in the northern and southern regions of France (corresponding to the main dimension along which protection varied). It shows that the productivity distributions in cotton spinning in the two areas are remarkably similar, suggesting that varying trade protection does not drive our results.

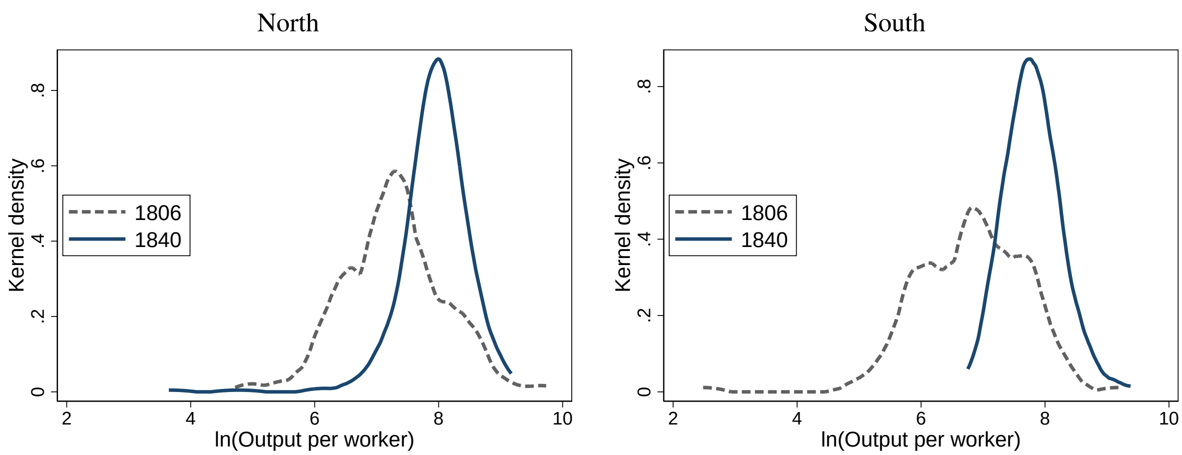


Figure A.19: Spinning: Productivity growth in the 'North' and 'South' of France

Notes: The figure shows the productivity distribution of cotton spinning plants in 1806 and 1840, separating France into North and South. Northern plants are those located in communes with above-median latitude. Southern communes are those located in below-median latitude communes. Median latitude is time invariant and defined based on the sample of 1806 plants.

Plant survival. Could the blockade explain the lower plant survival rates observed in cotton spinning relative to the other sectors? In Table A.24 we split mechanized cotton spinning plants into the same northern and southern regions and report survival rates separately. Indeed, consistent with Juhász (2018), survival rates are lower in the south than in the north (which experienced a relative increase in trade protection during the blockade). However, survival rates remain low relative to the other two sectors even when we narrow our sample to only northern plants.[52] That is, even

[52]Note that the restricted sample survival rate for northern cotton spinning plants is below, but close to that observed in paper milling (22% and 24.6%, respectively). Recall, however, that the cotton spinning survey was conducted much later than paper milling (1806 as opposed to 1794).

comparing only cotton spinning plants in the north of France to the comparison sectors (calculated for all of France), survival rates for northern cotton spinning plants were low. This suggests that an important part of low survival rates in mechanized cotton spinning are not driven by the uneven effects of the Napoleonic blockade across France.

Table A.24: Plant Survival Rates in Cotton Spinning in the North and South of France

	'North'	'South'
Survival rate	6.8%	2.7%
Number of plants	192	148
Restricted sample survival rate	22%	5.9%
Number of plants	36	51

Notes: The "survival rate" is defined as the percentage of plants from the initial period that survived to the later period based on matching either by name or location (see Section B.5 for detail). The "restricted sample survival rate" adjusts for the fact that different sectors have single-plant communes to a varying degree. It is based on the subset of plants located in communes that had only one plant in the initial period. Northern communes are the set of plants with above-median latitude in 1806. Median latitude is time invariant and defined on the sample of 1806 plants.

We note that France also experienced high raw cotton prices (the input to producing yarn) during the blockade (which ended in 1814) as documented in Juhász (2018). However, high input prices are unlikely to explain the high exit rate of plants in the sector for the period 1806 – 1840, as mechanized cotton spinning activity increased dramatically at the aggregate level during the period of the Napoleonic Blockade (Juhász, 2018).

