The London School of Economics and Political Science

Regional Economic Development under Trade Liberalisation, Technological Change and Market Access.

Evidence from 19th century France and Belgium

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Declaration

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

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Abstract

This PhD thesis analyses the spatial dimension of economic development in 19th century France and Belgium. During the 19th century Western European economies underwent a socio-economic and technological transformation to sustained rates of economic growth. The integration of domestic and foreign markets driven by declining transport costs and the reduction of trade barriers, shaped the economic geography of Western Europe. Consisting of three articles, this PhD thesis provides detailed empirical analyses of the spatial effects of trade liberalisation, technological change as well as the relative importance of market access and factor endowments.

The first article studies the spatial effects of the Cobden-Chevalier treaty of 1860 which lifted all import prohibitions on British manufacturers, exposing French producers to intensified British competition. The results show that increased British competition has led to a shift in the spatial distribution of French production and employment. Regions located closer to Britain lost employment and output shares in industries which experienced a rising importance of British imports.

The second article analyses the interrelatedness between the diffusion of power technologies and urbanisation. I ask the research question whether French adherence to water power, and slow diffusion of steam technologies, was associated with low urbanisation, limited gains from urban agglomeration and through this mechanism constrained economic development. I find that steam-powered firms were around twice as likely to be located in urban regions while water-powered firms were highly associated with rural municipalities. Moreover, urban firms paid higher wages and were more productive than their rural counterparts.

The third article studies the importance of access to coal and markets to explain regional patterns of Belgian industrialisation. The analysis shows that both access to coal and markets played important roles, suggesting that supply and demand factors should be seen as necessary rather than sufficient conditions of 19th century industrialisation.

299 words

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Chapter 1

Introduction

1.1 The topic

During the long 19^{th} century (1789 to 1914) Western European economies underwent a socio-economic and technological transformation to modern economies of sustained rates of economic growth. The economies of Western Europe entering World War I (WWI) were structurally different from the economies entering the Napoleonic Wars. Mechanisation and modern steam powered technologies crossed the Channel and diffused across the Continent, employment moved out of agriculture into industry and services, and new industries developed alongside major technological breakthroughs and continuous technological improvements. One, of many, important dimensions of this new phase of accelerated economic development is the regional, or spatial, dimension. New spatial clusters of people and firms emerged, changing the economic geography of those economies affected. Spatial concentration alongside sectoral specialisation was a feature not only in British industrialisation (Hudson, 1989) but can also be observed in Continental European economies and the United States. It is, therefore, not surprising that an emphasis on the importance of regions during 19^{th} century industrialisation has a long tradition in economic historical research on this period going back to the seminal contribution by Pollard (1981). More recently, this tradition has experienced a renaissance. Concepts and ideas from the *New Economic Geography* (NEG) literature have found broad acceptance in quantitative economic history, while *Evolutionary Economic Geography* (EEG) has found a rather limited number of historical applications, so far.[1]

My PhD thesis forms a continuation of the regional tradition in economic history and, more generally, contributes to our understanding of the regional dimension of economic progress. The title of the PhD thesis, *Regional Economic Development under Trade Liberalisation, Technological Change and Market Access. Evidence from 19^{th} century France and Belgium*, highlights important aspects which help to identify the focus of the thesis. The contextual framework within which the thesis is located is *Regional Economic Development*, the time period under consideration is the *19^{th} century* and the geographical focus lies on *France and Belgium*. Within these contextual, temporal and geographical boundaries, three empirical articles analyse the spatial effects of different features of 19^{th} century industrialisation: *Trade Liberalisation, Technological Change and Market Access*. The first

[1] See section 2.2.3 for a survey of both the NEG as well as the EEG literature.

