The London School of Economics and Political Science

Temporary Protection, Technology Adoption and Economic Development

Data and Evidence from the Age of Revolution in France

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Declaration

I certify that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I warrant that this authorisation does not, to the best of my belief, infringe the rights of any third party.

I declare that my thesis consists of 46,574 words.

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Abstract

This thesis examines industrial development in early 19th century France, a period of momentous sea-change often referred to as the 'Age of Revolution'. A novel dataset makes it possible to examine key sectors of the economy as they developed from rural cottage industries into modern, factory-based production units. The Napoleonic Blockade against British trade (1803-1815) provides within country, exogenous variation in trade protection from the industrial leader, Britain.

In the first chapter, *"The Spatial Dynamics of Structural Transformation in France"*, I present the new dataset and document some spatial patterns which seem to comove with the switch to modern technology. I find that the time period was disruptive to the existing spatial structure of the economy, at least for the modernising sectors which I observe.

The second chapter, *"Temporary Protection and Technology Adoption: Evidence from the Napoleonic Blockade"*, uses an exogenous shock to trade protection, driven by the Napoleonic Blockade against British trade, to assess whether temporary protection from trade with industrial leaders can foster development of infant industries in follower countries. I show that in the short-run, regions (départements) in the French Empire which became better protected from trade with the British increased capacity in mechanised cotton spinning to a larger extent than regions which remained more exposed to trade. Moreover, temporary protection affected the long-term location of mechanised cotton spinning in France.

The third chapter, *"Inter-Industry Linkages: The Indirect Effects of the Napoleonic Blockade"* explores the wider implications of the exogenous shock to trade protection. Using variation in the location of post-blockade mechanised cotton spinning caused by the trade shock, I find evidence of coagglomeration for technologically proximate spinning sectors. The effects do not seem to be driven by input-output linkages, suggesting a role for technology spillovers or labour market pooling.

Contents

List of Figures

List of Tables

Chapter 1

The Spatial Dynamics of Structural Transformation in France

1.1 Introduction

One of the most salient features of the contemporary spatial landscape is the extent to which economic activity is concentrated.[1] Concentration is higher than what can be explained by natural advantage alone (Ellison et al., 2010). Increasing returns to scale (IRS), either internal or external to the firm, feature prominently in theories of agglomeration.[2] In light of this, we would expect that moving from an economy in which most output is produced using a constant returns to scale, cottage industry technology, to a world in which increasing returns to scale feature more prominently would disrupt the existing spatial structure along a number of interesting dimensions.

The Industrial Revolution in the early 19th century entailed precisely this type of switch in production technology. In the late 18th century, manufacturing activity in Europe had been organised as a cottage industry. Workers generally worked in their own homes using very simple equipment. A "merchant-manufacturer" supplied workers with the raw material and capital used in production, and secured outlets for their output (Mokyr, 2009). In many ways it is a textbook example of a constant-returns to scale production technology.

One of the major changes to take place during the Industrial Revolution was the widespread adoption of the factory system. Production methods across a large num-

[1]Rosenthal and Strange (2004) discuss the evidence on agglomeration economies.

[2]Krugman (1991) showed how agglomeration economies arise from the interaction of transport costs and IRS internal to the firm. Marshall (1920) was the first to emphasise labour market pooling and technology spillovers.

ber of industries became more capital intensive and increasingly reliant on inanimate sources of power (Landes, 1969). Work was now organised in large-scale factories, where the management of labour and the careful organisation of work-flow presented new problems (Allen, 2009). As such, scale economies arguably became much more prevalent. The historical literature has also argued the technology spillovers, a form of external IRS central to some models of agglomeration, was an important engine of innovation (Mokyr, 2009).

In this chapter, I examine the spatial dynamics of a number of industries during the early stages of the Industrial Revolution in 19th century France. I explore how industry concentration (localisation), persistence in industry location over time, and coagglomeration patterns changed as various sectors in France switched from a CRS, cottage industry technology to a method of production in which IRS were arguably increasingly important.

I examine these patterns by exploiting a unique, newly constructed dataset on a number of industries, observed at various points in time between the late 18th and mid-19th century in France. Importantly, I observe some sectors both while they were organised as a rural industry, and once they began to mechanise and organise work in factories. Moreover, the industries I observe mechanised at different points in time, which mitigates concerns that aggregate trends, such as decreasing transport costs, were driving these patterns.

I observe five sectors between 1790-1860; cotton spinning and weaving, wool spinning and weaving and the leather industry. The dataset is constructed from a number of large-scale, industrial surveys conducted between 1790-1815. I link these surveys to two industrial censuses which were conducted in the 1840s and 1860s. For each industry, I observe employment at the level of the department, along with a number of other variables. For mechanised cotton spinning, I also observe data at the level of the firm at two points in time, allowing me to examine how the scale of the firm and its capital intensity changed as mechanisation proceeded.

The range of sectors covered in the dataset was dictated by data availability. However, these five sectors provide insight into one of the most important industries during this time period, textiles. Moreover, the leather industry is a natural benchmark, as it remained more or less a rurally organised industry throughout this time period.

Textiles was one of the leading industries in the Industrial Revolution. Its patent intensity was second only to engines. In Britain, cotton manufacturing is estimated to have accounted for 25% of TFP growth between 1760-1860 (Crafts, 1985). In France, textile manufacturing accounted for 60% of all manufacturing employment in 1840. In contrast to the changes taking place in textiles, leather was one of the industries in which change seems to have been almost imperceptible. It was one of the least patent intensive industries, and it mostly remained rurally organised throughout my time period of interest. As late as 1840, the median firm in leather production in France had four employees.

A further advantage of the data is that I am able to observe developments within the textile industry. In particular, I observe developments for two different fibres at two different part of the production process. This provides some interesting time variation, as there were significant time lags in mechanisation, both across wool and cotton, and between upstream spinning and downstream weaving.

Among textiles, cotton spinning was the sector where mechanisation was first invented around 1760. Efforts were soon under way to adapt the technology to spinning other fibres, and to mechanising other parts of the production process. Both took time. Woollen spinning was not mechanised until after 1820, and it did not become widespread on the Continent until the 1840s (Jenkins, 2003). Mechanising downstream weaving took about half a century. Power looms only began to replace hand-loom weaving in the middle of the century (Mann, 1850).

I document a number of interesting patterns which seem to comove with mechanisation. First, I examine variables observed at the level of the firm in order to document the extent to which industries were indeed modernising in France during the period I examine. Mechanised cotton spinning firms became larger and more capital intensive between 1806 and 1840, suggesting that scale economies internal to the firm became increasingly important. Looking at firm level variables in 1840 across the different industries, I also find that firms seemed to be more reliant on inanimate power sources in industries which mechanised sooner.

I then turn to examining persistence in the location of activity between 1810 and 1860, and 1840 and 1860. The pairwise raw correlations for employment across the time periods are smaller for industries in which there was more mechanisation taking place between the two points in time, suggesting that mechanisation may have disrupted the location of manufacturing activity. It should be noted that this pattern would also be consistent with changing natural advantage requirements for industries.[3]

I then show that localisation, that is the concentration of a particular industrial activity, seemed to increase with mechanisation. Finally, I examine coagglomeration patterns over time. I find that initially, coagglomeration was strongest for industries with strong input-output linkages. Over time however, these correlations weakened, and the horizontal linkages between cotton and wool became stronger. This latter would be consistent with technology spillovers or labour-market pooling.

While these patterns are certainly suggestive of an explanation in which the switch from cottage industry to modern factory based production caused a change in the spatial structure of the economy along a number of important dimensions, the aim of the present chapter is not to establish causality. In Chapters 2 and 3, I focus on establishing causality for two outcomes of interest. Chapter 2 deals with the question of how trade affected the location of the mechanised cotton spinning industry within France, while Chapter 3 exploits exogenous variation in the location of cotton spinning to examine the coagglomeration of textile spinners. In this chapter, my aim is to document a larger number of spatial regularities associated with mechanisation without establishing causality for any specific outcome.

Irrespective of the specific mechanisms driving my results, the patterns documented in this chapter contrast with an emerging literature which shows a surprising amount of persistence in the location of economic activity (Davis and Weinstein, 2002 and Bleakley and Lin, 2012). Seen in this light, the contribution of the chapter is to document that, at least for the case of France, industrialisation disrupted the existing spatial structure along a number of interesting dimensions.

A number of papers have examined the spatial dynamics of economies over longer time horizons. The paper most closely related to this chapter is Rosés (2010), which examines the regional dynamics of Spain across 8 regions during the 19th century. One of the main findings is that while traditional industries grew more or less equally across the 8 Spanish regions, modern sectors had far more uneven growth, eventually leading to uneven industrialisation across Spain. Relative to that paper, the main advantage in this chapter is that I am able to observe the *same* industry before and during modernisation, albeit for much a smaller set of industries.

A number of other papers have documented the bell-shaped curve in spatial

[3]As machines were increasingly powered by water or steam, proximity to fast-flowing streams or coal could be a location-specific, exogenous natural advantage which changed firms' location decisions.

inequality predicted by new-economic geography (NEG) models.[4] In these models, steadily falling transport costs lead first to an increase, and then a decrease in regional disparities. Most importantly, Combes et al. (2011) confirms the bell-shaped pattern in regional disparities in value added across departments in France for agriculture, manufacturing and services for the period between 1860 - 2000. Kim (1995) shows this pattern using US manufacturing employment data between 1860 - 1987, while Rosés et al. (2010) shows the same for Spain, where the turning point did not occur until the 1970s. Relative to these papers, the focus of this chapter is not on the role played by transport costs, but rather on how spatial dynamics for a number of key industries evolved during the period when production technology switched from CRS to a technology where internal, and potentially external, scale economies became increasingly prevalent.

The chapter is structured as follows. In the next section, I discuss the historical context. In Section 3, I introduce the dataset. Section 4 documents the firm level variables and discusses the spatial dynamics observed. The final section concludes. A detailed description of the dataset, its construction and potential limitations can be found in Appendix A.

1.2 Historical Context

The first half of the 19th century brought momentous changes to the French economy. For the textile industry in particular, both the method of production and the organisation of labour were transformed during this period, fundamentally altering the way in which economic activity was organised. The new technology, which was adopted from Britain, had enormous effects on the economy. It is estimated that cotton accounted for an extraordinary 25% of TFP growth in British industry between 1780 - 1860, for 22% of British industrial value added, and 50% of British merchandise exports in 1831 (Crafts, 1985). In France the textile industry became similarly dominant. Cotton manufacturing alone accounted for 18% of manufacturing employment in 1840, while textiles in general claimed 58%. Chapter 2 deals in detail with the adoption of mechanised cotton spinning technology in France, which initially proved difficult. Chapter 3 discusses how the technology in spinning, and downstream cotton weaving was adapted to suit other fibres in the textile industry,

[4]See Fujita et al. (2001) for an overview of the literature.

and how this affected coagglomeration patterns in the industry. In this chapter, I focus on documenting a larger set of patterns related to how the spatial structure of the economy changed over this time period, at least for the subset of industries which I examine. To this end, I focus on two aspects of the historical setting which are important for interpreting the patterns in the data.

1. New technology entailed a switch from CRS to IRS

As a consequence of the new technology used to spin cotton yarn, the capital intensity of production and the location of production changed dramatically. As late as the end of the 18th century, textile manufacturing was predominantly a rural activity across Europe organised as a cottage industry. It was performed using very simple equipment, generally in the workers' own homes, often as a means of supplementing income during agricultural down-time. Workers were organised by merchants and middle-men who supplied them with the raw materials, and sometimes also the equipment that they used (Mokyr, 2009). In many ways, it could be thought of as the quintessential constant returns to scale technology. Production was scaled up or down depending on the eb and flows of demand.

During the 1760s, a number of key inventions in cotton spinning revolutionised almost the entire textile industry. Previously, a spinner had used one wheel to spin a single yarn. The new machines now made it possible for one spinner to simultaneously spin multiple threads as twist was imparted to the fibre not by using the workers' hands, but rather by using spindles. In the space of a generation, the new machines invented for spinning cotton yarn were adopted across the British countryside and production moved into modern factories where work-flow was organised by managers, and workers were employed at a wage. As early as the 1780s, machines powered by inanimate sources (initially water, and later steam) were developed. For all these reasons, the fixed costs of production increased, suggesting that IRS internal to the firm became more important with the adoption of the technology. The changes were dramatic relative to the technology that was replaced, however, at least initially, the fixed costs for most firms were arguably fairly modest. The early spinning jenny was estimated to cost about 70 shillings, which was about 7 times a worker's weekly wage (Allen, 2009). The machines did become more sophisticated over time and production seems to have become more capital intensive. However, as late as the 1840s, the median mechanised cotton spinning firm used no steam-powered motors and one water-powered motor in France.

The historical literature has focused to a much larger extent on IRS at the level of the localised industry, and in particular on learning-by-doing externalities. There are at least three reasons for this.[5]. First, the machines were fairly crude devices to begin with. Many important innovations were made by anonymous workers or inventors who were able to improve upon existing designs by tweaking the machines. These improvements were not patented, but rather they became part of the tacit, best-practice knowledge embedded in machine builders skills (Mokyr, 2009). Second, for both the spinners and the downstream weavers, working with the new technology and using machine-spun yarn required different skills. Horn (2006) describes in detail how both the pre-1789 Bourbon government and private entrepreneurs in France paid for English workers to spend time in France to train spinners in working the new machines.[6] Third, Allen (2009) argues that there were important spillovers generated by the invention of factory based production. Indeed, Chapman (1970) has found that cotton mills in Britain had a remarkably similar structure. The reason for this has to do with the fact that they were all built by the same person, who had acquired his skills on the job. In sum, the new technology in cottons disrupted the existing structure in several important dimensions.

2. Time lags in mechanising other parts of the production process and other sectors

One attractive aspect of the setting is that there was a significant amount of variation in the extent to which different sectors had mechanised and adopted factory based production at any given point in time. As I will show, many of the patterns which emerge in the data seem to be systematically related to the degree to which a given sector was mechanised at the time. It is therefore useful to establish approximately when different sectors mechanised.

While there is significant debate in the historical literature about the extent to which developments in textiles were matched by similar changes in other sectors, the limited set of industries which I examine in this paper (cotton, wool and leather) are fairly straightforward to rank in terms of the timing and extent to which they mech-

[5]In Chapter 2, I document the historical evidence in support of learning-by-doing spillovers in far more detail.

[6]It should be noted that this was illegal, as Britain prohibited both the emmigration of textile workers and machine builders, and the export of the machines themselves.

anised.[7] Following Voigtländer and Squicciarini (2014), I match French industries from the census data to Nuvolari and Tartari's (2011) data on British patents by industry.[8] Table 1.1 shows that the leather industry was one of the least innovative industries in terms of patent intensity, while the textile industry was second only to engines. This is very much in line with historical evidence. Bonin and Langlois (1997) emphasise that the industry served mostly local markets and used predominantly local materials. The only locational constraint was its dependence on access to water, which makes it an ideal comparison to cotton and wool, which both become reliant on access to fast flowing streams as production methods mechanised.

Within the dynamically changing and highly innovative textiles sector, there was a significant amount of variation in the extent to which different fibres and different parts of the production process mechanised, and also large differences in the onset of these changes. With the notable exception of silk manufacturing, textile production was a technologically very similar process for the three other fibres which dominated 19th century textile production in Europe. In the case of cotton, wool and flax, the production process entails the following four steps; (1) Preparation of the fibre (called carding for wool and cotton and heckling for flax). (2) Spinning the fibre into yarn. This is the stage which imparts the twist to the fibre necessary to produce yarn. (3) Weaving, which is the stage at which cloth is produced by weaving together the yarn. (4) Finishing, which can involve printing, dyening and/or bleaching.

As a result of the large productivity gains in mechanising the production of cotton yarn, efforts were soon under way in Britain and elsewhere to adapt the spinning machines to the spinning of other fibres and to mechanise other parts of the production process, notably downstream weaving.[9] However, because of inherent differences in the fibre, adapting the machines for other fibres took decades. In the case of woollens, Jenkins (2003) estimates that mechanised spinning replaced hand-spinning by the 1820s in Britain, and by the 1840s on the Continent. What this implies is that there was variation in the extent to which two technologically very similar sectors (wool and cotton) employed CRS or IRS technologies at any given

[7] For two opposing views on the extent to which the Industrial Revolution was limited to a few innovative sectors see Crafts and Harley (1992) and Sullivan, 1990.

[8] These data cover the period 1617 - 1841 and thus stop slightly short of the last point in time (1860), when I observe employment data for the industries in the sample.

[9] Allen (2009) estimates that with the first spinning jenny, the cots of spinning a pound of cotton yarn decreased from 7 to 2.33 shillings for the coarsest yarn, where the productivity gains were the lowest.

point in time.

Mechanising downstream weaving proved to be more difficult than mechanising spinning. Mann (1954) estimates that weaving lagged mechanisation in spinning by about fifty years, as the power-loom did not become more productive than hand-loom weaving until about 1840. In the case of both cotton and wool, mechanisation of downstream weaving lagged mechanisation of spinning by decades.

1.3 Data

Data are compiled from a variety of primary and secondary sources which cover the period 1792-1865. Table 1.2 summarises the years for which data are available for the cotton, woollen and leather industries. For the later 18th - early 19th century, I have collected data from a number of large-scale industrial surveys conducted either by the Revolutionary French government in the early 1790s, or the Napoleonic regime in the early 19th century.[10] In each case, the data were requested by the government in Paris. For each department, the prefect was responsible for collecting and compiling the data. Of the 83 departments which made up France at the time, data are consistently available for about 70 departments throughout my period of interest.[11] Importantly, these data were never used for the purposes of taxation, reducing the incentive to hide or misrepresent economic activity.

I link data from these industrial surveys to two industrial censuses from the 1840s and 1860s which covered almost all manufacturing activity. Chanut et al. (2000) collected, cleaned and classified the data published by the French government at the time. Data from the first census are available at the level of the firm, while data from the second is available at the level of the arrondissement.[12]

The outcome variable which is consistently observed across industries and time is the level of employment. This will be the outcome variable of interest which I focus on, however, I also report summary statistics for other variables of interest. For

[10] For the latter, the data cover all of the departments of the Continental French Empire. To ensure consistency across earlier and later years, I only use data from departments of the French Empire at its 1789 borders.

[11] These departments correspond, with a few exceptions, to the departments which make up present-day France. The only territorial discrepancy in the time period which I examine is "Tarn et Garonne" which was formed in 1808 from a number of surrounding departments. In post-1808 years, I add Tarn et Garonne to Tarn.

[12] One important missing variable is spinning capacity (number of spindles) for each firm, which I have collected from the original data in order to be able to compare outcomes for cotton spinners across time.

mechanised cotton spinning, physical capital (measured as the number of spindles) is measured across a large number of time periods.[13] For weaving, the number of non-mechanised weaving frames used in pre-industrial production is observed in the initial periods. For leather tanning, the number of tanning pits, a measure of physical capital, is observed for the initial time periods. Finally, the census data report sales and variables measuring the intensity of use of water and steam-power for both periods and all industries.

In the analysis, I focus on outcomes measured at the level of the department. The borders of these administrative units were drawn during the Revolution with the intention that the boundary of any department should be within a day's travel from the prefecture. In the case of mechanised cotton spinning firms, I observe data at the firm level at two points in time, 1803-06 and 1840, making it possible to examine along a number of dimensions how firms evolved during this time period. Appendix A describes all data sources, construction of the data set, the imputation models used to impute missing spindle data and possible limitations.

1.4 Patterns of spatial dynamics

In this section, I document some of the patterns which emerge from the data. My interest lies in examining whether the spatial structure of the economy changed in interesting ways in line with the differential timing in the adoption of mechanisation. To this end, I begin by examining the firm level outcomes. I then examine industry specific persistence in order to discern the extent to which the spatial structure in France displayed interesting dynamics over this time period. I then examine whether the patterns on persistence are related along other dimensions to the timing of mechanisation. Finally, I look at coagglomeration patterns across industries and over time.

1.4.1 Firm level outcomes

I begin the analysis by establishing some pattern at the firm level. Table 1.4 examines how mechanised cotton spinning firms evolved between 1806 and 1840. In general, cotton spinning firms became much larger and more capital intensive be-

[13] Spindles are imputed for firms which report the number of machines instead of the number of spindles. Details of the imputation model are provided in Appendix A.

tween the two points in time. In particular, the median firm had 664 spindles (which corresponds to around 3-4 state of the art machines at the time) and 30 employees in 1806. By 1840, this number had risen to 4,000 spindles and 72 employees. We also see a large increase in terms of the capital intensity of the firms; the median firm had 24 spindles per employee in 1806. By 1840, this number had increased to 55. Despite the increase in the size of the firm and the capital intensity of the technology used, most firms used very little inanimate power. As late as 1840, the median firm used no steam-powered motors, and only one water-powered one.

It is useful to contrast cotton spinners to firms in other industries, which we are able to do in Table 1.5 for 1840. The most interesting comparison is that of woollen spinning, where the technology was similar, however, developments lagged those in cotton spinning.[14] Consistent with a lag in technology adoption, the firms seemed to be smaller, and they used less inanimate power. The median firm in woollen spinning employed only 40 workers relative to 72 in cottons. Similar to cotton spinning, the median firm employed no steam-powered motors, and only one water-powered one, however, the means were smaller for both water and steam power in the case of woollens.

Both cotton and wool weaving firms seemed to be generally larger in size than their counterparts in spinning. The median cotton weaving firm employed 80 workers (relative to 72 in spinning), while the median wool weaver employed 55 (relative to 40 in spinning). However, they both used far less steam and water-power. In fact, the median firm in both cotton and wool weaving used neither steam, nor water-power, consistent with mechanisation lagging developments in spinning. Finally, firms in the leather industry were far smaller in scale. The median firm had 4 employees, and used no steam or water-powered motors.

1.4.2 Persistence patterns

Table 1.3 examines persistence in the location of economic activity by calculating the raw correlation and rank correlation for employment between the given year and 1860. A number of interesting patterns emerge.

First, I compute persistence correlations for aggregate employment levels across the five industries for each department in my sample. The raw correlation of per-

[14] Recall that by 1840, mechanised woollen spinning technology had mostly replaced hand-spinning across the Continent.

sistence for France in these five sectors between 1810-1860 is 0.66 , while the same number for the period between 1840 and 1860 is 0.81.[15]

It is interesting to compare these numbers to those calculated for Japan during industrialisation from Davis and Weinstein (2002). Persistence relative to 1998, calculated using the density of population across regions, is 0.76 for 1872 (about the time when Japanese industrialisation began, and thus corresponds to the figures for 1810 in France) and 0.94 for 1920, a point in time when industrialisation was well under way, but 50% of the population was still working in farming. As can been seen, these numbers relate to much longer time horizons, yet are somewhat larger.

However, when comparing the results to the French data, it is worth bearing in mind that despite the fact that wool and cotton textiles alone accounted for about 30% of manufacturing employment in 1840 in France, and could be thus argued to capture a sizeable share of manufacturing activity, my measure in no way accounts for employment in agriculture, which is where the large majority of the population was employed in this time period.

Persistence between 1810 and 1860 was lower for industries which mechanised, or began to mechanise during this period. As a benchmark, it is useful to examine the leather industry which did not undergo significant change throughout this period. The raw correlation in employment between 1810 and 1860 is 0.65, while it is 0.63 between 1840 and 1860.

For mechanised cotton spinning, the persistence coefficient with 1860 is 0.63 in 1810, while the same number for rural, woollen hand-spinning is 0.34. That is, the location of woollen spinning changed to a far larger degree between 1810-1860 than it did for mechanised cotton.

Other industries, which were also rurally organised in the early 19th century, but later mechanised display a similar pattern of persistence; cotton weaving and wool weaving have persistence parameters in the range of 0.40 - 0.45, which are lower than non-mechanising leather, and mechanised cotton.

Similarly, in 1840, the raw correlation with employment levels in 1860 is higher for sectors that were more mechanised by 1840. It is 0.98 for mechanised cotton spinning, and 0.89 for woollen spinning. The numbers are somewhat lower for cotton

[15] I also computed persistence for the entire manufacturing sample in the years between 1840 - 1860. For this period the raw correlation is 0.90, and the rank correlation is 0.82. These numbers omit the Seine and Rhone departments as data reporting was not consistent across the two points in time.

and wool weaving at 0.63 and 0.57. Recall that mechanisation only started to diffuse in weaving from around the 1840s, while in cotton and wool spinning the technology had diffused much earlier. In sum, the aggregate numbers mask a substantial amount of spatial industry dynamics. Moreover, at any given point in time, persistence seems to have increased in the degree of mechanisation.

1.4.3 Industry-level concentration

I now turn to examining how localisation of each industry evolved over time. To do this, I use two measures. *Top share* measures the share of total industry employment claimed by the five largest departments, while I also examine the Gini coefficient to account for changes taking place across the entire size distribution.[16] In general, concentration appears to have increased in the level of mechanisation.

I observe the concentration of mechanised cotton spinning activity at different points in time between 1806 and 1840. The top share is relatively high in 1806 at 63%, and it increases to 78% by 1860. As we will see in the following, this is a modest increase, from a high initial level. The Gini coefficient shows even more stability as it increases from 83% to 88% throughout the time period. Interestingly, industry concentration drops from 63% to 54% in the space of 3 years between 1803 and 1806, and then recovers to 70% by 1812. I show in Chapter 2 that between 1803-1815, the location of mechanised cotton spinning underwent a fundamental change as a result of the Napoleonic Blockade against British trade. The initial drop in concentration is consistent in its timing with these events.

It is most interesting to contrast localisation patterns in mechanised cotton spinning to woollen spinning. Concentration in woollen spinning was far lower in both 1792 and 1810, when the industry was still organised as rural hand-spinning. The top share for the two years was 39% and 40% respectively, while the Gini coefficient was also fairly stable at initially 66% and then 71%. These numbers are far smaller than those measured in *mechanised* cotton spinning at the same point in time. As woollen spinning mechanised in later years, it is interesting to see how localisation patterns changed. Indeed, concentration is measured to be markedly higher both in 1840 and again in 1860. The top share in employment was 63% and 67% respectively, while the Gini coefficients were 82% and 84%. By the 1860s, the industry had

[16] Another measure which is often used in the literature is the Theil index. I do not use this because of the large number of departments which have zero employment in a given industry.

a localisation pattern which was almost as concentrated as that of cotton spinning.

To what extent was the localisation pattern in an industry matched by similar localisation in the downstream industry? Again, the historical setting provides some interesting variation. In the early decades of the 19th century, both wool and cotton weaving, the downstream industry, were rurally organised, as mechanisation had not yet been developed. There was thus symmetry in cotton and woollen weaving to the extent that neither had switched to the new technology, however the upstream of cotton weaving was mechanised, and highly localised, while woollen spinning was still rurally organised. Localisation patterns in weaving mirrored the pattern in upstream spinning, both in terms of levels, and in terms of dynamics.

Cotton weaving was highly localised as early as 1803, despite the rural structure of the industry. 85% of employment in cotton weaving was located in 5 departments in 1803, which is a higher level of concentration than that measured for cotton spinning. Concentration remained remarkably stable through to 1860, when the top five departments accounted for 86% of industry employment. The Gini coefficients are 91% and 92% respectively. Similarly to cotton spinning, there is a decrease in concentration during the period of the Napoleonic Blockade.

In contrast, woollen weaving was less localised in the late 18th - early 19th century, consistent with findings in woollen spinning. The top shares in 1792 and 1810 are measured as 38% and 48%, while the Gini coefficients are 67% and 76% respectively. These are very similar to the level of concentration found for woollen spinning. Similarly to woollen spinning, concentration increased over time, though the levels do not reach those of woollen spinning. In 1840, the top share was 57% (relative to 72% in woollen spinning). It increased to 60% by 1860 (the same measure was 67% for spinning). The pattern is identical for the Gini coefficients. This finding is particularly interesting given that in the next section, I find that in the early 19th century, spinning and weaving were highly coagglomerated.

Finally, I turn to examining localisation for the leather industry. In terms of both measures, the level of localisation was far smaller for leather. It had the lowest levels of localisation, and the increase over time was much smaller. The top share was 20% in 1811, and it increased slightly to 29% by 1860. The Gini coefficients display a similar pattern, increasing from 41% to 50%. In sum, switching to the modern IRS technology is associated with increasing industry localisation. Moreover, input-output linkages may also play a role in shaping localisation patterns.

1.4.4 Coagglomeration

Given the patterns of localisation documented in the previous section, an interesting question is the extent to which the various industries were concentrated in the same departments and how this evolved over time. Table 1.11 examines inter-industry correlations at different points in time. A number of interesting patterns emerge. First, industries linked through input-output linkages (spinners and weaving in cotton and wool) were initially located in the same departments. Around 1810, the correlation between employment at the level of the department for spinning and weaving was 0.83 for cottons and 0.84 for woollens. However, the strength of these correlations *decreased* over time. In the case of cotton weaving, the correlation had decreased to 0.7 by 1860, and in the case of woollens it had dropped to 0.22. It would seem that throughout the course of the first half of the 19th century, coagglomeration in industries linked via input-output linkages was weaker, at least in the case of the textile industry.

On the other hand, coagglomeration of industries using a similar production process (cotton and wool spinners, and cotton and wool weavers) was initially low, but in both cases increased over time. The correlation between wool and cotton spinning was 0.17 in 1810, but by 1860 it had increased to 0.27, while for cotton and wool weaving, co-location increased from a low of 0.05 to 0.19.

Finally, there seems to be no clearly discernible pattern in the coagglomeration of leather tanning and any other industry. The correlations oscillate between effectively zero and 0.2 with no pattern across industries or time.

1.5 Conclusion

This chapter has presented a novel dataset which can be used to study spatial dynamics during industrialisation. I have found that firms tended to become larger in scale and capital intensity in mechanised spinning throughout the first half of the 19th century. In the cross section, increased mechanisation seems to have been associated with a higher reliance on inanimate power sources. This lends credence to the idea that scale economies internal to the firm became increasingly important as industries mechanised and adopted factory based production.

I have also documented some spatial patterns that seem to comove with mechanisation. Localisation seems to have increased for mechanising industries, and persistence was lower for industries which made larger strides in mechanisation throughout my time period. Coagglomeration for upstream and downstream firms was initially high and decreased over the time period, while coagglomeration seems to have become stronger for horizontally linked firms (spinners and also weavers).

What does this episode teach us about how the spatial structure of the economy is affected as an economy moves towards modern, factory based production? First, it seems to be the case, at least for these industries in early 19th century France, that moving towards modern manufacturing disrupted the spatial structure of the economy along a number of dimensions. There could be a number of reasons for this. As I have noted, transport costs fell significantly throughout the 19th century (Bairoch, 1997), which could also predict similar patterns. Mitigating these concerns is the fact that the observed patterns are related not to specific points in time, but rather to the time path of sector's own mechanisation time-line.

A different explanation may focus on changing underlying natural advantage requirements for industries. For example, reliance on steam and water power may lead industries to locate close to fast-flowing streams and coal. However, in my data firms in general do not seem to be using a large amount of inanimate power. With the exception of spinners, the median firm in other industries uses neither.

Irrespective of the *cause* behind the documented changes, the finding that the spatial structure was disrupted along several dimensions during industrialisation in France counteracts an emerging literature which documents significant persistence in the location of economic activity over time.[17]

The two findings are not contradictory. In fact, in Chapter 2 and 3, I explore how a temporary event in the early 19th century, the Napoleonic Blockade, disrupted the existing spatial structure for mechanised cotton spinners, and led to long-run effects both within and outside the cotton industry. In particular, Chapter 3 builds on the patterns of coagglomeration found in this section to explore the type of causal forces which may give rise to horizontal coagglomeration. In this way, further work could shed light on the precise mechanisms at work in settings where persistence seems to be more or less important.

[17] Davis and Weinstein, 2002 and Bleakley and Lin, 2012 are two examples of papers which encompass the period of structural transformation in their analysis.

1.A Tables

Table 1.1: Patent intensity by industry

Industry	Number of patents
Mining	62
Glass	89
Leather	158
Pottery, bricks, stone	169
Clothing	196
Military equipment and weapons	216
Medicine	244
Agriculture	287
Paper, printing and publishing	337
Construction	400
Instruments	410
Manufacturing machinery	457
Metal manufacturing	466
Furniture	473
Shipbuilding	481
Carriages, vehicles and railways	513
Food and drink	529
Hardware	628
Chemicals	753
Textiles	1154
Engines (steam and water wheels)	1177

Notes: The table is constructed by matching the aggregate categories from the French census data as classified by Chanut et al. (2000) to the British patent data published in Nuvolari and Tartari (2011). The latter dataset covers all patents filed in Britain between 1617-1841. All data sources are discussed in more detail in Appendix A.

Table 1.2: Data coverage

Year	Branches	Coverage	Rural/Mechanised
		Cotton	
1803	Spinning	Firm	Mechanised
1803	Weaving	Department	Rural
1806	Spinning	Firm	Mechanised
1806	Weaving	Department	Rural
1812	Spinning	Department	Mechanised
1812	Weaving	Department	Mechanised
1840	Spinning	Firm	Mechanised
1840	Weaving	Firm	Mechanised
1860	Spinning	Arrondissement	Mechanised
1860	Weaving	Arrondissement	Mechanised
		Wool	
1792	Spinning	Arrondissement	Rural
1792	Weaving	Arrondissement	Rural
1810	Spinning	Department	Rural
1810	Weaving	Department	Rural
1840	Spinning	Firm	Mechanised
1840	Weaving	Firm	Mechanised
1860	Spinning	Arrondissement	Mechanised
1860	Weaving	Arrondissement	Mechanised
		Leather	
1792	Tanneries	Arrondissement	Rural
1810	Tanneries	Arrondissement	Rural
1840	Leather industry	Firm	Rural
1860	Leather industry	Arrondissement	Rural

Notes: All data from 1840 and 1860 are from Chanut et al. (2000). Data for the cotton sector for 1803 and 1806 are from Champagny's survey of the cotton industry from 1806. Data for the cotton and woollen sectors are from the *"Enquêtes Industrielles"*. Data for 1792 for the wool and leather sectors are from two industrial surveys. Data for the leather sector from 1811 is from an industrial survey. All data sources are discussed in more detail in Appendix A.

Table 1.3: Persistence in location

	Cotton spinning		Cotton weaving		Wool spinning		Wool weaving		Leather tanning		Total employment	
	Corr.	Rank corr.	Corr.	Rank corr.	Corr.	Rank corr.	Corr.	Rank corr.	Corr.	Rank corr.	Corr.	Rank corr.
1792	–	–	–	–	0.54	0.33	0.24	0.44	–	–	–	–
1803	0.56	0.47	0.23	0.43	–	–	–	–	–	–	–	–
1806	0.66	0.61	–	–	–	–	–	–	–	–	–	–
1810	0.63	0.58	0.44	0.44	0.34	0.38	0.41	0.52	0.65	0.62	0.66	0.77
1840	0.98	0.82	0.63	0.58	0.89	0.64	0.57	0.60	0.63	0.40	0.84	0.82
1860	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
N	67	67	72	72	69	69	71	71	69	69	47	47

Notes: Each cell reports the correlation or rank-correlation between employment at the level of the department in a particular sector for a given year and the corresponding employment level in the same sector-department pair in 1860. I drop “Ardeche”, from the leather industry as it is an extreme outlier. The persistence correlations are lower when Ardeche is included (for 1810, the raw correlation is 0.42, the rank correlation is 0.59. For 1840, the same correlations are 0.30 for both the raw and the rank correlation). All data sources are discussed in Appendix A.

Table 1.4: Firm level summary statistics for mechanised cotton spinners, 1806 - 1840

Variable	Mean	Median	Std Deviation	Min	Max	Top share	N
				Firms 1806			
Spindles	1,621	664	3,500	26	49,200	20%	389
Labour	62.34	30	99.41	1	950	14%	387
Capital intensity	27.33	23.64	18.30	1	120	–	387
				Firms 1840			
Spindles	6,269	4,000	7,279	300	85,000	8%	531
Labour	112.05	72	147.76	4	1,413	10%	531
Capital intensity	74.77	54.55	85.72	5.31	961.54	–	531
Steam-powered motors	0.43	0	0.58	0	4	6%	531
Water-powered motors	0.86	1	1.70	0	35	13%	531
Sales	264,478.6	182,000	332,541.8	6,250	4,060,000	10%	531

Notes: Number of spindles employed is the standard measure of physical capital in mechanised spinning. Labour measures the number of employees reported by the firm. Capital intensity is defined as capital per worker. Two firms in 1806 do not report labour employed, for these firms, labour is thus missing and capital per worker is undefined. Steam and water-powered machines measure the number of motors in use by power type. Sales is the value of production as reported by the firm. Top share is the share claimed by the top five firms relative to the total value across France of the given variable. Data for 1806 from Champagny's survey of the cotton industry. Data from 1840 from Chanut et al. (2000). Further details of data construction can be found in Appendix A.

Table 1.5: Firm level summary statistics by industry, 1840

Variable	Mean	Median	Std Deviation	Min	Max	Top share	N
	Cotton weaving firms 1840						
Labour	132.49	80	177.40	2	1800	7%	730
Steam-powered motors	0.07	0	0.30	0	4	21%	730
Water-powered motors	0.13	0	0.41	0	3	15%	730
Sales	157,538	79,625	216,859	1,680	2,036,601	7%	730
	Wool spinning firms, 1840						
Labour	61.16	40	71.29	1	700	8%	511
Steam-powered motors	0.29	0	0.59	0	8	12%	511
Water-powered motors	0.73	1	0.95	0	14	9%	511
Sales	276,603	155,135	378,028	600	4,165,000	9%	511
	Wool weaving firms, 1840						
Labour	96.57	55	129.99	1	1,200	8%	592
Steam-powered motors	0.07	0	0.36	0	5	0.30	592
Water-powered motors	0.62	0	1.06	0	8	10%	592
Sales	299,363	150,000	565,675	1,200	6,000,048	14%	592
	Leather industry, 1840						
Labour	11.67	4	28.33	1	440	15%	809
Steam-powered motors	0.02	0	0.16	0	2	31%	809
Water-powered motors	0.31	0	1.14	0	18	25%	809
Sales	85,405	33,000	228,497	250	3,680,000	17%	809

Notes: Labour measures the number of employees reported by the firm. Steam and water-powered machines measure the number of motors in use by power type. Sales is the value of production as reported by the firm. Top share is the share claimed by the top five firms relative to the total value across France of the given variable. Data from Chanut et al. (2000). Further details of data construction can be found in Appendix A.

Table 1.6: Cotton spinning activity across departments 1803 - 1860

Variable	Total	Mean	Median	Std Deviation	Min	Max	Top share	Gini	N
				Departments 1803					
Spindles	291,764	4,168	460	12,309	0	73,328	71%	85%	70
Labour	12,421	177.44	24.50	464.63	0	3,190	63%	83%	70
				Departments 1806					
Spindles	460,892	6,584	723	14,992	0	73,920	61%	81%	70
Labour	18,386	262.68	30	597.66	0	3975	54%	80%	70
				Departments 1812					
Spindles	1,116,662	16,666	770	40,496	0	236,453	60%	82%	70
Labour	35,942	536.44	25	1410.75	0	7138	70%	85%	67
				Departments 1840					
Spindles	2,890,707	38,318	625	137,603	0	935,458	79%	88%	70
Labour	51,936	741.94	4.5	2,364	0	13,648	72%	87%	70
Steam-powered motors	220	3.14	0	10.95	0	63	81%	90%	70
Water-powered motors	349	4.99	0	17.46	0	130	74%	88%	70
Sales	121,000,000	1,724,312	21,000	5,757,614	0	35,900,000	77%	88%	70
				Departments 1860					
Labour	52,114	744.49	0	2,624.14	0	15,877	78%	88%	70
Steam-power	11,107	158.67	0	629.58	0	4,162	84%	92%	70
Water-power	5,817	83.1	0	283.65	0	1,752	77%	90%	70
Sales	195,000,000	2,787,814	0	10,800,000	0	77,100,000	83%	91%	70

Notes: All variables are measured at the level of the department. Number of spindles employed is the standard measure of physical capital in mechanised spinning. Labour measures the level of employment in cotton spinning. Note that different measures were used for measuring steam and water-power between 1840 and 1860. Steam and water-powered machines measure the number of such engines in use in 1840, while in 1860 total horse-power was reported by power source. Sales is the value of production. Top share is the share claimed by the top five departments relative to the total value across France of the given variable. Data for 1803 - 1806 from Champagny's survey of the cotton industry. Data from 1812 from *"Enquêtes Industrielles"*. Data from 1840 form Chanut et al. (2000). Further details of data construction can be found in Appendix A.

Table 1.7: Woollen spinning activity across departments, 1792 - 1860

Variable	Total	Mean	Median	Std Deviation	Min	Max	Top share	Gini	N
	Handspinning by department, 1792								
Labour	366,058	5,305	2,000	8,192	2	47,000	39%	66%	69
	Handspinning by department, 1810								
Labour	155,631	2,256	687	3,705	0	18,740	40%	71%	69
	Mechanised spinning by department, 1840								
Labour	30,708	445.04	60	1,127	0	6,896	63%	82%	69
Steam-powered motors	146	2.12	0	7.91	0	59	76%	90%	69
Water-powered motors	368	5.33	1	12.84	0	85	52%	78%	69
Sales	138,000,000	2,004,847	180,000	5,580,803	0	32,900,000	70%	85%	69
	Mechanised spinning by department, 1860								
Labour	44,590	646.23	70	1,846	0	12,946	67%	84%	69
Steam-power	5,850	84.78	0	343.31	0	2,714	78%	90%	69
Water-power	5,846	84.72	18	195.77	0	1,238	55%	77%	69
Sales	328,000,000	4,756,681	272,000	14,800,000	0	96,900,000	75%	87%	69

Notes: All variables are measured at the level of the department. Labour measures the level of employment in cotton spinning. Note that different measures were used for measuring steam and water-power between 1840 and 1860. Steam and water-powered machines measure the number of such engines in use in 1840, while in 1860 total horse-power was reported by power source. Sales is the value of production. *Top share* is the share claimed by the top five departments relative to the total value across France of the given variable. Data from 1792 from a large-scale industrial survey. Data from 1812 from *"Enquêtes Industrielles"*. Data from 1840 and 1860 from Chanut et al. (2000). Further details of data construction can be found in Appendix A.

Table 1.8: Cotton weaving activity across departments, 1803 - 1860

Variable	Total	Mean	Median	Std Deviation	Min	Max	Top share	Gini	N
	Rural weaving by department, 1803								
Weaving frames	100,484	1,396	17.5	5,847	0	47,350	79%	91%	72
Labour	208,930	2,902	36.5	11,376	0	80,548	85%	92%	72
	Rural weaving by department, 1810								
Weaving frames	77,759	1,079	0	2,996	0	16,112	70%	88%	72
Labour	84,560	1,174	0	3,160	0	17,207	67%	87%	72
	Mechanised weaving by department, 1840								
Labour	90,314	1,254	0	6,498	0	53,152	84%	93%	72
Steam-powered motors	52	0.72	0	3.29	0	25	88%	94%	72
Water-powered motors	73	1.01	0	3.88	0	25	84%	93%	72
Sales	106,000,000	1,472,859	0	7,332,809	0	58,300,000	85%	93%	72
	Mechanised weaving by department, 1860								
Labour	137,433	1,909	0	7,018	0	39,835	86%	92%	72
Steam-power	5,421	75	0	428	0	3,347	96%	96%	72
Water-power	2,012	28	0	207	0	1,759	99%	98%	72
Sales	267,000,000	3,706,542	0	14,300,000	0	81,800,000	90%	93%	72

Notes: All variables are measured at the level of the department. Weaving frames measures the number of (non-mechanised) weaving frames in use in the department. Labour measures the level of employment in cotton weaving. Note that different measures were used for measuring steam and water-power between 1840 and 1860. Steam and water-powered machines measure the number of such engines in use in 1840, while in 1860 total horse-power was reported by power source. Sales is the value of production. *Top share* is the share claimed by the top five departments relative to the total value across France of the given variable. Data for 1803 - 1806 from Champagny's survey of the cotton industry. Data from 1812 from *"Enquêtes Industrielles"*. Data from 1840 and 1860 from Chanut et al. (2000). Further details of data construction can be found in Appendix A.

