

# Temporary Protection and Technology Adoption: Evidence from the Napoleonic Blockade

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Job Market Paper

*November 13, 2014*

## Abstract

This paper uses a natural experiment to assess whether temporary protection from trade with industrial leaders can foster development of infant industries in follower countries. Using a new dataset compiled from primary sources, I find that in the short-run regions (départements) in the French Empire which became better protected from trade with the British for exogenous reasons during the Napoleonic Wars (1803-15) increased capacity in a new technology, mechanised cotton spinning, to a larger extent than regions which remained more exposed to trade. Temporary protection had long term effects. In particular, by exploiting the fact that the post-war location of the cotton industry was determined to a large extent by the historical accident of the wars, I first show that the location of cotton spinning within France was persistent, and firms located in regions with higher post-war spinning capacity were more productive 30 years later. Second, I find that after the restoration of peace, exports of cotton goods from France increased substantially, consistent with evolving comparative advantage in cottons. Third, I show that as late as 1850, France and Belgium - both part of the French Empire prior to 1815 - had larger cotton spinning industries than other Continental European countries which were not protected from British trade during the wars; this suggests that adoption of the new technology was far from inevitable.

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\*r.juhasz1@lse.ac.uk. I thank Silvana Tenreyro and Steve Pischke for their continued guidance and support. This paper has also benefited from discussions with Oriana Bandiera, Tim Besley, Francesco Caselli, Nick Crafts, Guillaume Daudin, Jeremiah Dittmar, Maitreesh Ghatak, Knick Harley, Ethan Ilzetzki, Balázs Muraközy, Gianmarco Ottaviano, Guy Michaels, Michael Peters, Thomas Sampson, Daniel Sturm and seminar and conference participants at LSE, Warwick, FREIT-EIIT, 2014, NEUDC, 2014, ETSG, 2014, the Belgrade Young Economist Conference and the Hungarian Academy of Sciences Summer Meeting. Financial support from STICERD and CEP is gratefully acknowledged. I thank Bertrand Blancheton, Guillaume Daudin, Alan Fernihough, Gilles Postel-Vinay, and EURO-FRIEND for kindly sharing data.

*“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<sup>1</sup>*

## 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.<sup>2</sup> 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.<sup>3</sup> 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).<sup>4</sup> 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.<sup>5</sup>

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

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<sup>1</sup>Edwards, (1967) p. 51.

<sup>2</sup>Early proponents include US founding father Alexander Hamilton, and the 19th century economist, Friedrich List.

<sup>3</sup>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.

<sup>4</sup>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 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.

<sup>5</sup>In Section 4, I discuss the fact that in general, trade policy is not the most efficient way of correcting the market imperfection.

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 paper, 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 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.<sup>6</sup> 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.<sup>7</sup>

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

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<sup>6</sup>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.

<sup>7</sup>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.

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 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.<sup>8</sup>

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.<sup>9</sup> As distance is a barrier to trade, it plays a role similar to that of tariffs or other trade policy instruments. Geographic

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<sup>8</sup>In its use of a historical blockade as a source of exogenous variation, the paper is related to Hanlon (2011) 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.

<sup>9</sup>See Head and Mayer (2013) for a recent review of the gravity literature.

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.<sup>10</sup>

To conduct the empirical analysis, 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.<sup>11</sup>

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 be conducive to the development of modern industry, and cotton spinning in particular. These variables include locational fundamentals important for mechanised cotton spinning such

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<sup>10</sup>In this sense, the paper is related to recent contributions which use changes in trade routes or the introduction of trade-cost reducing technology to estimate the effect of trade on growth in a cross-country setting. See Feyrer (2009), Feyrer (2009) 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).

<sup>11</sup>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.

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 more productive and were able 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 paper 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.<sup>12</sup> 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

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<sup>12</sup>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.

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 the paper contribute to several strands of the literature. First, the main contribution of the paper 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 counterfactual of no-protection.<sup>13</sup> 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, and as such they constitute lower-bound estimate on welfare. The paper 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 paper 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 focus of this study is not to evaluate whether temporary shocks can shift the location of a given activity within a country, but rather whether activity can be shifted across countries, in a context where labour mobility is much smaller and the underlying mechanism is very different.

The paper 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) and Bustos (2011) both find that increased international competition induced firms to upgrade technology, albeit at different regions of the productivity distribution. The mechanism in both cases is a complementarity between exporting and technology.<sup>14</sup> Both studies share the common

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<sup>13</sup>Baldwin and Krugam (1986 and 1988), Head (1994), Luzio and Greenstein (1995), Hansen, Jensen, and Madsen (2003) and Irwin (2008).

<sup>14</sup>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.



feature that they examine trade liberalisation between countries at a similar level of development. In contrast, the economic mechanism underlying infant industry protection assumes a technological gap which drives initial differences in static comparative advantage for the sector in question. For this reason, it is more plausible to expect this mechanism to be at work in the context of trade between countries at a different level of development. The findings of this paper should thus be seen as complementing the existing literature.

Finally, the paper 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 paper finds support in favour of an infant industry mechanism, and in this way, relates to Williamson's (2011) work on 19th century development.<sup>15</sup>

The paper 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.

## 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

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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.

<sup>15</sup>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.

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 comparative 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.

## 2.1 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.<sup>16</sup>

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.<sup>17</sup> Asian cotton cloth was initially introduced to the European market by merchants in the 17th century to enormous success.<sup>18</sup> The 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.<sup>19</sup>

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

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<sup>16</sup>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.

<sup>17</sup>Strictly speaking, silk is not indigenous to Europe either, however silk production had been practised throughout Europe for centuries.

<sup>18</sup>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 with indigenous European textiles such as wool, linen or silk (Chapman and Chassagne, 1981).

<sup>19</sup>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.

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.<sup>20</sup> 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 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 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.<sup>21</sup>

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

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<sup>20</sup>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).

<sup>21</sup>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.

half of the 19th 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 1. This machine was relatively simple, small and cheap.<sup>22</sup>

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.<sup>23</sup> In the case of spinning machinery however, adoption across Britain was remarkably fast (Allen, 2009). As 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

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<sup>22</sup>Allen (2009) puts the cost of a jenny at 70 shillings (a spinner would earn a weekly wage of 8-10 shillings).

<sup>23</sup>See Geroski (2000) or Rosenberg (1981).

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 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.<sup>24</sup> 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.

### 2.3 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-à-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.<sup>25</sup>

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<sup>24</sup>As a comparison, 50% of woollens and under a third of silk was exported.

<sup>25</sup>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.

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 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.

## 2.4 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.<sup>26</sup> 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

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<sup>26</sup>This was equally true for all of Continental Europe.

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.<sup>27</sup> 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 competitive disadvantage of French spinners. Figure 4 compares Paris and London prices for the full range of counts on the eve of the Blockade.<sup>28</sup> 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 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 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.<sup>29</sup> By way of comparison,

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<sup>27</sup>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.

<sup>28</sup>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 C.

<sup>29</sup>Data sources for French trade statistics are discussed in Appendix C.



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.

## 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 Oberkamp 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, Oberkamp 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 which was 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.<sup>30</sup>

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 14 shows the geographic dispersion of weaving in 1803, where capacity 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.

### 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.

#### 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 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.

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<sup>30</sup>For example, Chapman and Chassagne (1991) discuss Oberkampf's efforts in securing Pernambuco (Brazilian) cotton from Lisbon merchants by way of Nantes during the blockade.

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.<sup>31</sup> 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 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.<sup>32</sup> 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 countries collapsed, however the countries were able to continue trading with little interruption by way of neutral carriers and nearby neutral ports.<sup>33</sup> 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 to the imposition of the Continental Blockade (1803-06), and 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

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<sup>31</sup>By 1800, the British had twice the number of warships as the French did (Davis and Engerman, 2006).

<sup>32</sup>The map of the French Empire relative to France at its 1789 borders can be seen in Figure 15.

<sup>33</sup>Figure 6 shows that this was the case during the French Revolutionary Wars (1793-1802).

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.<sup>34</sup>

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.<sup>35</sup> 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 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).

## 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 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 from the Lloyd's List, and will be described in more detail in Section 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

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<sup>34</sup>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.

<sup>35</sup>The interested reader can consult Davis and Engerman (2006).

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 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 6 shows time series evidence of the uneven effects of the blockade. In each panel of Figure 6, the same port level shipping data used to construct Figure 5 from the Lloyd’s List has been aggregated up to the regional level in order to examine the evolution of shipping over time.<sup>36</sup> 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.

### 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 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

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<sup>36</sup>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.

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 Tonnung 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.

### 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".

### **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.

### **3.6 Evidence from British trade statistics**

Consistent with evidence from 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 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 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 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.

### 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 Frankfurt, 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)<sup>37</sup>

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

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<sup>37</sup>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.

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.<sup>38</sup> 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.<sup>39</sup>

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 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, 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 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.

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

<sup>39</sup>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.

## 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 growth 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.

### 4.1 Setup

The world consists of the frontier (Britain),  $F$ , and two follower regions  $i = 1, 2$  (French regions).<sup>40</sup>  $F$  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 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:<sup>41</sup>

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

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  $C_i = \min\{a_{it}^C L_i^C, R_i\}$ .  $L_i^A$ ,  $L_i^R$

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<sup>40</sup>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.

<sup>41</sup>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  $t > 0$ .