out of three articles studies the spatial effects of a bilateral trade deal between Britain and France, also known as the Cobden-Chevalier treaty of 1860, on the French economy. The Cobden-Chevalier treaty lifted all import prohibitions on British manufacturers, exposing French producers to intensified British competition. The article asks the research question how French regions responded to mid-19$^{\text{th}}$ century trade liberalisation. The second article studies the interrelatedness between two central features of modern economic development, the diffusion of steam power and accelerated urbanisation. It asks the research question whether French adherence to water power, and its slow diffusion of steam technologies, contributed to slow urbanisation, limited gains from urban agglomeration and through this mechanism constrained economic development. The French case study is of crucial importance, as in contrast to the industrialisation of Britain, Germany and the United States which experienced fast urbanisation alongside intense use of steam power, the French path of economic development was characterised by slow urbanisation and adherence to water power. The third article studies the importance of access to coal and markets to explain regional patterns of Belgian industrialisation. It contributes to our understanding of how the British industrial revolution spread to the European Continent and sheds light on the relative importance of demand and supply factors of industrialisation. For more extensive summaries of the three articles see section 1.2 below.

The thesis' focus on regional economic development is motivated by the broader question of how spatial inequalities change with economic development. The seminal contributions by Kuznets (1955) on the relationship between inequality and economic development, its regional adaptation by Williamson (1965) and the theoretical formalisation by Krugman and Venables (1995) based on declining transport costs and economies of scale, hypothesise an inverted U-shaped relationship. Empirical evidence on the development of spatial inequalities over the last 150 years for the United States (Kim, 1995), Spain (Rosés et al., 2010), and France (Combes et al., 2011) support this pattern.[2] In these long term studies, the 19$^{\text{th}}$ century is described as a period of intensified spatial concentration driven by market integration. Technological change in the transport sector reduced transportation costs considerably and transaction costs of trade were reduced by lowering barriers to trade. Therefore, the 19$^{\text{th}}$ century proves to be an important time period to study determinants of the spatial dimension of economic development and the economies of France and Belgium are historically as well as economically meaningful case studies. Both economies are characterised by substantial regional differences. In France, debates about spatial inequalities are focused on the dominance of Paris which was first highlighted by Gravier (1947). In Belgium the economic differences between the regions of Flanders and Wallonia dominate the discourse (Buyst, 2011). Moreover, both economies industrialised during the 19$^{\text{th}}$ century even though following different paths. On the one hand, Belgium was the first economy to adopt the British industrial revolution which makes it a crucial piece of evidence for our understanding of the diffusion of industrialisation. France, on the other hand, struggled to implement the British model of industrialisation and it is still debated whether the French path to modern economic growth was equally successful.[3] Within this

[2]An interesting exception to this pattern is Sweden where spatial inequality was in decline between 1860 and 1980(Enflo and Rosés, 2015).

[3]See section 2.1 for a discussion of the literature on the economic development of France and Belgium during the 19$^{\text{th}}$ century.

contextual, temporal and geographical framework, the three articles of this PhD thesis analyse specific determinants of spatial inequality. In light of the rising recognition of *path dependency* to understand features of regional disparities today, studies, which analyse the determinants shaping regional patterns in the past, are becoming increasingly important (Martin and Sunley, 2012).

The next part of this introduction presents summaries of all the main chapters of this PhD thesis before the overall thesis structure is outlined.

1.2 The main chapters in a nutshell

1.2.1 Spatial effects of Trade Liberalisation: Cobden-Chevalier and the Economic Geography of 19th century France

The mid-19th century was a period of substantial trade liberalisation. France was among the first economies to shift trade policy towards a free-trade agenda which peaked in the signing of a bilateral treaty between France and Britain on the 23rd of January 1860, also known as the Cobden-Chevalier treaty. The treaty lifted all import prohibitions on British manufacturers and reduced French manufacturing ad valorem import tariffs from 70% (1859) to 17% (1863) (Tena-Junguito et al., 2012). As Britain was the leading export-oriented manufacturing economy, French producers faced a substantial increase in competition on their domestic markets. The effects of the treaty on French economic development have been subject to much debate triggered by Bairoch (1976). Its implications for the development of spatial inequalities within France have not yet been assessed in spite of their distinct presence in the French economy (Combes et al., 2011). This article addresses the question how French regions responded to mid-19th century liberalisation in trade.