Napoleonic Wars. The Napoleonic Wars (1803-15) may have affected production in France over our initial sample period. However, to confound our results, war should have tilted the productivity distribution in cotton spinning disproportionately, relative to metallurgy and paper milling. Such a lower-tail bias could have been generated by war hitting some firms' production more than others' (by affecting inputs, the actual production, or output markets). We address this concern in several steps. First, region fixed effects partly accounts for this, as the effects of war would likely have been similar for firms in the same region.

Second, we use data on conscripts per capita by region during the Napoleonic wars (see Appendix B.6 for data construction details). As the Napoleonic Wars started in 1803, plants in cotton spinning and metallurgy may have been affected already in the early period – and plants in all three sectors may have still suffered the consequences of the wars in the 1840s. Thus, in Table A.25, we check the correlation between conscripts per capita and productivity in each of the three sectors in 1800 (columns 1-3) and in 1840 (columns 4-6). The coefficients are small and statistically insignificant throughout the different specifications – except for metallurgy in 1840, where the coefficient is marginally significant.[53] Overall, these results suggest that the conscription of soldiers does not confound our results.

Table A.25: Productivity in the Three Sectors and Conscripts During the Napoleonic Period

Dependent variable: log(Output per worker)

	1800			1840		
	Cotton	Metal	Paper	Cotton	Metal	Paper
	(1)	(2)	(3)	(4)	(5)	(6)
log(Conscripts pc)	-0.061	0.030	-0.079	0.041	0.366*	0.020
	(0.306)	(0.202)	(0.084)	(0.061)	(0.203)	(0.155)
N	321	426	507	519	863	343

Notes: log(Conscripts per capita) is the log of the number of men conscripted during the Napoleonic Wars in each French region per 1,000 inhabitants. Standard errors (clustered at the regional level) in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Third, while until 1813, battles in the Napoleonic Wars were fought outside French soil, the final battles of the Sixth Coalition (1813-14) and of the Hundred Days War (culminating in Napoleon's defeat at Waterloo) took place on French territory. We thus collect data on all battles fought in the 1813-15 period from Wikipedia and construct a dummy (*Near Battles*) equal to one for plants located within 10km of a battlefield (see Appendix B.6 for sources and data construction). Because these battles all took place after the initial survey years, we only examine their relationship with productivity in 1840. Table A.26 shows the relationship between productivity in 1840 in the three sectors and our *Near Battles* dummy. The coefficients for mechanized cotton spinning and metallurgy are quantitatively small and statistically insignificant. The positive and significant coefficient for paper milling is driven by five particularly productive plants that were within the 10km radius of battles. Excluding these from the paper milling sector does not affect the productivity growth pattern in paper milling (results available upon request).

[53]While we refrain from over-interpreting this one positive coefficient, one possible explanation is that demand for metal could have been higher in areas with higher conscription because military equipment also had to be provided to the soldiers.

Table A.26: Proximity to Battles during the Napoleonic Wars and Productivity in the Three Sectors

Dep. variable: log(Output per worker), 1840			
	Cotton	Metal	Paper
	(1)	(2)	(3)
Near Battle	0.005	0.023	1.146***
	(0.160)	(0.160)	(0.365)
N	528	896	347

Notes: Near Battle is a dummy equal to one for firms located within 10km of a battlefield during the Napoleonic Wars. Standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

E.10 Robustness: Excluding Small Plants and those that Used Spinning Jennies

This appendix section complements the discussion in Section 5.5, under 'early spinning workshops.' Table A.27 shows that the our results are robust to using only larger plants with more than 10 workers, in both periods and in all three sectors. The magnitudes remain similar to those in our baseline specification (Table 1), and the lower-tail bias of productivity growth remains unique to cotton spinning plants.