Table 1.9: Woollen weaving activity across departments, 1792 - 1860

Variable	Total	Mean	Median	Std Deviation	Min	Max	Top share	Gini	N
	Rural weaving by department, 1792								
Weaving frames	55,920	788	324	1,292	0	8,324	39%	66%	71
Labour	76,577	1,079	404	1,660	0	8,254	38%	67%	71
	Rural weaving by department, 1810								
Weaving frames	33,544	472	100	1,196	0	9,215	52%	77%	71
Labour	40,076	564	152	1,253	0	9,215	48%	76%	71
	Mechanised weaving by department, 1840								
Labour	54,491	767	67	1,782	0	11,272	57%	81%	71
Steam-powered motors	45	0.63	0	1.95	0	15	62%	86%	71
Water-powered motors	339	4.77	0	12.17	0	82	59%	84%	71
Sales	175,000,000	2,459,933	147,000	7,403,052	0	54,841,980	67%	85%	71
	Mechanised weaving by department, 1860								
Labour	68,514	964	54	2,213	0	11,208	60%	82%	71
Steam-power	1,787	25	0	68	0	408	66%	88%	71
Water-power	3,003	42.30	0	142.58	0	1,065	73%	89%	71
Sales	252,000,000	3,545,085	78,000	8,267,517	0	41,500,000	59%	84%	71

Notes: All variables are measured at the level of the department. Weaving frames measures the number of (non-mechanised) weaving frames in use in the department. Labour measures the level of employment in cotton weaving. Note that different measures were used for measuring steam and water-power between 1840 and 1860. Steam and water-powered machines measure the number of such engines in use in 1840, while in 1860 total horse-power was reported by power source. Sales is the value of production. *Top share* is the share claimed by the top five departments relative to the total value across France of the given variable. Data from 1792 from a large-scale industrial survey. Data from 1812 from *"Enquêtes Industrielles"*. Data from 1840 and 1860 from Chanut et al. (2000). Further details of data construction can be found in Appendix A.

Table 1.10: Leather tanning across departments, 1792 - 1860

Variable	Total	Mean	Median	Std Deviation	Min	Max	Top share	Gini	N
				Tanning, 1792					
Tanning pits	12,263.5	207.86	115	341.85	0	2,215	45%	58%	59
				Tanning, 1811					
Tanning pits	13,745.5	232.97	176	261.10	0	1,506	33%	50%	59
Labour	10,915	155.93	114.5	121.47	11	586	20%	41%	70
				Leather industry, 1840					
Labour	7,647	109.24	55.50	136.98	0	716	31%	60%	70
Steam-powered motors	13	0.19	0	0.46	0	2	54%	86%	70
Water-powered motors	190	2.71	0	6.22	0	41	54%	80%	70
Sales	56,100,000	801,603	364,015	1,116,654	0	5,634,936	35%	64%	70
				Leather tanning					
Labour	14,816	211.66	148.5	245.75	7	1,582	29%	50%	70
Steam-power	710	10.14	0	17.64	0	106	41%	74%	70
Water-power	1,662	23.74	7.50	35.19	0	202	35%	67%	70
Sales	155,000,000	2,217,386	1,377,500	3,397,485	42,000	25,700,000	35%	56%	70

Notes: All variables are measured at the level of the department. Tanning pits measure the number of pools in which leather is tanned across departments. Labour measures the level of employment in cotton weaving. Note that different measures were used for measuring steam and water-power between 1840 and 1860. Steam and water-powered machines measure the number of such engines in use in 1840, while in 1860 total horse-power was reported by power source. Sales is the value of production. *Top share* is the share claimed by the top five departments relative to the total value across France of the given variable. Data from 1792 from a large-scale industrial survey. Data from 1811 from a large-scale industrial survey. Data from 1840 and 1860 from Chanut et al. (2000). Further details of data construction can be found in Appendix A.

Table 1.11: Cross-industry correlations

	Cotton spinning	Cotton weaving	Wool spinning	Wool weaving	Leather tanning
			1810-12		
Cotton spinning	1.00				
Cotton weaving	0.83	1.00			
Wool spinning	0.17	0.16	1.00		
Wool weaving	0.08	0.05	0.84	1.00	
Leather tanning	0.21	0.25	0.21	0.01	1.00
			1840		
Cotton spinning	1.00				
Cotton weaving	0.81	1.00			
Wool spinning	0.19	-0.03	1.00		
Wool weaving	0.05	-0.03	0.58	1.00	
Leather tanning	0.03	0.09	0.12	0.23	1.00
			1860		
Cotton spinning	1.00				
Cotton weaving	0.70	1.00			
Wool spinning	0.27	-0.05	1.00		
Wool weaving	0.27	0.19	0.22	1.00	
Leather tanning	0.14	-0.01	0.20	0.15	1.00

Notes: Each cell reports the pairwise correlation between the level of employment in a department at a given point in time for the two sectors in question. All data sources are discussed in Appendix A.

Chapter 2

Temporary Protection and Technology Adoption: Evidence from the Napoleonic Blockade

> The principal advantage of the English cotton trade arises from our machines both for spinning and printing (...). It is impossible to say how soon foreign countries may obtain these machines, but even then, the experience we have in the use of them would give us such an advantage that I should not fear the competition.
>
> Joseph Smith and Robert Peel, 1786[1]

2.1 Introduction

A long-standing debate in economics is centred on the question of whether certain industries can benefit from temporary trade protection. The idea, widely known as the infant industry argument, has a long tradition in the history of economic thought.[2] In recent decades, endogenous growth theory has identified a number of market imperfections which could inhibit entrepreneurs from entering high growth sectors at free trade prices.[3] In the case of a learning-by-doing production externality for example, an economy which begins with an initial productivity lag with respect to the technological frontier can stay indefinitely stuck in low-growth sectors under free-trade prices (Krugman 1987, Lucas 1998, Matsuyama 1992 and Young 1991).[4]

[1] Edwards, (1967) p. 51.

[2] Early proponents include US founding father Alexander Hamilton, and the 19th century economist, Friedrich List.

[3] Rodríguez-Clare (1995) and Rodrik (1996) present multiple-equilibria models with coordination failures, Krugman (1987), Lucas (1988), Matsuyama (1992) and Young (1991) analyse models in which the market imperfection is a learning-by-doing production externality. In Grossman and Helpman (1991), the externality is in the R&D sector, while Aghion et al. (2012) have shown that sectoral policy targeted at production in a particular sector can enhance growth and efficiency by forcing firms to innovate vertically, instead of differentiating to escape competition.

[4] The mechanism works via a decreasing industry-wide cost curve which firms do not internalise. When learning gains are external to firms, no agent internalises the fact that increasing production

Under some conditions, temporary trade protection can foster the development of high-growth sectors, which, over time, can become competitive, though the effect on welfare is generally ambiguous.[5]

Assessing the empirical relevance of these types of mechanisms has proven difficult. The reason is that infant industry protection is generally granted by the policy-maker at the specific request of the industry itself. This makes identification of the economic mechanism at work challenging for two reasons. First, even if the industry becomes competitive in the long-run, it is difficult to answer the question of whether the industry would have become competitive anyway. The literature to date has tackled the issue by simulating the counterfactual (Baldwin and Krugman 1986, Head 1994, and Irwin 2000). Second, in the case of a specific policy intervention, it is not possible to disentangle the effect of the economic mechanism (measuring the existence and importance of the market imperfection) from the efficacy of implementation, which is determined to a large extent by the political-economy equilibrium. To the best of my knowledge, the literature to date has not attempted to separate the two mechanisms.

In this chapter, I present a natural experiment which replicates infant industry protection without the direct involvement of the policy maker, making it possible to address both identification challenges. In particular, I study the spatial pattern of the adoption of mechanised cotton spinning technology across regions of the French Empire during and after the Napoleonic Wars (1803-1815). Throughout these wars, the French Empire was exposed to a regionally differential shock to the cost of trading with Britain. I use variation in the size of the trade cost shock to identify the effect of trade protection on mechanised spinning capacity during and after the period of increased trade protection.

The setting is ideal to examine the effect of temporary trade protection on technology adoption in an infant industry. Exogenous, within country variation in trade protection makes it possible to compare outcomes in areas in which the cost of trading with Britain increased to a larger extent, to areas in which the increase was smaller, addressing the first empirical challenge. The fact that trade protection was

in the present will move the entire industry down along its industry cost curve. Therefore, if one country has a slight first-mover advantage, it will be further down its cost curve and firms in another country will not have an incentive to enter the sector even if they could become more productive than the country which is producing at present.

[5] In Section 2.4, I discuss the fact that in general, trade policy is not the most efficient way of correcting the market imperfection.

not driven directly by policy makes it possible to disentangle the economic from the political mechanism, tackling the second empirical challenge. Finally, large disruptions to trade usually affect both competition on the output side, and access to imported inputs, making it difficult to disentangle the two effects.[6] During the Napoleonic Wars however, access to the imported input, raw cotton, was affected fairly symmetrically across regions of the French Empire, as the source country for this product was not Britain. This allows me to focus on the effect of import competition on the output side, while holding fixed access to imported inputs.[7]

The industry I examine is mechanised cotton spinning, as this sector had a number of features which make it ideal for testing the empirical importance of the market imperfections supposedly driving infant industry mechanisms. First, by the turn of the 19th century, Britain had gained a significant head start in the industry. The technology, invented and developed in Britain in the late 18th century, was not adopted on a wide scale across the Continent, which was particularly surprising in the case of France, as it was Britain's closest competitor. Slow adoption was all the more puzzling, as historical evidence shows that the technology was widely known and available to cotton (hand-) spinners in France. Consistent with a static comparative disadvantage in cottons, by the beginning of the Napoleonic Wars, French machine spun yarn was twice as expensive as that spun in Britain, and France was a net importer of cotton goods. Learning-by-doing externalities, an example of a market failure which can lead to infant industry predictions, are argued to have been important in 19th century mechanised cotton spinning (David 1970, Mokyr 2009).

The Napoleonic Wars led to a unique historical episode whereby blockade of Britain was imposed in an unusual way. As Napoleon did not have the naval military power to impose a standard blockade of the British Isles whereby the French navy would surround British ports, he instead used his direct or indirect influence over much of Continental Europe to attempt to stop British goods from entering the

[6]Amiti and Konings (2007) is a rare example of a paper which disentangles the effect of trade liberalisation on imported inputs from import competition on the output side. Using detailed firm level data on imported inputs for a panel of Indonesian firms, they show that access to imported inputs increases firm productivity by at least twice as much as increases in import competition on the output side.

[7]A number of recent papers show that access to imported inputs is an important channel for static and dynamic gains from trade, particularly for developing countries. See Amiti and Konings (2007), Goldberg et al. (2010) and Halpern et al. (2009) for developing and emerging economies, and Bøler et al. (2014) for Norwegian firms.

mainland. Ports were closed to British trade, and the military was active in enforcing the blockade along the coastline. In practice however, holes in the system opened up almost immediately, and instead of achieving the original goal of stopping trade flows between Britain and the Continent, the blockade displaced trade to more circuitous, and hence more expensive routes.[8]

The key to my identification strategy is the uneven geographic success of the blockade. The blockade was generally effective in Northern Europe with exports from Britain falling fivefold from peak to trough. Trade intended for Northern European markets however, was diverted to Southern Europe. British exports to the region increased threefold, as Napoleon's inherent military weakness and the idiosyncratic political event of the Spanish insurgency against Napoleonic rule meant that the blockade against British trade was unsuccessful. The geographic asymmetry in the success of the blockade meant that trade flows to different parts of the French Empire were disrupted to a different extent.

In the North of France, effective distance between a given region and London increased markedly, as trade was diverted either to unreliable indirect routes through German regions, or through Southern Europe. In the southern regions of France, effective distance to London changed to a far smaller extent, as trade routes stayed more or less the same. Changing trade protection from Britain during the Napoleonic Wars was thus driven by one of the best-documented empirical regularities in economics; the fact that trade diminishes dramatically with distance.[9] As distance is a barrier to trade, it plays a role similar to that of tariffs or other trade policy instruments. Geographic distance however is constant over time, making it generally difficult to disentangle the effect of distance from other regional characteristics fixed over time. My empirical strategy exploits the fact that while geographic distance between Britain and French regions did not change during the blockade, the set of possible trading routes did, leading to changes in effective distance between London and a given French region.[10]

[8] In its use of a historical blockade as a source of exogenous variation, the paper is related to Hanlon (2015) who uses the shock to US supplies of raw cotton during the American Civil War to test the theory of directed technical change (Acemoglu, 2002). The author shows that as the British lost access to US supplies of raw cotton, they increased innovation activity in the cotton sector in order to adapt their machines to different quality cotton supplies. Another example of a historic blockade which has been used as a source of exogenous variation is Irwin (2005) who examines the static welfare loss from being shut out of world trade during the Jeffersonian embargo which took place simultaneously to the Napoleonic Blockade.

[9] See Head and Mayer (2013) for a recent review of the gravity literature.

[10] In this sense, the paper is related to recent contributions which use changes in trade routes

To conduct the empirical analysis, I use the dataset introduced in Chapter 1. I collected firm- and regional-level data from numerous primary sources on various aspects of the French economy during the first half of the 19th century. Most importantly, I have assembled a panel database of production capacity in mechanised spinning at the departmental level using detailed, handwritten archival sources which provide data, in some cases at the firm level, for mechanised cotton spinners. The dataset provides a unique look at a key industry at a very early stage of industrial development for important areas of Western-Europe which belonged to the French Empire.[11]

Second, to quantify how trade routes changed during the blockade, I extracted port level shipping data from the Lloyd's List, one of the oldest newspapers in the world. Using a text matching algorithm, I have built a dataset of journeys between Britain and Continental-European ports for a twenty year time period. Together, the two sources of data make it possible to estimate the effect of trade protection on technology adoption in mechanised cotton spinning.

The first part of the empirical strategy employs a difference in difference (DD) estimator with continuous treatment intensity. The strategy compares the size of mechanised cotton spinning capacity across regions which were exposed to smaller or larger increases in the cost of trading with Britain (trade-cost shock for short), before and after the Napoleonic Wars. Similarly to standard DD estimators, unobservables fixed at the departmental level over time, and aggregate shocks which affect departments equally are controlled for. Identification relies on there being no other shock contemporaneous to, and correlated with the trade cost shock. As the shock itself varied smoothly across the French Empire, the main challenge for identification is the question of whether different regions of France had the potential to develop modern industry.

To address concerns regarding underlying characteristics which would have inevitably rendered some locations more favourable for modern industrial production, I include the time-varying effect of a number of variables which have been argued to

or the introduction of trade-cost reducing technology to estimate the effect of trade on growth in a cross-country setting. See Feyrer (2009a), Feyrer (2009b) and Pascali (2014). Keller and Shiue (2008) use the introduction of trains and trade liberalisation within Germany to show that trade-cost reducing technology (trains) had a larger effect on market integration than institutional change (the abolishment of the Zollverein).

[11] The data covers regions which include all of present day France, Belgium, Luxembourg, parts of the Netherlands, the left-bank of the Rhine (part of present-day Germany), a part of Switzerland and the North-West of present-day Italy.

be conducive to the development of modern industry, and cotton spinning in particular. These variables include locational fundamentals important for mechanised cotton spinning such as access to fast-flowing streams and coal, the level of human capital, the size of the downstream sector, urbanisation and population density, institutional change within the French Empire and labour supply shocks. I show that while different regions of the Empire did have somewhat different characteristics, regions were sufficiently similar to expect that, given the same level of protection, modern cotton spinning could have developed.

I find that areas which received a larger trade cost shock during the Napoleonic Wars increased production capacity in mechanised cotton spinning to a larger extent than areas which received a smaller shock. The estimated effect is large and statistically significant. Moving from the 25th to the 75th percentile of the shock leads to a predicted increase in spinning capacity which is similar in size to mean spinning capacity at the end of the blockade. The results remain both statistically and economically significant when the time-varying effect of the aforementioned potential confounders is added.

I find no similar effect in two closely related industries, woollen spinning and leather tanning. Output in these industries was less intensively traded with Britain, and there was no technological change in either industry, strengthening the results in cotton spinning being driven by the trade cost shock. I also address the role of factor prices, which has recently been put forward as an explanation for the slow adoption of mechanised cotton spinning in France (Allen, 2009). Using data on the number of men conscripted by Napoleon's government, I find no evidence to support the theory that a negative labour supply shock drove firms away from labour-intensive hand-spinning into capital-intensive mechanised spinning during the Napoleonic Wars. Furthermore, different vintages of machines were capital-intensive to a different degree, meaning that even within mechanised spinning, firms could choose the degree of capital intensity. However, in contrast to the predictions of an uneven factor-price shock across the French Empire driving my results, I find that the trade cost shock had no impact on capital-labour ratios across departments in mechanised spinning.

The fact that production capacity in mechanised spinning increased in regions which were more affected by the trade cost shock is by no means obvious, as an alternative technology (hand-spinning) was also available to producers. However, if an infant industry type mechanism was inhibiting French entrepreneurs from switching into the new technology on a wide scale, we would expect not only that departments scaled up in mechanised spinning capacity during the period of temporary protection, but also that they became more productive over time. To answer this question, in the second part of the empirical analysis I ask to what extent temporary trade protection had long-term effects on the industry. I examine persistence in the location of the industry within France, and ask whether regions with higher spinning capacity after the blockade were more productive 30 years later. Both predictions emerge from an infant industry mechanism. In general however, testing these types of predictions is difficult, as other mechanisms, such as location fundamentals, would predict the same outcome.

The setting of the post-blockade cotton spinning industry provides a rare opportunity to disentangle lock-in effects from locational fundamentals. To do so, I exploit the fact that the post-blockade location of the cotton industry was determined to a large extent by the historical accident of the Napoleonic Wars. Using the trade cost shock as an instrument for the post-blockade location of the cotton industry, I find that regions with a higher level of spinning capacity at the end of the Napoleonic Wars, also had higher capacity thirty years later. The estimated effect is large and significant. A one standard deviation increase in the size of mechanised cotton spinning at the end of the Napoleonic Wars leads to a 0.75 standard deviation predicted increase in the value of production in 1840. Furthermore, areas with higher post-blockade production capacity had more productive firms 30 years later. Again, the effect is large and significant. A one standard deviation increase in spinning capacity per capita in 1812, leads to a 1.3 standard deviation predicted increase in productivity in 1840.

As tariffs were imposed on cotton goods between Britain and France following the end of the Napoleonic Wars, the long-term within country results show that certain French regions had become sufficiently productive to withstand increased competition after the Napoleonic Wars ended. It does not necessarily show however, that (a subset of) firms had become competitive at free trade prices. For this reason, I also examine exports of cotton goods from France. Consistent with evolving comparative advantage in cottons, I find that exports of cotton goods increased substantially after the end of the Napoleonic Wars. Finally, I examine whether convergence in cotton spinning was widespread across the Continent. I find that as late as the mid-19th century, France and Belgium, two parts of the French Empire which had benefited from a high trade cost shock, had a larger cotton spinning sector than other Continental countries. This fact suggests that adoption of the new technology was far from inevitable.

In what ways, if any, do the findings from this particular historical episode inform the broader question of how openness to trade effects development? The most important contribution of the chapter is to show that the types of market imperfections which can give rise to infant industry mechanisms appear to be empirically important, at least in the context of early 19th century France. An interesting aspect of this episode is the extent to which the setting seems general to the development experience of many countries at the point in time in which a sizeable fraction of the labour force moves out of agriculture and into unskilled labour-intensive textile manufacturing.

Differences between Britain and France were small prior to the invention of mechanised cotton spinning, at least relative to differences between rich and poor countries today. Seen in this light, it would seem that the extent to which market failures could inhibit economies from exploiting their underlying dynamic comparative advantage is large.[12] However, the fact that initial differences between late 18th century Britain and France were relatively small may also suggest why I find large effects of a short episode of extreme trade protection.

Many of the prerequisites for the development of mechanised spinning were in place across large areas of the French Empire, meaning that once import competition was sufficiently low, mechanisation was rapidly adopted. For example, the presence of downstream demand was important for the development of the industry. This suggests that in cases where the underlying conditions are not in place, infant industry protection, as implemented by the policy-maker, can turn out to be an extremely blunt tool.

The results of this chapter contribute to several strands of the literature. First, the main contribution is to evaluate the importance of the economic mechanism underlying the infant industry mechanism in a well-identified setting. As noted, a number of empirical challenges make the evaluation of infant industry promotion policy difficult. Most studies use estimated model parameters to simulate the coun-

[12]Dynamic comparative advantage is a term which is often used to refer to sectors in which a country does not have a comparative advantage at present, but in which it can develop one if the industry is given temporary support. See Redding (1999) for a formal discussion.

terfactual of no-protection.[13] This approach implicitly evaluates both the underlying economic mechanism – in general learning externalities – together with the efficacy of policy. The papers generally find evidence of learning gains and productivity improvements, and most studies find modest (positive or negative) effects on welfare. It should be noted however, that all studies abstract from inter-industry spillovers - an issue which I take up in Chapter 3 - and as such they constitute a lower-bound estimate on welfare. The chapter contributes to this literature by examining a setting in which within-country variation in trade protection is driven by exogenous events, providing a credible counterfactual for the regions which received the most protection.

More generally, the economic theory underlying the infant industry mechanism can be seen in the context of a large class of models which predict that industry location is not uniquely determined by what is known in the new economic geography (NEG) literature as locational fundamentals, and which would correspond in trade theory to underlying (latent) comparative advantage. In particular, the chapter is related to a growing empirical literature which examines whether temporary shocks can permanently shift the location of economic activity (Davis and Weinstein (2002), Redding et al (2011), Kline and Moretti (2014)). In contrast to existing papers however, which are motivated primarily by the predictions of NEG models, the primary focus of this study is not to evaluate whether temporary shocks can shift the location of a given activity within a country, but rather to evaluate whether temporary protection can lead to the wide-scale adoption of frontier technology in an industrial follower country.

The chapter is also linked to recent work which exploits firm-level data to examine the effect of trade on technology upgrading and productivity growth. In contrast to the findings of this paper, Lileeva and Trefler (2010), Bustos (2011) and Bloom et al. (2014) find that increased international competition induced firms to upgrade technology.[14] Most closely related is the latter paper, which examines increased im-

[13] Baldwin and Krugamn (1986 and 1988), Head (1994), Luzio and Greenstein (1995), Hansen, Jensen, and Madsen (2003) and Irwin (2008).

[14] Lileeva and Trefler (2010) and Bustos (2010) also find evidence of technology upgrading, albeit for firms at different parts of the productivity distribution. Exporting firms have access to a larger market, and for the most productive firms, this will justify paying the fixed cost of exporting as in Melitz (2003). Paying the fixed cost of technology upgrading will only be profitable for firms who have a large enough revenue, and these will be the exporting firms. Lileeva and Trefler (2010) introduce heterogeneity in the benefits of technology adoption to rationalise their finding that less productive new exporters have faster productivity growth upon entry to the export market than more productive new entrants. Both studies share the common feature that they examine trade

port competition in developed European countries following China's WTO accession in 2001. The different findings can be reconciled by the fact that European countries are arguably closer to the technological frontier than China. This implies that first-mover advantage effects, which drive infant industry mechanisms, are plausibly weak relative to the size of potentially counterbalancing forces. The findings of this chapter should thus be seen as complementing the existing literature.

Finally, the chapter contributes to the question of why mechanised cotton spinning was relatively slow to diffuse to Continental Europe in general, and France in particular. A large body of research in past decades has called into question Landes' claim (1969) that France was a backward economy held back by the incompetence and economic mismanagement of the Bourbon regime (O'Brien and Keyder 1978, Crafts 1995 and Horn 2006). Recently, Allen (2009) has documented factor price differences between Britain and France, which may have made the adoption of capital-biased mechanised spinning in high-wage Britain profitable, while adoption in relatively low-wage France was not profitable. In contrast to these explanations, this chapter finds support in favour of an infant industry mechanism, and in this way, relates to Williamson's (2011) work on 19th century development.[15]

The chapter is organised as follows. In the next section, I discuss mechanisation of cotton spinning and its effects on France. Section 3 discusses the way in which the Napoleonic Wars drive exogenous changes in trade protection from Britain. In the fourth section, I present a simple theoretical framework to guide the empirical analysis. In this model, geography is the driver of trade protection and a learning-by-doing externality is the market imperfection behind the infant industry mechanism. In Section 5, I turn to the short-run empirical analysis, which is followed by the long term results in Section 6. The final section concludes.

liberalisation between countries at a similar level of development.

[15]Learning-by-doing externalities, tariff protection and growth have been extensively debated in the literature in relation to the cotton industry in the 19th century, particularly for the case of the US. On this debate see Taussig (1931), David (1970), Harley (1992), Irwin and Temin (2001) for the US. Crouzet (1964) discusses the effect that the French Revolutionary and Napoleonic Wars had on infant industries in Continental Europe.

2.2 Mechanisation of cotton spinning in Britain and its effect on France

In this section, I discuss the development of cotton spinning in Britain and France up to the beginning of the Napoleonic Wars in 1803. I describe how the cotton industry in the two countries was fairly similar until the invention of mechanised cotton spinning in Britain in the late 18th century. I then examine why mechanisation of one part of the production process – spinning – had such a large impact on the industry. I document the rapid diffusion of the technology across Britain, and show how despite having knowledge of, and access to the new technology, mechanisation was not adopted on a large scale in France up to 1803. I show that by this time, France had a marked competitive disadvantage in mechanised spinning vis-a-vis Britain. Finally, I discuss the reasons behind the predominantly local structure of the market, which turns out to be important for discussing the short-run results.

2.2.1 Similar initial conditions in 18th century Britain and France

Britain's absolute dominance of the 19th century cotton industry is a widely known fact. It may thus be somewhat surprising that as late as the middle of the 18th century, Britain and France both had a similarly modest sized cotton industry. It has been estimated that about 3 million pounds of cotton yarn a year were spun in both Britain and France, which compares modestly to Bengal's 85 million pounds of yearly output (Allen, 2009). The cotton industry was not only small in relation to world output, but also relative to the size of other textiles in the domestic economy such as wool, linen, hemp or silk.[16]

Why was cotton a relatively marginal sector in Continental Europe prior to industrialisation in Britain? In contrast to other textiles, cotton was not an indigenous European textile.[17] Asian cotton cloth was initially introduced to the European market by merchants in the 17th century to enormous success.[18] The

[16]For example, Chabert (1949) estimates the size of the industries in 1788 and 1812 in France for textiles as follows (in millions of francs); 1788: Linen and hemp: 235, Wool: 225, Silk: 130.8, Cotton: no number given. 1812: Linen and hemp: 242.8, Wool: 315.1, Silk: 107.5, Cotton: 191.6.

[17]Strictly speaking, silk is not indigenous to Europe either, however silk production had been practised throughout Europe for centuries.

[18]Cotton's immense popularity has been attributed to the fact that cotton printers were able to make bright, lively coloured fabric with complex patterns, something which could not be done

boom in the consumption of cotton cloth led to a fierce backlash from traditional textile industries in both countries. To a certain extent, these vested interests were initially successful, as both countries prohibited imports of Asian cloth for domestic consumption. Furthermore, both countries banned the wearing of clothing made from cotton.[19]

However, two important loopholes to the general ban on cottons served as early catalysts in the various stages of production. First, domestic cotton manufacturing was tolerated. O'Brien et al. (1991) argue that the ban on imported Asian cloth was instrumental to the foundation of domestic industry as it would have been difficult for European producers to compete with Asian cloth both in price and in quality. As cotton cloth produced domestically could not be sold in home markets, it was initially used to barter for African slaves (Allen, 2009).

Second, most important European port cities imported plain cotton cloth for printing from Asia, as European spinners and weavers could not initially match the quality of Asian cloth.[20] Chapman and Chassagne (1981) document direct linkages between involvement in cotton printing and the formation of backward linkages to cotton spinning in both countries. Throughout the 18th century, both countries gradually relaxed the constraints on domestic production and consumption. Thus, not only was the size of cotton spinning similar in the two countries prior to mechanisation, but government involvement in the sector had also followed a similar path.

2.2.2 Mechanisation in Britain

Based on these observations, up to the mid-eighteenth century, there was little distinction between Britain and France's cotton industry. In both countries, the size of the industry was marginal, and it was a sector not viewed particularly favourably by the state. From these modest beginnings, it is hard to overstate the extent to which the mechanisation of spinning (and later other stages of production) revolutionised the cotton industry in Britain. According to Crafts' (1985) calculations, cotton alone accounted for an astonishing 25% of TFP growth in British industry

with indigenous European textiles such as wool, linen or silk (Chapman and Chassagne, 1981).

[19]O'Brien et al. (1991) discuss the political economy of the cotton industry in both countries in the decades leading up to the beginning of the mechanisation process.

[20]This was true for hand-spinning, the only technology available at the time. The same was initially true for machine spun yarn, but as a result of continuous improvements in productivity, British machine-spun yarn outcompeted the finest Indian yarn by the end of the Napoleonic Wars (Broadberry and Gupta, 2006).

between 1780 - 1860, for 22% of British industrial value added, and 50% of British merchandise exports in 1831.

To understand why the mechanisation of one stage of production – cotton spinning – had such a large effect on the industry, it is useful to examine the production process in detail. First, raw cotton was an imported good for both France and Britain, which were supplied by their respective colonies and the Levant.[21]

Upon arrival to Europe, the fibre was prepared - it was cleaned, carded and combed into rovings. The second step involved spinning the rovings into yarn. Spinning was usually performed by women in their own homes, generally as an additional source of income during agricultural down-time. The third step entailed weaving the yarn into cloth. This stage of the production process was also organised as domestic manufacture. The type of cloth woven depended on the fineness of the the yarn (measured as its count) and whether it was mixed with other fibres. Finally, the cloth was coloured and may have also been printed with designs. Printing, because of its greater capital intensity, was usually organised in small workshops.

A series of inventions mechanised the spinning of cotton yarn in Britain in the second half of the 18th century. Traditionally, spinners had spun one thread at a time using a simple wheel. Mechanisation increased output per worker as machines were able to spin multiple rovings simultaneously. The relevant measure of production capacity in cotton spinning became the spindle which is the piece of equipment onto which the roving is twisted. A picture of the original spinning jenny invented by James Hargreaves in 1767 with sixteen spindles can be seen in Figure 2.1. This machine was relatively simple, small and cheap.[22]

The water-frame and mule-jenny (the second and third generation machines), which arrived in quick succession after the spinning jenny, were larger, more complex and more expensive machines. They were better suited to spinning finer (higher count) yarns, and from an early date they were powered by water (Edwards, 1967). The literature on technology diffusion has documented a number of cases where the diffusion of technology has been surprisingly slow.[23] In the case of spinning machinery however, adoption across Britain was remarkably fast (Allen, 2009). As

[21] French colonial supplies of raw cotton were abundant and of a high quality. In fact, Edwards (1967) discusses the fact that as late as the 1780s, British spinners felt that their French counterparts had an advantage in accessing good quality raw material.

[22] Allen (2009) puts the cost of a jenny at 70 shillings (a spinner would earn a weekly wage of 8-10 shillings).

[23] See Geroski (2000) or Rosenberg (1981).

we will see below, relatively fast dispersion in Britain adds to the puzzle of why adoption across the Channel proceeded slowly.

Mechanisation had large effects on the cotton industry for a number of reasons. First, the machines disrupted the domestic structure of the industry. The size of the machines, their complexity and their reliance on inanimate power rendered production in the workers' homes obsolete and manufacturing was soon organised in large factories. Allen (2009) emphasises that part of the reason that cotton spinning proved to be so revolutionary was that for the first time, production was organised not rurally, but in large structures that required careful organisation of work-flow and management of workers. Historical evidence points to the fact that experimentation via trial and error, small improvements made by anonymous workers and entrepreneurs, and experience acquired on the job were important sources of productivity improvements (Mokyr, 2009).

For example, Chapman (1970) finds that most cotton mills in England had a remarkably similar structure. Chapman quotes a contemporary, Sir William Fairbairn, on the reason for this striking similarity; "The machinery of the mills was driven by four water-wheels erected by Mr Lowe of Nottingham. His work, heavy and clumsy as it was, had in a certain way answered the purpose, and as cotton mills were then in their infancy, he was the only person, *qualified from experience*, to undertake the construction of the gearing." (W. Pole (ed), 1877, quoted in Chapman (1970), my emphasis). Edwards (1967) notes that when the mule-jenny (the third generation spinning machine) "left Crompton's [the inventor's] hands it was a crude device, it had to be improved, and the spinners and weavers of muslins had to acquire their skills." (Edwards, 1967, p. 4). As workers were mobile between firms, and machines and factories were initially built by a handful of men as we have seen, small improvements in one firm could and did spill over to others.

Second, mechanisation had large effects for the productivity of spinning. The improvements in spinning technology are reflected in the price of yarn which declined significantly during the period as is shown in Figure 2.3. The trend is most dramatic for finer yarns, the real price of which dropped tenfold in as many years but there was also a decline in lower count (less fine) yarns.

The improvement in technology in spinning had disruptive effects on other parts of the production process. As mechanisation in weaving did not occur until well into the 19th century, an imbalance in spinning output and weaving capacity soon made

British cotton yarn uniquely reliant on exports markets, of which Europe was by far the most important. Crouzet (1987) estimates that around 56-76% of Britain's cotton output was exported either in the form of cloth or yarn.[24] The largest market for cotton yarn was Europe. 44% of cotton cloth and a full 86% percent of cotton yarn exports were destined for the European market. In comparison, only 27% of woollens and 8% of silks were destined for Europe. Crouzet notes that prior to the Blockade, only France, Germany, Switzerland and Russia consumed cotton yarn. This reliance on the export market for cottons in general, and the European market for cotton yarn in particular, explains why maintaining trade with Europe in cottons was so crucially important during the blockade, despite the risks and large increase in transport costs that were involved.

2.2.3 Diffusion of technology to France

Mechanisation of cotton spinning in France proceeded very slowly relative to events across the Channel. By the turn of the 19th century, France's productivity gap vis-a-vis Britain in cotton spinning was apparent. For many years, the conventional wisdom in the literature was that slow adoption was a result of French "retardation" and technological backwardness. The incompetence and economic mismanagement of France in the late 18th century has received much attention, as has Arthur Young's often repeated travel anecdotes of desperately poor, hungry and illiterate peasants across France (Young, 1889). In recent decades however, careful comparative analysis of the historical evidence, and systematic evaluation of the scarce statistics available in Britain and France has given rise to a different interpretation of events. According to this literature, differences in Britain and France were far smaller than previously thought, and both the state and cotton entrepreneurs played an active and helpful role in fostering economic development in France.[25]

This more recent literature emphasises both indigenous innovation activity in textiles in France simultaneous to those taking place in Britain, and a widespread effort to acquire British technology and best practice, once Britain's lead had been established. For example, McCloy (1952) notes that there were numerous inventions

[24] As a comparison, 50% of woollens and under a third of silk was exported.

[25] Landes' (1969) "Unbound Prometheus" is credited with being the most prominent exponent of French backwardness, while O'Brien and Keyder (1978), and later Crafts (1995) questioned the validity of this view. More recently, Horn (2006) and Squicciarini and Voigtländer (2014) discuss evidence of state and entrepreneurial efforts to modernise the French economy in ways similar to that observed in Britain.

in textiles in France throughout the 1700s, but predominantly in the last decades of the century. In particular, "in the carding of cotton and wool a dozen inventions, real or alleged, were made in the 1780's and 1790's", while in spinning, "the French anticipated the spinning jenny of James Hargreaves (1765) with two machines." (pp. 90 - 91.). With respect to the role of the government, Horn (2006) emphasises the importance that frequent industrial exhibitions had in fostering innovation activity and disseminating technological knowledge. For example, in 1800, the government invited submission for spinning machines and rewarded the best ones.

Both entrepreneurs and the French government were well aware of the momentous changes taking place across the Channel in the closing decades of the 18th century, and the need for French entrepreneurs to follow suit if they were to remain competitive in cottons. Importantly for my argument, the British prohibited both the export of spinning machinery and the emmigration of engineers and skilled workers. This put an artificial barrier on the diffusion of technology across the Channel. It meant that while the French were able to acquire blueprints of the machines, and with the help of some English and Irish engineers, British best practice, they didn't have wide scale access to the tacit type of knowledge that is acquired via learning-by-doing and that would be embedded in the export of machines or workers.

Contrary to traditional accounts of government incompetence, Horn (2006) writes that "the effort pivoted on acquiring English machines and spreading access to them as widely as possible. As is well known, the French state concentrated on acquiring Arkwright's water frame and the mule-jenny, both of which were crucial to England's competitive edge. Industrial spies (...) were commissioned to acquire these technologies. (...) British machine builders were rewarded for coming to France and given subsidies for each set of machine they sold. The Bourbon government paid the wages of at least 100 foreign workers in machine building and provided large subsidies to innovative French entrepreneurs who financed the construction of advanced textile machinery. Before the adjudication of Arkwright's second patent in 1785, no less than three mechanics were building roller-spinning machines in France. Doggedly, if haphazardly, government action enabled hundreds of English style (if not always functionally equivalent) carding and spinning machines to be put into operation in nearly every major industrial district in France between 1786-1789." (p. 78).

However, it was not just the state which fostered technology diffusion. Chassagne (1991) and Horn (2006) both emphasise that French cotton spinners played an even more important role in the transfer of technology. In Toulouse, Francois Bernard Boyer-Fonfrede recruited 12 engineers from Britain to build a six storey, water powered spinning mill which employed over five-hundred workers. After construction of the mill was complete, three were hired by a firm in Aix, and another by a firm in Gironde (Chassagne, 1991, p. 244). In Amiens, another entrepreneur, Jean-Baptiste Morgan, was similarly active in fostering technology transfer. According to Horn, Morgan sent agents to recruit English workers. "Arriving in yearly batches from 1788 to 1790, they provided Morgan with a detailed and precise knowledge of English techniques, and with the mechanical expertise to construct the needed machines and instruct workers in their use." (Horn, 2006, p. 83). Across France, entrepreneurs were engaged in similar forms of technology transfer.

The French Revolution and the subsequent Revolutionary Wars (1793-1802) did not put a stop to, but rather changed the nature of technology transfer. The French government offered English prisoners of war skilled in textile manufacturing the opportunity to work in France, which many took up (Chassagne, 1991). Horn (2006) notes that English machinery continued to be acquired by such important Continental innovators as Francois Bernard Boyer-Fonfrede (Toulouse) and Lieven Bauwens (Belgium).

What is striking about these accounts is the extent to which technology transfer seems to have been reliant on British know-how. Furthermore, it also seems to be the case that above and beyond the technological expertise required to build the mills and machinery, French workers were also reliant on British training in acquiring best-practice techniques in mechanised spinning and in training weavers to adapt to using the new type of yarn. As we have seen above, this was not something unique to French labour. Initially, British workers also experimented with and refined spinning techniques in a similar way. The difference between the two countries however, was that when French workers were experimenting and learning to spin with the new technology, they were already facing a more experienced competitor across the Channel.

2.2.4 Puzzlingly slow adoption across France

The preceding discussion may give the impression that technology adoption was rapidly advancing in France. According to all accounts, this was not the case. Despite both state and entrepreneurial attempts to foster mechanisation of cotton spinning, France lagged far behind Britain.[26] In 1790, the number of spinning jennies was estimated to be 900 in France, while the number in Britain has been put at 18,000 (Aspin and Chapman, 1964). Similarly, Wadsworth and Mann (1931) found that while in Britain, 150 firms were using the water-frame, the number in France was four, and the mills were all significantly smaller.

The literature has put forward a number of explanations for slow adoption across Continental-Europe and in particular France, which is widely seen as Britain's closest competitor at the time. French institutional backwardness has traditionally played a prominent role in explaining Britain's primacy in terms of the timing of industrialisation. For example Landes (1979) claimed guild restrictions were particularly harmful for entrepreneurial activity. This view is consistent with a recent literature which explains Britain's primacy in terms of its superior institutions (North and Weingast, (1989), Acemoglu and Robinson (2012)). Another strand of the literature has emphasised the role of differing factor prices between Britain and France. According to this view, Britain invented (capital-intensive) mechanised spinning because labour was relatively expensive in Britain, while French entrepreneurs did not have an incentive to switch from (labour-intensive) hand-spinning because labour was relatively cheap (Allen, 2009).

In contrast to these explanations, mechanised spinners active in France unambiguously laid the finger of blame on British competition. Spinners from across the Empire petitioned Napoleon to ban imports of all cotton cloth.[27] According to their pleas, the onslaught of competition was driving firms out of the market. French spinners were not competitive in home markets despite the fact that throughout most of the period in the lead-up to the Napoleonic Wars, trade between Britain and France was inhibited by tariff and non-tariff trade barriers and as such, French firms were not competing at international prices in home markets.

Comparing price data for machine spun yarn in Britain and France confirms the

[26] This was equally true for all of Continental Europe.

[27] AN/AFIV/1316 contains a petition from large spinners across the Empire requesting a complete ban on English cloth, while AN/F12/533 contains a petition from the Chamber of Commerce in Rhone (prefecture Lyon) requesting the same.

competitive disadvantage of French spinners. Figure 2.4 compares Paris and London prices for the full range of counts on the eve of the Blockade.[28] The vertical axis shows the price in francs, while the horizontal axis shows the count (finer yarns have higher counts). The solid line shows the Paris price for different counts of French machine-spun yarn, while the dashed line shows the London price for British spun yarn of exactly the same count.

Two points are worth noting from Figure 2.4. First, not only were French spinners out-competed in every count, but the gap becomes larger for higher counts. Consistent with the evidence in Figure 2.3 which shows that mechanisation benefited higher count yarns more, British advantage over the French was also higher in these counts. More sophisticated, harder to imitate machinery such as Crompton's mule was needed to spin these finer type yarns. Second, French prices are not available for counts above 100, as at this time, the French were not able to spin yarns of this finesse (Chassagne and Chapman, 1981). This is further suggestive evidence of productivity gains acquired through learning-by-doing. Machine spinning finer yarns was more difficult as with a finer thread, breakages were more likely. Better quality (more even) machines and more skilled workers necessary.

Consistent with comparative disadvantage in cottons, France was a net importer of cotton goods at the beginning of the 19th century. In 1802-03, trade was relatively free as peace had been momentarily restored to the Continent. In these years, imports of cotton goods to France made up 8% - 12% of total imports.[29] By way of comparison, the respective numbers for linen and hemp were .7% and .6% respectively, while woollen textiles were not listed as an import category.

The historical evidence paints a picture consistent with Britain acquiring a comparative advantage in cottons as a result of first-mover advantage in a sector with learning externalities. As the empirical analysis focuses on within country variation, a competing explanation of adoption which relies on uneven institutional change or factor-price shocks has to rely on time-varying, within country differences, which are arguably smaller than cross-country differences. Nonetheless, I return to the role that alternative explanations may play in the empirical analysis, and show that the results are robust to controlling for the time varying effect of institutional change and factor price shocks.