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.<sup>42</sup> 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:  $p^R = \frac{1}{a_F^R}$ ,  $p^C = \frac{1}{a_C^F} + a_F^R$  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  $a_i^R = 0$ .<sup>43</sup> 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

$$\begin{cases} \frac{\dot{a}_{it}^C}{a_{it}^C} = Q(C_{it}^c), & \text{if } a_{it}^C < a_C^F \\ \frac{\dot{a}_{it}^C}{a_{it}^C} = 0, & \text{if } a_{it}^C = a_C^F \end{cases} \quad (2)$$

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

Both follower regions start with an initial productivity lag in  $C$  relative to the frontier.<sup>44</sup> 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,  $\tau$ , which does not depend on geographic distance to the frontier. The

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<sup>42</sup>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.

<sup>43</sup>I make this assumption so that  $R$  is an imported input for follower regions.

<sup>44</sup>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.

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.<sup>45</sup> Note however, that the results which follow do not rely on any restriction on the size of  $\tau$  relative to  $t_i$ . Finally, if follower regions trade, they face symmetric unit shipping costs on cotton yarn,  $t_{12} = t_{21}$ .

## 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.<sup>46</sup>

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  $w_0^i = 1, i = 1, 2$ . 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<sup>47</sup>

$$p^C + t_i \geq \frac{1}{a_{i0}^C} + p^R \quad (3)$$

Inspection of Equation 3 reveals that there will be a cutoff distance  $\bar{t} = \frac{a_F^C - a_{i0}^C}{a_F^C a_{i0}^C}$ .<sup>48</sup> 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

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<sup>45</sup>Different regions within France had somewhat different access to different types of raw cotton, as I show in Section 6 because of non-negligible transport costs. This would imply that follower regions have different transport costs of raw cotton  $\tau_i$ , 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  $\tau$  constant across regions.

<sup>46</sup>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.

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

<sup>48</sup>The expression for the cutoff distance substitutes for  $p^C$ .

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  $p_i^C = p^C + t_i$ .

### 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 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  $C$ .  $\frac{a_{it}^C}{a_{it}^C} = 0, \forall t$  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.  $\frac{a_{it}^C}{a_{it}^C} > 0$  and  $\frac{p_{it}^C}{p_{it}^C} < 0$  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  $C$ .<sup>49</sup>
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  $C$

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<sup>49</sup>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.

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 specialisation 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.<sup>50</sup>

The empirical analysis is positive, it should be noted however, 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.

#### 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  $R$ .

In particular, let  $\Delta t_i \equiv t'_i - t_i$  denote the shock to trade costs for British yarn in

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<sup>50</sup>It is well known, that a tariff is not the most efficient way of fostering development of the infant industry. In general, a production subsidy 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.



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

$$\min\{p^C + t'_i; p_{jt}^C + t_{ij}\} \geq \frac{1}{a_{it}^C} + p_r + \tau_i \quad (4)$$

This expression differs from Equation 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, inasmuch 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  $\Delta t_i$  and  $\Delta\tau_i$  to be large enough such that the inequality in equation 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 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 growth. 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 6 and 7, I take the short- and long-run predictions to the data. In the following section, I describe data collection and data sources.

## 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, and the Lloyd’s List, which is the source for port level shipping data presented in Section 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 C. Examples of the original data are provided in Figures 21 and 22 in Appendix D.

### 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.<sup>51</sup>

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<sup>51</sup>More details on the imputation model and robustness to imputation can be found in Appendix C.

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.

## 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 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.

### 5.2.1 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 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.<sup>52</sup>

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 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 excluding 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

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<sup>52</sup>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.

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.

### 5.2.2 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 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.<sup>53</sup> Given the pattern in Figure 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

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<sup>53</sup>Recall Tonningen played a crucial role in maintaining trade between Britain and the Continent during the North-Sea blockade between 1803-1805.

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.<sup>54</sup> 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 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.

### 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 C. 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 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).

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<sup>54</sup>Corunna's share in smuggling is below 2%.

## 6 Short-term Empirical Strategy and Results

The theoretical framework presented in Section 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.

### 6.1 Mechanised spinning during the Napoleonic Wars

Figure 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.<sup>55</sup> 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 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

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<sup>55</sup>This figure is calculated using the 88 departments for which data is available in both 1803 and 1812.



the border with Spain saw outright decline in all departments. Modern firms in these areas went bankrupt and firms reverted back 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.

## 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.<sup>56</sup> 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 protection on mechanisation in spinning. This leads to the following specification, similar in spirit to a standard difference-in-difference (DD) estimator;

$$S_{it} = \alpha_i + \delta_t + \gamma \ln D_{it} + \epsilon_{it} \quad (5)$$

$S_{it}$  is a measure of mechanised spinning capacity in region  $i$  at time  $t$ ,  $\ln D_{it}$  is a measure of effective distance to Britain in department  $i$  at time  $t$ ,  $\alpha_i$  controls for time-invariant fixed effects at the regional level, and  $\delta_t$  controls for the effect of aggregate shocks over time.  $\gamma$  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 6, I show however that the results are robust to using either a log-specification, or the Poisson conditional fixed effects estimator.

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<sup>56</sup>See Head and Mayer (2013) for a recent discussion on the gravity literature.

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 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 1 and 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 14 and 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.

The quality of yarn spun by the firm was significantly higher for high-trade cost shock firms (at 10%), but it is not obvious that this will favour these firms as high quality raw cotton necessary for their production became more difficult to access during the

Napoleonic Wars. 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 effects of a potentially uneven labour supply shocks 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 the 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.

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.<sup>57</sup> 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 3 contains the results from estimating equation 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 4 and 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 3 show that indeed, treatment has a continuous 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

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<sup>57</sup>See Section 2 for a discussion.

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.

### 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 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).<sup>58</sup>

Table 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

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<sup>58</sup>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.

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 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 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.<sup>59</sup>

## 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.<sup>60</sup> 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 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

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<sup>59</sup>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).

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

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 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 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 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, 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, 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 16 in Appendix B, 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 16 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,<sup>61</sup> 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.<sup>62</sup>

## 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 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 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

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<sup>61</sup>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.

<sup>62</sup>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.

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.

## 6.6 No differential investment in machine type

In Table 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.

## 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 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.

## 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.

## 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.

## 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

$$Y_{i(j)t} = \alpha + \beta S_{i(t-1)} + \gamma' x + \eta_{i(j)} \quad (6)$$

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 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.<sup>63</sup> 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 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 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 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 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

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<sup>63</sup>Appendix C discusses this source in more detail.

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.

## 7.2 Competitiveness in export markets

In order to investigate whether some firms had become sufficiently productive to compete at international prices, Figure 17 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.<sup>64</sup> 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 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 (2009) 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.

### 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 18 shows evidence to the contrary. As late as 1851, there were two countries, France and Belgium

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<sup>64</sup>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.

– both part of the French Empire up to 1815 – that had a higher level of cotton spinning activity than other countries. Figure 18 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 19 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 18 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.



## 8 Conclusion

This paper 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 paper 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 paper 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, 2009) 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.

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# Appendices

## A Tables

Table 1: Pre-treatment comparison of firm level variables

	Low trade cost shock	High trade cost shock	Difference	N
Spindles	2207.15 (925.52)	1191.03 (278.09)	-1016.11 (966.40)	375
Employees	67.67 (14.53)	51.15 (12.60)	-16.53 (19.24)	360
Capital labour ratio	27.80 (4.97)	30.18 ( 3.14)	2.37 (5.88)	358
Age of firm	7.80 (1.86)	5.20 (0.75)	-2.60 (2.01)	374
Quality yarn	37.86 (3.63)	47.72 (4.04)	9.86* (5.43)	231
Proportion mule jenny	0.32 (0.12)	0.43 (0.10)	0.10 (0.16)	375

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: Pre-treatment comparison of departmental level variables

	Low trade cost shock	High trade cost shock	Difference	N
Spindles	10.51 (5.08)	14.80 (4.41)	4.30 (6.72)	102
Weaving	1.25 (0.59)	3.66 (1.57)	2.41 (1.67)	102
Historical cotton	0.019 (0.005)	0.027 (0.008)	0.08 (0.01)	87
Access to coal	5.24 (0.13)	5.36 (0.21)	0.12 (0.24)	110
Access to streams	1.38 (0.40)	1.96 (0.20)	0.59 (0.44)	110
Literacy	0.43 (0.04)	0.46 (0.04)	(0.03) (0.05)	78
Conscription rate	1.50 (0.05)	1.33 (0.05)	-0.17** (0.07)	106
Institutional change	1791.55 (0.74)	1790.42 (0.37)	-1.13 (0.83)	110
Urbanisation rate	0.06 (0.02)	0.10 (0.03)	0.04 (0.03)	77
Population density	54.20 (3.31)	79.24 (11.86)	25.04** (12.31)	110

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 location of the cotton industry is the number of district 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 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 C. Robust standard errors in parentheses, \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.