Table A.27: Productivity Growth by Quantiles – Plants with at Least 10 Workers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
Spinning (1806-1840)	2.261***	3.917***	3.191***	2.179***	1.612***	0.309	777
	(0.177)	(0.227)	(0.258)	(0.170)	(0.240)	(0.292)	
Metallurgy (1811-1840)	2.413***	2.056***	2.361***	2.001***	2.470***	2.558***	969
	(0.229)	(0.567)	(0.354)	(0.310)	(0.211)	(0.309)	
Paper milling (1794-1840)	1.263***	1.012***	1.146***	1.369***	1.506***	1.312***	511
	(0.137)	(0.223)	(0.150)	(0.116)	(0.170)	(0.333)	

Notes: The table reports the average annual productivity growth (in %) between the initial sample period (around 1800) and 1840 for the three sectors, as well as annual productivity growth estimated at various quantiles. Column 7 reports the number of observations. Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Table A.28 implements an even more conservative approach, dropping all plants that report using a spinning jenny (even if they also used other, newer vintages of capital). This drops overall 76 cotton spinning plants in 1806. The lower-tail bias of productivity growth in cotton spinning remains striking.

Table A.28: Productivity Growth by Quantiles – Excluding Plants that used Spinning Jennies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
Spinning (1806-1840)	1.983***	3.165***	2.678***	2.097***	1.213***	0.383	792
	(0.169)	(0.303)	(0.256)	(0.187)	(0.228)	(0.248)	

Notes: The table reports the average annual productivity growth (in %) between 1806 and 1840 in cotton spinning, as well as annual productivity growth estimated at various quantiles. Column 7 reports the number of observations. Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

E.11 Robustness: Controlling for Plant Scale

As mentioned in Section 5.5 in the paper, we address the concern that our results may be driven by increasing plant scale. For this reason, Table A.29 controls for the log number of workers at the plant level in all sectors and the two periods. Our results continue to hold: The lower-tail biases remains strong and unique to cotton spinning.

Table A.29: Productivity by Quantiles – Controlling for Number of Workers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
Spinning (1806-1840)	2.427***	3.941***	3.427***	2.292***	1.836***	0.974***	868
	(0.162)	(0.231)	(0.243)	(0.165)	(0.185)	(0.304)	
log(Workers)	-0.006	-0.073	-0.072	-0.048	-0.169**	-0.257**	
	(0.063)	(0.092)	(0.090)	(0.058)	(0.071)	(0.115)	
Metallurgy (1811-1840)	3.090***	3.501***	2.838***	2.681***	3.200***	2.940***	1,366
	(0.175)	(0.406)	(0.283)	(0.214)	(0.183)	(0.207)	
log(Workers)	-1.164***	-1.304***	-1.202***	-1.177***	-1.053***	-0.994***	
	(0.080)	(0.133)	(0.091)	(0.098)	(0.084)	(0.093)	
Paper milling (1794-1840)	0.806***	0.670***	0.664***	0.884***	0.897***	1.554***	867
	(0.128)	(0.141)	(0.154)	(0.117)	(0.160)	(0.254)	
log(Workers)	-0.106*	0.157**	0.076	-0.049	-0.169**	-0.469***	
	(0.059)	(0.066)	(0.072)	(0.050)	(0.071)	(0.097)	

Notes: The table reports the average annual productivity growth (in %) between the initial sample period (around 1800) and 1840 for the three sectors, as well as annual productivity growth estimated at various quantiles. We control for the log number of workers at the plant level across all specifications. Column 7 reports the number of observations. Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

E.12 Robustness: Capital Deepening

Table A.30 examines whether capital deepening can account for our results. It controls for the capital-labor ratio in cotton spinning plants (measured as the log of the number of spindles per employee at the plant level). The table shows that the lower-tail bias of productivity growth remains robust and similar in magnitude to the pattern in the baseline specifications.