[28]Both prices refer to January 1807. Raw cotton prices are 6.9 and 5.4 francs in Britain and France respectively. The source of these data is discussed in Appendix A.

[29]Data sources for French trade statistics are discussed in Appendix A.

2.2.5 Market structure of the cotton industry

In this section, I turn to examining the market structure of the cotton industry. Understanding the localised nature of the production process will aid the interpretation of short run results. First, it should be noted that at the turn of the 19th century, cotton yarn was produced using two technologies; traditional hand-spinning and mechanised cotton spinning. The technologies appear to have produced imperfect substitutes, as prices were quoted separately for the two products.

The market for yarn was predominantly local during the early stages of development. The reasons for this are the generally small firm size in mechanised spinning, and the rural structure of both hand-spinning and downstream weaving. As the downstream sector did not mechanise until well into the 19th century, the organisation of production remained rural.

These factors made establishing links farther away relatively expensive for most spinning firms at this stage of development. Maintaining links with a large number of small, downstream weavers was difficult at large distances for all but the largest spinners. Though some firms did integrate spinning and weaving, most large firms found it profitable to maintain the rural, putting out structure of weaving, and this was to remain as such until well into the 19th century. These factors retained the local structure of the market at the initial stages of development.

For example, one of the largest cotton cloth printers in the French Empire, Christoff Philipp Oberkampf established a large cotton spinning enterprise to supply his printing works which had been cut off from traditional supplies during the blockade. Even with both the upstream and downstream of weaving integrated in one firm, Oberkampf decided not to integrate weaving. " (...) it proved much easier to subcontract to rural workshop masters, consigning to them boxes of mounted yarns and of barrelled wefts every month. The masters were required to maintain exact accounts of the warps and wefts received and were held responsible for all the pieces they produced that were considered too lightly or badly woven. The supply of completed goods was ensured by the mortgage of the masters' property to Oberkampf." (Chapman and Chassagne, 1991 p. 168).

With the exception of some large spinners, most firms sold their output at the local marketplace or had a stable network of rural weavers to whom they gave the yarn. A report from Seine Inferieure (prefecture Rouen) confirms that it was only the small spinners who brought their goods to the market, while larger firms sold the yarn themselves. Consistent with a predominantly local market, a report from Dyle (prefecture Brussels) states that price differences in yarn across departments even relatively close to each other were not exploited. The coexistence of hand-spinning and mechanised spinning meant that increasing the supply of mechanised yarn did not have to simultaneously lead to an increase in weaving capacity, as it could have just substituted for hand-spun yarn.

Evidence on the market structure in the early days of mechanisation is in line with evidence from Britain, which only began to export cotton yarn in 1794, about two decades after the spinning jenny was invented. Edwards (1967) notes that small spinners with limited capital often sold their yarn to larger spinning mills, which saved them the cost of employing salesmen. Furthermore, receiving an advance in cash, rovings or cotton ensured the continuation of production. He also documents direct links between spinners and weavers. Employing middle-men such as yarn dealers who dealt directly with weavers was expensive and, particularly for the more liquidity constrained spinners, often infeasible as spinners had to wait 3 to 6 months before payment was made.

This is not to say that all demand was local. Both Oberkampf and Lenoir, two large spinners, had weavers working for them in numerous departments. Furthermore, even during the Blockade, as the industry developed, larger firms began to look farther away for profitable export opportunities. As early as 1808, spinners from northern departments and the Haut-Rhin began to lobby the government to lift the ban on exports of cotton yarn. In the south, the Chamber of Commerce in Rhone (prefecture Lyon) worried that export markets in Russia and Germany would be disrupted by the Blockade. For most firms however, the local market seems in to have been the main outlet for production.

The market for raw cotton, the key input, was far more integrated by all accounts. In Britain, dealers of raw cotton were initially not fully specialised, but rather they dealt in many different colonial goods. As opposed to most spinners, they had substantial capital (Edwards, 1967). Consistent with a more integrated market, the Journal du Commerce regularly reported prices for different types of raw cotton from markets across the French Empire together with the price for other colonial products, while yarn was reported only sporadically and in far fewer locations. Different varieties of cotton (Brazilian, Levantine, US and colonial) were generally available in all markets. However, small and large firms differed in the way in which they accessed raw cotton input. A report from Seine Inferieure describes how it was predominantly small firms which were effected by the day to day movements in prices, which were to become increasingly important in the uncertain years of the blockade, as bigger firms secured larger consignments of cotton directly from cotton dealers.[30]

Finally, given that local markets in cotton yarn were important, the location of weaving is an important element of the analysis. As has been discussed, weaving was to remain rural throughout our period of interest. Weavers worked mostly in their own homes or in small workshops across the country, and mechanisation did not take place until well into the 19th century. Panel C of Figure 2.14 shows the geographic dispersion of weaving in 1803, where capital is measured as the number of weaving frames per capita by department. In the empirical analysis, I control for the time-varying effect of downstream weaving, and show that the results are not being driven by spatially uneven downstream demand.

2.3 The Napoleonic Wars as a Source of Exogenous Variation

The rupture to trade and the resulting geographic variation in the extent to which trading routes between Britain and the French Empire were affected provides a rare opportunity to identify the effect of protection from competition with the industrial leader on infant industry development in follower countries. In this section, I first document the reasons which led to the unusual implementation of the blockade. I then examine geographic variation in the effectiveness of the blockade using both port-level data from the Lloyd's List and data from British trade statistics. Finally, I describe how goods made their way from smuggling ports into the French Empire.

2.3.1 Unusual implementation of the blockade

Napoleon's Continental Blockade (1806-1813) took place within the context of the Napoleonic Wars (1803-1815). It is within this historical setting that the motivations

[30] For example, Chapman and Chassagne (1991) discuss Oberkampf's efforts in securing Pernambouco (Brazilian) cotton from Lisbon merchants by way of Nantes during the blockade.

and military constraints for both Britain and France can be understood.

Starting in 1803, a newly belligerent French Empire began its expansion on the Continent to the increasing alarm of the British. These wars should be viewed as a continuation of the French Revolutionary Wars which played out between France and various coalitions led by Britain between 1793-1802. Between 1803 and 1815, as in the previous decade, France fought Britain and its allies in a series of campaigns. Though the threat of an actual invasion by the French never completely subsided, following the defeat at Trafalgar in 1805, Napoleon more or less gave up on his plans of direct military invasion of Britain. He instead turned his efforts increasingly towards defeating Britain by economic means.

The primary aim of the blockade was thus to weaken Britain economically by denying her access to important Continental European markets. However, the stark asymmetry of naval power between Britain and France meant that traditional blockade of British ports by the French navy was militarily infeasible, as Britain unambiguously controlled the seas.[31] In contrast however, Napoleon was increasingly successful in exerting his direct or indirect influence over most of the Continent. In this way, though Napoleon could not blockade British ports, he could use his land-based power to do the next best thing, which was to attempt to stop British goods from entering the Continent.

The political map of Europe in 1812 in Figure 2.2 shows the extent of the Emperor's power over the European continent. Though Napoleon's power wasn't quite so all-prevailing in 1806, with the notable exception of Sweden, at one point or another all other European powers passed laws in line with the aims of the blockade. By 1806, the French Empire had expanded in size to include all regions of present-day Belgium, parts of Holland, the entire left bank of the Rhine, regions of present-day Switzerland up to and including Geneva, and regions in the North-West of the Italian peninsula, up to Genoa.[32] In addition, Napoleon's relatives were on the thrones of the Kingdom of Holland, the Kingdom of Italy, the Kingdom of Naples and the Kingdom of Spain. The Portuguese royal family had fled to Brazil and Napoleon's relatives were also in power in key German states (Connelly, 1990).

Historically, when Britain and France were at war, direct trade between the two

[31] By 1800, the British had twice the number of warships as the French did (Davis and Engerman, 2006).

[32] The map of the French Empire relative to France at its 1789 borders can be seen in Figure 2.15.

countries collapsed, however the countries were able to continue trading with little interruption by way of neutral carriers and nearby neutral ports.[33] The period that I examine here differs from other wars between Britain and France in the sense that the entire Continent was affected. To understand the disruption to trade, it is worth examining two periods separately; the three years leading up the imposition of the Continental Blockade (1803-06), and the the blockade (1806-13) itself.

Disruption to trade along the North-Sea ports began in 1803 with the onset of the Napoleonic Wars. “Neutral” ports along the North-Sea (Hamburg in particular), together with Dutch ports had been traditionally used to continue trading with the British in times of war. However, in a highly symbolic event, Hanover (the royal dynasty to which monarchs of Great Britain belonged to) was occupied by the French army. Britain retaliated by imposing a tight blockade of the entire North Sea coast between the Weser and the Elbe, which was then expanded to include ports along the French Channel and the North Sea in 1804 (Davis and Engerman, 2006). Crouzet (1987) considers this period a prequel to the Blockade in the sense that trade to Northern Europe was forced onto land routes for the first time significantly driving up the price at which goods entered the Continent. Goods were taken from Britain to Altona and Tonning (both North of Hamburg). They were then smuggled into Hamburg and taken into Northern Europe via land routes.

The Continental Blockade prohibiting the entry of British goods onto the European Continent was declared in Berlin in late 1806 following the defeat of the Fourth Coalition against France in Jena - Auerstadt. Prussia and Russia, two allies of the British, were forced to implement the blockade along their coastline.[34]

The historical events that followed the introduction of the Berlin Decree are fairly complex and they involve much back and forth retaliation between Britain and the French, the details of which are not relevant for my purposes.[35] The following points are worth noting regarding the implementation of the blockade. First, the series of laws passed by Britain and France had the effect of completely wiping out neutral shipping on top of the evident damage they did to domestic shipping interests. Neutral carriers such as the US found themselves in violation of one or the other

[33]Figure 2.6 shows that this was the case during the French Revolutionary Wars (1793-1802).

[34]It is generally believed that the outline of the decree had been planned well in advance of the British Orders in the Council which the French used as a pretext on the basis of which to retaliate. The Orders in the Council, declared earlier in 1806, had widened the blockade already in place further west to the home of the French Navy’s Atlantic fleet in Brest.

[35]The interested reader can consult Davis and Engerman (2006).

powers' decrees which made capture by Britain or France almost inevitable. This had the effect of severely increasing the costs and risks involved with sea-transportation and hence diverting a large proportion of sea-borne trade onto more expensive land based routes.

Second, the extent to which Napoleon could ensure successful implementation of the blockade depended on his ability to keep areas outside of France under his control. Regions not directly under Napoleonic rule generally dragged their feet in implementation of the blockade because of the evident harm it did to merchant interests. Though Napoleon was well aware of the hardships involved, defeating Britain enjoyed primacy above all other considerations. Furthermore, the extent to which Napoleon could effectively implement the blockade depended on his military commitments. The blockade was enforced to a far greater extent during years in which Napoleon could commit more troops to patrolling the coastline (Crouzet, 1987).

2.3.2 Geographic variation in the effectiveness of the blockade

Geographic variation in the effectiveness of the blockade was driven by the fact that while the closure of ports was generally effective in Northern Europe, a number of factors contributed to the blockade being ineffective in Southern Europe. This was the case to such an extent that trade to this region actually increased markedly.

Figure 2.5 gives a snapshot overview of the intensity of trade with Britain at the port level across Continental Europe in 1802, a year of relatively free trade and 1809, a blockade year. These data are form the Lloyd's List, and will be described in more detail in Section 2.5. Each circle is proportionate to the number of ships sailing between Britain and the given port. Comparison of 1802 and 1809 confirms that while the blockade dramatically disrupted trade between Britain and the Continent, shipping did not come to a standstill, but rather trade was diverted through a number of "smuggling ports".

To smuggle successfully, the British needed access to stable ports from which merchants could conduct their business. To this end, they either used ports which they directly controlled such as Gibraltar, Malta and Helgoland, or which were stably allied to them, such as Gothenburg in Sweden. Figure 2.5 labels these four smuggling centres. Napoleon's inherent military strength in the North meant that the British had to resort to smuggling via more difficult routes than in the South, where they had the upper hand.

Furthermore, and perhaps most catastrophically, the Spanish insurgency against French rule which started in 1808 meant that the entire Iberian peninsula became open for trade with the British. Together with their control of Gibraltar and shipping on the Mediterranean sea, Southern Europe became the main outlet for British goods, and in particular cotton. French prefects in the south-western regions complained that Spain was awash with British cotton goods which steadily made their way into France through the Pyrenees. French consular reports described markets for British yarn in Malta and Bosnia. With respect to the latter, the consul noted that there was no domestic demand for yarn in Bosnia, instead it was purchased exclusively by Viennese merchants for export.

Two features of the blockade are key to my empirical strategy. (1) The blockade was for most parts well-enforced along the coast of the French Empire. (2) The blockade was unevenly successful across Northern and Southern Europe. I now turn to examining the reasons for these in more detail. Figure 2.6 shows time series evidence of the uneven effects of the blockade. In each panel of Figure 2.6, the same port level shipping data used to construct Figure 2.5 from the Lloyd's List has been aggregated up to the regional level in order to examine the evolution of shipping over time.[36] Each line represents a given region's shipping with Britain as a share of total European shipping with Britain. Panel A examines shipping to the Northern ports of Europe excluding ports that belonged to the French Empire. Panel B examines shipping to Southern European ports, again excluding ports which belonged to the French Empire, while Panel C examines shipping along the coast of the French Empire.

2.3.3 Events in Northern Europe

Turning first to Panel A, Northern Europe is divided into three regions; the Baltic, the North Sea and Scandinavia. From the onset of the French Revolutionary Wars in 1793 until the peace of Amiens in 1802, there was a clear upward trend along the

[36] I collected data for a wide time-frame starting in 1787 in order to confirm that the Napoleonic Wars induced a rupture to trade different to previous episodes such as the French Revolutionary Wars.

North Sea and Baltic reflecting substitution from French ports to these regions. The Napoleonic Blockade differed from other trade wars between Britain and France exactly because of the involvement of all European powers. Without neutral shipping to substitute for the loss of direct trade between Britain and France (as was the case during the French Revolutionary Wars), trade costs became significantly larger.

From 1803 onwards, the North-Sea could not be used to substitute for the loss of direct shipping between Britain and France as it had been during the Revolutionary Wars because of the British blockade of the coastline. Instead, much shipping was diverted further East to the Baltic. Between 1803 and 1806, as shipping along the North-Sea declined, the share of shipping to the Baltic picked up. Discussing the effects of the North-Sea blockade on cotton exporters, Edwards writes; "During 1804 and 1805, when the Elbe was blockaded, Germany's share of the total cotton exports to Europe dwindled to a mere three percent, while there was a sharp jump in the trade to Denmark and Prussia." (1967, p. 55).

Accessibility of both the Baltic and the North-Sea worsened with the onset of the Continental Blockade in 1806 (denoted by the second grey line) as Prussia and Russia both implemented the blockade. Edwards (1967) notes that between December, 1806 and March, 1807 there was an almost complete standstill in trade to Northern Europe, with insurance premia rising sharply. With the increasingly difficult situation in Hamburg, some cotton merchants relocated to Tonning and Altona. Their letters to Britain were initially positive about the sales being made, noting that large quantities were being smuggled successfully into France.

However, the blockade became even more severe from August, 1807. It was during this time that Gothenburg became the important smuggling centre in the North, which can be seen by the increase in shipping to Scandinavia until around 1808. Marzagalli (1999) describes how merchants from Britain, Holland and Hamburg relocated their business to Gothenburg to organise smuggling routes from this point. However, the problem with Gothenburg was the lack of land connections to the German and French regions, which were the final destination for most of these goods. Crouzet (1987) describes how during a number of months in 1808 when the blockade was fully effective both along the North-Sea and the Baltic, stocks piled up in Gothenburg as ships arriving from Sweden were continuously denied entry.

It was possibly the increasingly difficult situation in the Baltic that encouraged merchants to begin to lobby the British government for trading licenses to Helgoland.

This tiny island about 50 kilometres off the German coast, measuring only a couple of square kilometres was taken by the British navy in 1807. The intent was to track movements of the French army along the North Sea. The British government started granting licenses to merchants to trade in Helgoland in late 1808, but smuggling began in earnest in 1809. The increase in the share of shipping witnessed in the North-Sea is accounted for single-handedly by this tiny island. Helgoland was more advantageous as a smuggling centre for three reasons.

First, it was closer to the final destination of the German and French markets reducing the land distances that goods would need to travel. Second, small fishing boats could be used to smuggle goods onto alcoves and inlets on the North-Sea coast during the night (Crouzet, 1987), something that had not been possible from Gothenburg. Third, the Baltic was only accessible by military convoy. To get to the Baltic, British ships needed to cross narrow straits controlled by the Danish, who had become Britain's fiercest enemies as a result of Britain's unprovoked bombardment of Copenhagen in December, 1806.

Despite considerable efforts on behalf of both the British government and entrepreneurs to find reliable routes via which to introduce their goods onto the mainland, northern smuggling routes were extremely risky and precarious by virtue of the fact that for both Helgoland and Gothenburg, there was no direct overland connection to Germany and France. The trade via Helgoland in particular was reliant on diminished vigilance along the German coast during Napoleon's campaign against Austria. Kirkman Finlay, a Glaswegian exporter of cottons noted that in 1810 "(...) the trade from Helgoland was also destroyed, since the French emperor whenever peace was made with Austria again closed up entirely every means of introduction from that island" (quoted in Edwards, 1967 p.58). On the other hand, Gothenburg was reliant on Baltic ports granting entry to ships obviously stocked with British cargo. Enforcement again fluctuated with military events and Russia's and Prussia's shifting allegiances.

2.3.4 Events in Southern Europe

The situation in Southern Europe was completely different as is evident from Panel B which shows the evolution of shipping for the Iberian Peninsula, the West- and East- Mediterranean. First, it is important to highlight the Iberian peninsula's key importance in determining the fate of the blockade. From the onset of the blockade in 1806, this region's share of shipping increased dramatically. In fact, for two years, 60% of total European shipping with Britain was conducted via the Iberian-Peninsula. Gibraltar carried a large proportion of this trade, as did Lisbon and Cadiz, both of which were under British control from most of the blockade.

Even prior to the Spanish insurgency, with Gibraltar firmly in their possession, and significant sway over much of Portugal, the British had access to a direct, overland connection to France. Edwards notes that between 1805 and 1807 (prior to the Spanish insurgency) cotton goods were exported in increasing quantities to Portugal, the Straits of Gibraltar, Malta and Sicily in order to penetrate parts of France. The increase in shipping on the West-Mediterranean was driven almost single-handedly by Malta. Crouzet (1987) describes in detail the key importance played by Malta, especially in the smuggling of cotton goods. At one point, 8.8% of exports from Britain were taken into Europe via Malta.

Why was France's military position weaker in Southern Europe? To begin with, the French navy was in a desperate state on the Mediterranean as a result of an indiosyncratic political event which took place during the French Revolution (Rogder, 2006). As Jacobite power was unravelling in Paris, the city of Toulon on the Mediterranean, home to the French navy's Mediterranean fleet, declared revolt. As troops from Paris began to encircle the town, the Toulonnais called in the British navy. As a consequence of the fighting, a significant part of the French fleet was destroyed or captured, an event from which the French navy could not recover during Napoleon's reign.

Furthermore, as a result a Napoleon's misadventure in Egypt (interpreted in Britain as an attempt to reach India), the British made control of the Mediterranean a policy of strategic importance. They controlled a number of points of primary importance in Southern Europe, such as Gibraltar and Malta, both of which became important smuggling centres. Furthermore, they exerted significant influence on Portugal, a historically important ally, but also Sardinia and Sicily. Finally, the British were also directly involved militarily in the Spanish insurrection which began in 1808. Crouzet (1987) describes how throughout the Napoleonic Wars, the British were able to single-handedly control shipping in the Mediterranean, which he called a "British Sea".

2.3.5 No direct shipping with France

Finally, Panel C shows the evolution of British shipping with the French Empire which has been divided into three regions; ports along the French side of the Channel (including Belgian ports), ports along the coast of the Atlantic and ports along the French Mediterranean (including Italian ports which belonged to the French Empire). First, it is clear that from the point of view of the French Empire, the Napoleonic Wars weren't particularly different from traditional trade war with Britain. The picture that emerges for the French Revolutionary Wars (1793-1801) is basically the same as that which we see during the Napoleonic Wars (1803-1815). In both cases direct trade between the two states collapsed as they went to war. As we have seen however, the difference in the case of the Napoleonic Wars was that cheap (water-borne) indirect trade via neutral ports was eliminated as a result of the trade war encompassing all of Europe.

2.3.6 Evidence from British trade statistics

Consistent with evidence form the Lloyd's List, trade statistics for British exports of manufactured goods and other British produce confirm the stark divergence between trade to Northern and Southern Europe as Panel A in Figure 2.7 makes clear. Exports to the Mediterranean increased threefold from the onset of the blockade to 1811, while exports to North-Western Europe (including France) were consistently lower. In fact, the peak-to trough decrease in exports to these markets was five-fold. Furthermore, consistent with the British using southern trading routes in years when northern smuggling became particularly difficult, exports to the Mediterranean were lower when exports to North-Western Europe were higher.

I also examine evidence on cotton exports in Panel B of Figure 2.7. Absent evidence on exports of cotton goods by region, it is nonetheless important to assess the extent to which cotton goods remained at all traded. If exports of cotton goods dramatically decreased, it would call into question the extent to which regional variation in exposure to British trade was in fact taking place. Figure 2.7 shows that in fact, both cotton yarn and cotton cloth continues to be exported.

Exports of cotton yarn were increasing prior to the onset of the Blockade, and they initially declined to about a third of their value. In 1809 and 1810 however (during the blockade), the value of exports was the same as in 1805. The pattern was similar for exports of cotton cloth, though exports of cotton cloth were actually consistently higher than in pre-blockade years. Unfortunately, these statistics are for total exports, so it is not possible to rule out that part of the pattern was being driven by substitution to export markets outside of Europe. However, two factors make this highly unlikely.

First, substitution to new markets was generally unsuccessful because of a lack market information. Heckscher's (1922) anecdote about ice-skates arriving in Buenos Aires in December is one extreme example of this. Furthermore, cotton yarn was particularly reliant on European markets by virtue of it being an intermediate good, possibly explaining why cloth exports did not fall at all during the period, while yarn exports did. Second, the peak export years in 1809-10 coincided with years where enforcement of the blockade was generally lax, implying that European markets drove the ups and downs for both cotton cloth and yarn during the blockade.

2.3.7 New trade routes into the French Empire

In the last part of this section, I examine how goods made their way from smuggling centres into the French Empire. To answer this question, I rely on historical accounts on the routes which smuggled goods took. There is fairly widespread consensus among historians of the blockade that one entry point for goods was Strasbourg. From the North, once goods had made their way either into a Baltic port or a point of entry along the North Sea, they were transported overland to Strasbourg. Ellis writes " (...) smuggling was more active along the inland than the maritime frontiers of the Empire. One reason for this was the nature of the terrain (...). Another was the proximity of foreign entrepots like Frankfrurt, Darmstadt, Mannheim, Heidelberg, Rastatt, Kehl and above all Basel. Within the Empire itself there were many smuggling bases up along the Swiss frontier and down the left-bank of the Rhine." (Ellis, 1981, p. 203)[37]

Regarding Southern smuggling, historians agree that many of the goods taken

[37]It may seem somewhat surprising that goods needed to be taken quite as far down south as Strasbourg. Why weren't they smuggled into the Empire via the Kingdom of Holland, a much shorter route? The Kingdom of Holland proved to be far too permeable to the entry of British goods for Napoleon's liking. While increasing pressure was placed on his brother, Louis, the King of Holland, to increase enforcement of the blockade, the decision was made to close the Franco - Dutch border from 1808 effectively shutting off the potential entry of any smuggled British goods from the north (Heckscher (1922) p. 181.) For this reason, British goods smuggled via the north took land routes all the way to Strasbourg prior to entry into the Empire.

by the British to smuggling centres in the Mediterranean were destined for French and German markets. There seems to have been a number of routes that goods took. First, Livorno (part of the French Empire) seems to have been an important entry point for smuggled goods (Marzagalli, 1999 and Galani, 2011). However, this likely changed with annexation to the French Empire and both authors find that ships arriving from Malta decreased significantly after this date.[38] Second, there is also widespread consensus that another favoured route was that taken via Trieste, consistent with the existence of markets for cotton yarn in this region (Marzagalli, 1999, Crouzet, 1987). Heckscher (1922) gives details of a smuggling route that began from Trieste and brought goods up along the Danube into Germany and finally into France.

Finally, goods were smuggled into France from Spain via the Pyrenees. Archival sources contain hundreds of letters between prefects in south-western departments and the government in Paris. Based on these reports, the smugglers were well organised, often being deserters of the army. Clashes between smugglers and the police resulting in casualties were not infrequent and the authorities were evidently outnumbered. Similarly to the inland border in the east, the mountainous terrain provided smugglers with a multitude of potential routes which made detection difficult. The Canal du Midi, linking the Mediterranean to the Atlantic was supposedly riddled with smuggling centres. All border departments reported a multitude of routes with destinations ranging from Bordeaux, Toulouse and Paris.[39]

One final piece of quantitative evidence from internal trade routes within the French Empire confirms that with the onset of the Napoleonic Wars, the direction of trade with Britain within France changed from a North-South route to a predominantly South-North route. Figure 2.8 shows the time series for trade from Strasbourg up and down-river along the Rhine. Coinciding with the onset of the Blockade, down-river trade (in the south-north direction) increased dramatically,

[38] For this reason, in quantifying the trade cost shock, I do not incorporate Livorno as an open trade route during the Napoleonic Wars.

[39] One worry is that smuggling via the Iberian peninsula is overstated if the British also used the Iberian peninsula as a point of access to markets in Latin-America. Crouzet (1987) discusses the trade from Britain to Spanish and Portuguese colonies in detail. He finds that in fact, because of the weakened state of the Spanish and Portuguese monarchy, the British actually had direct access to these markets in contrast to the period before the blockade when British goods could only enter the markets in Latin-America indirectly via either Spain and Portugal or smuggling via free-ports in the Caribbean. This implies that if anything, comparing shipping between Britain and the Iberian peninsula before and during the Blockade will understate the extent to which the peninsula was used for smuggling.

while up-river trade (in the north-south direction) remained stable.

In summary, this section has shown that the unusual implementation of the blockade led to geographic variation in the extent to which Northern and Southern trading routes between Britain and Europe were affected. In Section 2.5, I describe how the change in protection from British competition is measured using the data and historical evidence which was described in this section. First however, I present a simple model to guide the empirical analysis.

2.4 Theoretical Framework

This section develops a simple framework to guide the empirical analysis. In this model, the presence of dynamic learning-by-doing externalities, combined with differences in geographic distance to the frontier (Britain) play the key role in determining whether regions are productive enough in the initial period to produce cotton yarn domestically. Absent any shocks, initial specialisation determines how productivity evolves over time as is standard in infant industry models. Learning-by-doing externalities have been extensively discussed in the endogenous groth literature (Krugman 1987, Lucas 1988, Young 1991, Redding 1999, Melitz 2007). Most closely related to the framework presented in this paper is Rodríguez-Clare (2007) who also studies the case of a small open economy. The main difference in terms of other papers is the focus on geographic distance as a driver of protection across otherwise similar "industrial follower" economies. Furthermore, I include an imported input necessary for the production of cotton yarn to clarify the effect that a trade cost shock will have on the incentives for domestic production when the price of both the imported output and imported input necessary for domestic production increase.

2.4.1 Setup

The world consists of the frontier (Britain), F, and two follower regions $i = 1, 2$ (French regions).[40] F is sufficiently large relative to the combined size of the follower regions, i, such that international prices are set at the frontier as if it were a closed

[40]The framework can be extended to accommodate an arbitrary number of follower regions, however as the economies are allowed to trade with each other, this complicates the analysis significantly. Two follower regions are sufficient to illustrate how initial differences in specialisation between the two can lead to different long-term outcomes.

economy. Therefore, follower regions take international prices as exogenously given. The size of the two regions, in terms of their labour force, is the same: $L_i = \bar{L}$. Labour is not mobile across regions, but goods are traded across all three regions. There are three tradeable goods; agriculture, A, cotton yarn, C, and raw cotton, R. Consumers everywhere derive utility from the consumption of A and C, but not R. Raw cotton, R, is needed as an input in the production process of yarn, C. All goods are perishable and economies live in financial autarky. Consumers maximise the following instantaneous utility function:[41]

$$U(A, C) = A^{\alpha} C^{(1-\alpha)} \tag{2.1}$$

Goods around the world are produced using the following constant returns to scale production technologies: $A_i = L_i^A$, $R_i = a_i^R L_i^R$ and $C_i = min\{a_{it}^C L_i^C, R\}$. L_i^A, L_i^R and L_i^C are labour employed in agriculture, production of raw cotton and cotton yarn respectively. A and R use labour as the only input in the production process, while producing one unit of cotton yarn requires one unit of raw cotton and $\frac{1}{a_{it}^C}$ units of labour.[42] The i subscript refers to the region, while t denotes time.

International prices (set at the frontier) are straightforward. Choosing A as numeraire, equilibrium prices given perfect competition, strictly positive final goods demand for A and C, and intersectoral labour mobility are as follows: $p^R = \frac{1}{a_F^R}$, $p^C = \frac{1}{a_F^C} + a_F^R$ and $w^F = 1$.

At $t = 0$, follower regions differ from each other only with respect to their geographic distance to the frontier d_i. They differ from the frontier in two important respects. First, they do not have the blueprint to produce R, which amounts to assuming that $a_i^R = 0$.[43] Second, they have an initial productivity disadvantage in C. In particular, the evolution of a_{it}^C over time is given by the following equations

$$\begin{cases} \frac{\dot{a_{it}^C}}{a_{it}^C} = Q(C_{it}^c), & \text{if} a_{it}^C < a_F^C \\ \frac{\dot{a_{it}^C}}{a_{it}^C} = 0, & \text{if} a_{it}^C = a_C^F \end{cases} \tag{2.2}$$

[41]In general, we only need to assume a utility function in which marginal utility becomes unbounded as consumption of C approaches zero. I assume a specific functional form for utility to pin down specialisation patterns if the two regions begin trading with each other at some $t > 0$.

[42]I assume a Leontieff-production function for C in R and L in order to highlight in the simplest way possible the effect of an increase in the price of R on competitiveness of domestic production of C. Results do not change qualitatively with positive, bounded substitutability between the inputs.

[43]I make this assumption so that R is an imported input for follower regions.

where $a_{i0}^C = \bar{a^C} < a_F^C$ for $i = 1, 2$, $C_{it}^c \equiv \int_0^t C_{iz} \mathrm{d}z$, $Q(C_{it}^c) > 0$.

Both follower regions start with an initial productivity lag in C relative to the frontier.[44] All follower regions have the potential to close the productivity gap via the production externality. The learning function, Q, is strictly positive in cumulative production but is otherwise unrestricted. I make three stark assumptions about the nature of learning. (1) Productivity gains are fully external to the firm; no firm internalises the effect that increasing production today will have on future labour productivity. (2) The externality is spatially concentrated within the borders of the region. (3) Learning-by-doing gains are bounded. At $t = 0$, firms at the frontier have exhausted all productivity gains from learning-by-doing.

Follower regions take international prices as given, however, not all goods imported from the frontier are available to consumers and firms at these prices. While A is traded costlessly, both R and C face trade costs. In particular, if C is imported to region i, there is a t_i unit shipping cost, which is pure waste. The per unit trade cost is a function of region i's geographic distance to the frontier, $t_i = c(d_i)$, where d_i is (geographic) distance to the frontier and $c(d_i)$ is a function which is everywhere weakly positive and increasing in distance. Shipping one unit of raw cotton, R, incurs a unit shipping cost, τ, which does not depend on geographic distance to the frontier. The fact that C's shipping costs depend on distance, while R's does not is motivated by the fact that while Britain was the source for yarn, it was not the source for raw cotton. Prior to the blockade both Britain and France had similar access to raw cotton, which is why I take $\tau = 0$ initially.[45] Note however, that the results which follow do not rely on any restriction on the size of τ relative to t_i. Finally, if follower regions trade, they face symmetric unit shipping costs on cotton yarn, $t_{12} = t_{21}$.

[44] I assume $a_{it}^F = a_i^F \forall t$, and for this reason I suppress time subscripts for the frontier. At the frontier, the industry is no longer in its infancy as dynamic learning-by-doing gains have been fully exploited.

[45] Different regions within France had somewhat different access to different types of raw cotton, as I show in Section 2.6 because of non-negligible transport costs. This would imply that follower regions have different transport costs of raw cotton τ_i, giving them a larger or smaller advantage in domestic production of C. To the extent that differential access to raw cotton does not vary over time, they will not affect the predictions of the model, or the empirical analysis as this effect will be subsumed in the regional fixed-effects. For this reason, I simply take τ constant across regions.

2.4.2 Static Equilibrium

From the point of view of region i, firms only need to make a decision about whether it is profitable to produce yarn domestically (and import the raw cotton needed for production) or import it from the frontier. At $t = 0$, when $a_{10}^C = a_{20}^C$, follower firms will not be competitive in each others' markets, as they are equally productive in C, but face a non-zero transport cost. Note that A will always be produced as it is needed either to pay for imports of raw cotton or cotton yarn.[46]

Given international prices as faced by agents in region i, we can easily solve for specialisation patterns and equilibrium prices in i. Production of A and intersectoral labour mobility will imply that $w_0^i = 1$, for $i = 1, 2$. Will region i produce cotton yarn, C, or import it? This depends on whether firms can break even at prevailing prices. Firms in region i will find it profitable to enter C at time 0 if [47]

$$p^C + t_i \geq \frac{1}{a_{i0}^C + p^R} \tag{2.3}$$

Inspection of Equation 2.3 reveals that there will be a cutoff distance $\bar{t} = \frac{a_F^C - a_{i0}^C}{a_F^C a_{i0}^C}$.[48] Firms in regions with a trade cost $t_i \geq \bar{t}$ will find it profitable to enter production of cotton yarn, while regions with $t_i < \bar{t}$ will import yarn from the frontier.

Regions with $t_i \geq \bar{t}$, will be incompletely specialised; they will produce agricultural products and cotton yarn. They will export agricultural products in exchange for raw cotton needed in yarn production. Prices are as follows: $p_i^A = 1$ and $p_i^C = \frac{1}{a_{i0}^C} + p^R \leq p^C + t_i$. Regions with $t_i < \bar{t}$, will be fully specialised in the production of A which they will export in exchange for C. Prices are $p_i^A = 1$ and $p_i^C = p^C + t_i$.

2.4.3 Dynamic Equilibrium

Given the static equilibrium from the previous section, characterising the dynamic path of follower economies is straightforward. Regions which began producing cotton

[46] At first, it may seem surprising that yarn cannot be exported in exchange for raw cotton. However, given that follower regions at their most productive can produce at p^C when catch up is complete and $\tau = 0$, they can only sell in F at $p^C + t_i$; a price that is t_i higher than the prevailing market price at the frontier. The only exception to this is if the two follower regions trade with each other. In this case, the region with a comparative advantage in C can be fully specialised, a possibility I explore in the next subsection.

[47] The equation comes from the requirement that at price $p^C + t_i$ domestic producers of C must make weakly positive profits

[48] The expression for the cutoff distance substitutes for p^C.

yarn at $t = 0$ will increase their productivity in this sector via the production externality further strengthening their competitive edge in the domestic market until $a_{it}^C = a_F^C$ and catch up is complete. Regions which import yarn from the frontier at $t = 0$ will continue to import yarn and $a_{it}^C = a_{i0}^C$, meaning that productivity will stagnate at the initial level.

The dynamic path is slightly more complicated if one region begins producing C at $t = 0$, while the other does not. Productivity in the region producing C may increase sufficiently for the follower region to become competitive in exporting C to the follower region specialised in A. In this case, the economy with a comparative advantage in producing C will supply the other with cotton yarn in exchange for agriculture, while both are supplied with R from the frontier. Depending on parameters, the following outcomes are therefore possible:

1. If $t_i < \bar{t}, i = 1, 2$, both economies will specialise in the production of A and import C. $\frac{\dot{a}_{it}^C}{a_{it}^C} = 0, \forall t$ and $p_{it}^C = p^C + t_i$.

2. If $t_i \geq \bar{t}, i = 1, 2$, both economies will be incompletely specialised in A and C from $t = 0$ onwards. $\frac{\dot{a}_{it}^C}{a_{it}^C} > 0$ and $\frac{\dot{p}_{it}^C}{p_{it}^C} < 0$ while $a_{it}^C < a_F^C$. Once $a_{it}^C = a_F^C$, $p_{it}^C = p^C, \forall t$.

3. If $t_i \geq \bar{t}$ but $t_j < \bar{t}$ and $p^C + t_j = \frac{1}{a_{iT}^C} + p^R + t_{ij}$, for some $t = T$, then i will be incompletely specialised in producing A and C and j will be fully specialised in producing A and importing C from the frontier while $t < T$. However, once $t \geq T$, i will be competitive at exporting yarn to j. This will change the direction of trade and potentially alter specialisation patterns. Trade between the two regions will be as follows: j will be fully specialised in producing A, which it exports to i in exchange for C.[49]

4. If $t_i \geq \bar{t}$ but $t_j < \bar{t}$ and $p^C + t_j < \frac{1}{a_{it}^C} + p^R + t_{ij}, \forall t$, i will be incompletely specialised in A and C and j will be fully specialised in producing A and importing C from the frontier. Labour productivity in C in region i will never be high enough for firms to become competitive in market j. This implies that i and j do not trade with each other.

A number of points are worth noting in light of this result. First, initial spe-

[49]Depending on parameters, i can be completely or incompletely specialised in producing C. It exports (or re-exports) A in exchange for R from the frontier. If $p^R a_{it}^C \geq 1 - 2\alpha$, i is incompletely specialised in A and C. However, for $p^R a_{it}^C < 1 - 2\alpha$, i is fully specialised in C. As technology improves via the production externality, complete specialisation becomes more difficult. This is the general equilibrium effect of C becoming cheaper. As C becomes cheaper, consumers in i and j increase consumption of C, but this requires more imports of R, which in turn increases demand for A. Supply of A can only be increased if i becomes incompletely specialised and this requires the wage to fall to one, where production in A is once again profitable.

cialisation at $t = 0$ will determine whether a domestic cotton yarn production is able to develop in a follower region i. This depends only on geographic distance to the frontier. Second, cotton yarn production is an infant industry in all follower regions. With sufficiently high *temporary* protection from trade with the frontier in the production of yarn (ie. a sufficiently high t_i), all follower economies can develop a domestic sector which is competitive with the frontier at *any* distance. To see this, observe that once catch up is complete, $a_{it}^C = a_F^C$, follower regions have the same labour productivity as the frontier.[50]

It should be noted that in general the extent to which temporary protection is welfare improving depends on the speed of learning relative to discounting. If the industry is not competitive at initial distance to the frontier, t_i, consumers are worse off during the time period where the cotton industry is protected, because they pay a higher price for cotton yarn than they would if they were to import yarn at $p^C + t_i$, but once the sector is competitive they are better off, as the price of cotton yarn decreases below that of competing imported yarn. The net effect thus depends on whether the long-term welfare gains outweigh the short term losses.

Finally, to the extent that one follower region is developing, while the other is not, the time paths discussed in (3) and (4) differ only to the extent that under (3) the developing economy integrates with the stagnating economy, while in (4) it does not. The time path discussed in (3) will prevail if productivity gains in C outweigh the trade cost t_{ij} between i and j. In particular, at $t = 0$, integration between i and j cannot take place, because i and j have the same productivity, but i incurs the trade cost when exporting to j. As i produces C, a_{it}^C increases and higher productivity can overcome the trade cost. The possibility of integration between the two economies will be important for understanding the long-term effects of temporary protection.

2.4.4 Understanding the trade cost shock

I now use this framework to guide the empirical analysis. I allow for the trade cost shock to effect both the costs of trading C and R.

[50] It is well known, that a tariff is not the most efficient way of fostering development of the infant industry. In general, a production subsisdy which targets the industry with learning externalities is more efficient than an import tariff, as it does not distort consumer prices. Melitz (2005) shows that in settings in which a production subsidy is not feasible, an import quota may be more efficient than a tariff. The reason for this is that if there are adjustment costs to changing the tariff, an import quota – fixed at the long-run level of import demand for example – is less costly, as the effective tariff it is equivalent to will decline over time as learning in the domestic sector increases.

In particular, let $\Delta t_i \equiv t_i^{'} - t_i$ denote the shock to trade costs for British yarn in region i, where t_i and $t_i^{'}$ denote the trade costs between Britain and region i before and during the Napoleonic Wars respectively. Similarly, let $\Delta\tau_i = \tau_i$ denote the shock to the price of raw cotton.

Domestic production of cotton yarn is profitable if the following condition holds

$$min\{p^C + t_i'; p_{jt}^C + t_{ij}\} \geq \frac{1}{a_{it}^C} + p_r + \tau_i \tag{2.4}$$

This expression differs from Equation 2.3, because the fact that the shock occurs at $t > 0$ means that, given sufficient learning, follower regions could have been trading with each other, making $p_{jt}^C + t_{ij}$ the effective price at which domestic firms become competitive in market i.

The effect of the change in trade costs depends on three forces. First, the increase in the price of raw cotton will make all regions less competitive in yarn production relative to the frontier. Second, a larger shock to the costs of trading in yarn makes domestic producers more competitive. Third, if the region was previously producing yarn, then $a_{ct}^i > a_{c0}^i$, meaning the region is, all else equal, more likely to remain competitive at producing yarn despite the shock. I now examine the conditions under which regions switch into and out of C.

1. **Switching into C:** A necessary condition for an economy i which was not producing prior to the shock to switch into C is that $\Delta t_i > \Delta\tau_i$ and $\frac{1}{a_{jt}^C} + t_{ij} < \frac{1}{a_{i0}^C}$. The first condition is trivial, domestic production will only become profitable if the shock to output prices outweighs the shock to input prices. Second, insomuch as economy j was producing prior to the trade cost shock, the increase in productivity cannot have been large enough to outweigh the trade costs between the two regions, otherwise j will continue to have a comparative advantage in producing C as t_{12}, the trade cost between the two follower regions, remains unchanged. Sufficiency requires the difference between Δt_i and $\Delta\tau_i$ to be large enough such that the inequality in equation 2.3 is reversed.

2. **Switching out of C:** A necessary and sufficient condition for an economy which was previously producing C to switch to importing C from the frontier is $p^C + t_j^{'} < \frac{1}{a_{jt}^C} + p_r + \tau_i$. Furthermore, any economy i out-competed by the frontier producer in market i will also necessarily be out-competed in j because of the triangle inequality.

How can this simple framework be used to guide empirical analysis? First, the model makes clear that the price shock to raw cotton is a potential confounder. The previous section has shown that the Napoleonic Wars led to an asymmetric shock to trade costs for British yarn across the French Empire. The presence of an imported input necessary for production implies that identification of the effect of protection on development in mechanised cotton spinning relies on either observing both trade costs in each department at all points in time, or in showing that the trade cost shock to imported raw cotton was even across regions. In Section 2.6, I show the latter. In particular, while the blockade against British trade had the spillover effect of making access to raw cotton more costly, the effect of this was even across the French Empire, implying that time fixed effects will capture the effect of more expensive inputs in the empirical specification. In light of this, there are two predictions I will take to the data in the following sections.