The results show that increased British competition has led to a shift in the spatial distribution of French production and employment. Regions located closer to Britain lost employment and output shares relative to the rest of France in industries which experienced a rising importance of British imports. Within the industrial sector the relocation effects of export industries was limited such that the effects of import competition dominated the overall trade effects. Focusing on the industrial sector positive effects on wine producing regions are not considered. Apart from the spatial effects of trade liberalisation French industries responded positively to backward-and-forward linkages, a more diversified industrial structure and exploited internal economies of scale. Moreover, I find evidence for within-industry dispersion effects at a fine level of industry disaggregation suggesting that agglomeration forces were stronger with respect to inter-industry spillovers than within industries.

These results have been derived based on the analysis of a rich three-dimensional panel dataset. The two industrial censuses of 1839-47 and 1861-65 present detailed information about the regional and industrial structure of mid-19th century France and are well situated within two different trade policy regimes. The industry-regional information on employment and output is linked to bilateral product-level export and import data from the French annual trade statistics. Spatial effects of trade liberalisation are identified within a difference-in-difference specification of the industrial location model used by Hanson (1998). The primary treatment is an interaction term between the change in British trade shares and distance to Britain. Distance to Britain is based on a mid-19th century multi-modal transport network applying a least cost route algorithm.

This research is an important contribution to the existing literature of spatial effects of trade liberalisation. Most studies identify positive effects for border regions as their relative access costs to export markets decline (Brülhart, 2011). This case study shows that import competition can be an important factor in shaping the spatial allocation of economic activity. The spatial pattern of the French economy has been significantly altered by reducing barriers to trade which helps us to understand the distinct geographic patterns of the French economy. The evidence presented in this case study shows that in addition to the export mechanism import competition can be an important factor in shaping the spatial allocation of economic activity. Hence, it is important to acknowledge the diversity within the industrial sector, which has recently been supported by the findings of Autor et al. (2013) for the role of Chinese import competition on US regional labour markets. Thus, spatial and sectoral effects of trade liberalisation should be seen as highly intertwined. The 19th century can help to improve our understanding of effects of trade policy on regional economies with France being an important example.

1.2.2 Technological Choice and Urban Agglomeration: Steam vs Water power in French industrialisation

The diffusion of steam power and accelerated urbanisation are seen as central elements of modern economic development during the 19th century. In spite of the simultaneous occurrence of these two processes their interrelatedness has only recently led to empirical investigations for the United States (Kim, 2005) and Germany (Gutberlet, 2014). This article contributes to this evolving literature by adding a case of slow urbanisation and adherence to water power: the case of France. Economic historians like Crouzet (1996) and Cameron (1985) have pointed towards a close relationship between power-choice and urbanisation. Besides testing this relationship, the article goes one step further and links the urbanisation effect of steam to economic development through benefits of urban agglomeration. This is the first attempt to answer the research question whether French adherence to water power was associated with low urbanisation, limited gains from urban agglomeration and through this mechanism constrained economic development.

Applying various models of urban location, from a discrete choice model following Kim (2005) to a fully continuous specification, I find strong evidence that French adherence to water power was associated with lower levels of urbanisation. The analysis is based on two mid-19th century industrial censuses which provide detailed information on power source at a high level of regional and industry disaggregation. This information is linked to city level urban population derived from 19th century population censuses. Depending on the exact specification and the time period, I find that steam-powered firms were between 1.3 and 2.5 times more likely to be located in urban regions compared to non-steam and non-water powered firms. On the other hand, water powered firms were marginally, though, statistically significantly more likely to locate in rural regions (1.2-1.3 times). Looking at cities instead of regions, water powered firms are much more likely to be located in rural municipalities (2-2.8 times). The urban preference of steam powered firms is less clear on the municipality level than it is on the regional level. Larger firms or factories, irrespective of their power source, are both statistically and economically highly significantly associated with urbanity.