Table A.30: Spinning Productivity by Quantiles – Controlling for Capital Deepening

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
Spinning (1806-1840)	1.960***	3.555***	2.930***	1.966***	1.254***	0.755***	868
	(0.167)	(0.267)	(0.247)	(0.178)	(0.190)	(0.281)	
log(Spindles per worker)	0.522***	0.374***	0.467***	0.389***	0.379***	0.542***	
	(0.075)	(0.082)	(0.085)	(0.068)	(0.090)	(0.141)	

Notes: The table reports the average annual productivity growth (in %) between 1806 and 1840 in cotton spinning (column 1), as well as annual productivity growth estimated at various quantiles (cols 2-6). Column 7 reports the number of observations. K/L is the capital-labor ratio in the plant, measured as the log of the number of spindles per employee.) Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

E.13 Robustness: Quality Upgrading

Finally, we also considered quality upgrading as a potential confounder in Section 5.5. Table A.31 addresses the concern that even if quality is not directly driving the lower-tail bias, it could still affect it indirectly through higher sales and larger plant size. To address this, we estimate quantile regressions using prices *not* adjusted for quality in 1806, *and* controlling for plant size using the number of employees. The lower-tail bias of productivity growth in cotton spinning remains strong.

Table A.31: Annual Productivity Growth (in %) at Different Parts of the Distribution—Using prices not quality-adjusted and controlling for number of workers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average	At the following quantiles:					N
		0.1	0.25	0.5	0.75	0.9	
Spinning (1806-1840)	2.517***	3.488***	2.886***	2.420***	1.994***	1.657***	868
	(0.143)	(0.295)	(0.223)	(0.198)	(0.141)	(0.218)	
log(Workers)	-0.140**	-0.055	-0.127	-0.210***	-0.200***	-0.211**	
	(0.058)	(0.103)	(0.087)	(0.068)	(0.057)	(0.090)	

Notes: The table reports the average annual productivity growth (in %) between 1806 and 1840 in cotton spinning, as well as annual productivity growth estimated at various quantiles. Column 7 reports the number of observations. Robust standard errors in parentheses. Notation for statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

F Summary of Evidence

Evidence for Learning About Organization of Factory-Based Production	
We argue that learning about the efficient organization of factory-based production can explain the lower-tail bias of productivity growth in mechanized cotton spinning. Here we summarize the evidence in line with our proposed mechanism.	
Type of evidence: **H**istorical/**E**mpirical	Description of Evidence
Learning About Best-Practice Methods	
H: Section 2.2	Section 2.2 documents how early adopters of the factory system in mechanized cotton spinning needed to engage in trial and error along multiple dimensions related to the organization of spinning mills. This process led to the development of best-practice methods for operating the new technology efficiently.
Learning About Optimal Mill Design	
E: Figure 4 and Table A.8	Figure 4 shows that there was large variation in the layout of cotton mills and the number of floors in cotton spinning plants in the early period. Best practice converged to cotton mills with a more rectangular shape and around 3.5 floors. Table A.8 shows that there is a systematic relationship between these design elements of cotton mills and a proxy for productivity: plant survival.
Learning About Management Challenges and Strikes	
E: Table A.9	Using strikes as proxy for labor management challenges, Table A.9 shows that strikes were more frequent in textiles than in the comparison sectors.
Spatial Diffusion of Knowledge	
E: Figure 5 and Table A.10	Figure 5 and Table A.10 show that plants located closer to high-productivity plants (in the same sector) were themselves more productive. This relationship is strong only for cotton spinning plants and only during the initial period of technology adoption. This evidence is in line with spatial spillovers of knowledge in mechanized cotton spinning in 1800.
Plant Survival Across Sectors	
E: Table 2	Table 2 shows that plant survival rates in mechanized cotton spinning were lower than in our comparison sectors. This is consistent with a mechanism in which owners of a cotton spinning mill faced considerable challenges along the organizational dimension of factory design. Those that invested in mills with poor layout had to exit the market.

Evidence for Learning About Organization of Factory-Based Production (ctd.)	
Type of evidence: **H**istorical/**E**mpirical	Description of Evidence
Plant Exit and Productivity	
E: Table A.18	Table A.18 shows that exiting plants in mechanized cotton spinning were much less productive than those that survived. In the comparison sectors, the productivity handicap of exiting plants is also present, but less pronounced. In other words, early cotton plants that 'got it wrong' were particularly unproductive, which can explain the fat lower tail of productivity in this sector. These plants eventually exited the market, and for many of them, the same building was not used by another plant in the industry. This pattern is consistent with large organizational challenges and low initial guidance in switching to factory-based production in cotton spinning.
Age Profile of Plant Productivity	
E: Tables 3, A.19, A.20, and A.21	Table 3 shows that around 1800, cotton spinning plants that entered the market later had higher productivity. This is in line with the argument that knowledge about the optimal organization of mechanized cotton spinning diffused slowly. On the other hand, if learning about technology was the dominant dimension, older plants that had accumulated more experience should have had a productivity advantage. In addition, we show that younger spinning plants were not more productive in 1840 (Table A.19) and that in metallurgy, young plants were as productive as older ones in both periods (Tables A.20 and A.21). This is consistent with the idea that later entrants in mechanized cotton spinning could draw from a better pool of knowledge about organizing production. This process was muted in cotton spinning in 1840, when best practice had diffused, and in metallurgy, where plant-based production methods had been established much earlier.