1. *Short-run prediction:* Changes in production of C should be positively related to the size of the trade cost shock to British yarn.

2. *Long-run prediction:* Productivity increases in the level of local production.

The short-run prediction shows how time variation in geographic distance from the technological frontier can be used to identify the immediate effect of trade protection on infant industry development. In the interest of clarity, I have kept the framework simple, however it should be noted that the short-run prediction should not trivially hold in the data. One missing aspect of the analysis is the technology choice which firms evidently faced in practice. As Saure (2007) shows in a theoretical model with a choice of production technology, infant industry protection in developing countries can fail to deliver on the hoped for dynamic gains if the profit-maximising technology choice is different to that in developed economies.

In particular, the paper analyses a model in which firms face a technology choice, with one technology featuring dynamic external returns to scale, while the other does not. If the individually optimal technology choice for firms is the traditional one, then protection will simply foster usage of the traditional technology without increasing productivity. To understand the intuition in this specific framework as simply as possible, imagine firms in follower regions have access to two technologies at $t = 0$; the one analysed above with learning externalities and initial labour productivity $\bar{a}^C$, and another without dynamic externalities but with marginally smaller initial productivity $\bar{a^C} + \epsilon$. Faced with this choice, firms will choose the latter technology when trade costs are sufficiently high to make domestic production profitable and once temporary protection is lifted, they will return to importing yarn.

This simple example seems particularly relevant in this setting as French spinners had access to both the traditional hand spinning technology and mechanised spinning. As Allen (2009) argued, France had a lower wage to capital price ratio, implying that the returns to adopting the more capital-intensive technology were arguably smaller than for the British. Given the technology choice, observing adoption of mechanised spinning systematically related to the trade cost shock is not trivial. If mechanisation is not the profit-maximising technology choice, we would expect to see no effect of the trade cost shock on this margin.

I take the long-run prediction of productivity increasing in the aggregate level of local production to the data in two ways. First, I ask whether there was persistence in the location of spinning activity within France, and second, I ask whether firms located in regions with high post-blockade mechanised spinning activity were more productive in the long-term than firms located in regions with a lower level of activity.

The persistence prediction relies on regions which received a larger shock becoming sufficiently competitive to survive competition with Britain under decreased trade costs following 1815, which depends on the speed of learning. The prediction that firm productivity increases in the level of activity at the regional level is a direct consequence of the learning externality. In Sections 2.6 and 2.7, I take the short- and long-ru predictions to the data. In the following section, I describe data collection and data sources.

2.5 Data

To answer the question of how the rupture to trade affected the development of mechanised spinning within the French Empire during the Napoleonic Wars, I collected data from various primary sources. The most important of these are handwritten prefectural reports from the Archives Nationales in France used to construct the panel dataset of mechanised spinning capacity examined in Section 2.2, and the Lloyd's List, which is the source for port level shipping data presented in Section 2.3. In this section, I provide a brief overview of the most important sources and I describe construction of my two measures of the trade cost shock. A more detailed description of all sources, construction of each dataset and potential limitations can be found in Appendix A. Examples of the original data are provided in Figures A.2 and A.3 in Appendix A.

2.5.1 Data on mechanised cotton spinning

Napoleon's government went to extraordinary efforts to collect detailed, systematic data on many aspects of society and the economy during the Emperor's rule. Data from this period are of a very high quality, and they provide a unique opportunity to examine development at an early period of structural transformation. Departmental reports from the Archives Nationales provide systematic evidence on various stages of the production process for the cotton industry. Remarkably, data for 1803 and 1806 are available at the firm level, while data for 1812 are available at the departmental level.

Using these data, I constructed a panel of spinning capacity at the departmental level. My preferred measure of spinning capacity is the number of mechanised spindles in department i at time t (which is the relevant measure of physical capital), however I show that the results are robust to using the number of workers employed in mechanised spinning as the outcome variable. In the firm level dataset for 1803 and 1806, many firms only report number of machines and not number of spindles. For these firms, I have imputed the missing observations using a predictive mean matching model.[51] Departmental spinning capacity for both 1803 and 1812 is observed for 88 departments of the French Empire. These are the departments which make up my baseline sample. I also exploit the availability of firm level data for the initial period of the Napoleonic Wars in the empirical analysis in order to examine baseline characteristics and the margins of initial adjustment in the 1803-06 period.

2.5.2 Data on the trade cost shock

I use the Lloyd's List, one of the oldest newspapers in the world, to reconstruct trade routes between Britain and the Continent before and during the Napoleonic Wars. The Lloyd's List was, at the time , a bi-weekly newspaper for shipping

[51] More details on the imputation model and robustness to imputation can be found in Appendix A.

news which, amongst other things, printed the destination for all ships sailing from British ports, and similarly, the source for all ships arriving to British ports. Early editions have been digitised by Google and are made available by the Hathi Trust. I used an optimal character recognition (OCR) programme to convert the images into machine-readable format. This procedure converts the images into a text-file based on pattern recognition of images which was manually set. By manually searching through editions, I compiled a list of European port names. I then extracted British-Continental journeys using a text-matching code which searched for the names of the listed European ports for all years between 1787-1814. I found that the algorithm extracted about 70-80% of journeys depending on the quality of the image for a given year, by checking the accuracy of the algorithm for a subsample in each year. The number of mismatches was minimal, and omissions (where the algorithm did not pick up a port that it should have) were not systematic. I also had an entire year manually entered to check the accuracy of the algorithm, which yielded very similar results. An observation is a journey between Britain and a Continental European port i in year t. This period spans the full length of the French Revolutionary and Napoleonic Wars in order to show that the rupture to trade during the Napoleonic Wars was radically different to a traditional trade war between Britain and France – an example of which is the French Revolutionary Wars (1793-1802).

The theoretical framework predicts that changes in mechanised spinning capacity were driven by changes in the cost of trading with Britain. I construct two different measures which account in different ways for changing trade costs during the Napoleonic Wars and show that the results are similar when using both measures. The first measure is based on a shortest route algorithm which accounts for the extent to which trade routes changed for each department. The second measure accounts for the fact that not all smuggling routes were open at any given time during the blockade and some smuggling ports faced more severe capacity constraints than others. Instead of calculating a shortest route, it weighs smuggling routes by the traffic which passes through them.

Measure 1: Shortest route algorithm

The first measure uses a shortest route algorithm to calculate the mean distance between London and each department. I account for one of the most important drivers of increasing trade costs; the difference between water- and land-borne routes, by calibrating the ratio of the two to match the fact that, during this period, sailing from Rouen to Marseille was two-thirds of the cost of going overland when all trade costs are accounted for (Daudin, 2010). Based on these numbers, 1 sea kilometre is equivalent to about 0.15 kilometres on land.

To quantify the shortest route prior to the onset of the Napoleonic Wars, I allow trade to go through any port that was in use between 1787-1814. To calculate the shortest route between London and each department during the Napoleonic Wars, I restrict possible routes to the ones which were in operation during the Napoleonic Wars. These are the routes discussed in Section 2.3. In particular, Malta, Gibraltar, Gothenburg and Helgoland are the main smuggling ports to which goods arrived from London. To make it to France, these goods could either take the northern overland smuggling route via Strasbourg, or a southern smuggling route via Trieste, Bilbao or Barcelona. Trieste was a documented smuggling centre (Marzagalli, 1999 and Crouzet, 1987), while free shipping in Spain implied that water-borne routes could be used to get goods close to the French border.[52]

For any department i, the algorithm then picks the least cost path. The trade cost shock, defined as the log-change in the shortest route to London for each department, can be seen in Figure 2.9, where darker shading shows a larger shock. As expected, departments along the Channel have the highest trade cost shock. However, the shock worked in a more complicated way than simply increasing in size from southern to northern France. For example, departments along the Rhine witnessed almost no increase in their effective distance to London by virtue of their proximity to Strasbourg, the route via which goods entered the department. The routes that goods took prior to the Napoleonic Wars were almost identical to the routes which they took during the period 1803-1812. In contrast, the Atlantic seaboard witnessed a much larger increase in trade costs, as these departments were initially easily accessible via sea-routes which were not available during the blockade.

To what extent does this measure accurately capture the increase in trading costs between Britain and a given department in France? One worry is that by exclud-

[52] Direct shipping between London and a number of ports in northern Spain also increased fairly significantly suggesting that, at least for some years, routes cheaper than the London-Gibraltar-northern Spain-France route were in operation. This implies that assuming goods came to the south-western border of the French Empire via Malta or Gibraltar (from London) is a conservative estimate.

ing any form of direct smuggling between Britain and France, we are introducing measurement error. While it is certainly true that some direct smuggling between Britain and France took place during the Napoleonic Wars, historians seem to agree that this was far riskier than the indirect smuggling routes which I use to construct the measure of the trade cost shock (Heckscher, 1922). The fact that third-country ports were used is indicative of the fact that either direct smuggling was quantitatively unimportant as the blockade was mostly effective along the coastline of the French Empire, or that the risks associated with it were sufficiently high that taking more circuitous routes was also profitable. In either case, this implies that my measure should do a relatively good job of capturing the change in trade costs.

The second concern has to do with the fact that not all smuggling routes were open at any given time. Furthermore, some ports (such as Helgoland) were more obviously subject to capacity constraints than others (such as Malta). For this reason, I construct another measure of the change in trading costs which relies on quantifying the extent to which various ports were used for smuggling.

Measure 2: Weighted distance

An important source of measurement error when using the shortest route algorithm to quantify the change in trade costs stems from the fact that it does not account for capacity constraints and periods where smuggling centres were not open. As I have shown, military events played a role in determining which areas of the European Continent were more or less were open to trade and this variation had a time dimension to it. For example, in years where the blockade in the north was almost perfectly enforced, goods made their way into Continental Europe exclusively via the south. The second measure therefore focuses on capturing the intensity of use of any smuggling centre between 1803-12 instead of the shortest route approach.

To capture the intensity of port-usage, I use the Lloyd's List to identify ports which were intensively used during the Napoleonic Wars. I experimented with various definitions to quantify smuggling at the port level, but the concentration of trade through a small number of ports implies that the same ports played by far the most dominant role in maintaining trade between Britain and Continent during the Napoleonic wars for any sensibly defined measure. These are Cadiz, Gibraltar, Gothenburg, Helgoland, Lisbon, Malta, and Tonningen.[53] Given the pattern

[53]Recall Tonningen played a crucial role in maintaining trade between Britain and the Continent

in Figure 2.5, it should not be surprising that these ports played by far the most important role in smuggling British goods onto the Continent. Depending on the precise method used for quantification, a number of different ports enter the list, however their weight is always very small and as such, should not influence the results in an important way.

The measure I use defines a smuggling centre as a port where the number of ships sailing to or from Britain and the given port in any of the war years between 1803-1812 was greater than the amount of ships in any of the years before the onset of the wars for which we have data (1787-1802). I use this condition in order to avoid mis-classifying ports which happen to be open to trade with Britain but are not used as smuggling centres. To focus on the quantitatively important smuggling centres, I further refine this measure by using only the ports where the maximum yearly shipment in a blockade year exceeds 80. The threshold is not particularly strict, as large and important smuggling centres such as Malta have above 300 shipments in peak years.

Based on these conditions the following ports are classified as smuggling centres; Cadiz, Corunna, Gothenburg, Gibraltar, Helgoland, Lisbon, Malta and Tonningen.[54] The final step is to quantify the relative importance of each centre. I take total shipments between 1803-1812, the years of the Napoleonic wars, and subtract total shipments between 1793-1802. The difference between the two is a crude measure of smuggling. Weights are calculated based on a port's share of total smuggling. According to this measure, shipments to the southern smuggling ports accounted for roughly 70% of total smuggling, which is similar to what differently defined measures give.

I proxy for the trade cost between London and a department prior to the Napoleonic Wars by using Euclidean distance to London, while distance during the wars is given as a weighted average of the Euclidean distance to each smuggling centre. Note that by calculating distance in this way, I am being conservative in the sense that while there is evidence for trade flowing in the south-north direction, (eg. from Malta to the northern parts of Europe) there is no historical account of trade flowing in the north - south direction (eg. from Helgoland to Southern Europe). This makes sense, seeing as the binding supply constraint was in the North and not

during the North-Sea blockade between 1803-1805.

[54]Corunna's share in smuggling is below 2%.

in the South. In this way, the measure is probably overestimating the south's shock relative to the north, stacking the cards against finding an effect of trade protection on capacity.

2.5.3 Other data sources

To conduct robustness checks, data was collected from a variety of sources which are discussed in more detail in Appendix A. Data on raw cotton prices were collected from editions of the most important commercial newspaper of the time in France, the "Journal du Commerce" and they were supplemented with London prices from Tooke and Newmarch (1848). To conduct falsification tests, I also collected data from handwritten departmental reports on leather tanning and woollen spinning. To test robustness to a number of potential confounders, I collected data from a variety of primary and secondary sources. Data on access to coal is from Fernihough and O'Rourke (2014), data on mean stream flows for rivers across the French Empire is from the European Water Archive, the historical location of the cotton industry is from Daudin (2010), literacy rates are from Furet and Ozouf (1982), conscription rates are from Hagenvilliers (1937), departmental population is from Chabert (1951), urban population is from Bairoch et al. (1988), and population density is calculated by geo-coding a historical map of the French-Empire in order to measure the area of each department. The long-term effects of the trade cost shock discussed in Section 2.7 are estimated using data on cotton spinning firms from the first French industrial census (1839-47) which was collected by Chanut et al. (2000).

2.6 Short-term Empirical Strategy and Results

The theoretical framework presented in Section 2.4 predicts that a sufficiently large increase in the distance to the technological frontier will result in departments switching into domestic production in mechanised spinning. The exogenous variation in effective distance to London provides us with a setting which we can use to take theory to the data. To the extent that the mechanism is at work, we would expect increases in spinning capacity during the period of the Napoleonic Wars to be systematically related to the size of the trade cost shock. In this section, I first describe the evolution of mechanised cotton spinning during the Napoleonic Wars and then turn to estimating the short-run effect of trade protection.

2.6.1 Mechanised spinning during the Napoleonic Wars

Figure 2.11 shows the variation in spinning capacity which will be used to estimate the effect of trade protection on increases in domestic production capacity. Panel A shows the spatial distribution of spinning capacity across the French Empire in 1803, prior to the onset of the Napoleonic Wars, while Panel B shows the same for 1812, towards the end of the Blockade.

Between 1803 and 1812, spinning capacity in the French Empire increased by about 370%, from 380,000 to around 1.4 million spindles.[55] As a comparison, it has been estimated that Britain had around 6.8 million water and mule spindles in 1811 (Chapman, 1970). This should be taken as a lower bound estimate on total number of spindles as it does not include older type machines such as spinning-jennies.

A look at Figure 2.11 reveals the differential impact of the Napoleonic Wars on mechanisation of cotton spinning across the French Empire. Particularly striking is the increase in spinning capacity along the English Channel. By 1812, the two largest spinning departments in the French Empire were Seine-Inferieure (prefecture Rouen) and Nord (prefecture Lille), both along the English Channel. The enormous increase in spinning capacity in the Nord from an almost irrelevant 2,700 spindles (contrast to Rhone with more than 70,000 in 1803) to over 200,000 spindles is particularly impressive.

In general, the more Southern regions of the Empire stagnated during this time period. The Rhone and Loire, two of the departments with the largest spinning capacity in this region prior to 1803 showed varied performance. Spinning capacity in the Loire decreased significantly (from 47,000 to 37,000 spindles), while the capacity in the Rhone increased (from 72,000 to 96,000 spindles). However it is difficult to know what to make of these latter numbers as spinners in the Rhone moved out from Lyon and back into the surrounding countryside (which is where rural spinning was traditionally located), which is the opposite of what we see in Seine-Inferieure and Nord where firms tended to concentrate increasingly in Rouen and Lille. The South-West of the Empire along the border with Spain saw outright decline in all departments. Modern firms in these areas went bankrupt and firms reverted back

[55] This figure is calculated using the 88 departments for which data is available in both 1803 and 1812.

to hand-spinning.

The prefectural reports from various departments paint a picture consistent with the numbers. Southern departments unanimously complained about a collapse in demand. The prefect of Tarn (prefecture Albi) in the south-west described how the spinning machines that were used in the department had not been in use for years and the demand for all forms of cloth had collapsed. The prefect of Rhone (prefecture Lyon) was even clearer in blaming foreign yarn for the collapse in demand.

The situation in the more Northern departments could not have been more different. A report from the Nord (prefecture Lille) stated that there was not much change in activity in linens, woollens and hemp. In contrast, he stated, trends in mechanised cotton spinning were completely different. In this branch of the textile sector, *despite* the high price of raw cotton, activity had picked up considerably, particularly during 1809 and 1810. Consistent with learning gains, the prefect also described how there had been significant progress made since 1806 in the fineness of the yarn that they were able to spin, claiming that they were now able to spin yarn as fine as 200 counts, which, if true, was on par with the British.

It is worth bearing in mind, that the large increase in spinning came at a time when the economic environment was highly uncertain and a number of factors specific to the cotton industry made any form of development surprising. At the turn of the 19th century, France had already been at war for the best part of a decade and was continuously at war during the period of interest. The country had recently emerged from severe hyperinflation and general economic uncertainty was, and continued to be pervasive. With respect to the cotton industry, in 1810, high import tariffs were placed on raw cotton, the price of which was already much higher than in Britain. Finally, cotton did not enjoy particularly favourable government support. The army used exclusively woollen textiles (Grab, 2003) and Napoleon remained highly ambivalent of developments in the cotton industry because of its reliance on imported inputs.

It is particularly interesting to note that cotton was the only textile to flourish in the French Empire during the Napoleonic Wars, despite it being the only textile singularly reliant on an imported input traded via sea-routes. For silks, woollens, linen and hemp there was ample domestic supply of raw material and neighbouring countries also produced significant quantities. This was not the case for cotton wool, and it also explains why Napoleon was never fully supportive of the increase in the spinning capacity in cotton spinning. Heckscher (1922, p. 272) notes " (...) there was no point where the two opposing tendencies of the Continental System were so much in conflict with one another as here; and the reason was, of course, that the industry was based on a raw material which was for the most part unobtainable by other means than by the forbidden route across the seas." On the one hand, increasing domestic production in cotton meant a weakening of Britain's economic advantage, however, the fact that the industry was reliant on an imported input meant that the industry would always remain reliant on sea-borne trade.

This point should be taken into consideration when thinking both about the importance of state support for the cotton industry. Heckscher recounts that Napoleon was constantly trying to find substitutes for cotton. As early as 1809, he declared that "it would be better to use only wool, flax and silk, the products of our own soil, and to proscribe cotton forever on the Continent" (Heckscher, 1922 p. 277). In 1810, he offered a prize of one million francs for the invention of a flax-spinning machine. Even later, in 1811, when the cotton industry faced a severe crisis as a result of the high tariffs put in place in 1810, he banished all cotton goods from the imperial palaces.

2.6.2 The short-run effect of trade protection

My empirical strategy is based on the well-documented fact that trade diminishes dramatically with distance, implying that geographic distance plays a role similar to that of artificial barriers to trade such as tariffs.[56] Geographic distance however is constant over time, making it generally difficult to disentangle the effect of distance from other regional characteristics fixed over time. My empirical strategy exploits the fact that while geographic distance between Britain and French regions did not change during the blockade, the set of possible trading routes did, leading to changes in effective distance between London and a given French region. In this setting, the change in the direction of trade between Britain and France changed effective distance between a given department and London by changing the length of the journey which goods needed to take to reach their final destination. The varying size of the shock to effective distance to London measures the size of trade costs, which drives the variation that can be exploited to estimate the effect of trade

[56] See Head and Mayer (2013) for a recent discussion on the gravity literature.

protection on mechanisation in spinning. This leads to the following specification, similar in spirit to a standard difference-in-difference (DD) estimator;

$$S_{it} = \alpha_i + \delta_t + \gamma lnD_{it} + \epsilon_{it} \tag{2.5}$$

S_{it} is a measure of mechanised spinning capacity in region i at time t, lnD_{it} is a measure of effective distance to Britain in department i at time t, α_i controls for time-invariant fixed effects at the regional level, and δ_t controls for the effect of aggregate shocks over time. γ is the parameter of interest, which we expect to be positive if effective distance to Britain is an important driver of mechanisation.

The unit of observation in the main analysis is the department, which I observe in 1803, prior to the Napoleonic Wars, and in 1812, towards the end of the blockade. There are 88 departments in the sample. Spinning capacity is measured as the number of spindles per thousand inhabitants. Spindles is the standard measure of physical capital in mechanised cotton spinning. The relationship is estimated in levels because of the large number of zeros in the data. In Table 2.6, I show however that the results are robust to using either a log-specification, or the Poisson conditional fixed effects estimator. Spindles are normalised by departmental population to account for the fact that larger departments may increase spinning capacity more in response to the same shock simply because of their size. Effective distance to London in 1803 and 1812 is quantified using the two different measures described in Section 2.5. Standard errors are clustered at the department across all specifications to account for serial correlation. I also estimated Conley's (1999) spatially clustered standard errors. As these were generally smaller, suggesting negative spatial correlation, I report the clustered standard errors across all tables.

The estimation strategy compares outcomes in regions of the French Empire which received a large trade cost shock to regions which received a smaller shock before and after the disruption to trade. Differently to a standard DD strategy, treatment intensity is continuous. Furthermore, the nature of the trade cost shock is such that all units are affected to some extent by the disruption to trade. The latter is not problematic for identification to the extent that the effect of interest is trade protection and not the effect of the blockade itself. Put differently, we are interested in comparing outcomes in mechanised cotton spinning across otherwise similar regions which received higher and lower levels of trade protection. The period of the Napoleonic Wars provides a source of exogenous variation in trading costs which allows us to identify the effect of trade protection on mechanisation. The fact that the effective level of protection from trade with Britain may not be the same as it was prior to the wars anywhere would be a problem only if the effect we wanted to estimate was that of the blockade.

Similarly to a standard DD strategy, identification relies on there being no shocks contemporaneous to and correlated with the trade cost shock. The main concern for identification is that some areas of the French Empire may simply have been more conducive to the new technology. If these variables were correlated with the trade cost shock, and they exerted a time-varying effect on spinning capacity, my identification strategy would be undermined. For this reason, before discussing the estimation results, I begin by examining the extent to which "pre-treatment" firm and departmental level variables differed across areas receiving a lower or higher cost-distance shock. Tables 2.1 and 2.2 divide firms and departments respectively into two groups depending on whether they are above or below the median of the trade-cost shock (defined as the log change in effective distance to London - measure 1). Figures 2.14 and 2.15 also show the spatial variation for a number of these departmental level variables across the Empire.

Reassuringly, for the majority of variables, there is no statistically significant difference in means between the two groups. This is a stronger statement than what is needed for identification in the DD setting, as – conditional on parallel trends – differences in levels do not undermine identification. It does however give us an idea of the extent to which we can think of different regions of the Empire being comparable in terms of their capacity to develop modern industry.

Conscription rates were higher for low trade cost shock departments (at 5%), and population density was higher in high trade cost shock departments (at 5%). In terms of the former, significantly higher conscription rates in low trade-cost shock departments are reassuring for our empirical strategy, as conscription rates are used to control for the effect of a potentially uneven labour supply shock driving mechanisation. The fact that it was the low-trade cost shock departments which had a higher negative labour supply shock works against a factor price confounder driving the results. Population density has been argued to be important for demand side explanations of industrialisation, however, in the empirical analysis, I will control for the time-varying effect of population density and show that results are robust to accounting for these differences.

Turning to firm-level differences, the only statistically significant difference between high and low trade cost shock firms seems to be their age. In particular, high-trade cost shock firms are significantly younger. I return to this issue when examining pre-treatment trends and show that the difference is driven entirely by the time-varying effect of population density, which we have seen is significantly different across the two sub-samples.

Based on the point estimates, firms in low trade cost shock areas seem to have been initially larger, both in term of capital and labour employed, but these differences are not significant. To the extent that low-trade cost shock firms were initially bigger, they seem to have been at an advantage both in terms of better access to raw cotton during the volatile years of the Napoleonic Wars, and in terms of access to a larger market for their output as a result of their size, which works against finding a positive effect on the trade cost coefficient.[57] Taken together, it seems that prior to the Napoleonic Wars, different regions of the Empire were sufficiently similar to make a comparison between them meaningful.

Table 2.3 contains the results from estimating equation 2.5 using both measures of the trade cost. In both cases, the estimated effect of protection is large and statistically significant. The point estimate of 33.11 in column (1), which uses measure 1 based on the shortest route algorithm, implies that moving from the 25th to the 75th percentile of the trade cost shock leads to a predicted increase in spinning capacity per capita that is about the same size as mean spinning capacity in 1812 across departments.

To understand the source of identifying variation, Tables 2.4 and 2.5 present the results from estimating a standard difference in difference specification using the median trade cost shock to define the“large” and “small” trade cost shock groups for both measures of the shock. “Large” and “small” in this setting, corresponds to the the treated and untreated groups in a standard binary DD. For both measures of the trade cost, spinning capacity increases in both groups between 1803 and 1812, but to a significantly larger extent in the case of the high-trade cost shock group. Part of the variation is thus coming from a crude North-South comparison.

Is there variation at a finer level in line with continuous treatment intensity? Columns (2)-(3) and (5)-(6) in Table 2.3 show that indeed, treatment has a continu-

[57] See Section 2.2 for a discussion.

ous effect, and there is sizeable variation even within the North and South of France. Columns (2) and (5) estimate the effect using only the sub-sample of above median latitude departments using the two measures of the trade cost shock, while columns (3) and (6) do the same for the sub-sample of below median latitude departments. In three of the four columns, the estimated effect is positive within the Northern and Southern subsample, and for the Northern departments, both estimates are also statistically significant.

Taking these results together, the variation used to identify the effect of protection on spinning capacity in columns (1) and (4) comes both from large differences in the extent to which Northern and Southern departments scaled up production capacity, but also from variation at a finer level of disaggregation. This strengthens the evidence in favour of differential protection driving the results.

2.6.3 No similar effect on placebo industries

One concern may be that the results are driven by a contemporaneous shock which effected different areas of the Empire differentially, such as a spatially uneven demand shock. To strengthen evidence in favour of the trade cost shock driving the results, Table 2.7 shows that the effect which I find for cotton spinning is not present for two other industries, wool yarn (a direct substitute) and leather. Both products were less intensively traded with Britain, and there was no technological change in either industry. For these reasons, the shock should not have had a significant effect on the spatial distribution of activity.

At the turn of the 19th century, both industries were still very much organised as rural, domestic manufacturing in contrast to mechanised cotton spinning. Mechanisation had not been introduced in the woollen industry because of inherent differences in the fibre which made mechanisation of wool spinning more difficult (Landes, 1969). For this reason, in woollen spinning, the dependent variable is labour employed. As argued previously, wool was not an intensively traded good with the British, and the raw material was also predominantly domestically supplied. Finally, it was an entrenched industry which enjoyed a high level of state support. For example, the army used exclusively woollen products (Bonin and Langlois, 1997). The caveat with using wool spinning is that there may be spillovers from the cotton industry. It is conceivable that in the areas where cotton spinning became widespread, wool spinning was squeezed out.

For this reason, I also collected data on the leather industry. Leather was similarly rurally organised, with some military demand during the period and no significant technological improvement. More than either woollens or cotton, it mostly served local markets and used local supply. Access to water was the one locational constraint making it an ideal industry with which to contrast cotton spinning (Bonin et Langlois, 1997).[58]

Table 2.7 contains the results from estimating the effect of the trade cost shock on capacity in tanning (number of pits), employment in woollen spinning, and, for comparability with the latter, employment in *mechanised* cotton spinning. The estimated effects of the trade cost shock are not statistically different from zero for tanning and woollen spinning, but are large and statistically significant for employment in mechanised cotton spinning.

In the case of capacity in tanning, the positive point estimate is in fact non-negligible. Moving from the 25th to the 75th percentile of the shock leads to a predicted increase in tanning capacity that is equal to about 40% of the mean tanning capacity at the end of the blockade. However, inspection of the scatterplot in Figure 2.12 shows that two departments (Var and Ardennes) are extreme outliers. Dropping these leads to a decrease in the point estimate from 0.28 (se 0.21) to 0.03 (se 0.11), which is basically a zero effect.

Consistent with a negative spillover from cotton to woollen spinning, the point estimates in Columns (3) and (4) are negative, albeit not significant. Moving from the 25th to the 75th percentile of the shock leads to a decrease in spinning employment that is about 20% of mean employment in woollen spinning at the end of the blockade. The point estimate is also less sensitive to outliers. Repeating the same exercise of dropping the two largest outliers, the estimated coefficient decreases marginally in absolute value from -2.23 (se 2.92) to -2.07 (se 2.01).

The estimated effect on mechanised cotton spinning is large and significant consistent with previous results, though not quite as large as the effect estimated for capital. Moving from the 25th to the 75th percentile of the shock leads to an increase

[58] There are three further considerations which should be taken into account when interpreting the results. First, in the case of both industries, the pre-blockade data point comes from industrial surveys carried out directly after the French Revolution in 1789. Second, in both cases, data from the pre-Napoleonic period are generally worse quality simply because the questionnaires were more qualitative in nature. Third, because in this case the first datapoint is from the 1790s (before France's territorial expansion), the sample is restricted to the territory of "ancien regime" France.

in predicted spinning capacity which is equal to about 75% of the mean employment in mechanised spinning at the end of the blockade. The finding that the effect on employment is smaller than the effect on capital (at least in terms of the point estimates) is plausible, as capital should expand to a greater extent than labour at a time when increasingly capital-intensive machines were being developed.[59]

2.6.4 Robustness to potential confounders

I now turn to addressing a number of important potential confounders. One important concern is that of a potentially asymmetric shock to raw cotton prices on the input side. Differently to cotton yarn, the source of raw cotton was not Britain, but other countries.[60] For this reason, imports of raw cotton were not resisted, and the French attempted to secure access to raw cotton using the same trading routes as before the blockade. The general difficulty of sea transportation meant however, that the trading routes became more risky and hence more costly. This drove up the price of raw cotton, but in a symmetric fashion across the Empire.

Figure 2.13 shows that for all four varieties of raw cotton in use across the French Empire, prices increased markedly during the Napoleonic Wars, but the shock was symmetric in the North and the South. In the case of Brazilian cotton, where one specific variety (Pernambuco) can consistently be matched to London prices, it is also clear that French prices increased to a greater extent than the British. All else equal, this negatively affected French competitiveness, and explains why exports of cotton goods did not increase until after the end of the Napoleonic Wars – a point to which I return in the next section.

Departmental fixed effects capture all unobservables constant over time. In Table 2.8, I show that the results are robust to controlling for the time-varying effect of a number of variables which may plausibly effect the adoption of mechanised technology. Across all columns, the coefficient of interest remains highly significant and relatively stable in size.

In Columns (2) and (3), I examine the time varying effect of location fundamentals such as access to fast-flowing streams and coal deposits. The literature has argued that both these variables were important determinants of the location of

[59] If the two largest outliers are dropped, the estimated coefficient remains large and statistically significant. The point estimate decreases from 0.93 (se 0.39) to 0.65 (se 0.29).

[60] In particular, the French used raw cotton from four sources; the Levant, Brazil (by way of Portugal), the US and cotton from colonial sources.

the cotton industry. Recently, Crafts and Wolf (2012) have found that in Britain, access to fast flowing streams was a particularly important factor in Lancashire's dominance of the British cotton industry. In this setting, neither have a statistically significant effect, more importantly the point estimate for effective distance is left virtually unchanged. In the case of coal, the result is not particularly surprising, as steam-power only began to play a more important role in cotton in later decades of the 19th century. Figure 2.14 shows that access to water power was available across various parts of France, and as such, it may not have been a particularly important determinant for where the industry would locate.

Column (4) controls for the time-varying effect of downstream weaving. Given the importance of local markets at the early stages of development discussed in Section 2.2, one worry is that mechanisation is simply being driven by demand from downstream weaving. For this reason, I add weaving capacity in 1803 (normalised by population) interacted with the time dummy, to control for the demand side of the market. As expected, the coefficient is positive and significant, implying that for the same trade cost shock, higher weaving capacity led to a larger predicted increase in mechanised spinning capacity. The effect of the trade cost shock remains large and statistically significant, though the point estimate decreases somewhat in size.

How should we think about the downstream result? It is clear from column (4) that weaving mattered somewhat, but the results are not driven simply by the demand side. This did not imply that increases in mechanised spinning had to lead to a proportionate increase in downstream weaving. Recall that hand-spinning was still sizeable in France at the time, and thus expansion in mechanisation did not have to lead to a simultaneous expansion in weaving. This was the case even if all demand was local, as smaller weaving centres which received a larger shock could have increased capacity in mechanised spinning by replacing hand-spinning.

Column (5) uses a slightly different measure of downstream demand, which encompasses all aspects of the production process for cotton cloth as of 1789. As such, it is only available for France at its pre-revolutionary borders. This measure contains the size of the hand-spinning of cotton yarn, and thus captures the extent to which prior experience in hand-spinning was important for mechanisation. The estimated coefficient on the time varying effect of the historical location of cotton spinning is positive and significant, but the size and significance of the effect of the trade cost is unchanged.

Columns (6) and (7) control for the time varying effects of population density and urbanisation. Both measure the strength of agglomeration based explanations in determining the location of mechanised spinning. Population density is indistinguishable statistically from zero, while urbanisation enters with a positive and significant coefficient. In both cases, the estimated effect of the trade cost shock remains large and significant.

Column (8) explores robustness to adding a measure for human capital across departments interacted with the time dummy. Human capital is measured as the proportion of men able to sign their wedding certificates by department as reported in Furet and Ozouf (1982). The estimated coefficient is large and highly significant, which is somewhat surprising as other studies have struggled to find an important role for human capital measured in this way, at the onset of industrialisation (Squicciarini and Voigtländer, 2014). The coefficient of interest remains highly significant and the point estimate increases somewhat in size.

In Column (9), I address a particularly important confounder - the role of factor price shocks. In Section 2.2, I discussed the factor price hypothesis as one of two prominent alternative explanations for the slow diffusion of spinning technology across France. According to this hypothesis, labour was relatively expensive in Britain and cheap in France rendering capital biased technological change profitable in the former, and adoption of the new technology unprofitable in the latter (Allen, 2009).

Given this argument, an uneven factor price shock across the French Empire may have rendered adoption of the new technology relatively more profitable in some regions rather than others. During the Napoleonic Wars, conscription was consistently high, and somewhat uneven across departments (Forrest, 1989). This is precisely the type of negative labour supply shock which could drive up wages and push cotton spinners into substituting expensive labour for cheaper capital. For this reason, I collected statistics on conscription by department from Hargenvilliers (1937), and in Column (9), I add a control for the time-varying effect of conscription rates in 1804-05. The point estimate for the trade cost shock is virtually unchanged. The effect of conscription, while statistically indistinguishable from zero, has the the expected positive sign.

As a further robustness check for factor price shocks, in Figure 2.19, I show that the shock does not differentially effect capital-labour ratios across departments in a systematic way. More sophisticated machines with a larger number of spindles substituted for relatively more labour, and thus an uneven factor price shock across the French Empire should alter the capital-labour ratio at the departmental level even within mechanised cotton spinning. Figure 2.19 shows that this is not the case. The estimated elasticity is small, it has the wrong sign, and is not statistically significant (point estimate -0.09, se 0.24).

In Column (10), I control for the time varying varying effect of institutional change using the approach developed by Acemoglu et al. (2011). In their study, the authors show that regions of Germany which received the institutional reforms of the French either through annexation or conquest, grew faster throughout the 19th century. In my setting, conquest by France meant annexation, and thus complete adoption of French institutions. For this reason, I use the date of annexation for each department, interacted with the time indicator, to control for the effects of institutional change. Departments belonging to France at the time of its 1789 borders are coded as receiving institutional change in that year. The point estimate on the effect of the trade cost is left virtually unchanged and remains highly significant, while institutional change enters with the expected negative sign,[61] but is statistically indistinguishable from zero. Finally, the most demanding test for robustness of the effect of the trade cost is the simultaneous inclusion of all time-varying controls. Column (11) shows that the estimated effect remains similar in size when all controls are added.[62]

2.6.5 Adjustment on the extensive margin

If learning externalities are indeed important, we would expect a substantial proportion of the expansion in spinning capacity to occur at the extensive margin. A large intensive margin raises the issue that perhaps the results are being driven by effects internal to the firm. Furthermore, if a couple of large firms are expanding in effected departments, it is harder to argue that firms don't internalise a substantial proportion of learning gains. Exploiting the fact that firm level data is available for

[61] Being annexed to France at a later date, at least according to this view, is bad for mechanisation. It should also be noted that the effect of institutional change cannot separately be identified from the effect of incorporation into a larger internal market.

[62] In Column (11), I drop institutional change which is highly correlated with the time indicator. The small sample size makes separate estimation of the two infeasible once other explanatory variables are added. Results are robust to dropping the time indicator instead of the institutional variable.

the initial period of the Napoleonic Wars, in particular during the North Sea blockade (1803-1806), I examine the extent to which adjustment to the shock occurred at the intensive and extensive margin. In Table 2.9, I begin by estimating the effect of the trade cost shock at the departmental level for the period 1803 - 1806 (Columns (1) and (4)). The effect is large and statistically significant (point estimate: 7.96, se 2.24 - contrast this to point estimate 33.11, se 9.78, estimated for 1803-12).

I take spinning capacity at the departmental level in 1806, and divide it into an intensive and extensive margin by using firm level information on spinning capacity at both points in time. I then estimate the effect of the trade cost shock on the extensive and intensive margin separately. I find that the extensive margin is highly significant and the attributed effect accounts for almost the entire combined effect (point estimate 6.84, se 1.81). In contrast, the effect on the intensive margin is small and statistically indistinguishable from zero (point estimate 1.119, se 0.822). To the extent that this pattern is representative for the full period, the evidence is strongly suggestive of the fact that the driving force behind increasing capacity in mechanisation was not driven by characteristics internal to firms alive in high-trade cost shock areas in 1803.

2.6.6 No differential investment in machine type

In Table 2.11, I use information on the type of machines in use in each department to estimate whether the trade cost shock differentially affected the type of machines firms used. The data allows me to differentiate between two types of machines "filatures continus" and "mull-jennys". The former were less modern machines, with fewer spindles on average per machine, and they were mainly used for spinning less fine yarn. To the extent that larger investments in the North during the Napoleonic Wars also entailed upgrading into more modern and capital-intensive machinery, the long term results which I find in the following section could be driven by investment decisions made within the firm. To the contrary, I find that the trade cost shock had no differential effect on the proportion of newer type machines in a given department.

2.6.7 No pre-treatment trends

Finally, I turn to addressing the question of differential pre-treatment trends. In the absence of similar data for this period, I have constructed an approximation to spindles in 1794 using firm level data from 1806. I take spinning capacity in 1803 for firms alive in 1794 as an approximation to actual spinning capacity at the departmental level in 1794, which I don't observe. Of course, this assumes that all growth in spinning capacity took place on the extensive margin and that firms didn't go bankrupt, neither of which are likely to hold. However, to the extent that results from the period 1803-06 are representative more generally, we should expect the extensive margin to be the main channel of adjustment.

Table 2.10 contains the estimation results for the period 1794-1803, which I contrast to the main results for 1803-12. The estimated coefficient for the period 1794-1803 without controls is small, positive and marginally significant at 10% (estimated coefficient: 5.53, se: 3.054). The confidence intervals for 1794-1803 are non-overlapping. More importantly, adding the same time-varying controls as in the previous section changes the sign of the estimated coefficient, and it is no longer significant at conventional levels. Population density seems to be the omitted variable which is driving the result in column (1). As was shown earlier, population density was significantly higher in high trade cost shock departments. Once the time-varying effect of population density is controlled for, the trade cost has no statistically significant effect in the pre-treatment period, while the effect is large and statistically significant for the period of the Napoleonic Wars.

2.6.8 Discussion

Taking all results together, though different regions of the French Empire were not identical prior to the Napoleonic Wars, they seem to have been sufficiently similar to expect that all else equal, a number of different regions could have developed mechanised cotton spinning on a large scale given sufficient protection from British competition. The finding that increased trade protection led producers to scale up in the new technology is by no means obvious. While it is true that a standard Ricardian-model without market imperfections would also predict that short-run protection increases production in the import-competing sector, the fact that two technologies were available for spinning cotton yarn makes the short-run result interesting in its own right. To the extent that it was factor price differences which rendered the adoption of mechanisation unprofitable in France, all else equal, the trade cost shock should have had no effect on mechanisation. The fact that it did, is the first piece of important evidence underpinning an infant industry mechanism at work. In the next section, I examine the extent to which temporary trade protection increased productivity in line with the prediction of an infant industry mechanism.

2.7 Long-term Empirical Strategy and Results

The previous section established that the trade cost shock had a positive impact on mechanised cotton spinning across the French Empire during the Napoleonic Wars. An infant industry mechanism would predict that, given sufficient temporary protection, the industry should survive competition at free trade prices once protection is removed. When the blockade ended in 1813, the traditional North-South direction of trade between Britain and Continental Europe was restored. Trade between Britain and France however was inhibited by high tariffs, making testing the competitiveness of cotton spinning slightly more complicated.

On the one hand, imports of British cotton yarn had been prohibited prior to the Napoleonic Wars, but as we saw in previous sections, the policy was highly ineffective until the Napoleonic Wars drove up trade costs between the two countries. In this regard, examining whether French spinners could survive competition at levels similar to pre-Napoleonic War years would be evidence of productivity gains, but it would not show that the industry had become competitive at free trade prices. For this reason, I also examine exports of French cotton goods, as this tests competition between Britain and France at international prices.

It is worth bearing in mind that aside from returning to pre-blockade levels of competition across France, the post-war years were generally difficult for the cotton industry. The dissolution of the French Empire proved tumultuous with fighting taking place within the borders of France. Many spinning mills reported having to stop production as a result of the invasion by foreign troops. The peace settlement restored the borders of France to their 1789 levels, contracting the size of the internal market for producers who remained within France.

2.7.1 Within country persistence and productivity outcomes

In this section, I examine long-term within country outcomes along two dimensions. An infant industry mechanism would predict that productivity increases as a result of temporary trade protection. If that is the case, then there should be persistence in the location of activity. Furthermore, firm productivity should increase in post-blockade spinning capacity.

Examining persistence in the location of spinning activity tests two somewhat distinct forces. First, for a sufficient increase in productivity, follower regions should survive increased competition from the frontier. In this setting, this translates into asking whether Northern regions which scaled up capacity during the wars were able to survive increased competition from Britain after the blockade ended. Second, as was shown in the theoretical framework, for a sufficient increase in productivity, follower regions can integrate. If firms in Southern regions along the border with France went bankrupt as a result of increased competition during the blockade, activity may not return to pre-blockade levels of production once the blockade ends, if Northern regions become sufficiently productive to compete in these markets. A return to pre-blockade levels of production would weaken persistence.

Taking the two forces together, finding persistence according to this mechanism is reliant on sufficient productivity increases. From an empirical point of view however, the fact that other mechanisms also generate persistence and higher productivity in areas with a larger concentration of activity makes identification a challenge in most settings. In particular, firms tend to locate in areas which are conducive to a particular type of activity. As locational fundamentals such as geography change slowly, if at all over time, disentangling lock-in effects from these types of locational fundamentals is an important empirical challenge.