Table 3: Baseline specification using two different measures of trade costs

DepVar Spindles	Trade cost (measure 1)			Trade cost measure 2		
	(1) Full sample	(2) North France	(3) South France	(4) Full sample	(5) North France	(6) South France
Trade cost (meas. 1)	33.11*** (9.775)	33.82* (17.11)	-2.075 (3.795)			
Trade cost (meas. 2)				58.76*** (14.15)	92.89*** (33.24)	13.99 (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 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 (2.82)	51.73 (12.15)	41.78*** (10.42)
Small shock	11.67 (5.87)	18.92 (7.31)	7.25* (3.62)
Difference	-1.72 (6.51)	32.81** (14.18)	34.53*** (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 5: DD using the median trade cost shock as a cutoff (measure 2)

Depvar Spindles	Pre-war	Post-war	Difference
Large shock	10.39 (2.80)	52.53 (12.17)	42.13*** (10.40)
Small shock	11.22 (5.88)	18.12 (7.35)	6.90* (3.57)
Difference	-0.83 (6.51)	34.40** (14.14)	35.23*** (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 6: Poisson fixed effects and OLS with log-specification

	Trade cost measure 1		Trade cost measure 2	
	(1) Poisson	(2) OLS	(3) Poisson	(4) OLS
DepVar Spindles				
Trade cost (meas. 1)	0.495** (0.214)	0.557*** (0.189)		
Trade cost (meas. 2)			1.039*** (0.319)	1.220*** (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  $\ln(1+\text{spindles per thousand inhabitants})$ . 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 7: Falsification test using wool and leather

DepVar	Tannery		Wool spinning		Mechanised cotton spinning	
	(1) Pits	(2) Pits	(3) Labour	(4) Labour	(5) Labour	(6) Labour
Trade cost (meas 1)	0.279 (0.215)		-2.228 (2.919)		0.930** (0.390)	
Trade cost (meas 2)		0.592 (0.420)		-4.85 (5.334)		1.880*** (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 8: Robustness to the addition of other variables

DepVar	Spindles	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Trade cost		33.11*** (9.775)	33.19*** (9.985)	34.69*** (10.38)	22.33*** (6.984)	34.41*** (10.23)	25.75*** (8.883)	39.87*** (11.75)	41.50*** (12.44)	33.56*** (9.600)	33.00*** (9.715)	27.92*** (7.298)
Streams			-0.261 (1.162)									-0.973 (2.226)
Coal				-4.571 (3.723)								3.072 (3.557)
D.stream					3.303*** (0.522)							2.273*** (0.437)
Hist. cott.						523.2*** (155.5)						303.8 (185.2)
Pop. density							20.88 (13.79)					4.954 (20.58)
Urbanisation								146.3* (78.12)				58.20 (65.24)
Human cap.									49.25** (21.32)			53.41*** (17.31)
Conscription										4.411 (11.94)		14.94 (13.30)
Institution											-0.853 (0.824)	
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Departmental FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	176	176	176	176	176	140	176	132	126	172	176	118
R-squared	0.337	0.337	0.347	0.576	0.539	0.539	0.356	0.400	0.426	0.338	0.340	0.722
Number of dept	88	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 C. Robust standard errors clustered at the department in parentheses, \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table 9: Extensive vs intensive margin of firm level adjustment 1803-06

	(1)	(2)	(3)	(4)	(5)	(6)
Spindles per thousand inhabs	total	ext	int	total	ext	int
Trade cost (measure 1)	7.962*** (2.243)	6.843*** (1.815)	1.119 (0.822)			
Trade cost (measure 2)				14.08*** (3.398)	11.87*** (2.785)	2.207* (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 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 10: Pre-treatment trends on the extensive margin

	Pre-treatment: 1794-1803			Napoleonic Wars: 1803-1812		
	(1)	(2)	(3)	(4)	(5)	(6)
DepVar Spindles						
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 C. Robust standard errors clustered at the departmental level in parentheses, \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table 11: No differential effect on type of machine used by firms

	(1)	(2)
DepVar: Proportion MJ		
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 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*** (24.45)	92.46*** (26.89)	96.68** (40.16)	134.2*** (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*** (0.0146)	0.0284*** (0.0101)	4.212 (2.600)	3.805*** (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 13: Productivity outcomes at the firm level, 1840

	OLS		2SLS	
	(1) Prod. 1840	(2) Prod. 1840	(3) Prod. 1840	(4) Prod. 1840
Depvar				
Spindles 1812	0.580*** (0.204)	0.425* (0.213)	1.811** (0.746)	3.847** (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) Spind 1812	(2) Spind 1812	(3) Prod 1840	(4) Prod 1840
Trade cost shock	0.0850* (0.0440)	0.0589** (0.0249)	0.154*** (0.0320)	0.227*** (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, \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

## B Figures

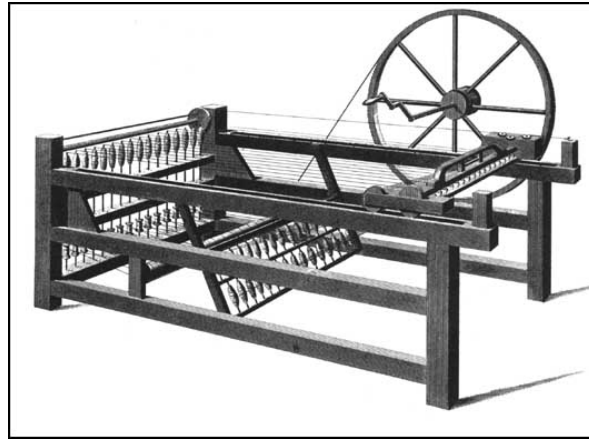


Figure 1: An early spinning jenny

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

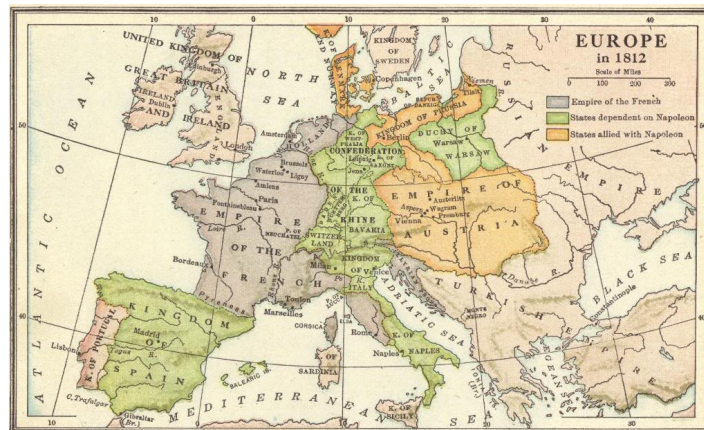


Figure 2: Political map of Europe, 1812

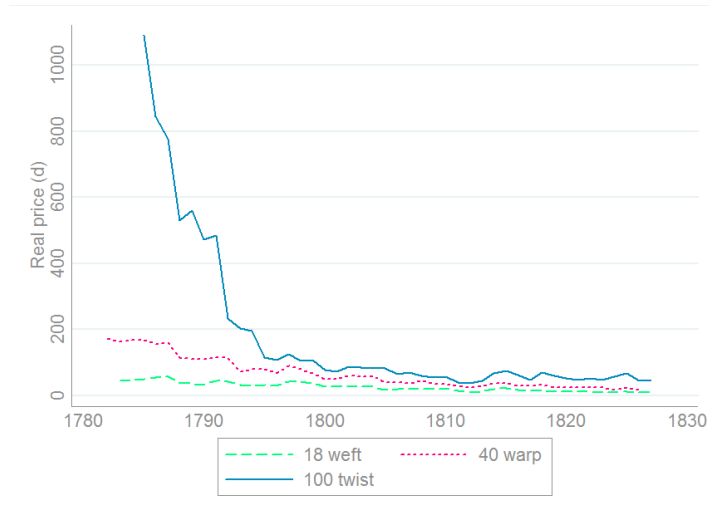


Figure 3: Real price of yarn in Britain, Harley (1998)

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

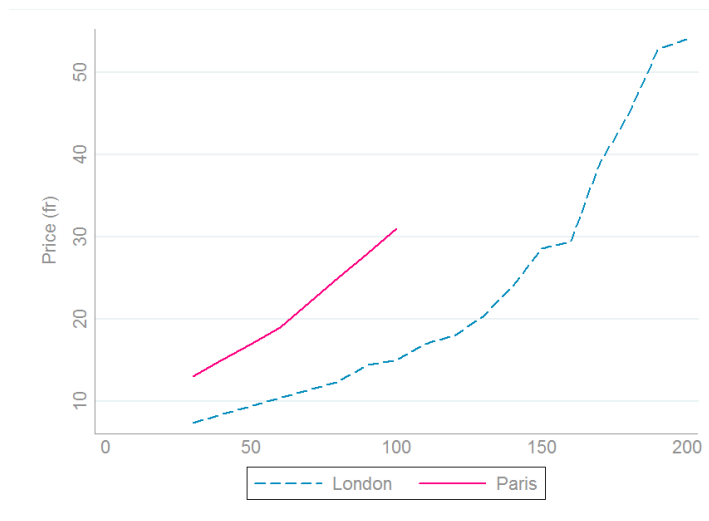
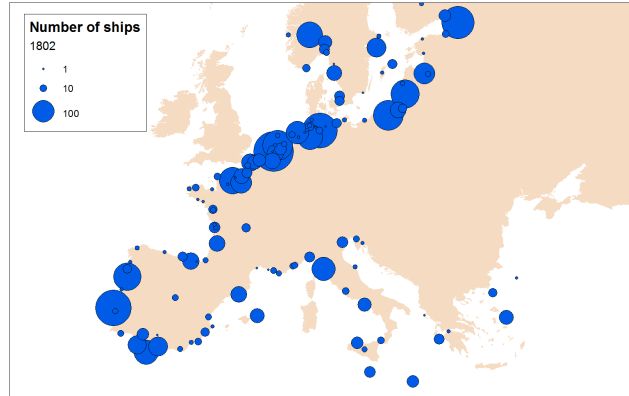
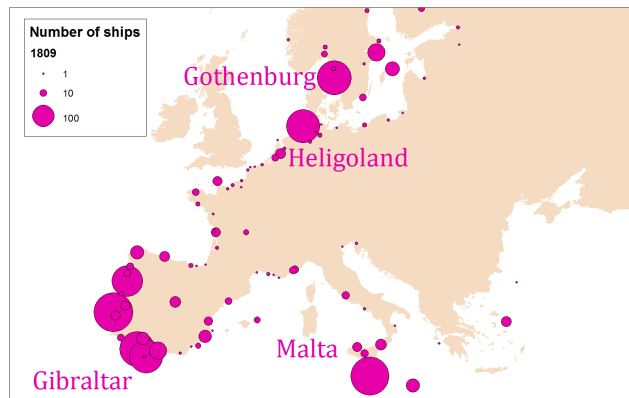