Alternative Explanations for the Spatial Diffusion of Knowledge	
We presented evidence for the spatial diffusion of organiziational knowledge in mechanized cotton spinning: Plants located closer to other high-productivity plants were themselves more productive, and this relationship is strong only for cotton spinning plants and only during the initial period of technology adoption. Here we show that this result holds when performing a series of robustness checks.	
Type of evidence: **H**istorical/**E**mpirical	Description of Evidence
Location Fundamentals	
E: Table A.11	Our results could be affected by prominent location fundamentals, not captured by *département* fixed effects (such as the availability of fast-flowing streams, proximity to coal, or the share of forest cover). Table A.11 controls for these factors and shows that the pattern of proximity to high-productivity plants holds.
Agglomeration Externalities	
E: Table A.12	Our findings could be driven by high-productivity plants emerging (within *départements*) where the density of production was large due to agglomeration forces. Table A.12 controls for the local density of production and shows that our results hold.
Unobserved Location Fundamentals	
E: Table A.13	If there are unobserved location fundamentals (within *départements*) not captured by our controls (in Tables A.11 and A.12), they could still confound our results. Table A.13 performs a placebo exercise and studies whether plant productivity in 1800 was related to distance to plants in the top-90th percentile of productivity in 1840 (i.e., plants that emerged later). The coefficient is close to zero and statistically insignificant, suggesting that our results are not driven by persistent unobserved location fundamentals within *départements*.
Distance to London	
E: Table A.16	As many innovations in all three sectors were developed in England, firms closer to the channel may have been able to better observe British practices. This concern is partly addressed by the inclusion of *département* fixed effects in our regressions. Table A.16 also controls for distance to London. The results are virtually unchanged.
Plant Selection	
E: Table A.14	Another concern is that ex-ante high-productivity plants selected into ‘productive locations’ (i.e., chose to locate near existing high-productivity plants). Table A.14 shows that the results hold when limiting to the subsample of plants that entered *before* the nearest high-productivity plant.
Learning Across Sectors	
E: Table A.14	Did spatial diffusion of knowledge occur across sectors? Table A.15 shows that this was not the case, suggesting that early cotton spinning mills were unlikely to learn from high-productivity plants in the more mature comparison sectors.

Alternative Mechanisms

We provided evidence that the lower-tail bias in mechanized cotton spinning was due to the reorganization of production. Here, we test for alternative (potentially confounding) mechanisms. Importantly, factors that affected the comparison sectors in similar ways (e.g., economy-wide trends, the introduction of innovations during our sample period, or improvements in power sources) are unlikely to explain our findings. Thus, we consider confounders that are either specific to cotton spinning or that may have affected this sector differentially.