The setting of the post-blockade cotton spinning industry provides a rare opportunity to disentangle the two effects. My identification strategy relies on the results established in the previous section showing that the post-blockade location of mechanised cotton spinning was determined to a large extent by the historical accident of the Napoleonic Wars. This provides a source of exogenous variation in the location of cotton spinning which makes it possible to identify persistence resulting from lock-in effects and productivity as a function of the scale of the industry.

To examine the effect of the post-blockade location and size of mechanised cotton spinning on persistence and productivity, I estimate the following equation

$$Y_{i(j)t} = \alpha + \beta S_{i(t-1)} + \gamma' x + \eta_{i(j)t} \tag{2.6}$$

where $Y_{i(j)t}$ is the departmental (i) or firm level (ij) outcome in 1840, $S_{i(t-1)}$ is a measure of the size of mechanised cotton spinning at the departmental level in 1812 and x is a vector of controls. We are interested in understanding whether the size of cotton spinning activity at the departmental level and the productivity of firms in a given department are affected by the post-blockade size of the industry. The worry is that $S_{j(t-1)}$ is correlated with unobservable that make some locations more attractive than others. Instrumenting the size of the post-blockade cotton spinning sector with the trade cost shock defined in the previous section solves the endogeneity problem as it only uses variation in the size of spinning activity determined by the historical accident of the Napoleonic Wars. Validity of the instrument relies on the trade cost shock being uncorrelated with unobservables which affect the location of mechanised spinning and firm productivity.

To take these predictions to the data, I use firm level observations on cotton spinning firms from the first industrial census of French firms which was conducted in 1840.[63] I measure the productivity of the firm as the log of the value of output per employee. The size of cotton spinning activity at the departmental level is measured by aggregating the firm level value of output up to the departmental level. The size of mechanised cotton spinning at the departmental level after the blockade is measured as the number of spindles in the department in 1812. Both measures of the size of the industry are normalised by departmental population to account for differences in the size of departments.

Table 2.12 contains the results from estimating the persistence in the location of cotton spinning. Both the OLS and 2SLS results point to a strong, positive effect of the post-blockade size of cotton spinning activity on the size of cotton spinning 30 years later. Columns (1) and (3) estimate the OLS and 2SLS effects using the specification in equation 2.6 without controls, while columns (2) and (4) add a number of controls measured at the departmental level. The estimated effects are large; a one standard deviation increase in the size of mechanised cotton spinning in 1812 leads to a 0.75 standard deviation predicted increase in the value of production in 1840.

Columns (2) and (4) add controls for a number of other drivers of persistence. In particular, I control for two potentially important sources of location fundamentals for cotton spinning; access to coal and fast flowing streams, and agglomeration

[63] Appendix A discusses this source in more detail.

effects measured using log-population density and urbanisation rates, each defined at the departmental level. I also add a measure of human capital. All controls are measured at their pre-blockade level as contemporaneous values would arguably be bad controls. Measurement error will attenuate the OLS estimates towards zero, while positive omitted variable bias from the endogeneity of locational choice will tend to bias the OLS estimates upwards. The 2SLS estimate is smaller than the OLS estimate in the specification estimated without departmental controls, while the opposite is true when controls are added. This is accounted for by the effect of one observation (Haut-Rhin) which, when dropped, gives 2SLS estimates which are consistently larger than the corresponding OLS estimates.

Table 2.13 contains the results from estimating the effects of the size of spinning capacity at the end of the blockade on firm productivity in mechanised cotton spinning 30 years later. Both the OLS and 2SLS results show that firms with larger spinning capacity in 1812 have more productive firms 30 years down the line. Columns (1) and (3) of Panel A contain the OLS and 2SLS estimates respectively using only firm level controls, while Columns (2) and (4) add departmental controls. The estimated effect is large and statistically significant, with the 2SLS estimates being larger in size than the OLS estimates. The coefficient in column (4) implies that a one standard deviation increase in spinning capacity per capita in 1812, leads to a 1.3 standard deviation predicted increase in productivity in 1840.

The firm level controls are the size of the firm (proxied using the log of primary materials used), the share of women and children in total labour employed and binary indicators for whether the firm uses coal or water power. Departmental controls include controls for urbanisation, log-population density and human capital.

Together, these results show that the trade cost shock had long term effects consistent with the predictions of the theoretical framework that worked through the increase in the size of spinning capacity. Despite having relatively similar conditions prior to the Napoleonic Wars, regions of France diverged dramatically even after peace was restored to the Continent. Consistent with learning externalities leading to location lock-in, spinning activity in the South of France remained low despite the fact that between 40% and 70% of French exports of cotton goods was destined for Mediterranean markets after the end of the Napoleonic Wars. Proximity to export markets arguably gave firms an incentive to locate in these regions, but it seems the forces of an established industry in the North outweighed these benefits.

Given the tariffs in place on imports of cotton goods, one may wonder whether the industry simply became sufficiently competitive to survive increased competition on internal markets, but not necessarily competition at international prices. In the next section I examine competitiveness at international prices using export data.

2.7.2 Competitiveness in export markets

In order to investigate whether some firms had become sufficiently productive to compete at international prices, Figure 2.16 examines outcomes at international prices. Panel A charts the evolution of the value of exports of cotton goods from France at constant prices. The data are somewhat imperfect, as French trade statistics did not differentiate between exports and re-exports until the mid-1820s and the classification of goods often changes from one year to the next.

In Panel A, data is constructed conservatively with respect to the positive slope of exports over time. Until the 1820s, French trade statistics did not differentiate between exports and re-exports. Most exports prior to 1803 were likely to have been re-exports, as France was a net importer of cotton goods at this time and not competitive in yarn. This will understate the increase in exports after the Napoleonic Wars, as I do not include re-exports in my measure once they have been separated. Furthermore, I omit exports to French colonies, as these regions were a protected market for French goods.

Exports of cotton goods increased sharply after the blockade ended in 1813, and the upward trend continued well into the 1820s when my data ends. By 1828, 7.5% of France's exports were in cotton goods showing the increasing importance of the sector in the French economy. As was the case at the end of the 18th century in Britain, as the industry developed, cotton yarn itself began to be exported. For the French, cotton yarn entered export statistics as a distinct category in 1822.[64] Six years later, the quantity exported had almost tripled.

It may be somewhat surprising that exports did not increase during the Napoleonic wars as producers in the French Empire were scaling up production. There seem to be two reasons for this. First, exports of cotton yarn were prohibited initially as result of lobbying from the downstream sector. Second, high raw cotton prices

[64] The British first stated exporting yarn in 1794, by which time 8% of British exports were made up of cotton goods. The French thus seem to have entered export markets in yarn when their cotton industry was at a similar level of development.

within the French Empire – a result of high trade costs and high import tariffs on the raw cotton – rendered producers uncompetitive in export markets. Prefectural reports claim that producers would be competitive in export markets if they had access to raw cotton at the same price as the British. It seems that this was indeed the case, as exports increased as soon as the blockade drew to a close in 1813 and raw cotton prices returned to levels similar to those in Britain. The almost immediate increase in exports is all the more striking as the period coincided with invasion by foreign troops and the dissolution of the Empire. The first disrupted production, while the second led to prominent cotton spinning regions, such as the Belgian departments, leaving the French Empire. Both factors would tend to decrease export potential, while the decrease in trade costs as the blockade ended would tend to promote exports to the extent that producers are competitive at free trade prices.

Panel A thus shows that some firms had become competitive at international prices during the years of the Napoleonic Wars. Panel B examines whether the dramatic lowering of tariffs later in the century affected exports of cotton goods. Harrison and Rodríguez-Clare (2010) argue that trade protection should have an asymmetric effect on exports when infant industry mechanisms are at work. In particular, while the imposition of tariffs should increase exports, the removal of tariffs should have no similar effect on exports if the firms are competitive at free trade prices. Panel B shows that this is indeed the case. The Cobden-Chevalier treaty, signed in 1860 by Britain and France, dramatically decreased tariffs on all French imports, but this had no discernible effect on French exports of cotton goods.

2.7.3 Cross-country comparison

Was the adoption of mechanised cotton spinning and the emergence of a competitive cotton sector simply a matter of time for Continental countries? Figure 2.17 shows evidence to the contrary. As late as 1851, there were two countries, France and Belgium – both part of the French Empire up to 1815 – that had a higher level of cotton spinning activity than other countries. Figure 2.17 follows the evolution of raw cotton usage per capita for various Continental European countries between 1830-50. Raw cotton measures the size of the industry as it is a raw input used solely in the production of cotton yarn spinning.

The size of the industry across Europe in 1850, over 30 years after the end of the blockade was much smaller in all other countries. Note in particular Sweden, Britain's most consistent ally throughout the Napoleonic Wars and a key smuggling centre for British products, which had no cotton spinning to speak of, even in 1850. Note also the time series for the Dutch, as well placed by their proximity to Britain as Belgium and Northern-France to benefit from technology flows, but less well protected during the Napoleonic Wars. The Dutch and Belgian regions were in fact one country between 1815-1830 giving them an even closer source of technology after 1815. With institutions that rivalled Britain's, they are as close to an ideal counterfactual as one could hope. The fact that they have a very small cotton industry according to the data and in line with other historical evidence (Mokyr, 1976), is strong evidence against the claim that technological catch-up was inevitable.

Perhaps however France and Belgium were different to other Continental countries in the sense that they had an underlying latent comparative advantage in cotton spinning, while other countries specialised in other sectors. Evidence comparing early and late industrialisers in Figure 2.18 suggests that in fact, developing a sizeable cotton spinning sector was an event closely related to the timing of industrialisation in general. Panel A reproduces Figure 2.17 for two early and two late industrialisers in Continental Europe; Belgium and France, and Germany and the Netherlands. As can be seen, up to 1850, Belgium and France had larger cotton spinning sectors than the other two countries. At this time, industrialisation in the former was well under way, while it had not really started in the latter group. By the end of the 19th century, when both Germany and the Netherlands were industrialising, their cotton spinning sectors had overtaken that of France and in the case of Germany, also that of Belgium. What this suggests is that cotton spinning was an industry in which most countries specialised at an early stage of structural transformation in much the same way as 20th century developing countries initially specialised in unskilled labour intensive textile manufacturing before moving into more sophisticated goods. The takeaway is not that cotton caused industrialisation in different countries, but rather that cotton spinning was common to the process of industrialisation across Western Europe. What this means is that it was not the case that France specialised in cotton and Germany specialised in another equally important textile rendering the cross-country comparison in raw-cotton usage meaningful.

2.8 Conclusion

This chapter has documented a sequence of events which suggests that in some settings, temporary trade protection can foster growth in some industries. The preceding analysis has shown that starting from a comparative disadvantage in cotton yarn spinning vis-vis Britain, regions of the French Empire which became better protected from trade with Britain during the Napoleonic Wars increased capacity in mechanised cotton spinning to a larger extent than regions which received a smaller trade cost shock. Consistent with infant industry models, the location of spinning activity showed strong persistence over time, and regions which had higher post-blockade capacity in spinning had more productive firms 30 years later. In line with competitiveness at international prices, exports of cotton goods increased substantially, and by 1830, 7.5% of France's exports were in cotton goods. The results from this chapter show that the infant-industry mechanism highlighted by a class of models in endogenous growth theory (Krugman 1987, Lucas 1998, Matsuyama 1992 and Young 1991) can be empirically important.

What do the findings from this episode teach us about the effect of trade on development more generally? An appealing aspect of this episode is the extent to which it is general to the setting of structural transformation. For many of today's developed countries, unskilled-labour intensive textile manufacturing was the first industry into which labour flowed from agriculture at the early stages of industrialisation. The findings of this chapter suggest that market imperfections which drive infant industry mechanisms may be at work in these types of settings.

This does not imply that trade policy will necessarily be an effective or desirable tool when implemented by a policy-maker targeting specific sectors. One reason why temporary protection may have had a large effect in France is that cotton yarn spinning was a well-established industry with a sizeable downstream sector spread widely across the Empire. Furthermore, many of the initial conditions which seem to be important for modern manufacturing seem to have been in place across large parts of the country prior to the Napoleonic Wars.

In the absence of these initial conditions, infant industry protection can turn out to be a blunt tool. Recent evidence suggests that instead of "hard" interventions (Harrison and Rodríguez-Clare, 2010) which distort prices to deal with market imperfections such as trade policy, "soft" industrial policies which deal directly with the market imperfection, while maintaining or increasing competition within a sector can increase productivity (Aghion et al, 2012). However, this reasoning implicitly assumes that policy-making is free from political capture, which, unfortunately, is not always the case.

2.A Tables

Table 2.1: Pre-treatment comparison of firm level variables

	Low trade cost shock	High trade cost shock	Difference	N
Spindles	2444.24	1007.65	-1436.59	304
	(1051.13)	(280.37)	(1087.87)	
Employees	75.96	47.54	-28.42	296
	(15.40)	(14.65)	(21.25)	
Capital labour ratio	25.11	30.52	5.41	294
	(4.50)	(3.82)	(5.90)	
Age	9.04	4.71	-4.34**	303
	(1.86)	(0.63)	(1.96)	
Quality yarn	39.37	45.66	6.30	208
	(4.18)	(3.67)	(5.56)	
Proportion mule jenny	0.38	0.40	0.02	304
	(0.13)	(0.13)	(0.18)	

Notes: Low and high trade cost shock are defined at the departmental level. A department is assigned to one or the other group depending on whether their trade cost shock is above or below the median. Spindles and employees is the number of spindles and workers employed at the firm level, the capital to labour ratio is calculated (in levels) as the ratio of the two former variables, quality of yarn spun gives the maximum count yarn spun by the firm (quality and fineness of yarn increases in its count). The capital labour ratio has less observations than both spindles and employees because two firms report zero workers, and for these, the variable is undefined. The observations for quality of yarn is low, because Belgian departments report their quality numbers according to a different scale and these are dropped. The proportion of mule jennys gives the proportion of mule jennys (high quality) to other types of machines (lower quality). Robust standard errors clustered at the department in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 2.2: Pre-treatment comparison of departmental level variables

	Low trade cost shock	High trade cost shock	Difference	N
Spindles	11.67	9.95	-1.72	88
	(5.87)	(2.82)	(6.51)	
Weaving	1.43	4.07	2.64	88
	(0.68)	(1.81)	(1.93)	
Historical cotton	0.023	0.031	0.008	70
	(0.007)	(0.010)	(0.013)	
Access to coal	5.25	5.53	0.28	88
	(0.15)	(0.24)	(0.28)	
Access to streams	1.24	1.88	0.64	88
	(0.19)	(0.49)	(0.53)	
Literacy	0.42	0.47	0.05	63
	(0.04)	(0.04)	(0.06)	
Conscription rate	1.51	1.33	-0.18**	86
	(0.05)	(0.05)	(0.07)	
Institutional change	1790.89	1790.43	-0.45	88
	(0.71)	(0.41)	(0.82)	
Urbanisation rate	0.07	0.08	0.01	66
	(0.02)	(0.01)	(0.02)	
Population density	52.61	69.25	16.64**	88
	(3.83)	(5.94)	(7.07)	

Notes: Low and high trade cost shock are defined at the departmental level. A department is assigned to one or the other group depending on whether their trade cost shock is above or below the median. Departmental variables: *Spindles* and *Weaving* are the number of spindles and weaving frames per thousand inhabitants; *Historical cotton* is a measure of historical cotton spinning at the departmental level. It is the number of districts supplied by the given department per thousand inhabitants in 1789. *Access to coal* is defined as the log transformation of the inverse distance to the nearest coalfield; *Access to fast-flowing streams* is defined as the (log) departmental average of mean water-flow rates; *Literacy rate* is defined as the proportion of men able to sign their wedding certificate in 1786-90; *Conscription rate* is the number of conscripts per thousand inhabitants in 1804-05; *Institutional change* is measured as the date of incorporation into the French Empire; *Urbanisation* is the share of population living in cities with more than 5000 inhabitants; *Population density* is defined as inhabitants per square km. Further details on variables and their definition can be found in Appendix A. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 2.3: Baseline specification using two different measures of trade costs

	Trade cost (measure 1)			Trade cost measure 2		
	(1)	(2)	(3)	(4)	(5)	(6)
DepVar Spindles	Full sample	North France	South France	Full sample	North France	South France
Trade cost (meas. 1)	33.11***	33.82*	-2.075			
	(9.775)	(17.11)	(3.795)			
Trade cost (meas. 2)				58.76***	92.89***	13.99
				(14.15)	(33.24)	(12.13)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Departmental FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	176	88	88	176	88	88
R-squared	0.337	0.376	0.056	0.406	0.456	0.075
Number of departments	88	44	44	88	44	44

Notes: Dependent variable is spindles per thousand inhabitants. Columns (1)-(3) use the shortest route algorithm to measure trade costs between London and the department (measure 1), Columns (4)-(6) use weighted distance to measure the same. Columns (1) and (4) contain the full sample. Columns (2) and (4) restrict the sample to above median latitude departments, Columns (3) and (6) restrict the sample to below median latitude departments. Robust standard errors clustered at the department in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 2.4: Binary DD using the median trade cost shock as a cutoff (measure 1)

Depvar Spindles	Pre-war	Post-war	Difference
Large shock	9.95	51.73	41.78***
	(2.82)	(12.15)	(10.42)
Small shock	11.67	18.92	7.25*
	(5.87)	(7.31)	(3.62)
Difference	-1.72	32.81**	34.53***
	(6.51)	(14.18)	(11.00)

Notes: Dependent variable is spindles per thousand inhabitants. The sample is split in two at the median trade cost shock and this gives the definition for large and small trade cost shock. Robust standard errors clustered at the departmental level in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 2.5: DD using the median trade cost shock as a cutoff (measure 2)

Depvar Spindles	Pre-war	Post-war	Difference
Large shock	10.39	52.53	42.13***
	(2.80)	(12.17)	(10.40)
Small shock	11.22	18.12	6.90*
	(5.88)	(7.35)	(3.57)
Difference	-0.83	34.40**	35.23***
	(6.51)	(14.14)	(10.97)

Notes: Dependent variable is spindles per thousand inhabitants. The sample is split in two at the median trade cost shock and this gives the definition for large and small trade cost shock. Robust standard errors clustered at the departmental level in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 2.6: Poisson fixed effects and OLS with log-specification

	Trade cost measure 1		Trade cost measure 2	
	(1)	(2)	(3)	(4)
DepVar Spindles	Poisson	OLS	Poisson	OLS
Trade cost (meas. 1)	0.495**	0.557***		
	(0.214)	(0.189)		
Trade cost (meas. 2)			1.039***	1.220***
			(0.319)	(0.259)
Time FE	Yes	Yes	Yes	Yes
Departmental FE	Yes	Yes	Yes	Yes
Observations	176	176	176	176
R-squared		0.254		0.323
Number of departments	88	88	88	88

Notes: Dependent variable in the Poisson fixed effects specification (Columns (1) and (3)) is spindles per thousand inhabitants. In the log specification it is ln(1+spindles per thousand inhabitants). Columns (1) - (2) use the shortest route algorithm to measure trade costs between London and the department (measure 1), Columns (3)-(4) use weighted distance to measure the same. Robust standard errors clustered at the department in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 2.7: Falsification test using wool and leather

	Tannery		Wool spinning		Mechanised cotton spinning	
	(1)	(2)	(3)	(4)	(5)	(6)
DepVar	Pits	Pits	Labour	Labour	Labour	Labour
Trade cost (meas 1)	0.279		-2.228		0.930**	
	(0.215)		(2.919)		(0.390)	
Trade cost (meas 2)		0.592		-4.85		1.880***
		(0.420)		(5.334)		(0.608)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Departmental FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	122	122	152	152	176	176
R-squared	0.056	0.019	0.194	0.200	0.112	0.153
Number of dept	61	61	83	83	88	88

Notes: The dependent variable in columns (1) - (2) is pits per thousand inhabitants employed in leather tanning (measure of capital), in columns (3)-(4) it is workers employed in woollen spinning and in columns (5)-(6) it is workers employed in *mechanised* cotton spinning. Column (1), (3) and (5) use the shortest route algorithm to measure trade costs between London and the department (measure 1), Columns (2), (4) and (6) use weighted distance to measure the same. Robust standard errors clustered at the department in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 2.8: Robustness to the addition of other variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
DepVar Spindles											
Trade cost	33.11***	33.19***	34.69***	22.33***	34.41***	25.75***	39.87***	41.50***	33.56***	33.00***	27.92***
	(9.775)	(9.985)	(10.38)	(6.984)	(10.23)	(8.883)	(11.75)	(12.44)	(9.600)	(9.715)	(7.298)
Streams		-0.261									-0.973
		(1.162)									(2.226)
Coal			-4.571								3.072
			(3.723)								(3.557)
D.stream				3.303***							2.273***
				(0.522)							(0.437)
Hist. cott.					523.2***						303.8
					(155.5)						(185.2)
Pop. density						20.88					4.954
						(13.79)					(20.58)
Urbanisation							146.3*				58.20
							(78.12)				(65.24)
Human cap.								49.25**			53.41***
								(21.32)			(17.31)
Conscription									4.411		14.94
									(11.94)		(13.30)
Institution										-0.853	
										(0.824)	
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Departmental FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Observations	176	176	176	176	140	176	132	126	172	176	118
R-squared	0.337	0.337	0.347	0.576	0.539	0.356	0.400	0.426	0.338	0.340	0.722
Number of dept	88	88	88	88	70	88	66	63	86	88	59

Notes: Dependent variable in all columns is the number of spindles per thousand inhabitants. The trade cost shock is measured as the log change in the shortest route between London and each department (measure 1). Controls are defined as follows (all controls interacted with the post-treatment time indicator); Streams: log of the mean stream-flow of rivers in the department (m^3/s). Coal: log-proximity to coal. Dstream: number of weaving frames in the department per thousand inhabitants in 1803. Histcott: measure of the size of the cotton industry in the department in 1789. Pop density: log of inhabitants per square kilometre. Urbanisation: share of population living in cities with above 5000 inhabitants. Human capital: proportion of men who are able to sign their wedding certificate. Data availability constraints on this measure restrict the sample size to 63. Conscription: proportion of the population conscripted in 1804-1805. Institutional change: date of incorporation into the French Empire. For data sources see Appendix A. Robust standard errors clustered at the department in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 2.9: Extensive vs intensive margin of firm level adjustment 1803-06

Spindles per thousand inhabs	(1) total	(2) ext	(3) int	(4) total	(5) ext	(6) int
Trade cost (measure 1)	7.962***	6.843***	1.119			
	(2.243)	(1.815)	(0.822)			
Trade cost (measure 2)				14.08***	11.87***	2.207*
				(3.398)	(2.785)	(1.286)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Departmental FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	204	204	204	204	204	204
R-squared	0.321	0.313	0.072	0.369	0.356	0.087
Number of dept	102	102	102	102	102	102

Notes: Dependent variable is spindles per thousand inhabitants. Columns (1)-(3) use the shortest route algorithm to measure trade costs between London and the department (measure 1), Columns (4)-(6) use weighted distance to measure the same. Columns (1) and (3) estimate the full effect of the trade cost shock shock for the period 1803-06. Columns (2) and (4) use only the extensive margin of firm adjustment, while columns (3) and (6) use only the intensive margin. Robust standard errors clustered at the departmental level in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 2.10: Pre-treatment trends on the extensive margin

	Pre-treatment: 1794-1803			Napoleonic Wars: 1803-1812		
DepVar Spindles	(1)	(2)	(3)	(4)	(5)	(6)
Trade cost	5.539*	-0.372	-3.491	33.11***	27.12***	28.74***
	(3.054)	(3.625)	(5.116)	(9.775)	(9.355)	(8.654)
Streams		-0.124	0.222		0.0379	-0.141
		(0.436)	(0.470)		(0.0356)	(0.146)
Coal		-1.107	-1.829*		-6.252	2.677
		(1.131)	(1.076)		(3.905)	(4.502)
Pop. density		17.96***	18.20*		24.22	11.98
		(5.786)	(10.50)		(14.70)	(20.60)
Urbanisation			-9.049			125.5
			(21.35)			(129.3)
Human cap.			-2.028			55.92**
			(6.055)			(22.61)
Hist. cott.			64.29			499.9***
			(47.46)			(167.3)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Departmental FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	176	176	118	176	176	118
R-squared	0.181	0.328	0.270	0.337	0.374	0.641
Number of dept	88	88	59	88	88	59

Notes: Dependent variable in all columns is the number of spindles per thousand inhabitants. The trade cost shock is measured as the log change in the shortest route between London and each department (measure 1). Controls are defined as follows (all controls interacted with the post-treatment time indicator); Streams: log of the mean stream-flow of rivers in the department (m^3/s). Coal: log-proximity to coal. Histcott: a measure of the size of the cotton industry in the department in 1789. Pop density: log of inhabitants per square kilometre. Urbanisation: the share of population living in cities with above 5000 inhabitants. Human capital: the proportion of men who are able to sign their wedding certificate. For data sources see Appendix A. Robust standard errors clustered at the departmental level in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 2.11: No differential effect on type of machine used by firms

DepVar: Proportion MJ	(1)	(2)
Trade cost (measure 1)	0.0381	
	(0.0858)	
Trade cost (measure 2)		0.0655
		(0.133)
Time FE	Yes	Yes
Departmental FE	Yes	Yes
Observations	112	112
R-squared	0.083	0.084
Number of dept	56	56

Dependent variable is the proportion of mule jennies used in the department as a ratio of all types of machines in use. Mule jennys spun finer, higher quality yarn. Where the total number of machines in 1803 or 1812 was zero, and thus proportion is undefined, the mean proportion of mule jennys in 1803 is used. Column (1) uses the shortest route algorithm to measure trade costs between London and the department (measure 1), Column (2) uses weighted distance to measure the same Robust standard errors clustered at the departmental level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 2.12: Persistence in the location of spinning activity, 1840

	OLS		2SLS	
	(1)	(2)	(3)	(4)
Depvar	Output 1840	Output 1840	Output 1840	Output 1840
Spindles 1812	113.6***	92.46***	96.68**	134.2***
	(24.45)	(26.89)	(40.16)	(41.98)
Departmental controls		✓		✓
Observations	74	68	74	68
R-squared	0.464	0.663		

	First Stage		Reduced form	
	(1)	(2)	(3)	(4)
Depvar	Spind 1812	Spind 1812	Output 1840	Output 1840
Trade cost shock	0.0436***	0.0284***	4.212	3.805***
	(0.0146)	(0.0101)	(2.600)	(1.408)
Departmental Controls		✓		✓
Observations	74	68	74	68
KP F-stat	3.74	5.57		
R-squared	0.220	0.379	0.074	0.348

Notes: Output 1840 is defined as the value of output in cotton spinning (in francs) in the department per thousand inhabitants at the time of the first industrial census in France (1839-47). Spindles 1812 is defined as the number of spindles per thousand inhabitants in 1812. Departmental controls: Access to fast flowing streams, access to coal, literacy, urbanisation and log population density. The instrument is the trade cost shock, measured as the log-change in effective distance to London during the Napoleonic Wars (measure 1). Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 2.13: Productivity outcomes at the firm level, 1840

	OLS		2SLS	
	(1)	(2)	(3)	(4)
Depvar	Prod. 1840	Prod. 1840	Prod. 1840	Prod. 1840
Spindles 1812	0.580***	0.425*	1.811**	3.847**
	(0.204)	(0.213)	(0.746)	(1.629)
Firm controls	✓	✓	✓	✓
Departmental controls		✓		✓
Observations	492	439	492	439
Number of departments	37	34	37	34
R-squared	0.190	0.288		

	First Stage		Reduced form	
	(1)	(2)	(3)	(4)
Depvar	Spind 1812	Spind 1812	Prod 1840	Prod 1840
Trade cost shock	0.0850*	0.0589**	0.154***	0.227***
	(0.0440)	(0.0249)	(0.0320)	(0.0552)
Firm controls	✓	✓	✓	✓
Departmental controls		✓		✓
Number of departments	37	34	37	34
Observations	492	439	492	439
KP F-stat	8.85	7.86		
R-squared	0.266	0.686	0.234	0.320

Notes: Prod. 1840 is defined as the log of the value of production per employee. The top and bottom 1% of the productivity distribution has been trimmed. Spindles 1812 is defined as the number of spindles in 1812 per thousand inhabitants at the departmental level. Firm level controls: share of women and children employed in the firm (separately), binary indicators for whether the firm uses steam or water-power, firm size proxied by the log of the value of primary materials. Departmental controls: literacy, urbanisation rate and log population density. The instrument is the trade cost shock, measured as the log-change in effective distance to London during the Napoleonic Wars (measure 1). Robust standard errors clustered at the departmental level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 2.14: Robustness to multiple imputation

Spindles per thous inhabs	(1) $m = 5$ imputations	(2) $m = 50$ imputations
Trade cost shock	33.09*** (9.780)	33.24*** (9.758)
Time FE	Yes	Yes
Departmental FE	Yes	Yes
Observations	176	176
Number of dept	88	88

Notes: The table examines robustness to multiple imputation. Depvar is spindles per thousand inhabitants across all columns, Column (1) estimates the baseline specification for $m = 5$ imputations, Column (2) replicates the regressions for $m = 50$ imputations. Robust standard errors clustered at the departmental level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

2.B Figures

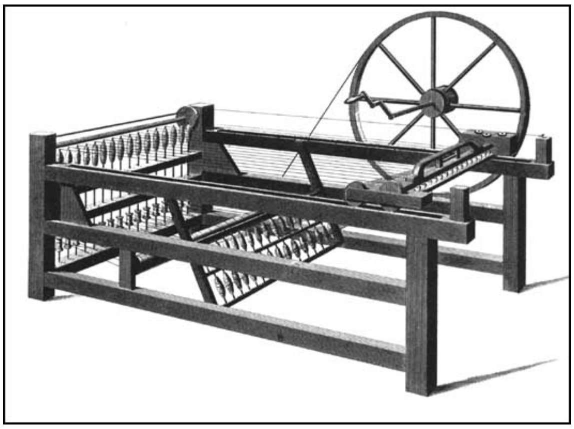


Figure 2.1: An early spinning jenny

Source: Engraving by T. E. Nicholson (1835)

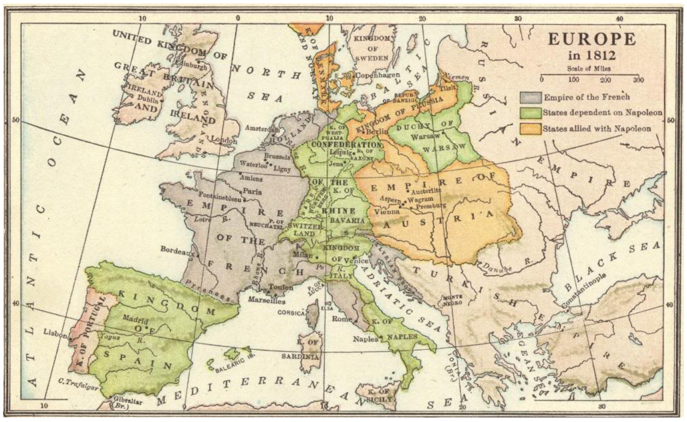


Figure 2.2: Political map of Europe, 1812

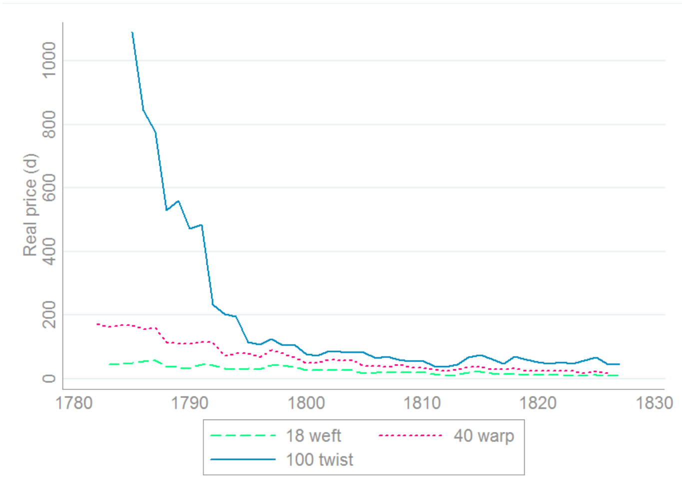


Figure 2.3: Real price of yarn in Britain, Harley (1998)

Real price of cotton yarn in Britain. Mechanisation decreased price of finer (higher count) yarns disproportionately. For data sources see Harley (1998).

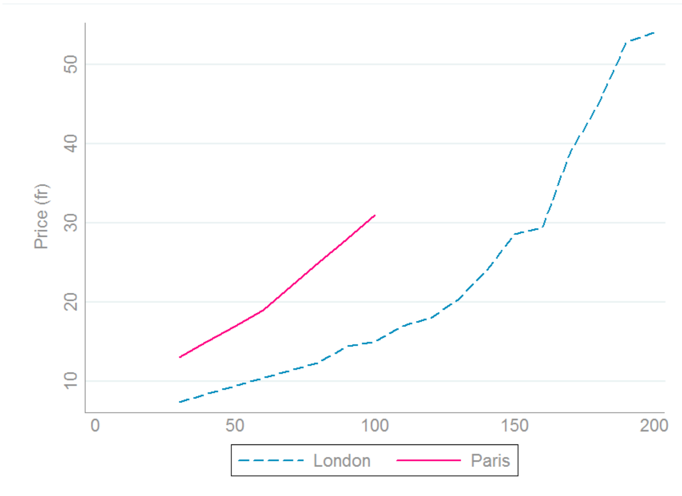
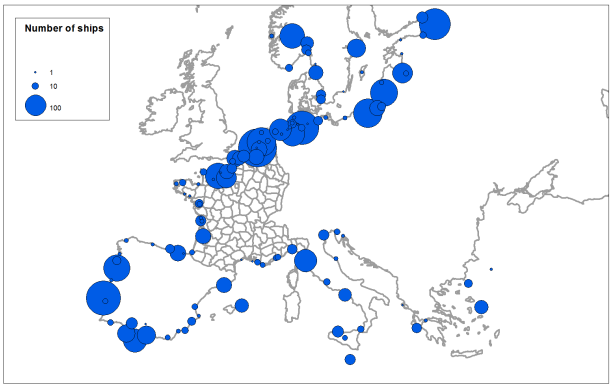
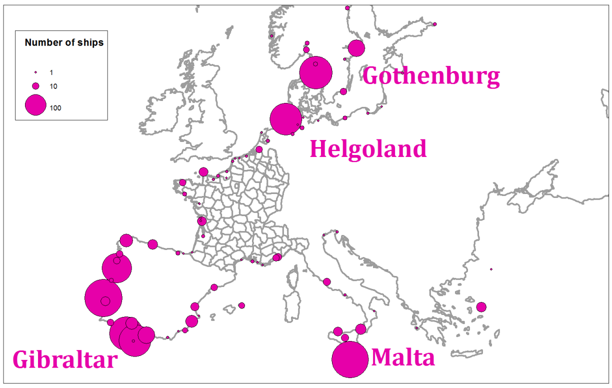


Figure 2.4: Price of different count cotton yarn in Paris and London, 1806-07

Price of machine-spun cotton yarn in Britain and France in francs by count. Finer yarn has higher count. See Appendix A for details on sources.



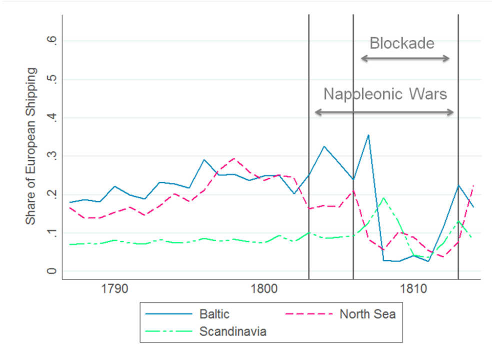
(a) Port usage, 1802



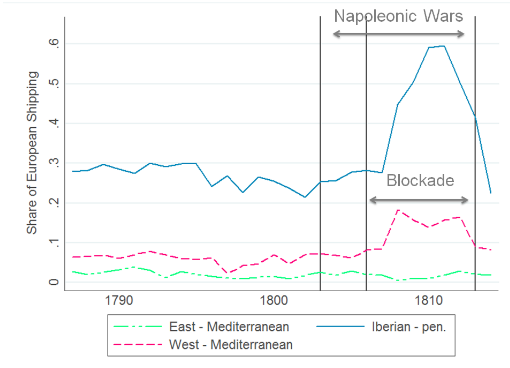
(b) Port usage, 1809

Figure 2.5: Intensity of port use in trade with the British, Lloyd's List

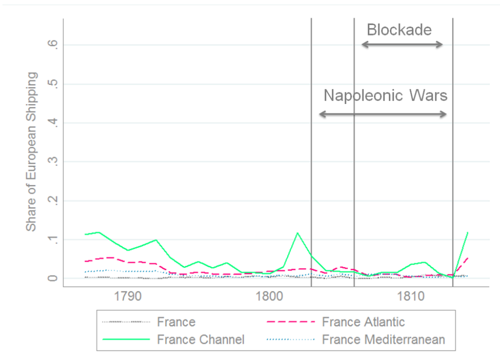
Each circle is proportionate in size to the number of ships sailing between Britain and the given port in the years 1802 and 1809. The former is the last year of peace and relatively free trade between Britain and the Continent, 1809 is a year during the Continental Blockade. Panel B shows the name of the main ports which the British used as smuggling centres during the Blockade: Gothenburg, , Gibraltar and Malta. Data are from the Lloyds List.



(a) British shipping with Northern Europe



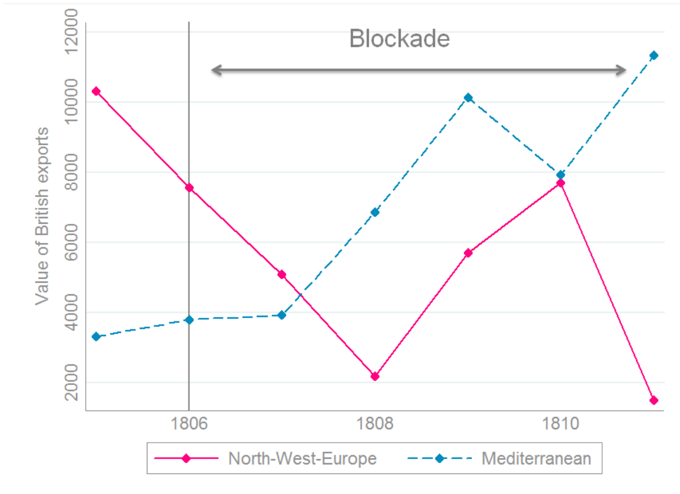
(b) British shipping with Southern Europe



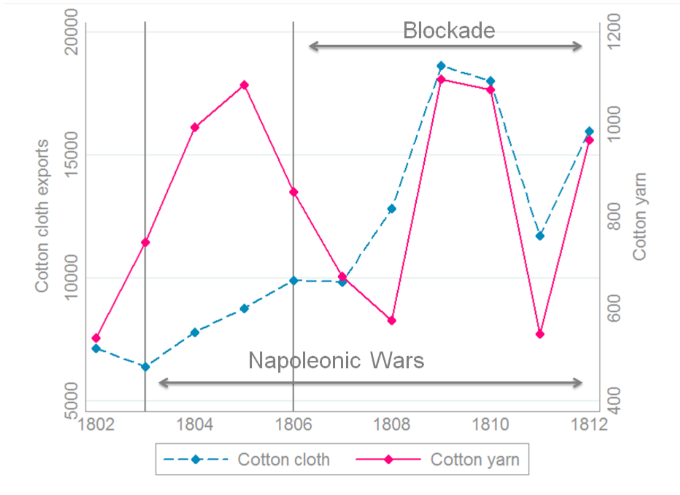
(c) British shipping with France

Figure 2.6: British shipping with European regions as share of total, 1787-1814 (Lloyd's List)

Figure 2.6 shows time series evidence on shipping between Britain and a given region as a share of total European shipping with Britain in order to understand regional variation in the effectiveness of the Blockade. For each year, the shares across the three subfigures add up to 1. The first grey line denotes the onset of the Napoleonic Wars in 1803, the second grey line indicates the onset of the Napoleonic Blockade in 1806 and the third grey line indicates the end of the Napoleonic Wars in 1813. Data from Lloyd's List.



(a) Exports of British merchandise and other produce



(b) Exports of British cotton cloth and cotton yarn

Figure 2.7: British exports, thousands of pounds

Panel A gives total value of exports (ex-cluding re-exports) to North-Western and Southern markets. The former comprises of Russia, Sweden, Denmark and Norway, Prussia, Germany (including), Holland, Belgium and France, the latter comprises Portugal, Madeira and Azores, Spain, The Canary Islands and Baleares, Gibrlatar, Italy, Sicily, Sardinia, Malta and the Turkish Empire. Panel B gives total value of cotton cloth and cotton yarn exports. Data source: Crouzet (1987).

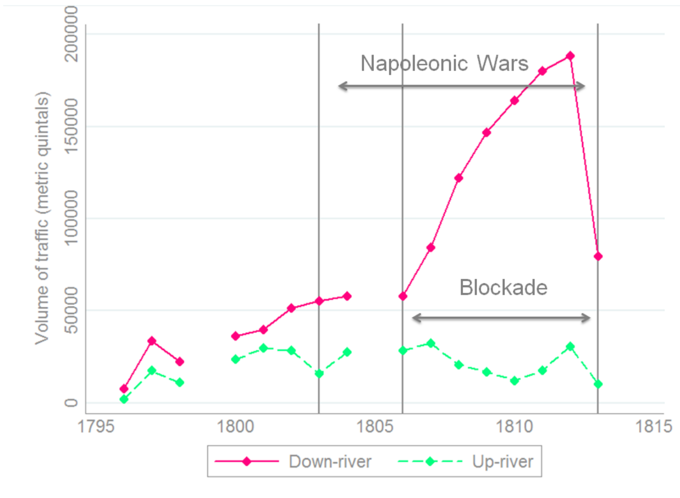
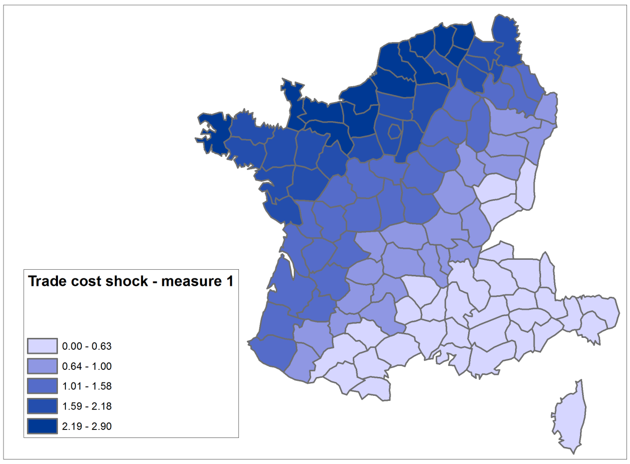
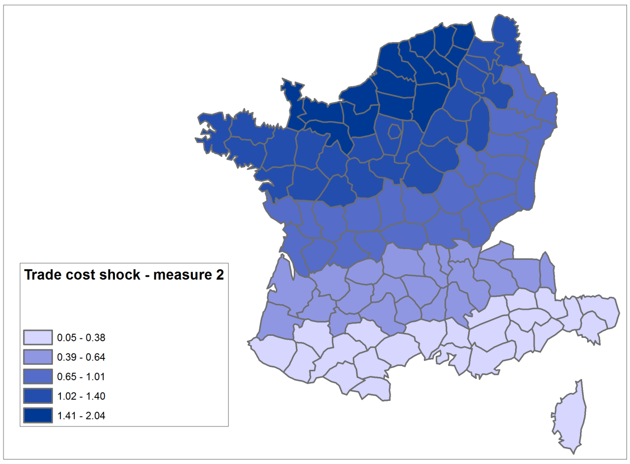


Figure 2.8: Traffic up-river and down-river from Strasbourg

Quantity transported up- and down-river along the Rhine from Strasbourg. Consistent with South-North smuggling, down-river transportation along the Rhine increased during the Napoleonic Blockade. Down-river transport was constant. Data source: Ellis (1981).