Figure 4: Price of different count cotton yarn in Paris and London, 1806-07

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



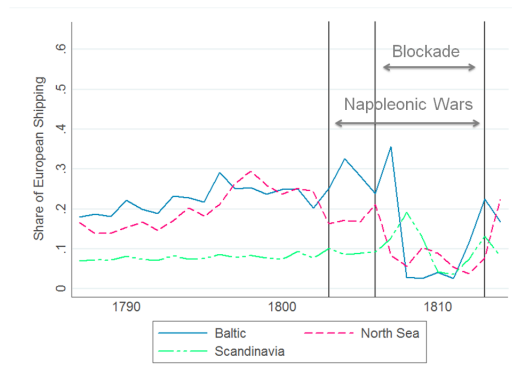
(a) Port usage, 1802



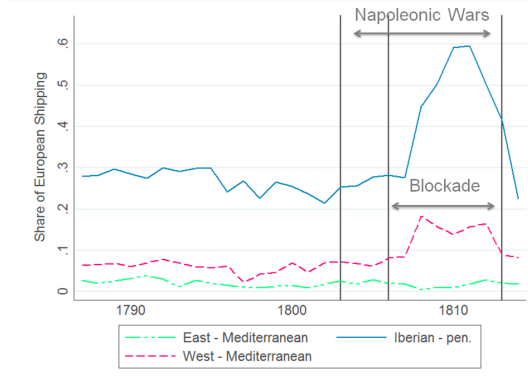
(b) Port usage, 1809

Figure 5: Intensity of port use in trade with the British, Lloyd's List

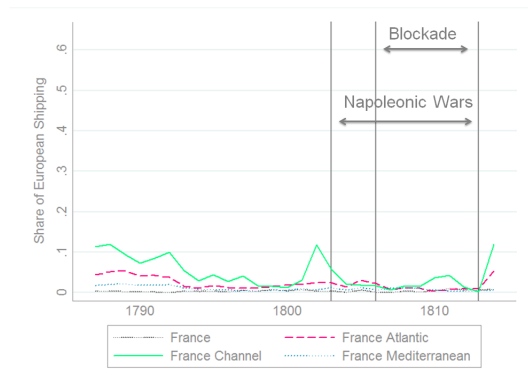
Each circle is proportionate in size to the number of ships sailing between Britain and the given port in the years 1802 and 1809. The former is the last year of peace and relatively free trade between Britain and the Continent, 1809 is a year during the Continental Blockade. Panel B shows the name of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



(a) British shipping with Northern Europe



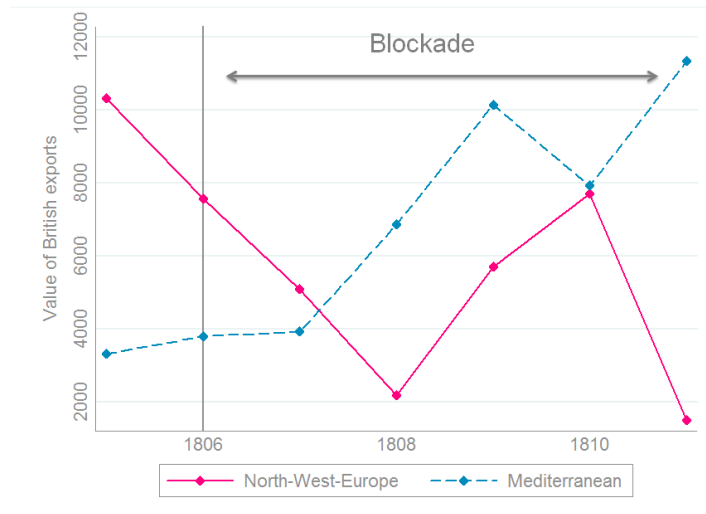
(b) British shipping with Southern Europe



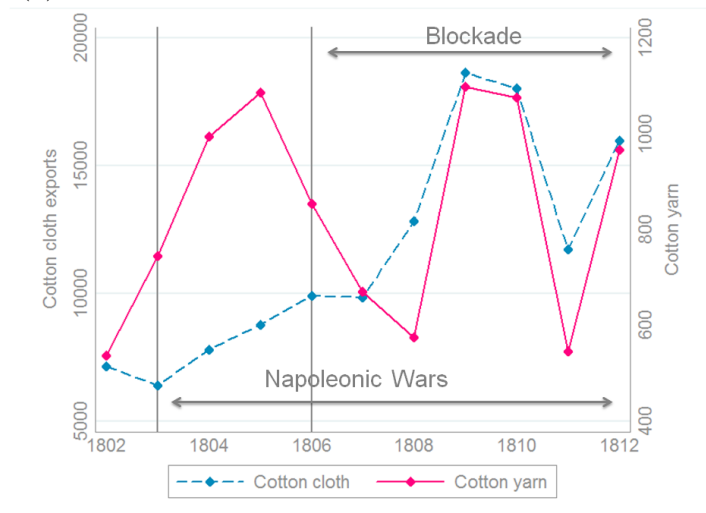
(c) British shipping with France

Figure 6: British shipping with European regions as share of total, 1787-1814 (Lloyd's List)

Figure 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 7: British exports, thousands of pounds

Panel A gives total value of exports (excluding 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 Balears, Gibraltar, Italy, Sicily, Sardinia, Malta and the Turkish Empire. Panel B gives total value of cotton cloth and cotton yarn exports. Data source: Crouzet (1987).

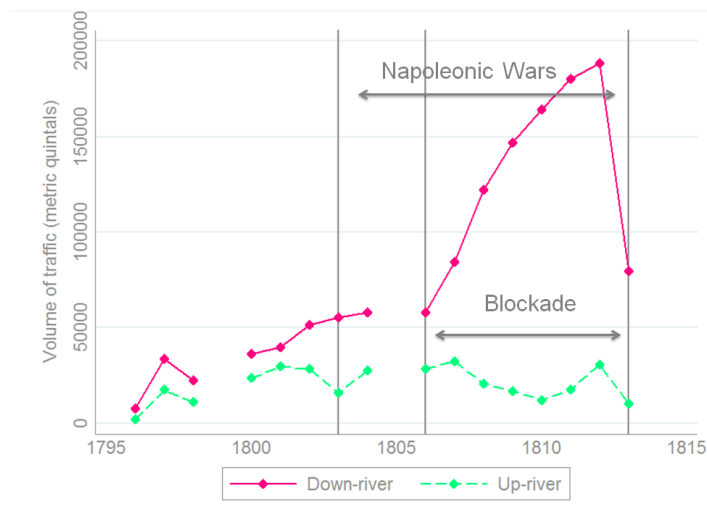
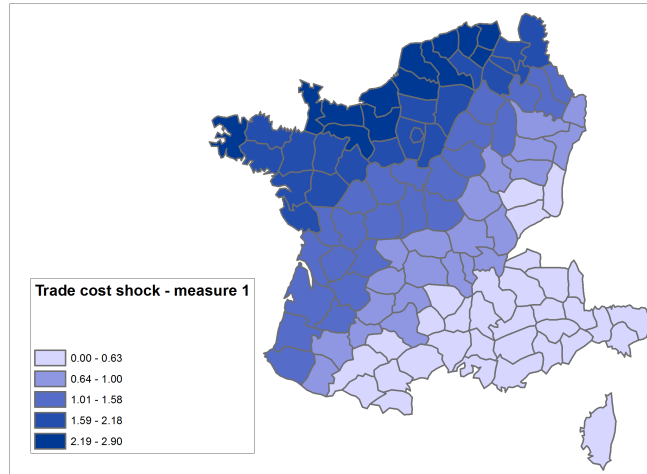


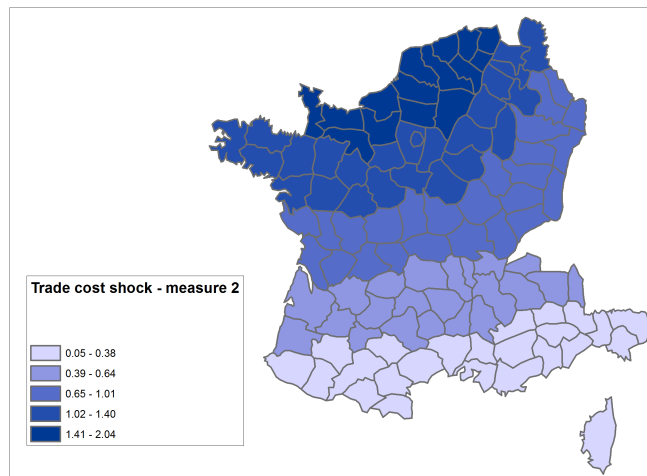
Figure 8: Traffic up-river and down-river from Strasbourg

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).