Type of evidence: **H**istorical/**E**mpirical	Description of Evidence
	A. Regional Differences
E: Table A.22	Different growth potential of French regions, access to better domestic suppliers of machines, or plants sorting into areas with better location fundamentals (such as fast-flowing streams) could potentially be driving our results. Similarly, wars and revolts (we deal explicitly with the various effects of the Napoleonic wars below) affected some regions of France more than others. Table A.22 performs the quantile regressions including region fixed effects and shows that our results are robust to using only within-region variation.
	A.1 Market Integration
E: Figure A.18, and Table A.23	As the French economy became more integrated, lower-productivity firms may have faced stronger competition and exited the market. However, this can only explain our results if market integration affected mechanized cotton spinning differentially, as we do not observe the lower-tail bias in the comparison sectors. Figure A.18 shows the extent of market integration in the three sectors and suggests that cotton plants were already competing in a larger market around 1800. In addition, Table A.23 performs the quantile regressions for mechanized cotton spinning controlling for different measures of market potential (market access within France, market access in Europe, and access to overseas market). The results on the lower-tail bias hold.
	A.2 Machine Quality
H: Section 2.2 and Appendix Section A.2	The quality of machines available to producers could potentially explain our findings. However, the historical evidence (reported in Section 2.2 and Appendix Section A.2) suggests that machine production and maintenance was external to most plants. This suggests that plants within the same region had access to the same suppliers. As our results hold when using within-region variation, it is unlikely that differential access to machine producers can account for the lower-tail bias.
	A.3 The Napoleonic Blockade
E: Figure A.19 and Table A.22	As shown by Juhász (2018), varying trade protection during the Napoleonic Blockade affected the location of mechanized cotton spinning plants. This raises the concern that the blockade may explain the lower-tail bias. Table A.22 shows that the results hold within region, where the pattern of protection was very similar. In addition, Figure A.19 splits the sample into northern and southern regions (the main dimension along which protection varied) and shows that in both regions, productivity growth until 1840 was due to a disappearing lower tail.

Alternative Mechanisms (continued)	
Type of evidence: **H**istorical/**E**mpirical	Description of Evidence
	A.4 Napoleonic Wars
E: Tables A.22, A.25, and A.26	The Napoleonic Wars may have affected plant productivity. This would be a concern if they affected the productivity distribution in cotton spinning disproportionately, relative to metallurgy and paper milling. First, region fixed effects partly accounts for this, as the effects of war would likely have been similar for firms in spatial proximity (Table A.22) Second, Table A.25, checks the correlation between conscripts per capita and productivity for each of the three sectors. The coefficients are small and statistically insignificant for cotton spinning. Finally, after 1813, some battles took place on French territory. Table A.26 shows the relationship between productivity in 1840 and a dummy for plants located within 10km of a battlefield. The coefficient for mechanized cotton spinning is statistically insignificant and small in magnitude.
	B. Early Spinning Workshops
E: Tables A.27 and A.28	Our results may be driven by the disappearance of small cotton spinning plants. It may be the case that there were systematic differences between small plants operating early vintages of spinning jennies (that did not necessarily need inanimate sources of power) and larger-scale factories. We test for this in two ways: first, we adopt a stricter definition of 'factory-production' and use only plants with more than 10 employees (see Table A.27); second, we drop plants that used the earliest vintage of machinery – the spinning jenny (see Table A.28). In both cases, the lower-tail bias remains striking.
	C. Changes at the Plant Level
	C.1 Plant Scale
E: Tables A.2-A.4 and A.29	Our findings could be driven by increasing plant scale. First, this is unlikely as all sectors witnessed an increase in plant scale (see Tables A.2, A.3, and A.4). In addition, Table A.29 shows that our quantile regression results are robust to controlling for the number of workers (at the plant level).
	C.2 Capital Deepening
E: Table A.30	Productivity growth in cotton spinning could be driven by technological improvements of the mechanized machinery after 1800. One important dimension of improving technology in cotton spinning was the increased capital per unit of labor (measured as spindles per worker). Table A.30 controls for the capital-labor ratio at the plant level (measured as the number of spindles per worker). The lower-tail bias of productivity growth remains robust.

Alternative Mechanisms (continued)	
Type of evidence: **H**istorical/**E**mpirical	Description of Evidence
C.3 Quality Upgrading	
E: Tables A.5 and A.31	The lower-tail bias could be driven by quality upgrading across plants over time. Table A.5 (Panel B) uses prices not quality-adjusted and shows that our results hold. In addition, if quality led to higher sales and thus larger plant size, it could still drive our results indirectly. Table A.31 estimates the quantile regressions not adjusting for quality differences in prices across plants and controlling for plant size. The lower-tail bias is robust to this specification.
C.4 Age Profile of Plants	
E: Tables 3	The median age of mechanized cotton spinning plants in 1806 was only 3 years. One concern is that our results could be driven by the fact that cotton spinning plants are very young and inexperienced. Table 3 shows that the opposite holds in the data: Younger plants were significantly *more* productive than older ones.

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