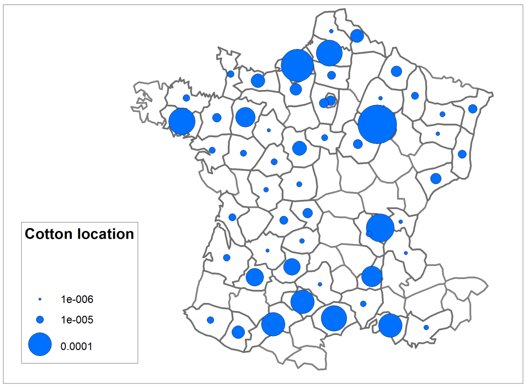
(a) Shortest route algorithm (Measure 1)



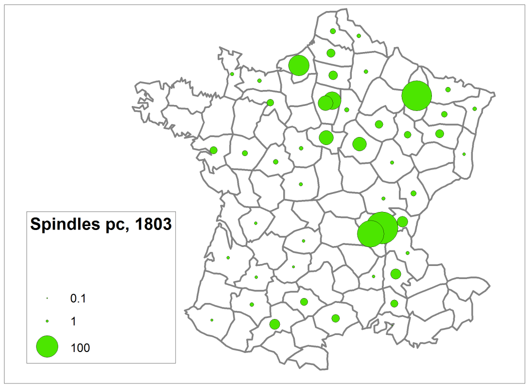
(b) Weighted distance (Measure 2)

Figure 2.9: Two measures of the trade cost shock

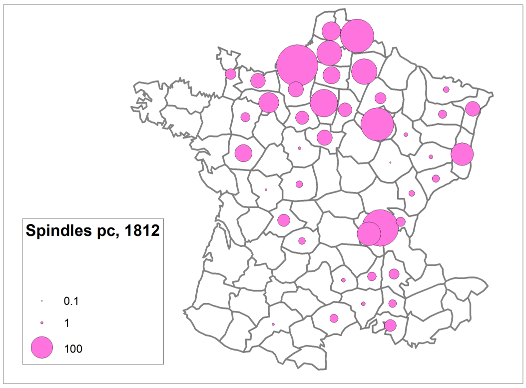
Measure 1 uses a shortest route algorithm to calculate the trade cost shock for each department. Measure 2 calculates the trade cost shock in the following way. Pre-war distance is simple Euclidean distance to London. Distance to Britain during the wars is calculated as the weighted Euclidean distance between each department and smuggling centres. Smuggling centres are identified as ports to which shipping increased during the wars and where shipping exceeded 80 yearly shipments. The weights are the share of a given smuggling centre in total smuggling. The log-difference between the two gives the shock. See text for details.



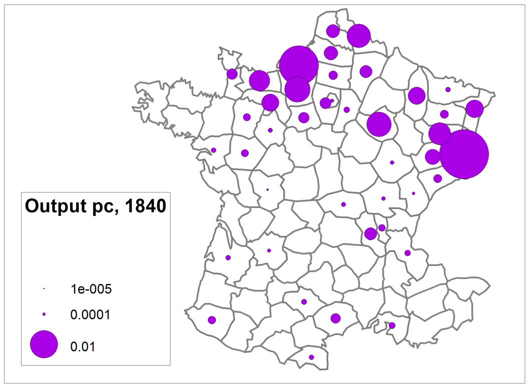
(a) Size of cotton industry pc, 1789



(b) Capital pc in mechanised spinning, 1803



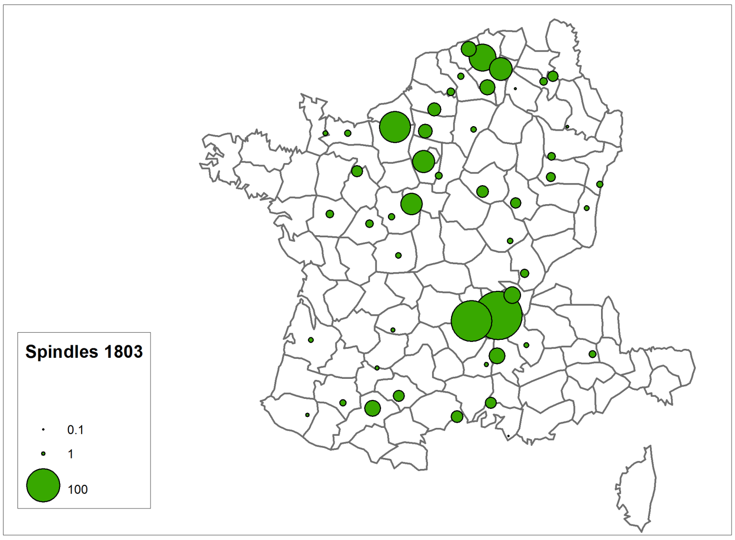
(c) Capital pc in mechanised spinning, 1812



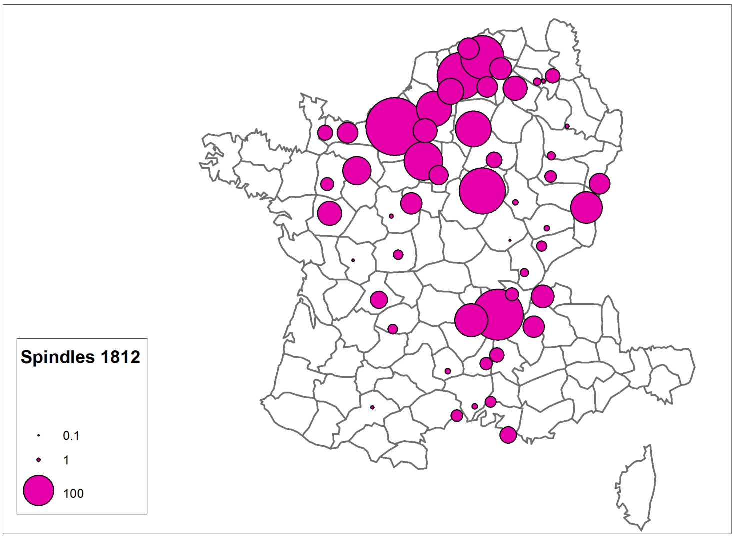
(d) Output pc in mechanised spinning, 1840

Figure 2.10: Evolution of the location of cotton spinning within the borders of ancien regime France, 1789-1840

The figure tracks the spatial distribution of the cotton spinning industry over time. Circles are proportionate within, but not across panels. The first row follows the evolution of cotton spinning up to the start of the Napoleonic Wars. In Panel A, each circle is proportionate to the size of the cotton industry at the departmental level, normalised by population. The data are from Daudin (2010). The localised nature of the production process implies that this is a good measure of where traditional cotton handspinning was located. Panel B depicts spindles per capita in 1803, before the Napoleonic Wars, Panel C shows the same for 1812, towards the end of the Napoleonic Wars. Data source: See appendix A. Panel D shows the value of output per capita in cotton spinning in 1840 in francs. Data source: Chanut et al. (2000)



(a) Number of spindles per capita by department, 1803

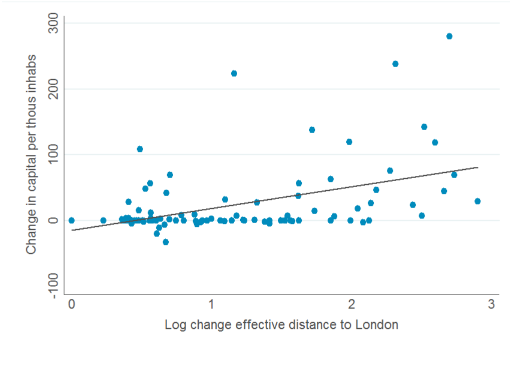


(b) Number of spindles per capita by department, 1812

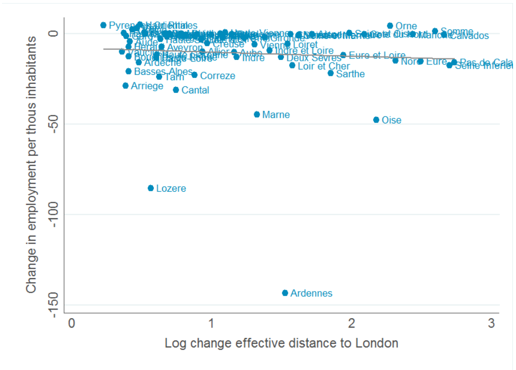
Figure 2.11: Variation used: short-run regressions

Each circle gives the number of spindles per thousand inhabitants by department at the beginning (1803) and towards the end of the Napoleonic Wars (1812) for the French Empire. Data sources are discussed in Appendix A.

(a) Mechanised cotton spinning



(b) Woollen spinning



(c) Leather tanning

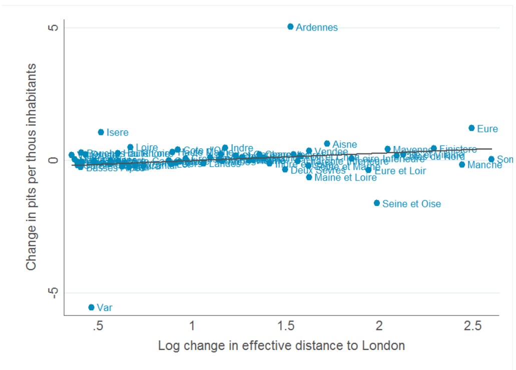
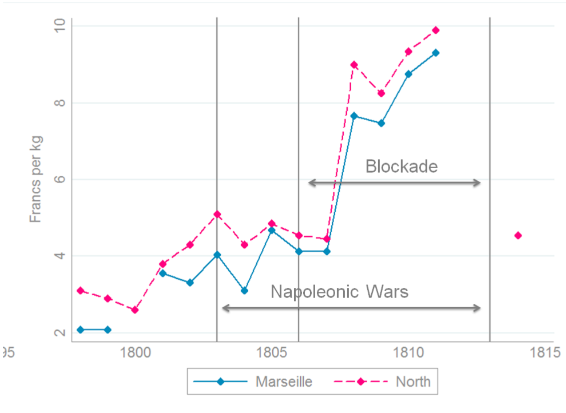
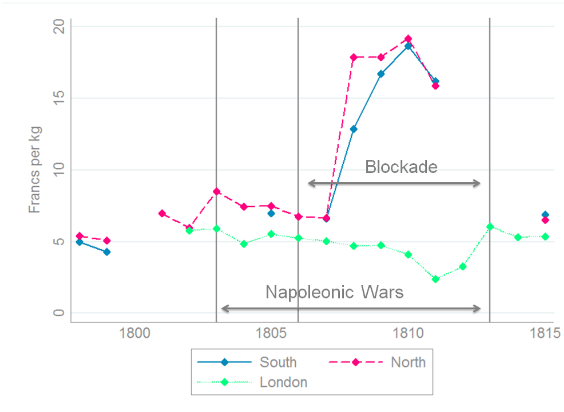


Figure 2.12: Change in production capacity vs trade cost shock

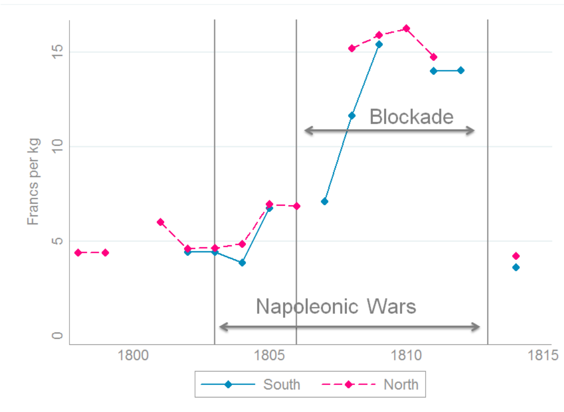
Each scatterplot depicts change in production capacity per thousand inhabitants vs. the log trade cost shock measured as the change in effective distance between the department and London (measure 1). Mechanised cotton spinning production capacity measured as spindles per thousand inhabitants. Woollen spinning production capacity measured as labour employed in woollen spinning per thousand inhabitants. Leather tanning production capacity measured as tanning pits per thousand inhabitants. For data sources, see Appendix A.



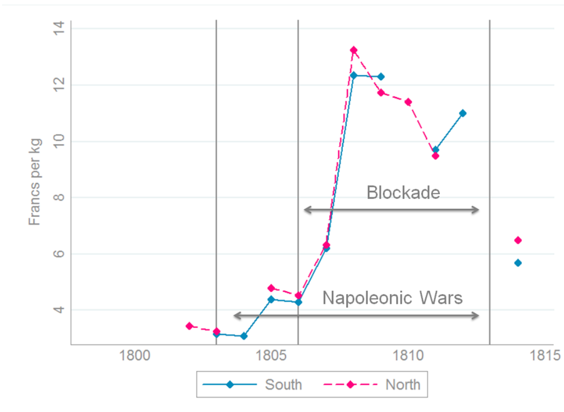
(a) Levantine cotton



(b) Brazilian cotton



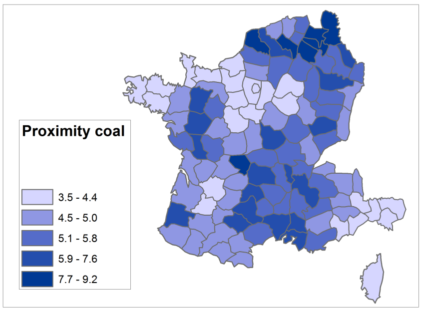
(c) Colonial cotton



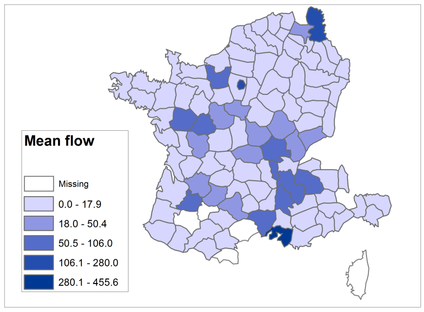
(d) US cotton

Figure 2.13: Price of raw cotton in northern and southern regions of the French Empire

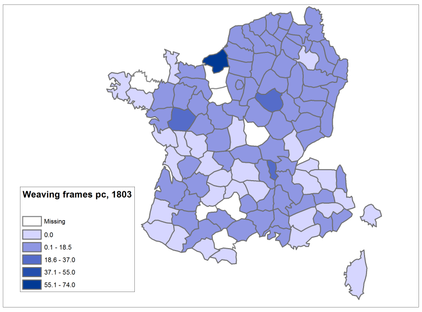
Prices are from “Journal du Commerce”. Prices are given in francs per kilogramme for a given day in a given city for a given variety. Within each category of cotton, the exact variety of cotton was matched for a southern and northern location within a short interval of time (within a few days to within a month) for the best comparability possible. Northern cities are: Anvers, Lille, Rouen, Paris, Havre or Gand. Southern cities are Bordeaux, Marseille, Toulouse, Lyon and Bayonne. For Levantine cotton, it was possible to match Marseille to a northern city for each year. See Appendix A for a more detailed description of the data.



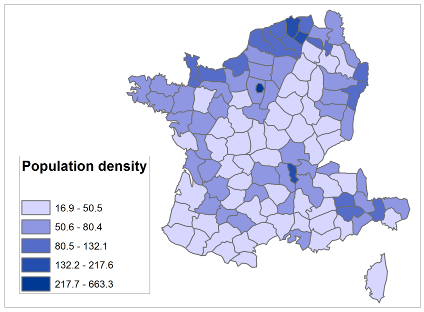
(a) Proximity to coal



(b) Access to fast-flowing streams



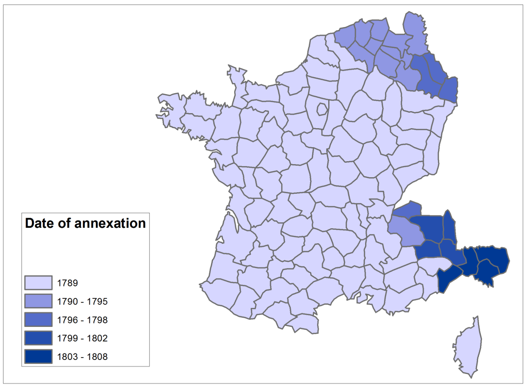
(c) Weaving frames per capita



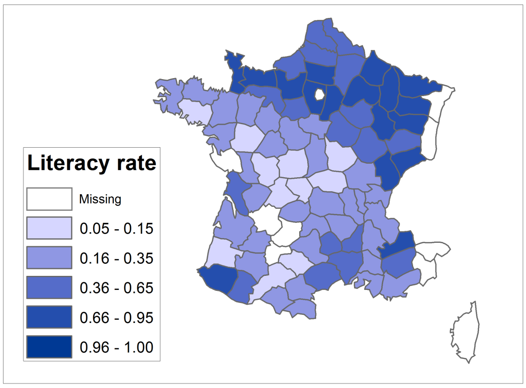
(d) Population density

Figure 2.14: Spatial distribution of potential confounders

Access to coal uses the Fernihough-O'Rourke (2014) dataset. To calculate the departmental datapoint I use the minimum distance to any of Europe's major coalfields from the capital of each department. Where data for the capital is not available, I use the closest city from the dataset. This distance is transformed into a proximity measure using the authors' measure. The mean flow rates across the French Empire are calculated using the average monthly flow-rate (m^3/s) for each station across the historical boundaries of the French Empire. The mean for each department is then calculated, and the natural log of this mean gives the mean-flow rate for each department. Results are robust to assigning zeros for the mean flow rates in departments with no observations, or assigning a missing value. Weaving frames measure the size of the downstream sector at its 1803 level (pre-Napoleonic Wars). Population density is the number of inhabitants per square kilometre according to departmental population in 1811. See Appendix A for details.



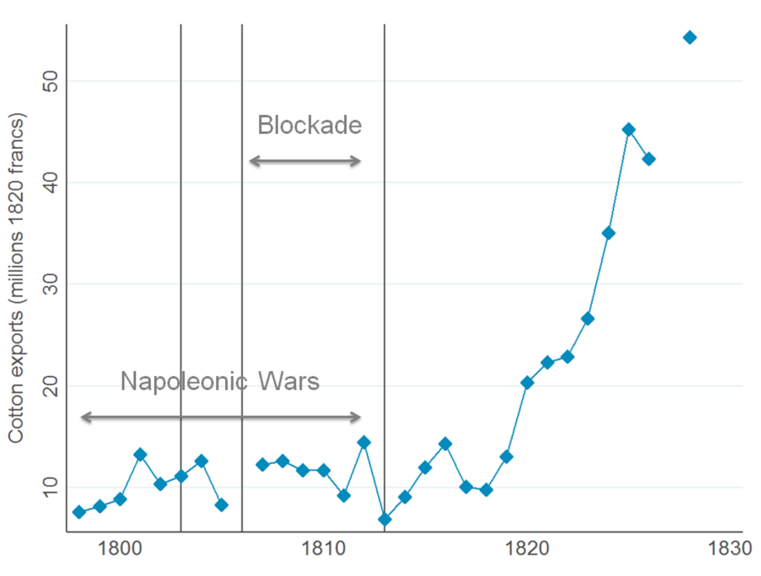
(a) Date of annexation to French Empire



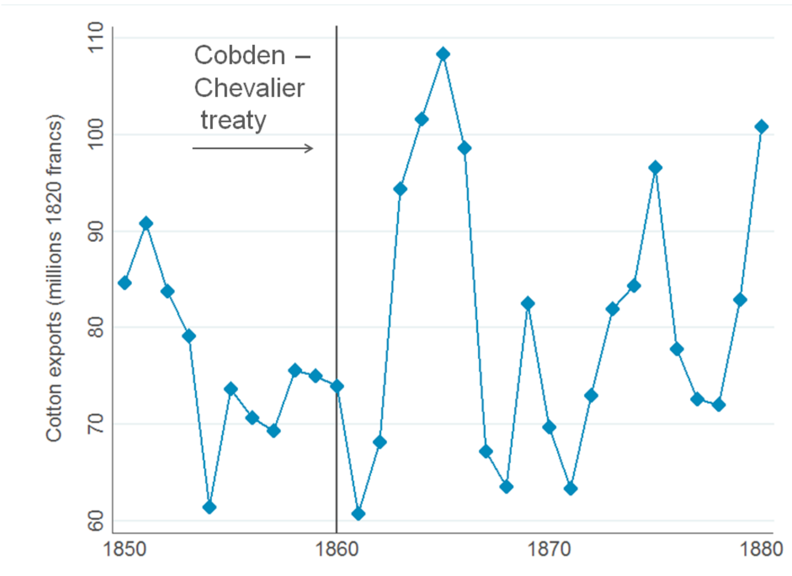
(b) Literacy rate, 1789

Figure 2.15: Spatial distribution of potential confounders

Panel A shows the spatial distribution of annexation to the French Empire, which is used to measure institutional change. For departments of ancien regime France, the date is taken to be 1789. Literacy data is only available for departments of ancien regime France. It is measured as the proportion of males able to sign their wedding certificate. See Appendix A for details and data sources.



(a) French exports of cotton goods, 1798-1828



(b) French exports of cotton goods, 1850-1880

Figure 2.16: French exports of cotton goods, millions of 1820 francs

Panel A displays the time series of French exports of cotton goods in millions of 1820 francs for the period 1800-1828. Panel B displays the same for the period 1850-1880. The grey line in Panel B indicates the signing of the Cobden-Chevalier treaty which dramatically reduced tariffs between Britain and France. Note that the source for the tade statistics in the two periods are not the same. Wholesale price deflator from Mitchell (2007). See Appendix A for data sources and variable definitions.

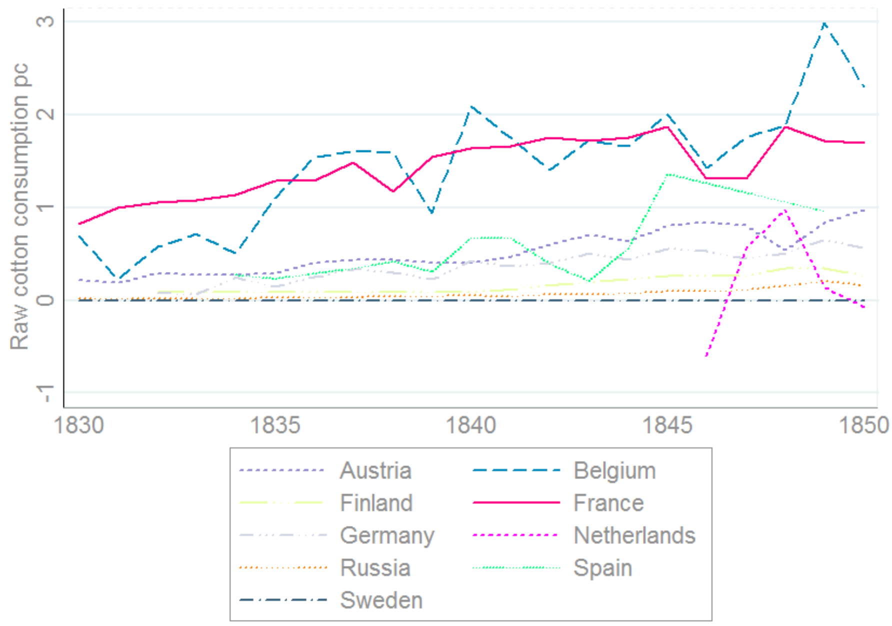
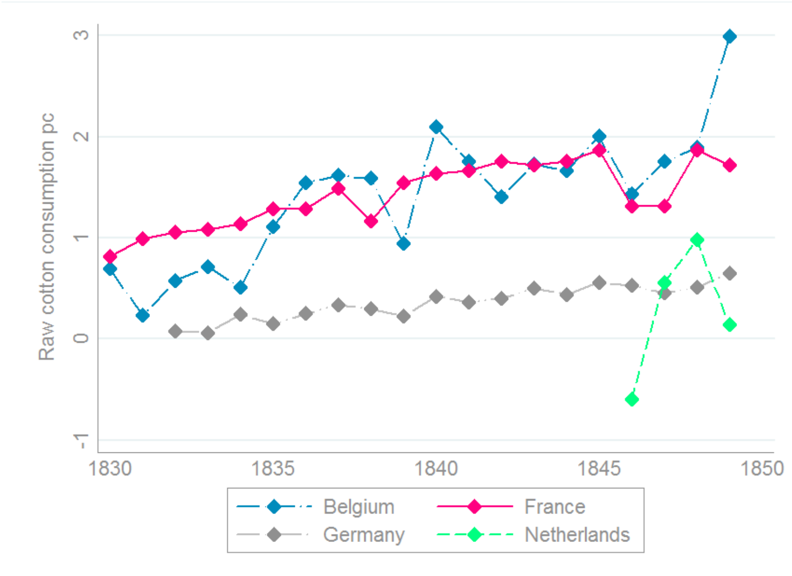
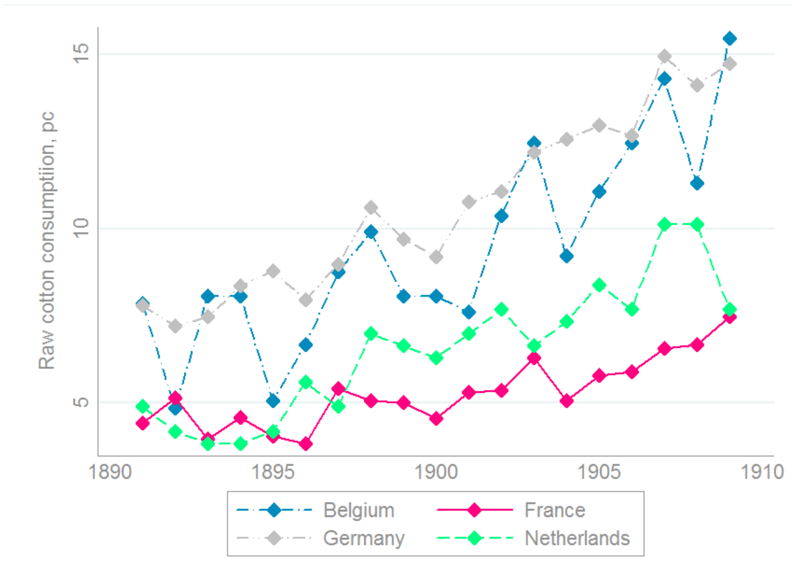


Figure 2.17: Raw cotton usage per capita

Imports of raw cotton per capita for the period 1830-1850. Imports of raw cotton measure the size of the domestic cotton spinning industry as this is the key input used in the production. There is no other use for raw cotton besides as an input in cotton spinning. Data source: Mitchell (2007).



(a) Raw cotton usage per capita, 1830-1850



(b) Raw cotton usage per capita, 1890-1910

Figure 2.18: Importance of cotton for early and late industrialisers in Europe

The two panels compare the size of the cotton industry in four countries at different points in time during the 19th century. France and Belgium were early industrialisers, while the Netherlands and Germany were late industrialisers. Data source: Mitchell (2007).

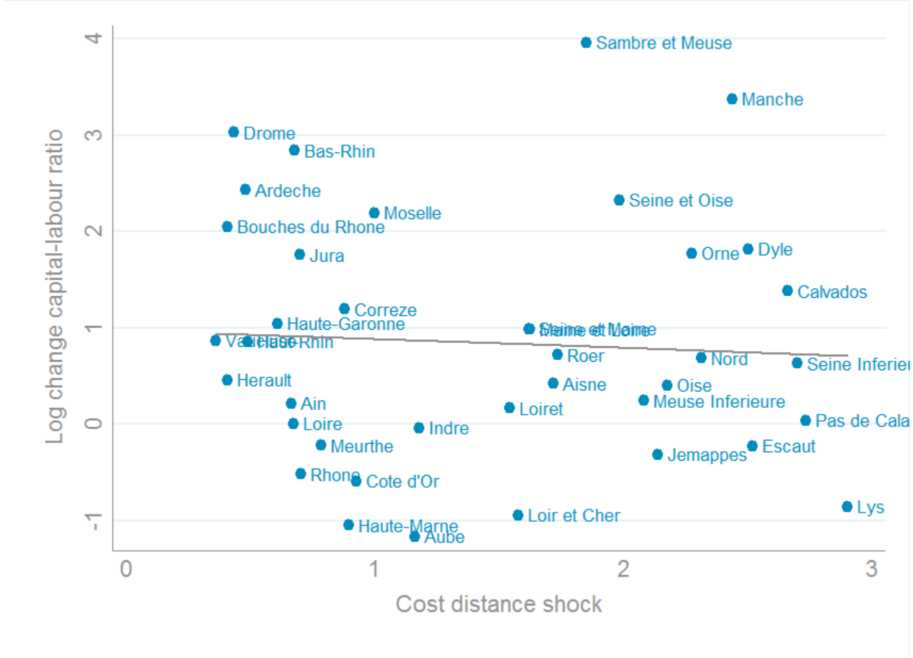


Figure 2.19: Change in log capital-labour ratio in mechanised spinning vs trade cost shock

Change in capital-labour ratio is the log change in the ratio of spindles to workers between 1803-12. The trade cost shock is calculated based on the shortest route algorithm (measure 1). The estimated elasticity is -0.09, (se: 0.24).

Chapter 3

Inter-Industry Linkages: The Indirect Effects of the Napoleonic Blockade

3.1 Introduction

Recent years have seen a renewed interest in the idea that specialisation patterns across countries display some level of indeterminacy. In an influential paper, Hausmann et al. (2007) have shown that countries that have a revealed comparative advantage in goods which closely resemble the mix of goods that rich countries tend to export grow faster than countries which are similar in terms of observables, but happen to produce more typical "poor country goods". The authors claim that this finding, to the extent that it is not driven by unobservable fundamentals, is consistent with a world in which indeterminacy in specialisation is empirically important.

Theoretically, a variety of models deliver predictions in which fundamentals do not uniquely pin down specialisation patterns across space.[1] In the case of inter-industry knowledge spillovers for example, specialising in a given product will, all else equal, increase productivity in technologically similar products. In this way, a region which specialises in a specific industry will become a more attractive location for other industries which are technologically similar. The scope for large effects on specialisation crucially depends on the existence of strong inter-industry linkages.[2] These linkages are generally hard to estimate, as a host of confounding factors makes

[1]The indeterminacy can be driven by production externalities as in Lucas (1988), Matsuyama (1992), Krugman (1987) and Young (1991), coordination failures as in Rodrik (1996) or Rodríguez-Clare (1995) or new-economic geography mechanisms discussed in Fujita, Krugman and Venables (2001).

[2]As Harrison and Rodríguez-Clare (2010) point out, inter-industry linkages are an example of a case in which a country need not have a latent comparative advantage for policy intervention to potentially be welfare improving.

disentangling the different forces at work notoriously difficult.

The previous chapter established that regions which received a larger shock to their costs of trading with Britain increased capacity in mechanised cotton spinning to a much larger extent than regions which remained more exposed to trade. I also found that the trade cost shock affected where mechanised cotton spinning located in the long-run. In this chapter, I exploit exogenous variation in the location of the first modern sector in France, mechanised cotton spinning, to assess the strength and importance of inter-industry linkages.

I examine the importance of horizontal linkages, that is linkages between firms producing similar products. In particular, I examine the co-location of firms which produced yarn using different types of fibres (wool, linen cotton and silk). I find that spinning sectors which were technologically more proximate to cotton spinning (flax and wool) co-located with cotton, while the same does not hold for sectors which were technologically more distant (silk).

In the empirical analysis, I examine the extent to which the post-blockade location of mechanised cotton spinning (in 1812) had an effect on where other spinning industries located in 1840 and 1860. I address endogeneity in the location of mechanised cotton spinning, by using only variation caused by the trade cost shock during the Napoleonic Blockade. This will identify the effect of horizontal linkages to the extent that the trade cost shock is uncorrelated with other, unobserved determinants of spinners' location decisions.

Marshall (1920) argued that firms may choose to coagglomerate for a variety of reasons. In particular, there could be gains from thick labour markets, input-output linkages, or technology spillovers. In my setting, I find that co-location does not seem to be driven by input-output linkages. I find no effect on machine builders, who supply firms with inputs, and no effect on downstream weaving either. Despite the fact that I measure proximity based on technological distance, it does not seem to be possible, based on this evidence alone, to differentiate between labour market pooling and technology spillovers.

Similarly to the development experience of other countries, textiles played a dominant role in the initial stages of France's structural transformation. During the period I examine in this chapter, textiles accounted for up to 60% of France's manufacturing employment. Besides the importance of the sector to France's economy at the time, a number of factors make this setting ideal for testing horizontal linkages.

First, the location of mechanised cotton spinning was determined to a large extent by the historical accident of the Napoleonic Blockade. In the previous chapter, I showed that as a consequence of the blockade against British trade, regions of France were differentially affected by the increased costs of trading with Britain. Regions which received a larger shock to their costs of trading with Britain increased capacity in the new technology, mechanised cotton spinning, to a larger extent than regions which remained more exposed to trade with the British. The differential shock to trade costs thus drives the plausibly exogenous variation in the location of mechanised cotton spinning activity.

Second, the French Revolutionary and Napoleonic Wars (1793-1815) coincided with the start of the Industrial Revolution in Britain. While changes in the British economy were not limited to cotton spinning at the time, other industries, particularly in textiles, developed mechanised production methods with a significant time lag. In fact, mechanisation of different parts of the textile industry took the best part of a century. My identification strategy relies on the fact that while the trade cost shock affected the location of mechanised cotton spinning, it did not have a similar effect on other textiles, nor the upstream and downstream sectors, simply because the technology was not available at the time.

In fact, mechanisation of production methods in the horizontal sectors (wool, flax and "waste-silk" spinning) lagged developments in cotton spinning by decades for reasons inherent to the nature of the different fibres. Mechanising downstream weaving took even longer. This aspect of the setting gives credibility to my identifying assumption, which requires all effects of the trade cost shock relevant to mechanisation in textiles to be channelled through mechanised cotton spinning.

Third, I am able to use cross-industry variation in the extent to which different fibres were amenable to mechanisation as an additional source of exogenous variation. I focus on four fibres; cotton, wool, flax and silk, which accounted for the vast majority of textiles employment at the time in France. Cotton is a flexible and versatile fibre, meaning that it was the easiest to mechanise both for the spinning of yarn and the weaving of cotton. Once production in cotton spinning had been mechanised, efforts were under way to adapt the spinning machinery for use with other fibres. However, both wool and flax are less flexible. For this reason, early generation machines were more likely to break the fibres, moreover, a number of bottlenecks in the preparation of the fibre needed to be overcome for mechanisation in spinning to be more efficient than hand-spinning. Silk is a very different textile. It is not spun, rather it is thrown using machinery which is completely specific to silk. For this reason, technological developments in silk followed a different path. Only "waste-silk", that is silk that cannot be thrown, is spun using a technology similar to that of cotton spinning.

To quantify the technological proximity of these different industries, I construct a novel measure based on the co-citation of patents from Britain. To this end, I collected data on the 385 patents that were filed for inventions in textile spinning between 1617-1852 from Woodcroft (1854). Consistent with the historical evidence, this measure of technological proximity also confirms that wool and flax were technologically more proximate to cotton spinning than silk. This pattern also manifests itself in the French data that I work with, as cotton, wool and flax spinning were more reliant on inanimate sources of power than silk-spinning.

Fourth, the fact that mechanisation of the textile industry was developed almost exclusively in Britain implies that the timing of innovations was more or less exogenous to events in the French economy. French firms adopted new inventions, for the most part, from Britain. Finally, different parts of the production process, notably spinning and weaving were not integrated within a firm for the vast majority of firms in my dataset. The same is true for the different fibres, meaning that I am able to examine inter-industry linkages outside the boundaries of the firm. Moreover, I can separately examine effects on spinning and downstream weaving.

Data on density in mechanised cotton spinning at the end of the blockade, measured as the number of mechanised spindles per capita across French departments, comes from handwritten prefectural reports on the cotton spinning industry introduced in previous chapters. My outcome variables of interest are measures of the size of economic activity in different textile sectors as measured in industrial censuses in 1840 and 1860. These data were collected and compiled by Chanut et al. (2000). Finally, the instrument, the size of the trade cost shock, is measured as the log-change in effective distance to London before and during the blockade.

I find strong support for sizeable inter-industry linkages in the case of wool and flax spinning, two technologically proximate sectors, while the same is not observed in the case of silk, where shared technology was significantly lower. Interestingly, the OLS and 2SLS estimates yield very different results. While the OLS results show a small, positive (negative) and generally statistically insignificant effect of mechanised cotton spinning at the end of the blockade on the value of departmental output per capita in wool and flax (silk) spinning, the 2SLS results are markedly different. Higher mechanised cotton spinning capacity leads to significantly higher output in wool and flax spinning both in 1840 and 1860.

The effects are sizeable and statistically significant across specifications; a one standard deviation increase in mechanised cotton spinning in 1812 increases the value of output per capita in 1840 in woollen spinning by about 0.6 standard deviations, while for flax spinning the increase is about a standard deviation. The point estimates are stable across time for a given industry. The estimated effect on silk is negative, though it is generally not significant at conventional levels.

I subject the baseline results to a number of robustness checks. In particular, the estimated effects are robust to the addition of potential confounders such as access to fast-flowing streams and coal deposits, the level of urbanisation and a measure of human capital. In the case of woollens, I conduct a placebo test and find no effect on the location of employment in woollen hand-spinning in 1792 and 1810.

I next turn to examining what may be the driver of coagglomeration. The results would be consistent with wool and flax spinners co-locating with cotton, if they were able to share inputs (machines). It could also be driven by mechanisms working through the downstream industry. Spinners may co-locate simply because their respective downstream sectors have coagglomerated. By looking at outcomes in downstream weaving and upstream machine building, I explore the possibility that horizontal co-location in spinning is driven indirectly by these forces. I find support for neither of these mechanisms. Two mechanisms which are consistent with my findings are technology spillovers in spinning or thick labour market effects.

The chapter has several links to the existing literature. The chapter is most closely linked to Ellison et al. (2010) who examine the three Marshallian forces of coagglomeration in a contemporary setting. The authors find evidence in support of all three forces, though input-output linkages seem to be the strongest of the three. This contrasts with my findings. However, this may well be because of the historical contingencies specific to this setting. As mentioned, textiles was a hugely dominant sector at the time in France. Moreover, weaving mechanised after spinning. It is entirely possible, that the spinning industries co-located, and the input-output linkage was weakened because of general equilibrium congestion forces. The findings should therefore be interpreted as providing a setting in which technology spillovers or labour market effects can be relatively cleanly estimated, and not as evidence that input-output linkages were not important.

The chapter is also related to a growing literature which examines the effect of temporary shocks on the long-term spatial structure of the economy (Davis and Weinstein, 2002 and 2008, Miguel and Roland, 2011, Redding et al. 2011, Bleakely and Lin, 2012, Kline and Moretti, 2013 and Hanlon, 2014). Most papers in this literature generally take the city as their unit of analysis and examine how temporary, large scale shocks affect the longer term growth trajectory of cities. As such, they have relatively little to say about the importance of inter-industry linkages relative to the importance of other agglomeration forces, which is the focus of this chapter.[3]

The chapter is structured as follows. In the following section, I present and discuss the timing of various innovations in the textile industry throughout the course of the 19th century. I discuss why adaptation of cotton spinning machines took time and illustrate the type of bottlenecks which needed to be overcome. I also introduce the measure of technological proximity used to quantify one potential source of inter-industry linkages. I discuss data used in Section 3, while Section 4 introduces my empirical strategy and discusses the estimation results. The final section concludes.

3.2 The textile industry

In this section, I examine the time-path of innovations in the textile industry. While a number of key innovations dramatically changed production methods in cotton spinning starting from around the 1760s, mechanisation in other parts of the production process and in other textiles, took the best part of a century. For technological reasons, adapting the machines invented for cotton spinning to the spinning of other fibres such as wool, linen and waste-silk, took a considerable amount of time and effort. Moreover, there was substantial variation in the extent to which the adapted technology was suitable for other fibres. The time-lag in mechanisation, together with the inherent differences in the adaptability of different fibres forms the basis of my identification strategy. Substantial time-lags in the mechanisation

[3] One exception in this respect is Kline and Moretti, 2013, who study the spatial effects of a large scale infrastructure investment project from the mid-20th century US. Here the authors differentiate between effects on manufacturing and agriculture, though by design, the paper does not look at inter-industry linkages.

of downstream weaving - relative to upstream spinning - will allow me to separate some input sharing reasons for coagglomeration from inter-industry linkages. In what follows, I discuss each of these facts in turn.

3.2.1 Mechanisation in the textile industries

Cotton proved to be very amenable to mechanisation because of certain properties of the fibre itself, most importantly its flexibility. Despite the technological similarities in the production process for other fibres, inherent differences in the properties of the fibre meant, first, that a number of adaptations needed to be made before the machines could be used for producing the other textiles, and second, mechanisation did not have such dramatic impacts on productivity in the other sectors.

Taken together, these two effects meant that mechanisation and the spread of factory based production lagged the developments in cotton by decades. I focus on innovation in the spinning of four fibres which accounted for the vast majority of textile production at the time; cotton, wool, flax and silk. In all four industries the main steps in production entail (1) preparing the fibre, (2) twisting the fibre into yarn (called spinning for cotton, flax and wool and throwing for silk), (3) weaving the yarn into cloth, and (4) finishing (dyeing or printing).

The breakthroughs in mechanising various parts of the production process first took place in cotton. Starting in the 1760s, a number of macro-inventions mechanised the spinning of cotton yarn in Britain. For centuries, spinners had imparted twist to the fibre using a simple wheel. The spinning of a single thread required one worker. With the advent of the first machine, Hargreave's spinning jenny, spindles now imparted the twist to the fibre, and a single machine could simultaneously spin multiple threads. The productivity gain was large.[4]

The new machines radically transformed production methods in the industry. Allen (2009) argues that mechanisation in cotton spinning had such a large impact on the economy partly because it changed how manufacturing was organised. In Britain, within a generation, factory based production replaced rural manufacturing in cotton spinning. Rural industry had predominantly relied on the merchant to organise the flow of work. Workers worked in their own home, mostly in agricultural down-time for a piece-rate (Mokyr, 2009). As second- and third-generation machines

[4] Allen (2009) estimates that the very first spinning jenny reduced the cost of spinning from 7 to 2.33 shillings.

were reliant on inanimate sources of power (water and steam), production needed to be organised centrally, in factories.

In many respects, cotton was the least likely candidate for an industry destined for a major technological breakthrough. Britain, and Europe in general was a relative newcomer to this industry (Riello, 2013). Production, both in terms of total world production of cotton cloth, and relative to the size of other textiles in Europe, was small (Allen, 2009). Prior to mechanisation, manufacturers could not match Indian cloth either in terms of quality or price. Moreover, Europe was completely reliant on imports of raw cotton. The reason cotton mechanised first seems to have more to do with properties of the fibre itself, namely that cotton led itself most easily to mechanisation because of the relative flexibility and versatility of the fibre (Mokyr, 1994).

Following the enormous success of mechanisation in cotton, efforts were made to mechanise production in the spinning of other fibres. Despite the apparent similarity of the production processes, a number of problems needed to be overcome before machine spinning became more cost-effective than handspinning for other fibres.