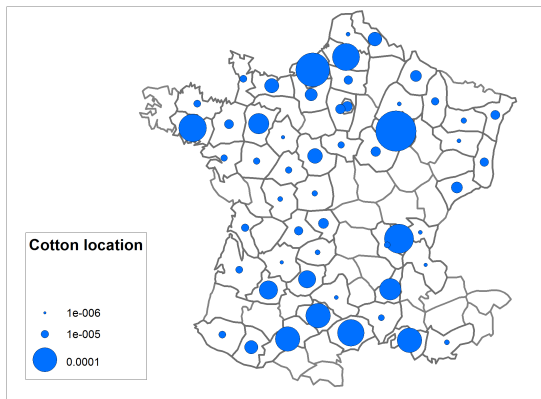
(a) Shortest route algorithm (Measure 1)



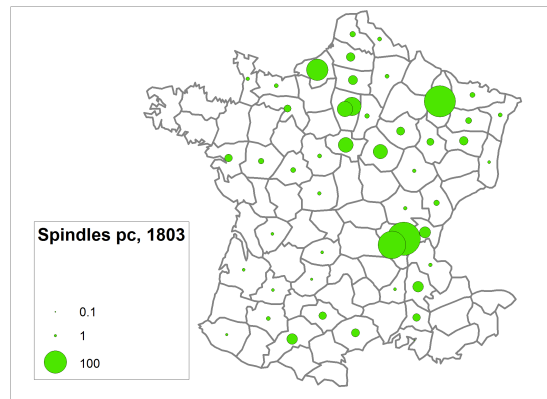
(b) Weighted distance (Measure 2)

Figure 9: Two measures of the trade cost shock

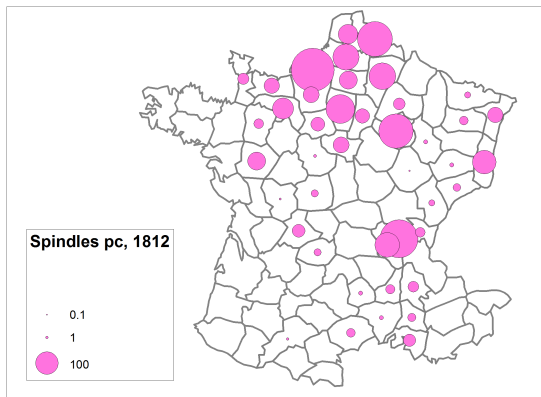
Measure 1 uses a shortest route algorithm to calculate the trade cost shock for each department. Measure 2 calculates the trade cost shock in the following way. Pre-war distance is simple Euclidean distance to London. Distance to Britain during the wars is calculated as the weighted Euclidean distance 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.



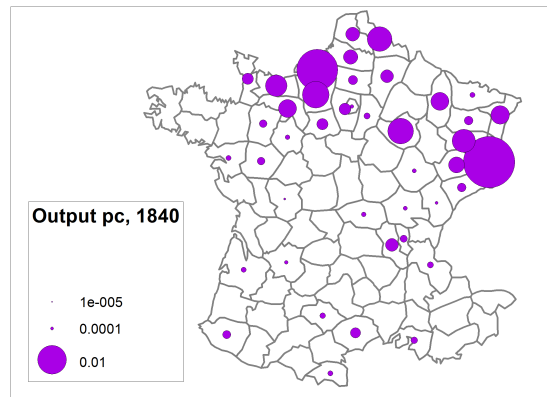
(a) Size of cotton industry pc, 1789



(b) Capital pc in mechanised spinning, 1803



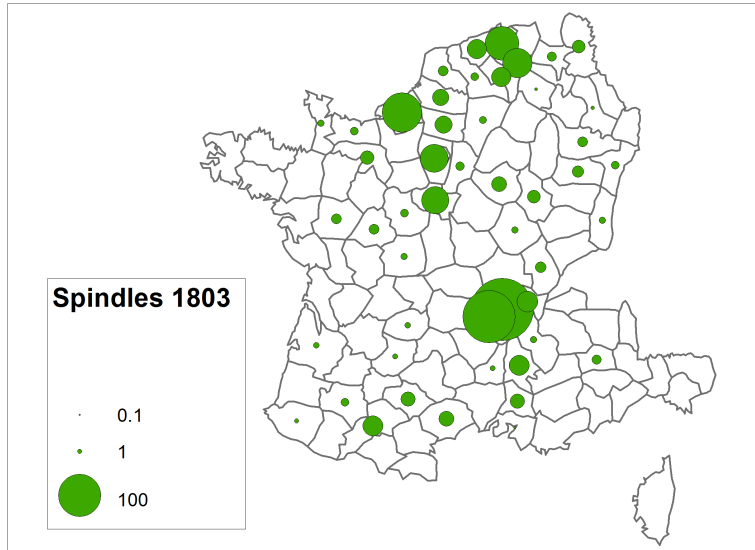
(c) Capital pc in mechanised spinning, 1812



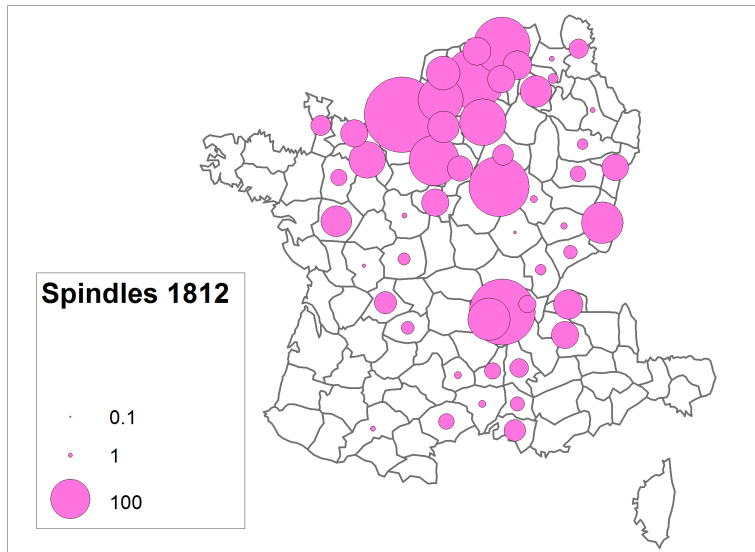
(d) Output pc in mechanised spinning, 1840

Figure 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 C. 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

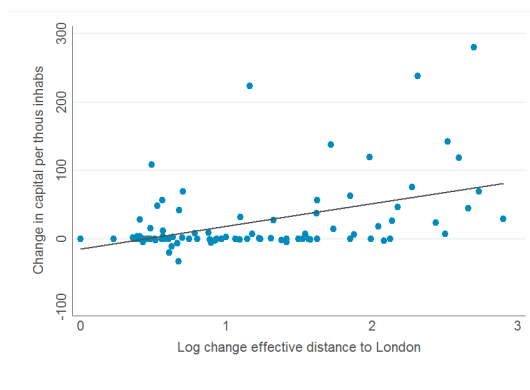


(b) Number of spindles per capita by department, 1812

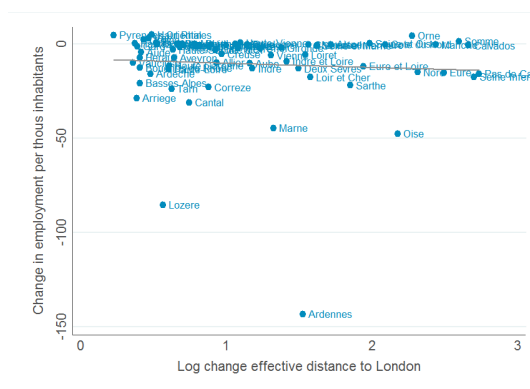
Figure 11: Variation used: short-run regressions

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 C.

(a) Mechanised cotton spinning



(b) Woollen spinning



(c) Leather tanning

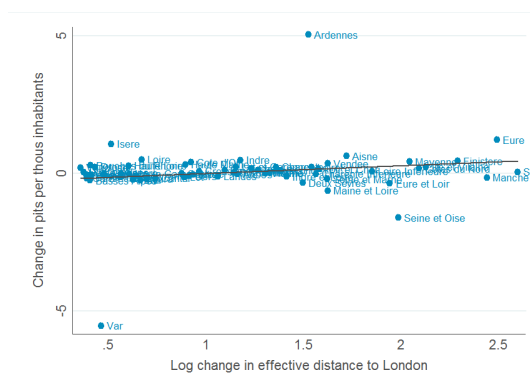


Figure 12: Change in production capacity vs trade cost shock

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 C.