In general, the spinning machines themselves needed only slight modifications. However it took time for inventors to establish precisely how the machines needed to be tweaked. Machine-spinning good quality yarn required that the fibre be well-prepared. Both flax and waste silk needed to be extensively prepared before machine spinning. Until innovations improved productivity in these parts of the process, mechanised spinning was unable to compete with hand-spinning. The other bottle-neck which needed to be overcome thus related to the preparation of the fibre (called carding for cottons and woollens, and heckling for flax). While seemingly trivial, in the case of flax and waste silk, the fibre was sufficiently different to cotton that this turned out to be a major obstacle which was not satisfactorily resolved for decades.

The challenges were first overcome in woollen spinning, where the necessary changes were minimal. Short wool was carded in the same way as cotton, and the longer wool was combed. Rollers for woollen spinning were placed further apart (Mann, 1954). Jenkins (2003) estimates that mechanised woollen spinning fully replaced hand-spinning in Britain in the 1820s, and the process was also complete in Continental Europe by the 1840s.

The adaptations necessary to machine spin flax were more complicated. To begin with, flax fibre consists of short filaments held together by a gummy substance which must be loosened before yarn can be spun. Second, to machine spin the finer yarns, it turned out to be necessary to moisten the fibres both before and during spinning. The innovations in wet-spinning and preparation were perfected during the 1830s and mechanised spinning became more widespread on the Continent from about the 1840s (Solar, 2003).

Solar (2003) notes that mechanisation never had such a dramatic impact on productivity in the linen industry because even once the machines had been adapted to spinning flax, the productivity improvement vis-a-vis traditional hand-spinning were not so large. The machines could not be run as fast as in cotton, because flax broke more easily, moreover, the fibre needed much more preparation before it could be machine-spun.

For silk, the manufacturing process is different to other fibres. The silk is first unwound from the cocoon (reeling). The stage which corresponds most closely to spinning in the sense that this is where the twist is imparted to the fibre is called throwing. The spindles used for throwing silk are completely specific to the fibre (Federico, 2009) and thus innovation followed a different trajectory. Richard (1954, p. 311) quotes a contemporary who claimed that up to the 1820s, "no machinery in Great Britain was so barbarous as that in the throwing trade."

Some silk, however, is unreelable. These are the damaged cocoons which will not unwind continuously, or the remains of cocoons. This material, known as "waste silk" can be spun in a way similar to that of other fibres. Adaptation of machinery to spinning waste silk, which needed modifications similar to that of flax, took the longest amount of time and was not perfected until the end of the 19th century (Richard, 1954).

3.2.2 Technological proximity to cotton spinning

The previous section described how machine spinning was adapted from cotton spinning to first wool, then flax, and finally silk. The historical evidence, together with the differences in timing suggest that different fibres were technologically more or less proximate to cotton. In this section, I use Bennet Woodcroft's (1857) patent data on all patents filed in Britain between 1617-1852 and compiled by industry in order to construct a measure of technological proximity.

The title of each patent gives a short description of the invention. For textile spinning, one detail that is often mentioned is the fibre or fibres that the invention is suitable for. Similar to co-citation of patents in modern patent data, it is then possible to construct a measure of technological proximity by looking at how often a given fibre is cited together with cotton.

I use a narrow definition of co-citation in the sense that I only count patents where cotton was cited with another fibre, and that fibre only. I do this in order to avoid counting patents where the owner attempts to inflate the value of the patent by claiming it to be suitable for spinning many different kinds of fibres. This is relatively common in the data; about a third of patents filed claimed to be suitable for spinning three or more fibres.[5] By not including these in the co-citation count, I narrow the focus to inventions where the focus is more tailored the specific properties of a given fibre.

I define technological proximity as the total number of quality adjusted co-cited patents relative to the sum of quality adjusted single-cited patents. I normalise by the count of single-cited patents, that is patents where only a given fibre is cited, to account for the fact that some textiles may be more patent intensive. I adjust both the numerator and the denominator by a measure of patent quality using the measure constructed and discussed by Nuvolari and Tartari (2011). The authors utilise Bennet's (1864) patent compilations which examine the number of times a patent was cited in contemporaneous engineering literature and legal disputes. The authors argue that these citations measure patent quality, as engineering literature would discuss important innovations more frequently, while litigation should be more intensive for economically more valuable patents. They also show that their measure of patent quality is correlated with other, less complete, measures of the quality of inventions.

Table 3.1 shows the results from examining data on the 385 patents that were filed for spinning machines.[6] A number of patterns emerge from examining the table. First, it is apparent from the table that patenting was far more intensive for cotton than other fibres, in line with cotton's supremacy as technological leader among other textiles. For each single-cited wool, flax or silk patent, there were roughly five patents for cotton.

Second, the proximity measure is by far the highest for wool, followed by flax and

[5] Often, the patent will claim the machine is suitable for spinning all and any fibre.
[6] I use Woodcroft Bennet's (1854) industry classification.

silk. This is also consistent with the historical evidence discussed in the previous section. Looking at the various components of the proximity measure also reveals that both patent quantity and quality drive these results. Patent quality is by far the lowest for the silk-cotton co-cited patents in line with the historical evidence that machinery was relatively difficult to adapt to waste silk. The average quality in the other groups was consistently higher. In terms of the raw quantities, co-citations were highest for wool, followed by flax and finally silk, consistent with the proximity measure.

In sum, given both the evidence from the historical literature together with the evidence from patent co-citations, wool seems to be technologically most proximate to cotton, followed by flax and waste silk. In the patent data it is not possible to distinguish between technology for spinning waste silk as opposed to silk throwing, so in this case, I rely solely on the qualitative evidence which argues that silk throwing followed a completely different path.

3.2.3 Mechanising downstream weaving

The large productivity gains in spinning were not initially matched by similar improvements in weaving. Despite continuous efforts to mechanise weaving, the power loom, which was also invented and improved upon in Britain, did not outperform the traditional handloom until the 1830s, half a century after the first spinning jennies appeared (Farnie, 2003). Similarly to spinning, the power loom was first successful in mechanising weaving cottons, and it was then adapted to weaving wool, flax and silk.

As with spinning, the flexibility of cotton made this fibre the most amenable to mechanisation. For woollens, the fragility of the yarn meant that the shuttle could not move faster than with the hand-loom. Hence the power loom only began to replace the handloom in Britain in the 1840s. In flax, the inelasticity of the fibre meant the thread would simply break in cases where cotton or wool would give. This problem only started being tackled in the 1850s, meaning that there were relatively few power looms in operation in linen prior to the 1850s (Mann, 1954).

Silk weaving followed a different path. The Jacquard-loom, invented in Lyon, was one of the last major inventions to be made to the handloom (Mann, 1954). Developed in France in 1801, it became possible to automate the weaving of elaborate designs using punch-cards. Though used for other fibres, it was designed for weaving silk. It is estimated that in 1812, there were 11,000 in use in France. Use of the power-loom was adapted from the cotton weaving technology with a lag similar to that of wool and flax.

3.3 Data

In this section, I describe the data used to conduct the empirical analysis. I begin with the outcome variables, which measure the density of various types of textile manufacturing activity at the level of the département. I then describe the explanatory variable of interest, mechanised cotton spinning capacity at the end of the Napoleonic Blockade, and the instrument which is the size of the trade cost shock across French départements. I also summarise additional control variables used in the empirical analysis.

3.3.1 Size of textile spinning across France

To measure the density of a particular manufacturing activity in a department, I turn to data from two large industrial surveys conducted by the French government in the 1840s and 1860s. These data, collected at the level of the firm, contain data on, amongst other things, the value of output, employment and the type of power used. They were compiled by Chanut et al. (2000) who have also rendered the industrial classification consistent between the two surveys.

Table 3.2 reports employment levels and shares broken down both by production process and type of fibre. Almost 60% of manufacturing employment is accounted for by textiles in 1840 confirming the importance of this sector at the early stage of France's structural transformation. Textile manufacturing moderately expands in levels between 1840 and 1860, however its share drops to 42% as manufacturing outside of textiles expands far more rapidly. In terms of the different stages of the production process, spinning and weaving account for the vast majority of employment. While spinning continues to expand in terms of employment levels between the two points in time, weaving employment falls quite significantly. This could be explained by the fact that mechanisation of weaving gathers momentum during the middle of the 19th century according to historical accounts. Finally, one advantage of this dataset is that different parts of the production process, notably spinning and weaving were generally not integrated within the firm which makes it possibly to separately to identify effects on different parts of the value chain.

The bottom panel of Table 3.2 examines textiles manufacturing by type of fibre. At both points in time, cotton accounted for the largest fraction of employment, followed by wool and silk, which were of a similar size, and linen, which was significantly smaller. It should be emphasised that this marks a dramatic change from the end of the 18th century. Chabert (1949) estimates production in 1788 as being dominated by linen and wool, followed by silk, while cotton was a marginal industry relative to the others. [7]

Within textiles, the authors classified firms according to 16 activities which broadly correspond to different parts of the production process and the fibre(s) used. The sectors, their levels of employment and their usage of water and steam-power across France in 1860 are reported in 3.3. Sectors are ordered from smallest to largest according to their reliance on steam-power. Power intensity is defined relative to the amount of labour employed.[8]

The energy intensity of these branches is one way of assessing the extent of mechanisation in 1860. Consistent with the historical and patent evidence reported in Section 3.2, silk spinning appears to have lagged other textiles in terms of mechanisation. Silk spinning and reeling was far less steam-intensive than wool, linen or cotton spinning. Wool spinning was more reliant on steam-power by a factor of six, while in cotton and linen the differences grew to a factor of nine and ten respectively. This finding is in line with Federico's (2009) findings for Italy in the early 20th century, who also finds mechanisation in silk to lag behind other textiles using a similar measure of reliance on inanimate sources of power.[9]

A similar pattern is confirmed when looking at the reliance on water-power. Cotton and woollen spinning are about three times as water-power intensive as silk spinning. Linen spinning also seemed less reliant on water-power, it was only slightly more water-power intensive than silk in 1860.[10]

[7]Chabert (1949) estimates the size of the industries in 1788 in France for textiles as follows (in millions of francs); 1788: Linen and hemp: 235, Wool: 225, Silk: 130.8, Cotton: no number given.

[8]The pattern is similar for 1840.

[9]It should be noted that silk spinning is reported together with reeling. However, reeling is a steam-power intensive process as steam is used when unwinding the silk from the cocoons. Federico (2009) shows that when steam-intensity is calculated separately for reeling and spinning, spinning becomes even less power-intensive.

[10]The fact that linen is far more reliant on steam than water-power may have to do with the

One advantage of the dataset is that both in 1840 and in 1860, almost all firms are engaged in one part of the production process for one particular fibre. It can be readily seen from Table 3.2, that the vast majority of firms either spin, or weave, only a small subset integrate the two within the firm. Similarly, Table 3.3 reveals that most firms focus on one particular fibre, very few make different types of yarn or cloth.[11] This aspect of mid-19th century France allows me to exploit inter-industry linkages in spinning *outside of the firm.* This feature of the dataset was also exploited by Chanut et al. (2000), when they compiled the dataset. Beyond the 16 categories reported within textiles, the authors also defined a finer, non-nested disaggregation of textiles manufacturing activities. For spinning and weaving of different fibres, they classified a subset of firms to be "pure" in the sense that they were engaged in one activity for one fibre. As the interest of this chapter is in measuring inter-industry linkages outside of the boundaries of the firm, I use this subset of the data in my empirical analysis.[12]

The outcome variable of interest is the total value of output, y_{ijt} in department i employing fibre j at time t. To account for the fact that departements vary in size, I normalise by departmental population in 1811 using data from Chabert (1954). I estimate the specification in levels because of the large number of zeros in the data. For robustness checks, I use data defined in a similar way for weaving activity at the departmental level. Figures 3.2 and 3.3 show the spatial variation in the location of both spinning and weaving across France in 1840 and 1860 respectively, by fibre.

Across fibre types, spinning and weaving seem to have located in roughly similar locations, despite the fact that most firms did not integrate the two activities. This suggests that any inter-industry linkage in spinning may in fact be driven by the co-location of downstream demand, an issue to which I return in the next section. Both cotton spinning and weaving are concentrated across the North-Eastern departments of the French Empire. This pattern is matched by woollens, though in this case, there is also a smaller concentration of spinning activity in the Southern departments. Linen spinning and weaving is concentrated in fewer departments in the North, particularly along the Channel and near the Atlantic seaboard. By 1860, only

specifics of the production process. Recall that the fibre is soaked in hot alkaline solution both before and during spinning, increasing its steam-power requirement all else equal.

[11]For cases in which firms spin or weave multiple fibres, the reason is that they are making a blend.

[12]The only exception to this is for linens, where I use linen spinnig and weaving as classified by Chanut et al. (2000), but not defined as pure.

the northern linen spinners were active. Finally, silk spinning and weaving were practised in only a few locations, almost exclusively in the South.

3.3.2 Density of cotton spinning in 1812

The question we are interested in is whether having higher density in mechanised cotton spinning leads to higher density in other mechanised textile spinning activities. To this end, I use data on production capacity from 1812. In particular, I use the number of mechanised spindles in 1812, normalised by departmental population similarly to the way the outcome variables are defined. I use spinning capacity as measured in 1812, as this was the time when cotton spinning had begun to mechanise is France, while other textiles were still organised almost completely rurally.[13]

3.3.3 Trade cost shock

In the next section, I use the trade cost shock defined in the previous chapter as an instrument for the density of cotton spinning in 1812. As I discuss in the next section, there are a number of reasons to believe that the density of cotton spinning will be endogenous to the determinants of mechanised textile spinning in other industries. The trade cost shock is defined as the log-change in effective distance to London at the level of the department during the Napoleonic Blockade, as discussed in the previous chapter.

3.3.4 Other variables

To conduct robustness checks, I also use data on human capital as proxied by literacy in 1787 from Furet and Ouzof (1982), access to coal from Fernihough and O'Rourke (2014) data on access to fast-flowing streams from the European Water Archive, and urbanisation artes from Bairoch et al. (1988). For woollens, it is also possible to examine the location of hand-spinning in the late 18th and early 19th century, which I do using industrial censuses from 1791 and 1812.

[13]This measure is introduced and extensively discussed in the previous chapter.

3.4 Empirical Strategy and Results

The previous sections have used historical evidence, a technological proximity measure derived from British patent data, and observed differences in the use of inanimate power sources across French textile spinners to argue that 1) There were important similarities in the technology necessary to mechanise production in textiles spinning, and 2) The extent to which adaptation of cotton spinning machinery for different fibres was feasible and successful showed significant variation. In this section, I turn to estimating the extent to which technological proximity led to co-location.

My identification strategy relies on the significant time lag between the invention and adoption of mechanised cotton spinning across France, and the adaptation and adoption of similar machinery in other branches of textile spinning. The previous section has shown that the time-lag was driven by a number of bottlenecks which needed to be overcome before the technology became profitable for other fibres. The overwhelming majority of these micro-inventions were developed in Britain and adopted in France, implying that the timing of these developments was more or less exogenous to internal conditions in the French economy.

I estimate the following equation to test for the strength of interindustry-linkages across different branches of textile-spinning firms.

$$y_{ijt} = \alpha + \beta s_i + \sum_j \beta_j s_i d_j + \phi s_i d_t + \sum_j \phi_j s_i d_t d_j + \delta_t d_t + \sum_j \alpha_j d_j + \sum_j \gamma_j d_t d_j + \epsilon_{ijt} \quad (3.1)$$

y_{ijt} denotes the value of output per capita in department i in industry j at time t. The sample is comprised of 75 departments, and I use data on the wool, linen and silk spinning industry. I observe the data in 1840 and 1860. s_i denotes my measure of the density of mechanised cotton spinning in 1812, which is the number of spindles per capita. I estimate the effect of density in cotton spinning flexibly across industries and time, meaning that there will be a separate coefficient for each industry-year pair. d_t and d_j denote time and industry dummies. Equation 3.1 includes all main effects and all double interactions. Absent additional controls which do not vary at the industry-year level, this specification is equivalent to estimating each year-industry coefficient separately.

There are six parameters of interest corresponding to the six separate year-sector effects we are interested in. Silk is the excluded sector in the regressions, so β will capture the extent to which higher mechanised cotton spinning capacity in a given department in 1812 increased density in silk spinning in the same department in 1840. All other coefficients of interest are sums of the effect on silk and corresponding interaction terms. To simplify the interpretation, I also present the coefficients of interest (each of the sums) in the regression tables along with the p-values from the F-test that the sum of coefficients is indistinguishable from zero. The effects of interest are standardised to aid the interpretation.

There are a number of reasons to believe that mechanised cotton spinning capacity will be endogenous to where other textile industries are located. To the extent that the different industries share the same locational fundamentals, we would expect the coefficients estimated using OLS to be biased upwards. Similarly, to the extent that there is regional specialisation in different spinning industries, we would expect there to be negative omitted variable bias. Recall from Chapter 1, Table 1.11 that in the early 19th century there was basically no coagglomeration between wool and cotton spinning. Moreover, textiles accounts for between 40%-60% of manufacturing employment, implying that general equilibrium dispersion forces may plausibly be present, biasing the coefficient downwards.

In the previous chapter, I showed that the disruption to trade during the Napoleonic Blockade against Britain meant that different regions of the French Empire received a smaller or larger shock to their costs of trading with Britain. This trade-cost shock had a sizeable, statistically significant effect on where mechanised cotton spinning technology was adopted within the French Empire. I exploit this finding to argue that the trade cost shock is a valid instrument for mechanised cotton spinning in Equation 3.1.[14] The identifying assumption requires that the trade cost shock be uncorrelated with the error term in Equation 3.1. There are two channels via which the identifying assumption may be violated in this context.

First, validity of the instrument assumes that the trade cost shock during the Napoleonic Blockade had no other differential effect on the economy which then affected the location of mechanisation in other textiles. In the previous chapter, I demonstrated the plausibility of this assumption, by showing that the trade cost

[14] In fact, all interactions with the measure of cotton spinning capacity will be endogenous. I instrument each interaction term with the trade cost shock's interaction with the industry-time dummy.

shock had no statistically significant effect on employment in woollen hand-spinning and capital in leather tanning. Both industries were less intensively traded with the British, implying that, apart from general equilibrium effects of the trade cost shock (working through factor prices for example), we should not expect to see regionally differential effects for these industries. As the historical section demonstrated, temporary protection could not have had similar, direct effects on technology adoption in the spinning of other fibres, as these technologies were not available at the time.

The second channel via which validity of the instrument could be violated is through unobservables correlated with the trade cost shock which affect adoption of mechanisation differentially across France *after* the period of the Napoleonic Blockade. For this reason, I will show that the results are robust to the addition of various departmental controls which may be important for mechanisation. However, one unobservable mechanism which could be problematic relates to the diffusion of technology from Britain to France. As can be readily seen from Figure 3.1, the trade cost shock decreased in intensity from the North-West to the South-East of France. If technology diffusion follows a gravity equation (Keller, 2004), the trade cost shock may simply be picking up the fact that northern parts of France had better access to the new technologies being developed in Britain following the period *after* the Napoleonic Blockade. This effect is less problematic in the context of 19th century France as Britain went to extensive efforts to protect its intellectual property. Both exports of machinery for textile spinning and the emigration of machine-makers was banned, significantly dampening the importance that direct technology-import could play.

3.4.1 Baseline Results

Table 3.4 contains the results from estimating Equation 3.1. I estimate increasingly flexible specifications using both OLS and 2SLS. All specifications are estimated in levels. To enable comparisons of the coefficients across different textiles, the bottom half of the table reports the standardised coefficients for all the partial effects of interest. I estimate robust standard errors clustered at the level of the department. In columns (1) - (2), I estimate the average effect of density in mechanised cotton spinning in 1812, on density in wool, flax and silk-spinning in 1840 and 1860. In Columns (3) - (4), I allow the effect to differ across industries, while in Columns (5)

- (6), I estimate a separate coefficient by industry - year. Silk in 1840 is the omitted category.

A number of patterns emerge from examining Table 3.4. First, estimation using OLS and 2SLS lead to fairly different results. The coefficients estimated using OLS are consistently smaller in absolute value than the corresponding 2SLS estimates. Moreover, almost no OLS coefficient is statistically significant at conventional levels of significance, while the estimated 2SLS coefficients are large and generally statistically significant. The most straightforward explanation for the difference between OLS and 2SLS results is that endogeneity is driven mostly by attenuation bias in the OLS results resulting from classical measurement error. Both negative and positive coefficients shrink towards zero in the OLS estimates. However, the results could also be driven by omitted variable bias. [15]

In general, based on the 2SLS results, density in mechanised cotton spinning seems to have a sizeable effect on where other mechanising textile industries located. Moreover, the effect varies by fibre type. The average effect of mechanisation in cotton spinning on subsequent mechanisation in other textiles is moderately large and marginally significant at 10%. Given the variation in technological proximity to cotton spinning across different fibres, it is interesting to see how the results vary when we no longer restrict the effect to be the same across fibres. Based on these results, the density of mechanisation in cotton in the early 19th century had a large and statistically significant effect on the density of mechanisation in wool and linen spinning (Columns (4) and (6)). A one standard deviation increase in mechanised cotton spinning per-capita in 1812 increased output in woollen spinning in the mid-19th century by 0.6 standard deviations, while in the case of linens, the increase is slightly above one standard deviation. Estimating a separate coefficient by industry-time does not change the significance or magnitude of the coefficients much. The effect on woollen and flax spinning is of the same magnitude in both the 1840 and 1860 period.

The effect on silk-spinning is negative, though the estimated coefficient is not generally significant. It should be noted however, that there are only a few silk spinning departments, meaning that the coefficients are noisily estimated. The pattern observed across industries is consistent with wool and flax being technologically

[15]If the main driver of endogeneity in the OLS regressions is OVB, the sign of the bias must be industry specific as the estimated coefficients are negative for silk and positive for the other two textiles.

proximate to cotton, while waste-silk spinning was far less so. It should also be noted that in the data, silk spinning is observed together with silk reeling and there is no differentiation in the data between waste-silk spinning, which shared some technology with cotton spinning and silk-throwing, the technology of which was completely sector specific. It is not clear whether theory would predict a zero or negative effect on industries with lower technological proximity. A negative effect is possible to the extent that dispersion forces such as higher land rents, or higher wages make regions with relatively high cotton spinning density relatively less attractive for silk spinning firms. It may be somewhat surprising that the effect on flax is estimated to be bigger than that on wool given that the latter fibre led itself more quickly and more easily to mechanisation, though it is not possible to reject the hypothesis that the two coefficients are equal. Nevertheless, to the extent that wool was indeed more proximate to cotton, it could still be possible to get larger effects on the late-comer industry (flax). If flax mechanised once wool had already mechanised, then the effect captured by the density of mechanised cotton spinning could be working through both the direct channel (cotton) and indirectly, through wool.

3.4.2 Robustness

Table 3.5 explores the robustness of the results to the addition of a number of departmental controls. I examine the effect of the rate of urbanisation, measured as the number of inhabitants in a department living in cities with more than 5,000 inhabitants in 1750 relative to departmental population. This measure controls for potentially confounding agglomeration forces which may induce firms to locate close to markets where the demand for final goods is large. Two important measures of locational fundamentals are access to fast flowing streams and coalfields, which serve as the main sources of power in the mid-19th century. Finally, I measure human capital as the number of men able to sign their wedding certificates in 1786. All controls are measured at their levels prior to the Napoleonic Wars (1803-15) to avoid the bad controls problem (Angrist and Pischke, 2009). As these variables do not vary by industry or time, but only at the level of the department, they only affect the coefficient common to all industry-years, denoted as β in Equation 3.1. Examining table 3.5 reveals that the point estimate of β changes only marginally across specifications, moreover none of the aforementioned potential confounders is close to statistical significance.

Another potential confounder may be the historical location of spinning for a given fibre. If regions which were specialised in woollens initially were more likely to adopt the new technology, the results in Table 3.4 may simply be picking up this effect, to the extent that historical location is correlated with the trade cost shock. Fortunately, for the case of woollens, departmental level data from 1789 and 1812 are available on the size of hand-spinning. Table 3.6 conducts a placebo test by asking whether the location of mechanised cotton spinning in 1812 had a significant effect on where employment in woollen hand-spinning was located in 1789 and 1812. The estimated effect is generally small and always statistically indistinguishable from zero across specifications.[16]

3.4.3 Understanding the mechanisms

A number of different mechanisms could drive the observed co-location of cotton, wool and flax spinning. It is possible for example, that industries co-locate because of up- and/or downstream linkages. Mechanisation in cotton spinning could have attracted machine builders to co-locate, and this could then drive the location decisions of other spinning sectors. Similarly, if downstream weaving firms used different varieties of yarn or there are technology spillovers in downstream weaving, mechanising spinning firms may co-locate with cotton in order to be close to their own downstream weaving.

To understand the potential importance of these mechanisms, Table 3.7 and 3.8 estimates the effect of density in mechanised cotton spinning in 1812 on the value of per capita output in the different weaving sectors and the machine-building industry respectively. Similarly to the spinning firms, I restrict the sample to firms which are specialised in weaving one particular fibre in order to estimate the effects by fibre type.[17] Neither the OLS, nor the 2SLS coefficients are statistically distinguishable from zero across specifications. The estimated coefficients are generally small, particularly for wool suggesting that the effect found for spinning is not being driven

[16] An alternative robustness check is to add the location of woollen spinning before mechanisation in either year as a control when estimating the baseline effect on woollens. These robustness checks yield very similar results in the sense that neither the significance, nor the magnitude of the coefficient of interest is affected.

[17] Firms in which spinning and weaving are integrated made up only 1-2% of total employment in this period, while firms specialised in only one fibre accounted for over 70% of all weaving firms.

by the downstream sector locating close to cotton spinning.[18]

This may seem surprising given the relatively large transport costs at the time. Recall however that, in general, mechanisation in weaving lagged that of spinning. In the middle of the 19th century, mechanisation in weaving was far less advanced than in spinning, meaning that most of the industry was still rurally organised. Consistent with this explanation, for both wool and flax, the point estimate for the later, 1860s period when mechanisation was more advanced, is somewhat larger. To the extent that the post-blockade location of mechanised cotton spinning was having some effect on weaving by 1860, the cleanest estimates of the direct, horizontal linkage across spinning firms would be the ones from 1840.

The effects on the machine building industry show a similar pattern. As I am not able to observe machine builders for spinning machines separately, I estimate the effect on all machine builders. Recall however, that the vast majority of manufacturing employment is accounted for by textile manufacturing implying that the sector overall will make up a large part of demand for machines. Examining the results in Table 3.8, reveals that the value of output in machine building in 1840 and 1860 is positively correlated with the location of mechanised cotton spinning activity in 1812. However, this relationship appears to be spurious, as the 2SLS estimates are generally insignificant statistically, moreover the point estimates are consistently very small across specifications. As Columns (5) and (6) show, part of the upward bias in the OLS results is driven by urbanisation patterns. Urbanisation has a positive and significant effect on the size of machine building in both the OLS and the 2SLS specifications. Moreover the point estimate on the size of cotton spinning also reduces in size.

Taking these results together, it seems that the baseline effect of horizontal linkages for wool and flax spinning are not being driven indirectly through mechanised cotton spinning's affect on upstream machine building or downstream weaving. Given that the linkages between cotton, wool and flax are, according to the evidence, horizontal, what can be said about the driving forces? There are at least two mechanisms which would be consistent with these results. First, if there are knowledge spillovers across firms in technologically more proximate industries, wool and flax-spinning firms would have an incentive to co-locate close to mechanised

[18]For flax, the point estimates are somewhat larger, and they are also closer to statistical significance. This suggests another reason why the estimated coefficient for flax-spinning is relatively large as part of the effect may be coming through a small effect on weaving.

cotton spinners in order to benefit from these externalities. Second, the effect could work through the labour market. Wool and flax-spinners may choose to locate close to cotton spinners to take advantage of a thicker labour market. With search and matching frictions, a thicker labour market could provide better matches, or it could insure against idiosyncratic shocks on both the demand and supply side. Both knowledge spillovers and labour market pooling are mechanisms consistent with the findings presented in this section.

3.5 Conclusion

This chapter has examined the importance of inter-industry linkages by exploiting a unique historical episode from 19th century France. I use plausibly exogenous spatial variation in the location of the first modern industry in France, mechanised cotton spinning, to examine the importance of inter-industry linkages in the textile industry. My empirical strategy builds not only on the fact that the trade cost shock resulting from the Napoleonic Blockade determined to a large extent the location of France's first modern industry, but also on the significant time lag between inventions in mechanised cotton spinning and other textile industries. Together, these two facts make up the main building blocks of my research design.

Using the trade cost shock as an instrument for the density of mechanised cotton spinning in post-blockade France, I find support for the importance of inter-industry linkages in technologically proximate sectors. In particular, I estimate the density of mechanised cotton spinning to have a positive and significant effect on the value of output per capita in technologically proximate woollen and flax spinning, but not on silk-spinning which shared less technology with cotton. I show that these effects are robust to the inclusion of potential confounders such as access to fast-flowing streams and coal deposits, urbanisation and a measure of human capital. In the case of wool, I also find no similar effect when I examine employment levels across departments in hand-spinning in periods prior to mechanisation.

The other main contribution of the chapter is to disentangle the effect of a number of potential mechanisms. In particular, input-sharing of machines and co-location of downstream weaving do not seem to play an important role in driving the co-agglomeration of wool, flax and cotton. The findings thus support mechanisms where horizontal knowledge spillovers across firms, or labour market pooling led to wool and flax spinning firms locating close to cotton spinners.

It seems, at least in the context of 19th century France, that horizontal inter-industry linkages played a role in shaping the distribution of textile activity across space. While the setting described in this chapter is general to the process of structural transformation, the 19th century world economy is in many ways a different environment to the one in which developing countries find themselves today. To what extent would these results inform our understanding about the importance of similar linkages in contemporary settings? It is important to note that French spinning mechanised in a setting where rural hand-spinning was still practised. What this meant was that mechanised wool and flax spinning were adopted in an economy in which both upstream material supply was organised, and in which there was a domestic downstream industry. Of course, in an open economy, the lack of domestic supply and demand need not hinder the industry. Nonetheless, the extent to which these results would hold in settings where industries are more isolated from their upstream and downstream suppliers and markets is an interesting question for future research.

3.A Tables

Table 3.1: Technological proximity

	Total Co-cited	Total Single	Avg. Quality Co-cited	Avg. Quality Single	Proximity
Wool	17	19	3.07	3.08	0.9
Flax	12	26	2.5	2.75	0.42
Silk	9	19	1.75	2.5	0.33
Cotton		94		2.74	

Notes: *Total Co-cited* is the count of patent titles filed in Britain for textile spinning machines in which the name of the given fibre appears together with cotton, and cotton only for the period 1617-1852, *Total Single* is the count of titles in which the name of the given fibre appears without reference to other fibres. *Avg. Quality Co-cited* and *Avg. Quality Single* reports the average quality of co-cited patents, and single-cited patents respectively. *Proximity* is defined as the quality adjusted co-cited patents relative to the quality-adjusted single-cited patents. Patent titles are from Woodcroft (1857), where I follow his classification of patents into industries. Patent quality is measured as the number of citations in technical or engineering journals or legal proceedings as compiled by Woodcroft (1855) and collected and discussed by Nuvolari and Tartari (2011). Note that the time coverage of Nuvolari and Tartari's data ends 10 years before Woodcroft's patent titles, so data coverage between patent data and quality is not fully consistent.

Table 3.2: Textile employment shares in manufacturing 1840 - 1860

	Employment		Employment share	
	1840	1860	1840	1860
	By production stage			
Preparation	9310	6573	0.79	0.39
Spinning	156,246	214,274	13.21	12.57
Weaving	440,112	384,871	37.2	22.58
Spinning and Weaving	25,720	13,354	2.17	0.78
Finishing	51,982	77,143	4.39	4.53
Other	9,179	16,229	0.78	0.95
Total textiles	692,549	712,444	58.53	41.80
	By type of fibre			
Linen	49,938	44,656	4.22	2.62
Silk	166,573	96,033	14.09	5.63
Wool	124,258	137,945	10.50	8.09
Cotton	211,113	251,152	17.84	14.74
Mixed, Other or Unspecified	140,487	182,658	11.87	10.72
Total textiles	692,549	712,444	58.53	41.80

Notes: Employment columns report the level of employment in the different parts of the production process and in different textiles for the years 1840 and 1860. Employment shares report the same relative to total employment in manufacturing.

Table 3.3: Water and steam-power intensity in the textile industry, 1860

	Employment	Water-power intensity	Steam-power intensity
Embroidery and Lace	27,826	0	0.05
Hosiery	37,812	0.02	0.53
Silk weaving	33,171	1.09	0.96
Linen weaving	18,712	0.52	1.34
Passementerie	15,102	0.24	1.50
Silk spinning and reeling	62,862	4.26	2.02
Wool weaving	75,937	4.40	2.70
Textiles other	4,143	4.25	3.50
Mixed or unspecified weaving	43,346	0.35	3.93
Cotton and cotton blend weaving	175,893	2.99	4.23
Wool spinning and weaving	9,046	14.21	5.16
Hemp	12,086	3.86	7.36
Mixed spinning	8,128	6.99	9.65
Wool spinning	46,389	13.13	12.93
Printing	18,273	0.60	13.39
Bleaching, dyeing and finishing	15,942	4.19	17.47
Spinning and weaving cotton	4,308	28.11	17.90
Carding, Fulling, Combing Wool	6,573	39.68	18.59
Cotton spinning	70,951	13.94	18.75
Linen spinning	25,944	5.29	22.82
Total	712,444		

Notes: Sectoral breakdown as defined in Chanut et al. (2000) for the textile sector. Employment reports the level of employment by sector in 1860. Water-power reports horse-power relative to one-hundred employees, steam-power is similarly defined.

Table 3.4: Baseline Estimation Results

DepVar Output_pc	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS
Spindles	25.94	68.84*	-7.870	-70.13	-3.456*	-28.37*
	(23.69)	(40.89)	(5.776)	(46.12)	(1.882)	(16.77)
Spindles x Wool			55.81	253.9**	18.54	143.9**
			(43.51)	(115.1)	(23.03)	(70.77)
Spindles x Linen			45.62	163.0**	20.61	73.01**
			(29.04)	(73.03)	(12.47)	(30.49)
Spindles X Time					-8.828	-83.53
					(8.275)	(62.69)
Spindles x Wool x Time					74.53*	220.1**
					(43.04)	(112.3)
Spindles x Linen x Time					50.03	179.9**
					(33.82)	(88.81)
Industry FE			✓	✓	✓	✓
Time FE					✓	✓
Industry x Time FE					✓	✓
Observations	450	450	450	450	450	450
Number of departments	75	75	75	75	75	75
min AP F-stat		7.13		7.07		6.98
R-squared	0.053		0.054		0.076	
	Partial effects - standardised coefficients					
β	0.12	0.31*	-0.06	-0.52	-0.09*	-0.75*
	(0.28)	(0.09)	(0.18)	(0.12)	(0.07)	(0.09)
$\beta + \phi$					-0.07	-0.61
					(0.21)	(0.14)
$\beta + \beta_{wool}$			0.14	0.73**	0.08	0.63*
			(0.27)	(0.04)	(0.51)	(0.06)
$\beta + \phi + \beta_{wool} + \phi_{wool}$					0.19	0.58**
					(0.22)	(0.05)
$\beta + \beta_{linen}$			0.37	1.53**	(0.43)	1.13**
			(0.19)	(0.04)	(0.16)	(0.02)
$\beta + \phi + \beta_{linen} + \phi_{linen}$					0.41	1.03**
					(0.21)	(0.05)

Notes: OLS and corresponding 2SLS estimates for increasingly flexible equations reported in the top half of the table. Columns (1) - (2) estimate the cross industry linkage restricting the effect to be the same across industries and years. Columns (3) - (4) allow the coefficient to differ across industries, but not years. Columns (5) - (6) estimate separate industry-year coefficients. The bottom half of the panel reports the standardised coefficients for each of the parameters corresponding to Equation 3.1. The top half of the column reports standard errors clustered at the departmental level in brackets, while the bottom half reports the p-values from the F-test for the null hypothesis of the sum of coefficients being statistically indistinguishable from zero. *** p<0.01, ** p<0.05, * p<0.1.

Table 3.5: Robustness checks

DepVar Output_pc	(1) 2SLS	(2) 2SLS	(3) 2SLS	(4) 2SLS	(5) 2SLS	(6) 2SLS
Spindles	-28.37*	-27.97	-27.99*	-27.52	-40.45*	-38.99
	(16.77)	(17.57)	(16.75)	(18.02)	(23.89)	(25.34)
Spindles x Wool	143.9**	143.9**	143.9**	143.9**	135.3**	135.3**
	(70.77)	(70.77)	(70.77)	(70.77)	(65.08)	(65.08)
Spindles x Linen	73.01**	73.01**	73.01**	73.01**	70.68**	70.68**
	(30.49)	(30.49)	(30.49)	(30.49)	(28.79)	(28.79)
Spindles x Time	-83.53	-83.53	-83.53	-83.53	-85.45	-85.45
	(62.69)	(62.69)	(62.69)	(62.69)	(62.48)	(62.48)
Spindles x Linen x Time	179.9**	179.9**	179.9**	179.9**	176.7**	176.7**
	(88.81)	(88.81)	(88.81)	(88.81)	(85.73)	(85.73)
Spindles x Wool x Time	220.1**	220.1**	220.1**	220.1**	212.8**	212.8**
	(112.3)	(112.3)	(112.3)	(112.3)	(107.0)	(107.0)
Urbanisation		-4.587				2.576
		(15.41)				(16.26)
Streams			-0.180			-0.291
			(0.447)			(0.357)
Coal				0.207		0.631
				(1.024)		(0.908)
Literacy					6.061	7.003
					(5.088)	(5.208)
Industry FE	✓	✓	✓	✓	✓	✓
Time FE	✓	✓	✓	✓	✓	✓
Industry x Time FE	✓	✓	✓	✓	✓	✓
Observations	450	450	450	450	414	414
Number of departments	75	75	75	75	69	69
min AP F-stat	6.98	6.96	6.72	6.96	6.82	7.66

Notes: Columns (1) - (5) estimate Equation 3.1 and add potential confounders one at a time. Column (6) includes all controls. Control variables are defines as follows. Streams: log of the mean stream-flow of rivers in the department (m^3/s). Coal: log-proximity to coal. Urbanisation: share of population living in cities with above 5000 inhabitants. Literacy: proportion of men who are able to sign their wedding certificate in 1786. Data availability constraints on this measure restrict the sample size to 69 departments. Standard errors clustered at the departmental level in brackets *** p<0.01, ** p<0.05, * p<0.1.

Table 3.6: Placebo for non-mechanised woollen spinning 1789-1810

DepVar Employment_pc	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS
Spindles	-0.0274	-0.00552	-0.0452	-0.0627
	(0.0328)	(0.0953)	(0.0410)	(0.121)
Spindles x Time	0.0170	-0.0261	0.0177	-0.0131
	(0.0224)	(0.0700)	(0.0232)	(0.0684)
Departmental controls			✓	✓
Time FE	✓	✓	✓	✓
Observations	141	141	125	125
Number of departments	75	75	66	66
min AP F-stat		6.86		7.55
R-squared	0.048		0.090	
	Partial effects - standardised coefficients			
β	-0.07	-0.01	-0.11	-0.16
	(0.41)	(0.95)	(0.27)	(0.61)
$\beta + \phi$	-0.06	-0.17	-0.15	-0.41
	(0.44)	(0.49)	(0.24)	(0.32)

Notes: Columns (1) - (4) estimate the effect of mechanised cotton spinning on the density of employment in woollen hand-spinning for 1789 and 1810. Columns (1) and (2) estimate Equation 3.1 for the case of a single industry using OLS and 2SLS respectively. Columns (3) -(4) add urbanisation, literacy and access ot coal and fast flowing streams as controls. The bottom half of the panel reports the standardised coefficients for the effect of mechanised spinning capacity on employment in wool-spinning in 1789 (β) and 1810 ($\beta + \phi$) . The top half of the column reports robust standard errors clustered at the departmental level in brackets, while the bottom half reports the p-values from the F-test for the null hypothesis of the sum of coefficients being statistically indistinguishable from zero. *** p<0.01, ** p<0.05, * p<0.1.

Table 3.7: Effects on weaving

DepVar Output_pc	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS
Spindles	347.5	-190.8	342.8	-214.3
	(317.8)	(196.3)	(318.7)	(204.2)
Spindles x Wool	-363.4	221.4	-374.9	219.0
	(320.9)	(218.3)	(331.7)	(220.3)
Spindles x Linen	-344.7	224.5	-354.2	228.7
	(318.9)	(205.3)	(329.5)	(209.8)
Spindles x Time	-311.0	117.4	-319.6	121.2
	(301.1)	(176.1)	(311.1)	(181.6)
Spindles x Linen x Time	328.7	-111.8	338.1	-116.0
	(299.5)	(178.5)	(309.4)	(183.7)
Spindles x Wool x Time	370.8	-50.62	381.5	-60.55
	(284.1)	(188.9)	(293.0)	(193.6)
Literacy			2.658	11.42
			(6.349)	(7.470)
Streams			0.110	-0.0746
			(0.763)	(0.624)
Coal			2.593	3.054
			(2.120)	(2.641)
Urbanisation			23.81	55.90
			(23.86)	(56.75)
Industry FE	✓	✓	✓	✓
Time FE	✓	✓	✓	✓
Industry x Time FE	✓	✓	✓	✓
Observations	450	450	414	414
Number of departments	75	75	69	69
min AP F-stat		6.98		7.66
R-squared	0.141		0.158	
	Partial effects - standardised coefficients			
β	0.45	-0.25	0.45	-0.28
	(0.28)	(0.33)	(0.29)	(0.29)
$\beta + \phi$	0.21	-0.43	0.13	-0.54
	(0.23)	(0.17)	(0.44)	(0.15)
$\beta + \beta_{wool}$	-0.05	0.09	-0.10	0.01
	(0.46)	(0.66)	(0.30)	(0.95)
$\beta + \phi + \beta_{wool} + \phi_{wool}$	0.15	0.33	0.10	0.22
	(0.35)	(0.22)	(0.60)	(0.48)
$\beta + \beta_{linen}$	0.05	0.63	-0.21	0.27
	(0.67)	(0.12)	(0.50)	(0.75)
$\beta + \phi + \beta_{linen} + \phi_{linen}$	0.36	0.69	0.12	0.34
	(0.25)	(0.13)	(0.77)	(0.67)

Notes: The top half of the panel reports the OLS and corresponding 2SLS coefficients for the effect of the emergence of mechanised cotton spinning on weaving density across departments. Columns (1) - (2) estimate Equation 3.1 using OLS and 2SLS respectively. Columns (3) - (4) add departmental controls. The bottom half of the panel reports the standardised coefficients for each of the effects of interest. The parameters correspond to those used in Equation 3.1. The top half of the column reports standard errors clustered at the departmental level in brackets, while the bottom half reports the p-values from the F-test for the null hypothesis of the sum of coefficients being statistically indistinguishable from zero. *** p<0.01, ** p<0.05, * p<0.1.