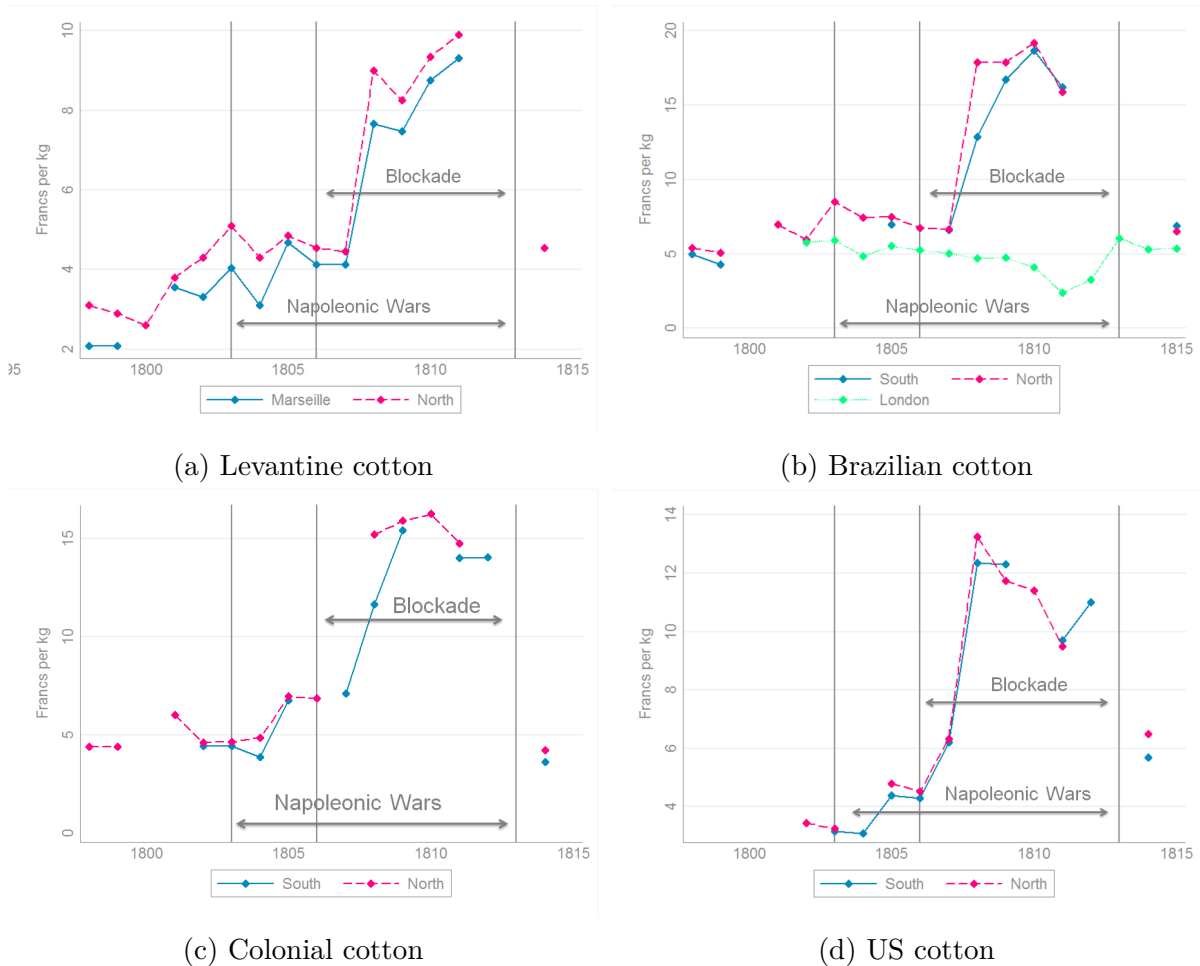


Figure 13: Price of raw cotton in northern and southern regions of the French Empire

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 C for a more detailed description of the data.

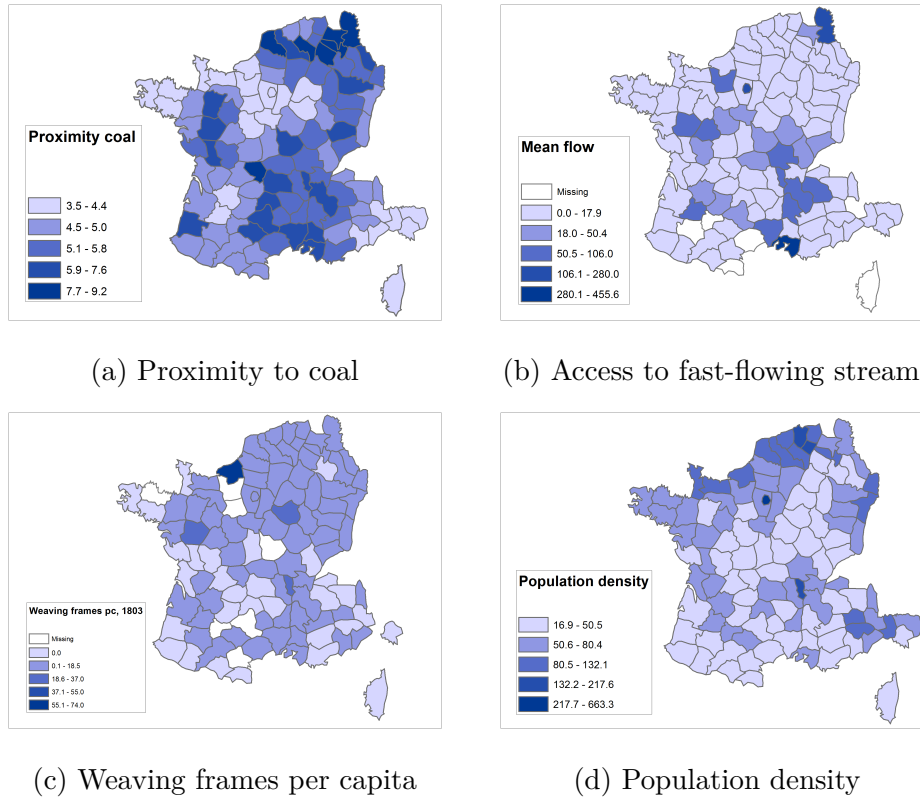
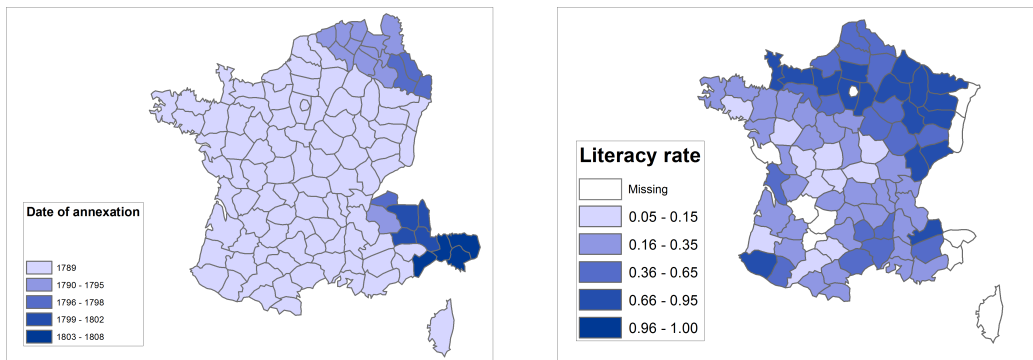


Figure 14: Spatial distribution of potential confounders

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 C for details.



(a) Date of annexation to French Empire

(b) Literacy rate, 1789

Figure 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 C for details and data sources.

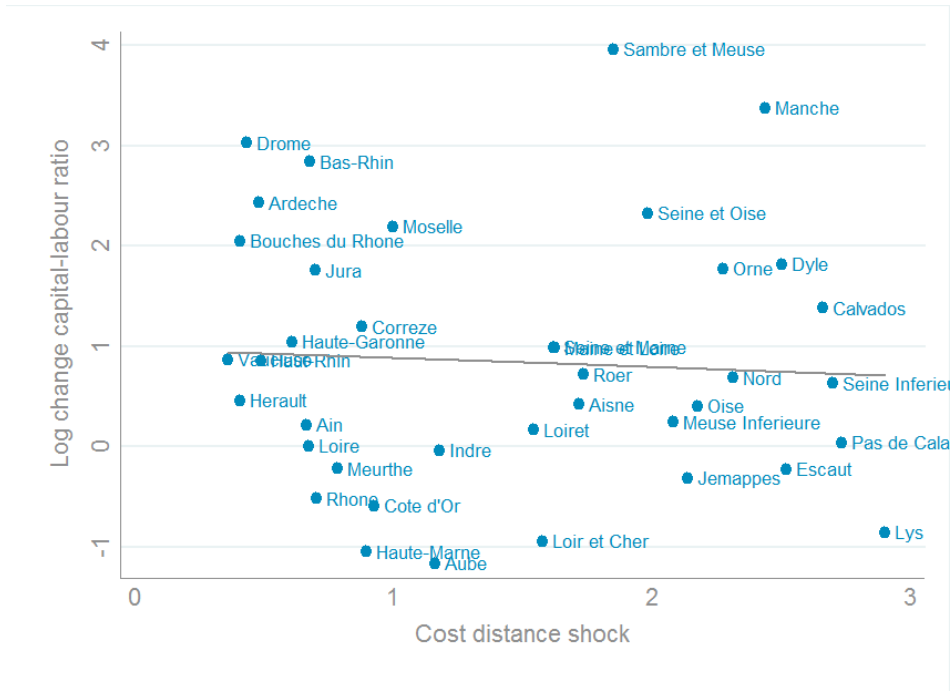
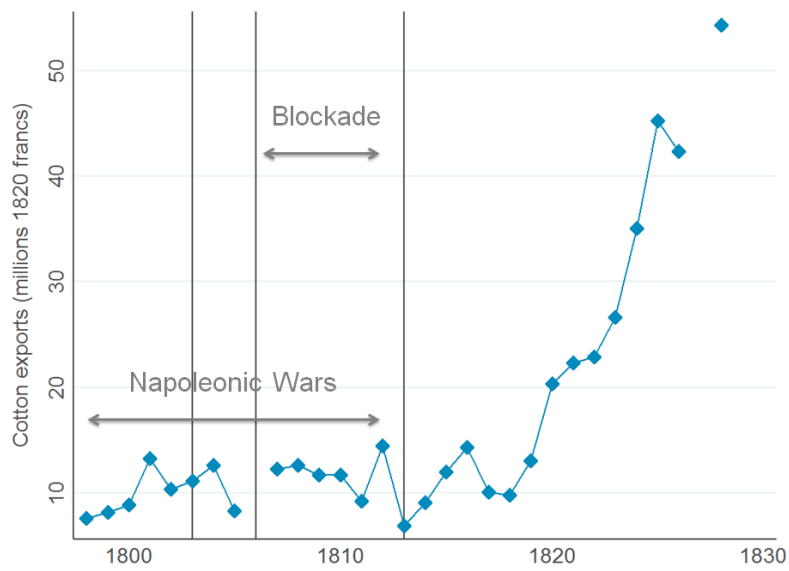


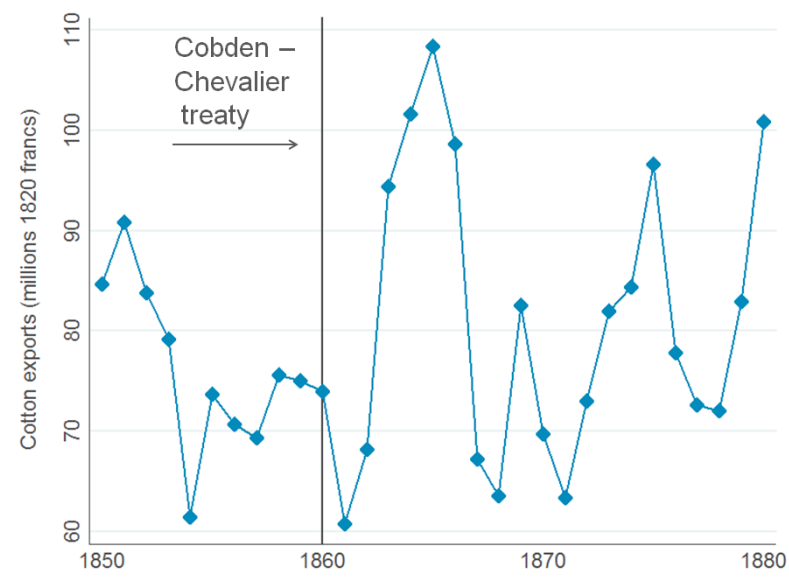
Figure 16: Change in log capital-labour ratio in mechanised spinning vs trade cost shock

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).





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



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

Figure 17: 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 trade statistics in the two periods are not the same. Wholesale price deflator from Mitchell (2007). See Appendix C for data sources and variable definitions.

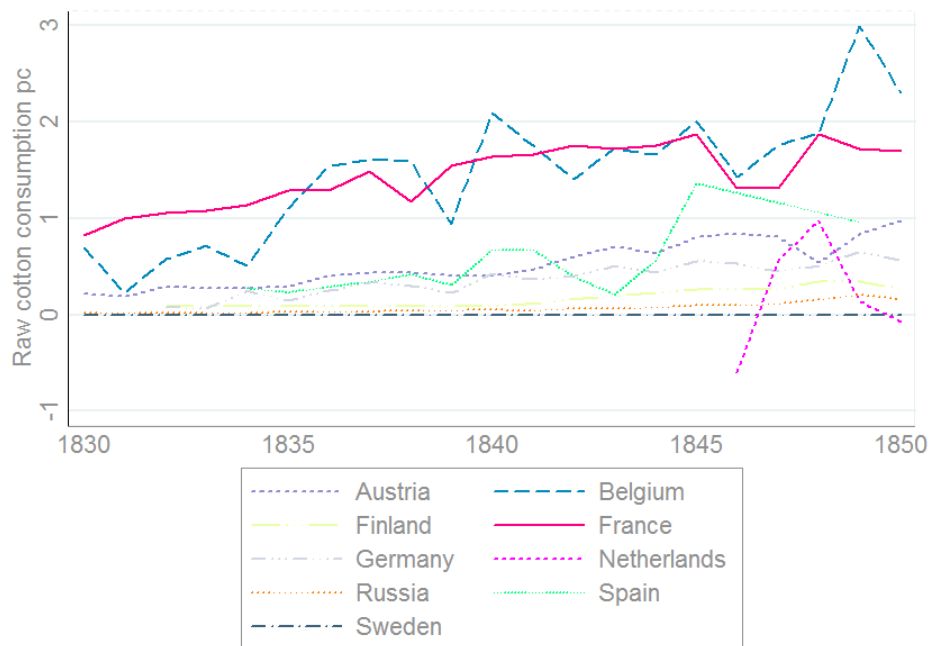
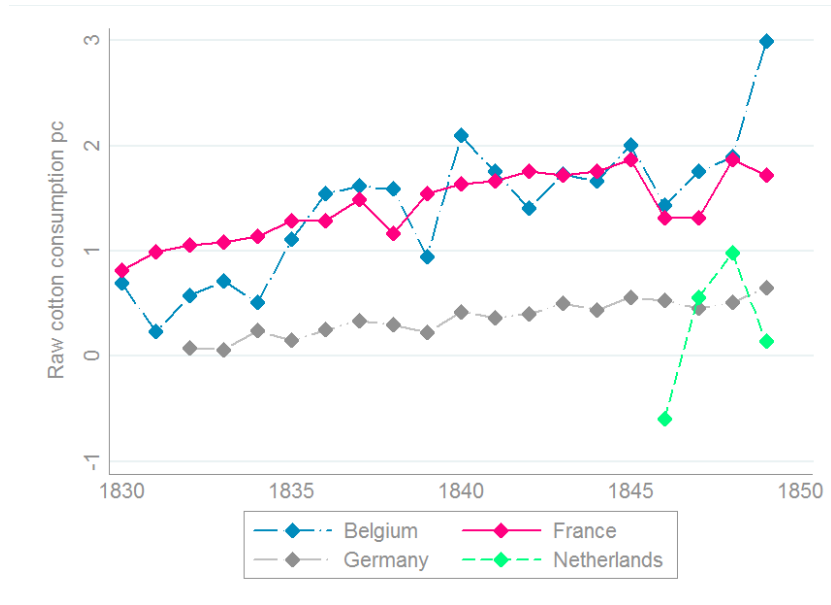
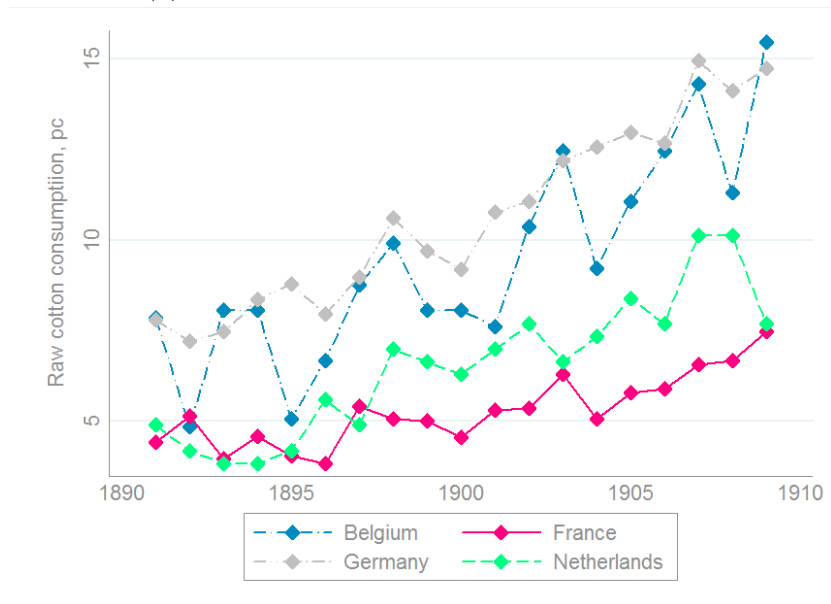


Figure 18: Raw cotton usage per capita

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 19: 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).

## C Data Collection

### C.1 Variable definitions and sources

This section describes the sources of the data used in the empirical analysis and their definition.

#### C.1.1 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). See the next section for a description of the construction of the dataset.

#### C.1.2 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*

The following section contains a detailed description of this data source. Here I only list the variables used in the empirical analysis and their definition.

- **Spinning capacity**

The baseline measure of spinning capacity is the number of spindles per thousand inhabitants in 1803 and 1812.

- **Labour employed in mechanised spinning:**

Labour employed in mechanised spinning (per thousand inhabitants) for 1803 and 1812 is used to conduct robustness checks. Spindles is the preferred measure of production capacity in mechanised cotton spinning as mechanisation substituted for labour. Using labour will therefore underestimate growth in the sector. It is also more sensitive to measurement error from misclassified handspinning.

- **Type of machine used**

Table 11 contains results on differential changes in the type of machine used within a department. The dataset differentiates between two machines used for weaving weft and warp.<sup>65</sup>

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<sup>65</sup>Results are robust to classifying "jeanettes" as mule jennys, or dropping them from the estimation (see the following section for a discussion on type of machines).

- **Downstream weaving capacity**

Initial weaving capacity is measured using the number of weaving frames by department (per thousand inhabitants) in 1803.

### **C.1.3 Woollen spinning**

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

The size of the woollen spinning industry in each department is measured as labour employed in woollen spinning per thousand inhabitants. The absence of mechanisation makes this the relevant measure of woollen spinning activity.

### **C.1.4 Tanneries**

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

Capacity in tanning is measured as the number of pits per thousand inhabitants.

### **C.1.5 Literacy rates**

*Data source: Furet and Ozouf (1982)*

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

### **C.1.6 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 perfectly proportionate to 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.

### **C.1.7 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.

### **C.1.8 Access to fast-flowing streams**

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

Data on monthly mean flow rates for 2412 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 paper, 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.