Table 3.8: Effects on machine industry

DepVar Output_pc	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS	(7) OLS	(8) 2SLS	(9) OLS	(10) 2SLS	(11) OLS	(12) 2SLS
Spindles	16.21***	-7.130	15.81***	-7.760	11.60**	-8.654	16.14***	-6.239	13.54***	0.446	5.992	-3.699
	(4.323)	(16.63)	(4.513)	(16.86)	(5.715)	(13.97)	(4.361)	(15.92)	(3.586)	(13.16)	(4.132)	(9.518)
Spindles x Time	27.43***	22.28	27.43***	22.28	27.43***	22.28	27.43***	22.28	25.89***	28.11**	25.89***	28.11**
	(6.656)	(14.93)	(6.679)	(14.93)	(6.679)	(14.93)	(6.679)	(14.93)	(7.149)	(13.78)	(7.231)	(13.78)
Streams			0.243	0.302							0.180*	0.163
			(0.153)	(0.187)							(0.101)	(0.103)
Urbanisation					10.89**	17.50***					14.11***	17.05***
					(4.432)	(5.142)					(1.998)	(4.038)
Coal							0.162	0.217			0.116	0.158
							(0.306)	(0.448)			(0.241)	(0.267)
Literacy									-0.849	0.0741	0.0776	0.880
									(1.213)	(1.053)	(1.130)	(1.109)
Time FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	150	150	150	150	150	150	150	150	138	138	138	138
Number of departments	75	75	75	75	75	75	75	75	66	66	66	66
min AP F-stat		7.01		6.72		6.96		6.96		6.82		7.54
R-squared	0.316		0.327		0.356		0.318		0.367		0.482	
	Standardised partial effects											
β	0.36***	-0.15	0.35***	-0.17	0.25**	-0.20	0.36***	-0.14	0.30***	0.01	0.13	-0.08
	(0.00)	(0.67)	(0.00)	(0.64)	(0.046)	(0.53)	(0.00)	(0.70)	(0.00)	(0.97)	(0.15)	(0.70)
$\beta + \phi$	0.22***	0.08	0.22***	0.07	0.21***	0.07	0.22***	0.08	0.20	0.14**	0.16***	0.12*
	(0.00)	(0.45)	(0.00)	(0.48)	(0.00)	(0.49)	(0.00)	(0.41)	(0.00)	(0.02)	(0.00)	(0.07)

Notes: Columns (1) - (12) estimate the effect of mechanised cotton spinning on the density of production per capita in the machine-making industry. Columns (1) and (2) estimate Equation 3.1 for the case of a single industry using OLS and 2SLS respectively. Columns (3) -(12) add urbanisation, literacy and access ot coal and fast flowing streams as controls one at a time, and then simultaneously. The bottom half of the panel reports the standardised coefficients for the effect of mechanised spinning capacity on the value of output per capita for 1840 (β) and 1860 ($\beta + \phi$) . The top half of the column reports robust standard errors clustered at the departmental level in brackets, while the bottom half reports the p-values from the F-test for the null hypothesis of the sum of coefficients being statistically indistinguishable from zero. *** p<0.01, ** p<0.05, * p<0.1. *** p<0.01, ** p<0.05, * p<0.1.

3.B Figures

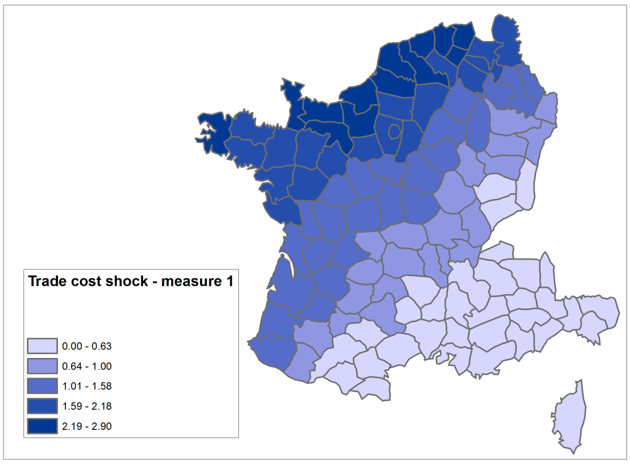
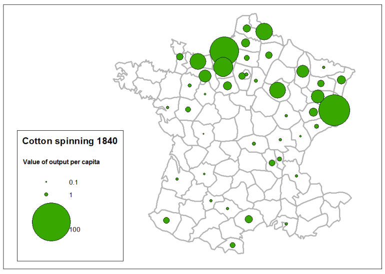
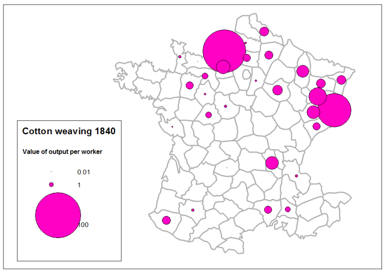


Figure 3.1: Trade cost shock

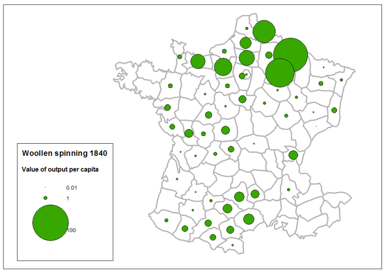
Measure 1 uses a shortest route algorithm to calculate the trade cost shock for each department. The shock is defined as the log-change in effective distance to London before and during the Napoleonic Blockade from each department. Pre-blockade distances are calculated using the unrestricted shortest route, while routes are restricted to those open to trade with the British during the blockade. Sea to land transportation is calibrated to match contemporary accounts of the relative cost of sailing between Rouen and Marseille or taking an overland route. According to this measure, one sea kilometre is approximately 0.15 land kilometres.



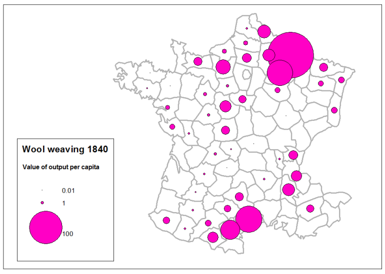
(a) Cotton spinning, 1840



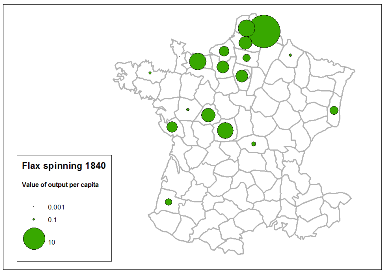
(b) Cotton weaving, 1840



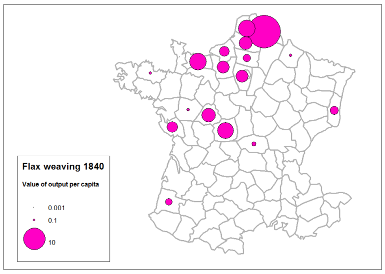
(c) Wool spinning, 1840



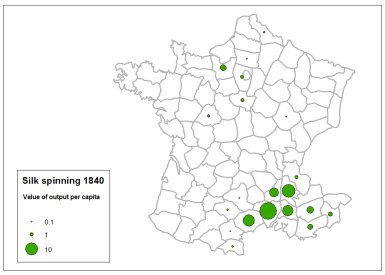
(d) Wool weaving, 1840



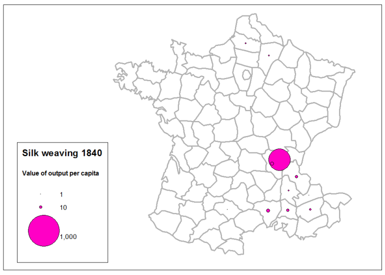
(e) Linen spinning, 1840



(f) Linen weaving, 1840



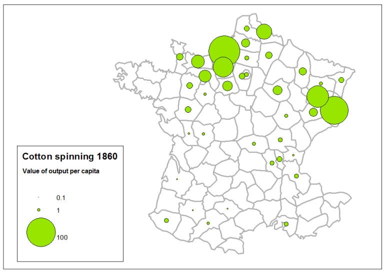
(g) Silk spinning, 1840



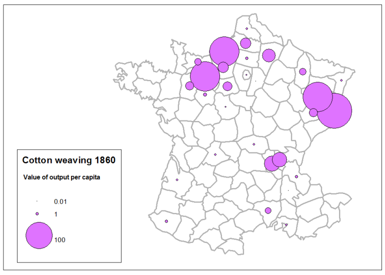
(h) Silk weaving, 1840

Figure 3.2: Value of output per capita in 1840 by department, spinning and weaving

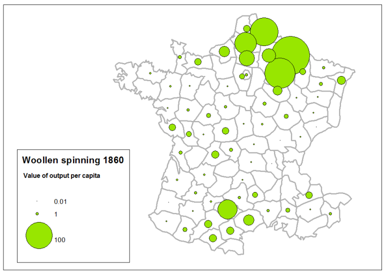
Data compiled by Chanut et al. (2000).



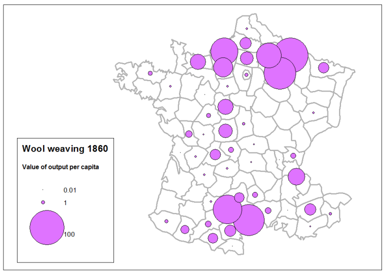
(a) Cotton spinning, 1860



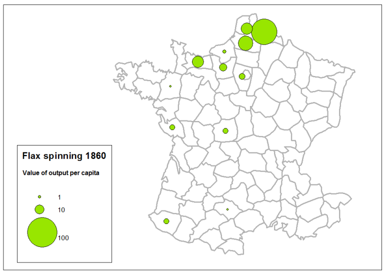
(b) Cotton weaving, 1860



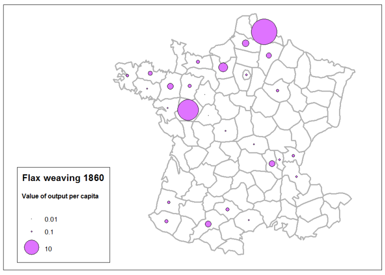
(c) Wool spinning, 1860



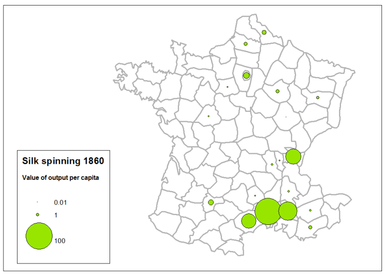
(d) Wool weaving, 1860



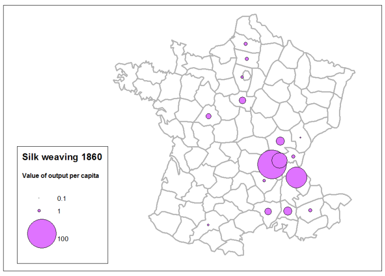
(e) Linen spinning, 1860



(f) Linen weaving, 1860



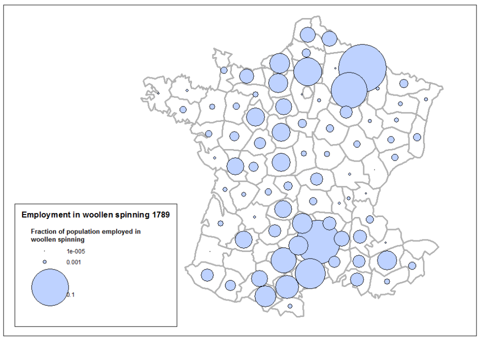
(g) Silk spinning, 1860



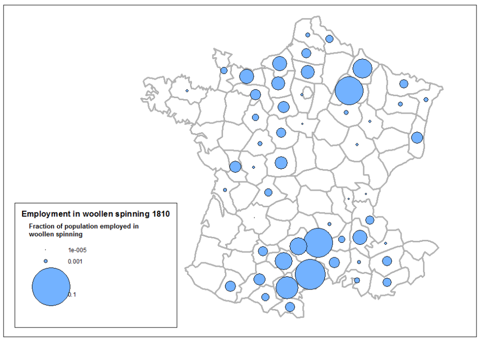
(h) Silk weaving, 1860

Figure 3.3: Value of output per capita in 1860 by department, spinning and weaving

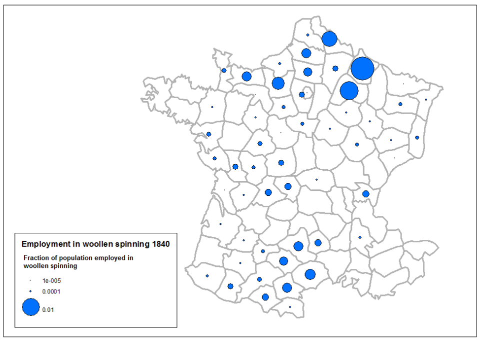
Data compiled by Chanut et al. (2000).



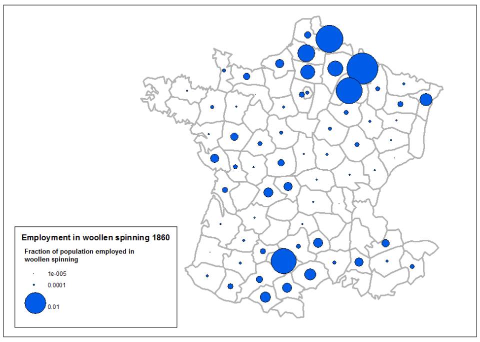
(a) 1789



(b) 1810



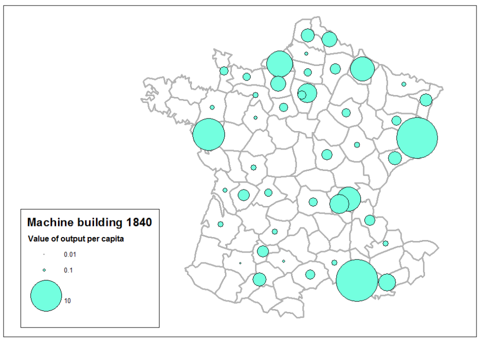
(c) 1840



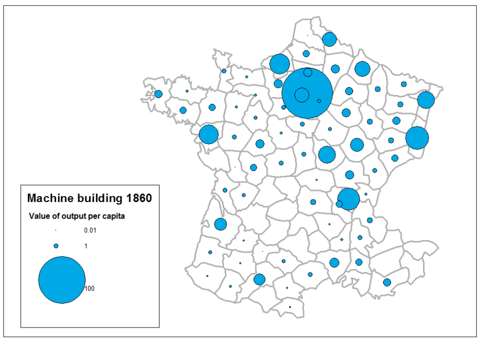
(d) 1860

Figure 3.4: Employment shares for 1789-1860 by department, woollen spinning

Employment numbers for 1789 and 1810 from prefectural reports pertaining to number of workers employed in hand-spinning. Employment numbers for 1840 and 1860 are from Chanut et al. (2000), and these numbers report workers employed in mechanised woollen spinning firms.



(a) 1840



(b) 1860

Figure 3.5: Value of output per capita for 1840-1860 by department, machine building

Data compiled by Chanut et al. (2000).

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Appendix A

Data Description

A.A Variable definitions and sources

This section defines the variables used in the empirical analysis throughout the thesis and provides the source from which they are constructed.

Shipping between Britain and Continental Europe

Data source: Lloyds List, 1787-1814, digitised by Google, made available by the Hathi Trust
Each observation is a journey which took place between a port in Britain and a port in Europe (excluding Ireland and Greenland).

Data on the cotton industry during the Napoleonic period

Data source: Champagny's survey: AN/F12/1562-1564, "Enquetes industrielles" 1810-1818: AN/F12/1570-1590, AN/F12/1602

- **Spinning capacity**

  The baseline measure of spinning capacity is the number of spindles, which is the standard measure of physical capital in mechanised spinning. In all regressions, I normalise by the departmental population. Data available for 1803, 1806 and 1812.

- **Labour employed in mechanised spinning:**

  Labour employed in mechanised spinning in 1803, 1806 and 1812. In all regressions, I normalise by the departmental population. In the empirical analysis, spindles is the preferred measure of production capacity as mechanisation substituted for labour. Using labour will therefore underestimate growth in the sector. It is also more sensitive to measurement error from misclassified hand-spinning.

- **Type of machine used**

  Data in 1803, 1806 and 1812 differentiate between two types of machine used for spinning; *"mul-jennys"* and *"filatures continus"*. One has, on average, more spindles than the other, and they were used for spinning either weft or warp. Table 2.11 contains results on differential changes in the type of machine used within a department.

- **Weaving capacity**

  Weaving capacity is measured using the number of weaving frames by department (per thousand inhabitants) in 1803, 1806 and 1812.

- **Weaving employment**

  Labour employed in hand-loom weaving for 1803,1806 and 1812.

Data on the wool industry during the French Revolutionary and Napoleonic period

Data source: 1792: AN/F12/1344-1348, 1810: AN/F12/1602

- **Labour employed in spinning:**

  Labour employed in hand-spinning in 1792 and 1810. In all regressions, I normalise by the departmental population. The absence of mechanisation makes this the relevant measure of woollen spinning activity.

- **Labour employed in weaving:**

  Labour employed in hand-loom weaving for 1792 and 1810.

- **Weaving capacity**

  Weaving capacity is measured using the number of weaving frames per department in 1792 and 1811.

Data on leather tanning during the French Revolutionary and Napoleonic period

Data source: 1792: AN/F12/1467-1472, 1811: AN/F12/1590-1600

- **Tanning capacity**

  Capacity in tanning is measured as the number of pits in 1792 and 1811. In the regressions, I normalise by departmental population.

- **Employment**

  Labour employed in leather tanning for 1811.

Literacy rates

Data source: Furet and Ozouf (1982)

Literacy rates are calculated from departmental statistics which give the percentage of males who could sign their marriage certificate between 1786-1790. The variable takes on values between 0 and 1.

Conscription rates

Data source: Hargenvilliers (1937)

Departmental conscription rates are defined as the number of men conscripted during the year 13 according to the French republican calendar (September 1, 1804 - August 30, 1805) divided by total departmental population in 1811. This is the last year for which detailed departmental statistics are available. Conscription was supposed to be proportionate to the size of the population across departments. In reality however, conscription rates differed somewhat. According to Forrest (1989), conscription rates had significant persistence over time. Departments in which fulfilling previous quotas had been easier were pushed harder in the following years. By 1813, this was something that even the *"Directeur general de la Conscription"* admitted, when he informed the prefect in Foix that the ability of an area to produce soldiers and past records of recruitment were being used (Forrest, 1987 p. 41). For this reason, conscription prior to our period of interest should be a reasonable proxy for differences in labour supply shocks owing to differential conscription during the Napoleonic Wars.

Access to coal

Data source: Fernihough and O'Rourke (2014)

For each city in their dataset, the authors calculate minimum distance (km) from any of Europe's major coalfields using Chatel and Dollfus (1931) for data on the location of coalfields. Cities located within a coalfield are coded as having distance 1km. The authors then transform this into a proximity measure by taking the inverse of this measure. To normalise the distribution, they multiply the inverse distance by 10,000 and take the natural logarithm. I transform this into a departmental measure for proximity to coal, by using the datapoint for the prefecture of the department. In a few cases when data for this city is not available, I use the closest city. I also calculate a different measure which takes the mean across all cities for which data is available in a department with very similar results.

Access to fast-flowing streams

Data source: European Water Archive, EURO-FRIEND River Discharge Data

Data on monthly mean flow rates for 2,412 collection points across the historical boundaries of the French Empire were averaged across time to obtain the mean monthly flow rate for each collection point. The average mean flow rate in each department is the average of all collection points located within the department. In the specifications presented in the thesis, I report results which use the natural logarithm of the mean flow rate, but results are similar when levels are used. Median flow rates across collection points for each department also give similar results.

Institutional change

Data source: Wikipedia

Institutional change is defined as the date of incorporation into the French Empire for each department. Departments belonging to France proper are coded as 1789.

Historic location of the cotton industry

Data source: Daudin (2010)

Historic location of the cotton industry is measured using the *"Tableaux du Maximum"*, compiled at the arrondissement (district) level during the French Revolution. The Tableaux provide information on trade links between 552 districts in France for fifteen different goods categories. Daudin collected a representative sample of arrondissements across departments in ancien regime France. A binary variable indicates whether a given consuming district reported consuming cotton goods from a given supplier district. Given this information, I construct a measure of how many other districts were supplied by districts in a given department. Normalising by departmental population gives a comparable measure of the size of the cotton industry for each department. A nice feature of this measure is that it captures cotton manufacturing for trade rather than own-consumption. Note however, that it is not a measure of spinning alone, but rather all aspects of the production process (spinning, weaving, printing).

Raw cotton prices

Data source: Journal du Commerce

Daily raw cotton prices were sporadically reported for various cities during 1798-1815 in the Journal du Commerce, the French commercial newspaper of the time. Within each category of cotton by supplying region (Levant, US, Colonial, Brazilian), the exact variety of cotton was matched for a southern and northern city within a short interval of time (within a few days to within a month) in order to attain as close a comparison between the north and south of France as possible. Northern cities used: Anvers, Lille, Rouen, Paris, Havre or Gand. Southern cities used: Bordeaux, Marseille, Toulouse, Lyon and Bayonne. For Levantine cotton, it was possible to match Marseille to a northern city for each year. These data were supplemented with London prices for Brazilian cotton from Tooke (1848).

Departmental population

Data source: Chabert (1951)

Departmental population is used to normalise measures of production capacity in cotton and woollen spinning and leather tanning. Population data is available for each department for 1811, including departments annexed to the Empire during the French Revolutionary and Napoleonic Wars. In 1806, Corsica was formed of two departments, Golo and Liamone, which were later merged and called Corse. As population data is reported for Corse in 1811, I combined the two departments in 1806 and used this in the analysis.

Industrial census data for 1839-47 and 1860-65

Data source: Chanut et al. (2000)

- The first industrial census in France was conducted between 1839-1847. Data is missing for firms in Paris and Lyon and for this reason, the departments Seine and Rhone (to which the respective cities belonged to) are excluded from all regressions. I use the following variables: value of production, workers employed, share of women employed, share of children employed, an indicator variable for whether the firm uses water or steam power and the log of primary materials used as a measure of firm size. Labour productivity is measured as the log of the value of production per employee. For cotton spinners, I collected data on spindles employed from the original data published by the French government.

- Data from the second industrial census, conducted between 1860-65, was published only at the level of the arrondissement (district). I use data on the value of production, number of employees in a given industry, and total use of water- and steam-power (measured as horsepower).

French exports and imports

Data source: F/12/251

Value of exports and imports by category and source-destination country for 1787-1828 (1790-1797 and 1806 are missing). All values in francs.[1] I supplement this with data on the value of British cotton exports and exchange rates from Mitchell (1971).

Consumption of raw cotton per capita

Data source: Mitchell (2007)

I use data on imports of raw cotton and normalise by population as of 1840 to calculate the size of the cotton spinning industry (for which raw cotton is an imported input) across Continental European countries for 1830-1850.

[1] Data kindly shared by Guillaume Daudin.

British patent data

Data source: Woodcroft Bennet: Subject-matter Index (made from Titles Only) of Patents of Invention, from March 2, 1617 (14 James I.), to October 1, 1852

This book contains the names of all patents filed in Britain between 1617-1852. The author classified the patents by industry. I use the 385 patents classified under textile spinning machinery to construct my measure of technological proximity. A patent title generally contains a brief description of the patent. For example, patent number 931, Richard Arwright's waterframe has the following title "Piece of machinery for the making of weft or yarn from cotton, flax, and wool, much superior in quality to any heretofore manufactured or made."

Quality measure for British patents

Data source: Nuvolari and Tartari (2011)

The authors collected data from Woodcroft Bennet's (1864) book which collected information on the number of times a patent was cited in contemporaneous engineering literature and legal disputes. The authors argue that these citations measure patent quality, as engineering literature would discuss important innovations more frequently, while litigation should be more intensive for economically more valuable patents. The quality measure is defined as 1+ total citations.

A.B Construction of data from primary sources

The cotton industry: 1803 - 40

Data on the cotton industry comes from large scale industrial surveys conducted in 1806 and on a quarterly basis between 1810-1815. The 1806 industrial census contains almost complete firm level data on all mechanised cotton spinning firms in regions which were part of the French Empire as of January 1, 1806.[2] The quarterly reports, by department, from 1810 onwards contain data only at the level of the department, which implies that the unit of observation in the empirical analysis is the department. Of the 110 departments which formed the French Empire in 1806, data for both 1803 and 1812 is available for 88 departments. In the following, I discuss construction of the database for each period.

Champagny's survey of the cotton industry: 1806

In January, 1806 (about 9 months before the onset of the Continental Blockade), the Minister of the Interior, Champagny set about conducting an industrial census of the cotton industry. The questionnaire, an example of which can be seen in Figure A.2, was sent to the prefects of all departments for completion. 8 out of the 110 departments failed to complete the survey. Data on the precise location of the firm, the name of the owner, date of foundation, number of employees, (for both 1803 and 1806) number of different types of machines (for both 1803 and 1806), output and quality of yarn spun (count variable) were provided. Of the 626 entries from the 102 departments which supplied data, I eliminated 43 entries which were not firms.[3] These entries are either charitable institutions or jails which produced some cotton yarn for their own use, or they are entries for rural spinners who used a small jenny instead of a wheel. I drop the former type of entries, as these are not organised as for profit institutions. Rural spinners, who generally worked in their own homes for a piece rate, represent an intermediate step between traditional, rural hand-spinning and modern, mechanised firms employing wage-labourers in a factory. This is not

[2] Chassagne (1976) gives the historical background to the survey. Chassagne also collected and analysed the data, but as spindle data was not available by department for 1803 and 1806, only a qualitative comparison is made between the location of mechanised spinning activity between 1806 and 1812. Detailed data collected by Chassagne was, to the best of my knowledge, never published, and for this reason, I transcribed all prefectural reports from original sources.

[3] Note that this is not equal to the number of firms in the dataset in 1806, because some entries contain data for firms alive in 1803 which went bankrupt by 1806.

the type of firm the survey asked for, and for this reason reporting was inconsistent across regions, which is why I drop these from the analysis.

The only other change I make to the raw data is to create a third category for type of machine. The survey asked for the number of “mull-jennys” (MJ - French name for mule jenny), for spinning weft, and “filature continus” (FC), for spinning warp.[4] Firms and prefects would often report “jeanettes” (JEA) which were much smaller, hand-powered, early type jennys, under the category of MJ. I therefore create a third category of machine to account for these. The average number of spindles for a JEA (37) is far smaller than the average number of spindles for an MJ (112) in the sample. As I impute average spindle by machines type for firms, it is important to make this distinction.

Imputation model for spindles in 1803 and 1806

Despite the fact that only the number of machines used by the firm was asked for in Champagny’s survey, some firms or departments reported only number of spindles, some reported both number of machines and number of spindles and some reported only number of machines. Because of the different availability of data on capital across firms, and, because subsequent surveys consistently reported spindles at the departmental level, it is necessary to impute spindles for the firms who are missing spindle data in 1803 and 1806. As the number of machines is known for these firms, once the average number of spindles by machine, for each firm is imputed, it is possible to calculate the total number of spindles both at the firm, and at the departmental level.

I imputed the average number of spindles by machine type for each firm and then aggregate these results up to the departmental level. I check robustness of the estimation results to the imputation model in two ways. First, I use multiple imputation (MI) to impute the data for firms. Differently to single imputation methods, multiple imputation does not treat imputed observations as known in the analysis. Instead, MI creates multiple imputations for each missing observation, and accounts for sampling variability due to the missing data. This procedure has been shown to be statistically valid from both a Bayesian and a frequentist point of view (Rubin, 2004). I show that both the point estimate and the standard errors change

[4] The two types of yarn differ in fineness.

very little when this sampling variability is accounted for. Second, in Chapter 2, I show that the results are similar when the number of workers employed in cotton yarn spinning is used as the dependent variable. As this variable is available for almost all firms in 1803 and 1806, this measure is not imputation-dependent.[5]

As the most detailed information is available for firms in 1806, I impute the average number of spindles for a given machine for a given firm for the data available in 1806 and then use average spindles from 1806 together with number of machines reported in 1803 to impute spindles in 1803 for the firms where this was missing. Of the 567 firms alive in 1806, 41 reported only spindles. As the number of their machines is missing, they need to be excluded from the imputation model and their data will simply be included when calculating total spindles by department. One firm reported neither number of machines, nor number of spindles, but only the average number of spindles per machine, so their machine data will be imputed.

The remaining 525 firms all reported machine data and some of them also reported number of spindles. These are thus the firms that are included in the imputation model. Table A.1 contains the pattern of missing data for firms in 1806 for the three different types of machines used by spinning firms, "jeanettes" (JEA), "filatures continus" (FC), and "mull-jennys" (MJ). Firms usually used only one or two types of machines, which is why the total number of firms who reported using a given type of machine is well below 525. As can be seen from the table, the average number of spindles per firm (by machine type) is missing for around 50% of the firms. Furthermore, in this particular case, imputation occurs at the level of the firm for a variable that has a restricted range (average spindle for each machine type varies based on a few varieties available). As we are interested in spindles *by department*, aggregating up to the departmental level should average out non-systematic variability in imputation making the results less sensitive to sampling variability.

Imputation proceeds as follows.[6] By machine type, I calculate average spindles per firm for the firms which reported both spindles and number of machines used. I then use this information, together with data on all other firm characteristics to

[5]In this sense, it may not be obvious why labour is not the baseline measure of capacity. The reason for this is that if capital substitutes for labour in the mechanised production process of spinning, then looking at changes in labour employed will underestimate growth in the sector. Furthermore, data on number of employees is more susceptible to measurement error because of fluctuations in capacity utilisation, and it may also contain data from hand-spinning in later years, when the absence of firm-level data makes this more difficult to detect.

[6]I use Stata's multiple imputation tool to estimate the model.

impute the average spindle per firm for the given machine type. A further complication arises from the fact that other firm level variables are also incomplete. Table A.2 contains the information on missing data patterns for all other firm level variables. As can be seen, the ratio of missing to complete observations is much smaller in the case of these variables. However, the fact that all variables contain missing observations in a non-monotone manner implies that imputation is based on a chain iterative model. Each variable is estimated using a univariate imputation model with all variables used as independent variables. Iteration is required to account for the possible dependence of estimated model parameters on imputed values. I use the date of foundation, output, maximum quality of yarn spun, minimum quality yarn spun, number of workers and number of each type of machine used to impute the average number of spindles by machine type for a given firm.

Almost all firm level variables are count variables, therefore a Poisson model is used for all variables except the three average spindle variables. For these, I use predictive mean matching to account for the fact that average spindles for a machine are bounded by technological constraints. In particular, each machine type had a a number of "varieties" available on the market. For example, MJs usually had 48, 96, 128, 196, 218 and sometime 248 spindles. As the histogram for the average number of MJs per firm shows in Figure A.1, there is a lot of mass at these points of the distribution.[7] The variable is continuous, because some firms use a combination of different varieties, and averaging at the firm level will give mass to other points.

Spindles for firm i in 1806 are then simply calculated as the sum of the number of machines multiplied by average spindles by each type of machine. Calculating spindles for firms in 1803 is also straightforward. There are 375 firms in the database, 16 of which go bankrupt between 1803 and 1806. For almost all the remaining firms, the average spindle data per machine type can be used to calculate number of spindles in 1803, based on how many machines the firm reported for that year. This clearly does not work for firms that went bankrupt by 1806, but also firms which switched into new types of machines between the two points in time. For these firms, I simply use average number of spindles across all firms for the given machine type. This should not substantially alter the results, as there are only 18 such changes across all firms and machine types. Finally, three departments (Seine Inferieure, Indre et Loire and Orne) do not report 1803 data. For these departments

[7]The figure contains data only for the firms where this information is observed.

(which do supply data for 1806), I take the 1806 numbers for the firms alive in 1803 as the best available measure of spinning activity.

"Enquêtes Industrielles": 1810-15

Data on spinning is only observed at the departmental level from 1810 onwards. Prefects were asked to initially send reports on industrial activity for various branches of industry including cotton at 6 month intervals between 1810/1 and 1811/2. From the beginning of 1812, the reports were to be sent to Paris on a quarterly basis. I observe number of spindles, number of workers and output at the departmental level. The reports were intended to inform the government in Paris about fluctuations in industrial activity and for this reason, prefects sometimes reported capacity and sometimes they reported utilisation. Therefore, there are sometimes large fluctuations in the numbers reported from one period to the next. To gain the best possible measure of capacity, I utilise the reports in the following way. In general, I take data from the year 1812 as this is the year closest to the end of the Blockade where data coverage was still sufficiently large.[8] However, if the number of spindles was larger in earlier reports (1810-11), I use these years. In accompanying qualitative reports sent to Paris, prefects usually indicate whether firms have gone bankrupt or whether they are idle for cyclical reasons. I don't use earlier numbers in instances where it is clear that activity in 1812 is lower because firms have gone bankrupt.

Industrial census data: 1839-47

Chanut et al. (2000) collected and compiled almost all the data available from the first large-scale industrial census in France (1839-47) which was published by the French government. One notable exception is the spindle data which was reported by 40% of cotton spinners.[9] I collected the spindle data from the original volume published by the French government and used the same iterative chained imputation model presented above to impute the missing spindle data. As I did not observe the average number of spindles, I used a predictive mean matching model to directly impute the number of spindles for each firm. I used all firm level variables in the imputation model (value of output, value of raw materials, rental value paid,

[8]As Napoleon's power unravelled, and troops invaded the territory of France, fewer and fewer departments submitted their reports.

[9]Of the 531 firms in the sample, spindle data was missing for 315 firms.

property tax paid, number of men, women and children employed and their wages.) Similarly to the other imputation model, I used a Poisson specification to impute the very small number of missing observations for other variables (in all cases, the number of missing observations was less than 5% of the sample).

Woollen spinning and leather tanning: 1792-1811

To construct data on capacity in woollen spinning and leather tanning, I use data collected at the 'arrondissement' (district - one administrative level below the department) level for both industries in 1792 and data collected at the departmental level in 1810 for woollen spinning and 1811 for leather tanning. Data from 1792 is aggregated up to the departmental level to gain a comparable measure of capacity. Data from 1792 are somewhat noisily measured as they were collected at the level of the district, and it is often impossible to determine whether a district's data point is missing or zero. Furthermore, the survey asked for the state of the industry in 1789, before the Revolution. The survey only covered departments belonging to France at the time of its 1789 borders.

Lloyd's List

Shipping data was extracted using all editions of the Lloyd's List between 1787-1814. The Lloyd's List, one of the world's oldest newspapers, was set up by Lloyd's Coffee House in London as a meeting point for underwriters of marine insurance. The underwriters needed up to date news on shipping conditions, and for a small subscription fee Lloyd's provided what was generally acknowledged to be the most up to date shipping bulletin of the time.

Lloyd's hired paid correspondents in each port to send information on ships arriving to or departing from a given port to the Post Master General with the word "Lloyds" written in the corner. Each edition featured news on ships sailing from and arriving to various ports. The coverage on arrival and departure of ships to all ports in Britain is believed to be a fairly reliable and representative source of information at the time (Wright and Fayle, 1927).

Editions of the Lloyd's List have been digitised by Google. To extract data from this source, I used an OCR programme to convert the images into machine-readable format and then used a text-matching programme that searched for the names of

European ports in the Lloyd's List. As port names have changed over time, and even within the time frame that I examine, numerous port names or spelling was in use for the same port, the names of ports were collected by manually searching through editions of Lloyd's Lists. There are multiple sources of measurement error inherent in this procedure. First, the OCR and text-matching programme introduce measurement error both in the form of matching mistakes and omitted names (the ones that could not be matched, or the European ports which I did not identify as such). By comparing samples to the original, I found that incorrectly matched names were minimal, and that the procedure picked up about 70-80% of the ports depending on the quality of the image. Finally, I also had one year (1808) manually entered in order to check that the sample with which I work is representative. There are around 3000 observations for each year.

One potential problem with this data source is that some authors claim that during the blockade, parts of the Lloyd's List was censored to protect smugglers and full information was only provided to insurers at the "Books and Notice Boards in the Subscribers' Rooms" (Wright and Fayle, 1927). Censoring would have effected direct routes between Britain and France where ships were at risk of violating the laws of the Continental Blockade, but not routes via smuggling centres which either belonged to the British, or were allied to the British. Censoring would undoubtedly lead to measurement error in quantifying trade routes, however, there are a number of reasons to believe that the extent of censoring was not quantitatively important.

First, censoring was only in place for part of the Blockade period, and uncensored and censored years show a very similar pattern calling into question the extent to which censoring was indeed practised. Second, in response to censoring by Lloyd's, a rival newspaper was actually set up by employees of the Post Office. This newspaper, "General Shipping & Commerce List" was supposedly not censoring shipping news, which would have given Lloyd's a disadvantage on the market were it to have been extensively censoring news. Second, the findings from the Lloyd's List are consistent with both historical evidence and other sources of quantitative evidence (British trade statistics). To the extent that direct smuggling to France and Germany was actually possible, the finding that indirect routes were used to a large extent points to either direct smuggling not being quantitatively important, or to the fact that direct smuggling was so risky (and thus costly) that indirect, and less risky routes were equally profitable. As I final robustness check, I construct two measures of the trade cost shock, only one of which relies quantitatively on results from the Lloyd's List.

A.C Primary sources consulted

Archives Nationales (Paris, France)

- *AN/IV/1318* Petition from cotton spinners to Napoleon requesting ban on imports of British yarn
- *AN/IV/1060-61* Ministerial reports on commerce and industry
- *AN/F7/3040* Daily price for merchandise (including raw cotton) at the Paris exchange (an 6 - an 10)
- *AN/F7/8777-8778* Reports on smuggling from Pyrenees and Eastern border.
- *AN/F12/1554-5* Reports on industry. Includes monthly reports from the cotton market in Rouen.
- *AN/F12/533* Various documents on the cotton industry from the Napoleonic period. Contains some prices for spun yarn in Eure department. "Bulletin de coton" provides qualitative overview of the state of the cotton industry for a given month (many missing). Firm level data for mechanised spinners in Seine department for 1808.
- *AN/F12/631* Daily price for merchandise (including raw cotton) at the Paris exchange (1806-1813). Qualitative departmental reports on the state of industry.
- *AN/F12/1245B* Annual reports from Beaucaire fair (an 6 - 1814).
- *AN/F12/1342* Tolozan's report on the state of the cotton industry in 1789.
- *AN/F12/1344-1348* Industrial survey of woollen industry (1792).
- *AN/F12/1467-1472* Industrial survey of leather tanning (1792).
- *AN/F12/1561* Statistics on cotton industry (predominantly for the period after 1810)
- *AN/F12/1562-1564* Champagny's survey of the cotton industry (1806)
- *AN/F12/1570-1589* Detailed departmental statistics and reports for textile industry, 1810-1823.
- *AN/F12/1590-1600* Industrial survey for leather tanning, 1811
- *AN/F12/1602* Aggregate tables for textile industry from industrial surveys (cotton, wool, linen, silk and hemp).
- *F12/1859* French consular reports from across Europe. Cotton yarn prices in Bosnia and Malta.

Bibliotheque National de France (France)

- *Journal du Commerce* Commercial newspaper which sporadically reported prices from markets across France. Contains raw cotton prices from across the French Empire for 1798-1815.

- *"Statistique de la France. Industrie: 1847". France: Ministère de l'agriculture et du commerce (1839-1852).* Original census published by the French government. Number of spindles used by cotton spinning firms was collected as this was not published in Chanut et al. (2000).[10]

[10]The data were kindly shared by Peter Solar.

A.D Tables

Table A.1: Missing data pattern for average spindles by machine at the firm level

	JEA	FC	MJ
Spindles and Machine	20	76	102
Machine only	70	136	190
Total	90	212	292

Table A.2: Missing data pattern for firm level variables

	Observed	Missing	Total
Foundation	560	7	567
Workers	546	21	567
Max quality	401	166	567
Output	522	45	567

A.E Figures

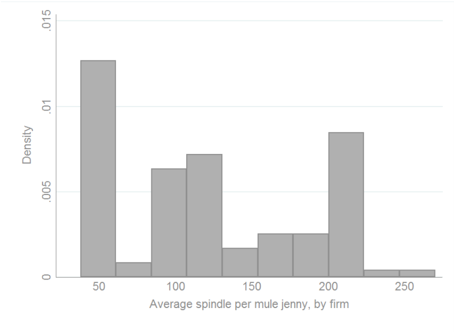
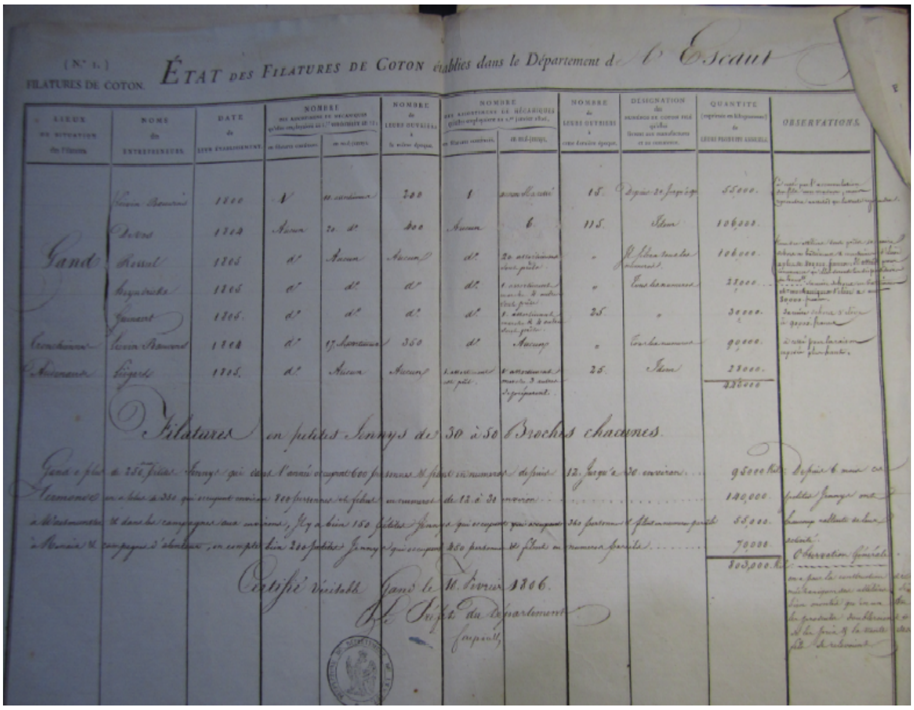


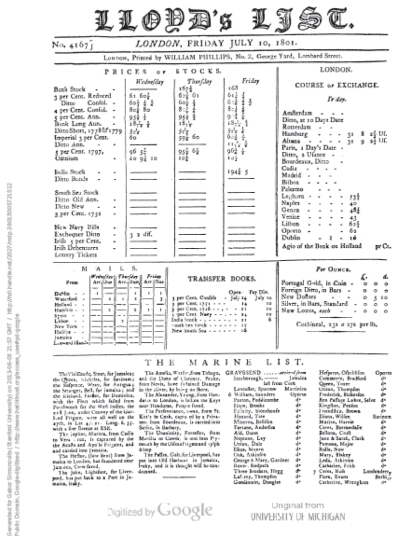
Figure A.1: Average spindles per firm for mule-jennys

A.F Examples of the Primary Data Sources


[N° 1.]
FILATURES DE COTON.
ÉTAT DES FILATURES DE COTON établies dans le Département de l'Escaut

Filatures en petites Jennys de 30 à 50 Broches chacunes.

Figure A.2: Example of prefectural report from 1806 for Escaut department


LLOYD's LIST.
No. 4167] LONDON, FRIDAY JULY 10, 1801.

PRICES of STOCKS.

LONDON.

COURSE of EXCHANGE.

MAILS.

TRANSFER BOOKS.

THE MARINE LIST.

Figure A.3: Example of Lloyd's List