### **C.1.9 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.

### **C.1.10 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 give 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 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).

#### **C.1.11 Raw cotton prices**

*Data source: Journal du Commerce*

Daily raw cotton prices were sporadically reported for various cities during my period of interest 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).

#### **C.1.12 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 use this in the analysis.

#### **C.1.13 Data on the cotton industry in the 1840s**

*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 the persistence regressions. I use data on all firms classified as cotton spinning firms. I use the following variables: value of production, 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.

### **C.1.14 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 missing). All values in francs.<sup>66</sup> I supplement this with data on the value of British cotton exports and exchange rates from Mitchell (1971).

### **C.1.15 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.

## **C.2 Construction of data from primary sources**

### **C.2.1 Cotton industry: 1803-1812**

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.<sup>67</sup> 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.

#### **Champagne'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 Appendix D,

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<sup>66</sup>Data kindly shared by Guillaume Daudin.

<sup>67</sup>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.



was sent to the prefects of all departments for completion. 8 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 are not firms.<sup>68</sup> These entries are either charitable institutions or jails which produce some cotton yarn for their own use, or they are entries for rural spinners who use 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, are an intermediate step between traditional, rural handspinning and modern, mechanised firms employing wage-labourers in a factory. This is not 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 asks the number of “mull-jennys” (MJ - French name for mule jenny), for spinning weft, and “filature continuus” (FC), for spinning warp.<sup>69</sup> 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 a JEA has (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 number of machines were 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 report 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

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<sup>68</sup>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.

<sup>69</sup>The two types of yarn differ in fineness.

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 very little when this sampling variability is accounted for. Second, in Section 6 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, and departments in later surveys, this is not imputation-dependent.<sup>70</sup>

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 is 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 report machine data and some of them also report number of spindles. These are thus the firms that are included in the imputation model. Table 14 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 use only one or two types of machines, which is why the total number of firms who report using a given type of machine is well below 525. As can be seen from the table, 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.<sup>71</sup> By machine type, I calculate average spindles per firm for the firms which report both spindles and number of machines. I then use this information, together with data on all other firm characteristics to impute the average spindle per firm for the given machine type. A further complication arises

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<sup>70</sup>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.

<sup>71</sup>I use Stata’s multiple imputation tool to estimate the model.

Table 14: 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

from the fact that other firm level variables are also incomplete. Table 15 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 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 an MJ, FC and JEA type of machine has in 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 is 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 20, there is a lot of mass at these points of the distribution.<sup>72</sup> 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.

Table 15: 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

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

<sup>72</sup>The figure contains data only for the firms where this information is observed.

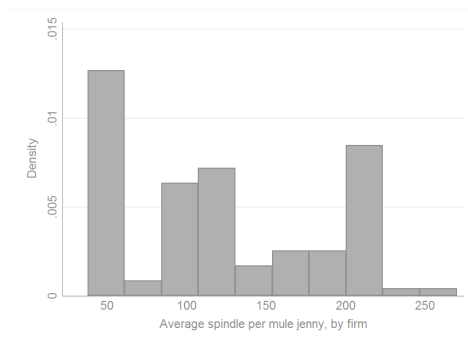


Figure 20: Average spindles per firm for mule-jennys

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 matter, 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 (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.

Table 16 compares the coefficients and standard errors for the baseline regressions using  $m = 5$  and  $m = 50$  imputations. As is evident, neither the point estimates, nor the standard errors are sensitive to increasing the number of imputations.

### “Enquêtes Industrielles”

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

Table 16: Robustness to multiple imputation

	(1)	(2)
Spindles per thous inhabs	$m = 5$ imputations	$m = 50$ 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, Col (2) replicates the regressions for  $m = 50$  imputations. Robust standard errors clustered at the departmental level in parentheses, \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

large.<sup>73</sup> 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.

## C.2.2 Woollen spinning and leather tanning

To construct data on capacity in woollen spinning and leather tanning, I use data collected at the 'arrondissement' (district - 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. The data from 1792 is somewhat noisily measured as data is collected at the level of the district, and it is often impossible to determine whether a district's datapoint is missing or zero. Furthermore, the survey asks for the state of the industry in 1789, before the Revolution. The survey only covers departments belonging to France at the time of its 1789 borders.

<sup>73</sup>As Napoleon's power unravelled, and troops invaded the territory of France, fewer and fewer departments submitted their reports.

### C.2.3 Shipping routes between Britain and Continental Europe

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 practiced. 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.

### **C.3 Primary sources consulted**

#### **C.3.1 Archives Nationales (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** Diverse documents on cotton industry from Napoleonic period. Contains some prices for spun yarn in Eure department. "Bulletin de coton" giving 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 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.

### **C.3.2** **Bibliothèque National de France (France)**

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



# D Examples of the Data

Figure 21: Example of prefectural report from 1806 for Escaut department

**LLOYD'S LIST.**  
LONDON, FRIDAY JULY 10, 1801.  
LONDON, Printed by WILLIAM PHILLIPS, No. 2, Gazette Yard, Lombard Street.

PRICES OF STOCKS.				LONDON.	
Bank Stock	100	100	100	COURSE OF EXCHANGE.	
3 per Cent. Bank	84 1/2	84 1/2	84 1/2	By day.	
4 per Cent. Bank	84 1/2	84 1/2	84 1/2	Amsterdam	
5 per Cent. Bank	84 1/2	84 1/2	84 1/2	Paris, 10 Days	
6 per Cent. Bank	84 1/2	84 1/2	84 1/2	Lisbon	
7 per Cent. Bank	84 1/2	84 1/2	84 1/2	Bombay	
8 per Cent. Bank	84 1/2	84 1/2	84 1/2	Calcutta	
9 per Cent. Bank	84 1/2	84 1/2	84 1/2	Madras	
10 per Cent. Bank	84 1/2	84 1/2	84 1/2	Banco	
11 per Cent. Bank	84 1/2	84 1/2	84 1/2	Sicily	
12 per Cent. Bank	84 1/2	84 1/2	84 1/2	Greece	
13 per Cent. Bank	84 1/2	84 1/2	84 1/2	Turkey	
14 per Cent. Bank	84 1/2	84 1/2	84 1/2	India	
15 per Cent. Bank	84 1/2	84 1/2	84 1/2	China	
16 per Cent. Bank	84 1/2	84 1/2	84 1/2	Japan	
17 per Cent. Bank	84 1/2	84 1/2	84 1/2	Africa	
18 per Cent. Bank	84 1/2	84 1/2	84 1/2	Australia	
19 per Cent. Bank	84 1/2	84 1/2	84 1/2	New Zealand	
20 per Cent. Bank	84 1/2	84 1/2	84 1/2	Other Islands	

**TRANSFER BOOKS.**

Name	Particulars	Price	Per Cent.
Bank	100	100	100
3 per Cent. Bank	84 1/2	84 1/2	84 1/2
4 per Cent. Bank	84 1/2	84 1/2	84 1/2
5 per Cent. Bank	84 1/2	84 1/2	84 1/2
6 per Cent. Bank	84 1/2	84 1/2	84 1/2
7 per Cent. Bank	84 1/2	84 1/2	84 1/2
8 per Cent. Bank	84 1/2	84 1/2	84 1/2
9 per Cent. Bank	84 1/2	84 1/2	84 1/2
10 per Cent. Bank	84 1/2	84 1/2	84 1/2
11 per Cent. Bank	84 1/2	84 1/2	84 1/2
12 per Cent. Bank	84 1/2	84 1/2	84 1/2
13 per Cent. Bank	84 1/2	84 1/2	84 1/2
14 per Cent. Bank	84 1/2	84 1/2	84 1/2
15 per Cent. Bank	84 1/2	84 1/2	84 1/2
16 per Cent. Bank	84 1/2	84 1/2	84 1/2
17 per Cent. Bank	84 1/2	84 1/2	84 1/2
18 per Cent. Bank	84 1/2	84 1/2	84 1/2
19 per Cent. Bank	84 1/2	84 1/2	84 1/2
20 per Cent. Bank	84 1/2	84 1/2	84 1/2

**THE MARINE LIST.**

Name	Particulars	Price	Per Cent.
Bank	100	100	100
3 per Cent. Bank	84 1/2	84 1/2	84 1/2
4 per Cent. Bank	84 1/2	84 1/2	84 1/2
5 per Cent. Bank	84 1/2	84 1/2	84 1/2
6 per Cent. Bank	84 1/2	84 1/2	84 1/2
7 per Cent. Bank	84 1/2	84 1/2	84 1/2
8 per Cent. Bank	84 1/2	84 1/2	84 1/2
9 per Cent. Bank	84 1/2	84 1/2	84 1/2
10 per Cent. Bank	84 1/2	84 1/2	84 1/2
11 per Cent. Bank	84 1/2	84 1/2	84 1/2
12 per Cent. Bank	84 1/2	84 1/2	84 1/2
13 per Cent. Bank	84 1/2	84 1/2	84 1/2
14 per Cent. Bank	84 1/2	84 1/2	84 1/2
15 per Cent. Bank	84 1/2	84 1/2	84 1/2
16 per Cent. Bank	84 1/2	84 1/2	84 1/2
17 per Cent. Bank	84 1/2	84 1/2	84 1/2
18 per Cent. Bank	84 1/2	84 1/2	84 1/2
19 per Cent. Bank	84 1/2	84 1/2	84 1/2
20 per Cent. Bank	84 1/2	84 1/2	84 1/2

Figure 22: Example of Lloyd's List