The findings of power-specific location choice are linked to the economic success of the French economy by testing for the existence of benefits of urban agglomeration. If benefits of urban agglomeration existed in the French economy during the 19th century, a faster diffusion of steam power, substituting water power, would have fostered economic growth through its positive effect on urbanisation. The existence of benefits of urban agglomeration is empirically analysed by estimating urban premiums in wages and labour productivity. After adjusting for endogeneity biases by instrumenting urbanity with urbanisation ratios in 1806, I find that urban firms paid 13-14% higher wages and were 16-22% more productive than their rural counterparts, depending on the census period. Hence, technological change had a distinct spatial dimension. However, it remains to be investigated through which mechanisms urban agglomeration economies operated. As growth benefits of new knowledge decay most rapidly with distance (Capello and Lenzi, 2014), the interplay between urban agglomeration and knowledge spillovers should be a fruitful area of historical research during a period, which has lately also been associated with the rising importance of knowledge-based industries (Mokyr, 2009).

1.2.3 Market Access, Coal and the Second Industrial Nation: Belgium 1846-1896

This article contributes to our understanding of how the British industrial revolution spread to the European Continent by studying the second industrial nation, Belgium. More specifically, the main objective of the analysis is to quantify the relative importance of coal and market access during Belgium's industrialisation. The role of demand in industrialisation is subject to much debate and Gilboy's (1932) emphasis that both supply and demand factors are important to understand the first industrial revolution has been challenged by Mokyr (1985) arguing that demand-side explanations of the industrial revolution are based on circular reasoning. Since then, however, insights from *New Economic Geography* (NEG) following Krugman (1991b,c) have formed new perspectives on demand factors in 19th century economic development.

Based on the descriptive analyses of Belgian regional economic development during the 19th century by De Brabander (1981), Boschma (1994) and Buyst (2011), demand and supply determinants of industrialisation are identified at the regional level for the industrial sector as a whole as well as for selected sub-industries based on the industrial censuses of 1846 and 1896. The statistical and economic significance of these determinants is evaluated by applying a Poisson regression analysis with an instrumental variable strategy to deal with potential endogeneity biases, both in coal and market access, and controlling for cultural, geographical, human capital, institutional and labour cost determinants of industrial location. Moreover, counterfactual estimates of industrial employment are calculated for 9 Belgian provinces by evaluating the employment effects based on deviations from the national mean.

The analysis shows that both accessibility of coal and markets play important roles in understanding Belgian industrialisation during the 19th century. The counterfactual results suggest that supply and demand factors should be seen as necessary rather than sufficient conditions. Regions of industrialisation had a strong advantage in either access to coal, such as the provinces Hainaut and Liege, or market potential, such as Brabant, without being significantly disadvantaged with respect to the other. Access to domestic markets is the strongest location factor at the aggregate level and is highly statistically significant across all sub-industries. Access to foreign markets plays a surprisingly limited role, at least at the aggregate level. Besides domestic market potential, proximity to coal is an economically significant location determinant, which is driven by the metal industries. Looking at specific industries, therefore, shows the Belgian sectoral composition can be well explained by its relative endowment with supply and demand factors. Belgian industrialisation was, indeed, focused on heavy industries, as for these industries coal as a location determinant was strongest. Therefore, the Belgian case study supports the findings for the German Empire by Gutberlet (2012) that access to coal was an important factor in 19$^{\text{th}}$ century industrialisation, for the metal industries in particular. However, it also shows that market access played an important role even in a comparatively small economy and has shaped the economic geography of Belgium already well before the 20$^{\text{th}}$ century as identified by Ronsse and Rayp (2016). As the relative importance of market access increased during the 20$^{\text{th}}$ century, the Belgian regional inequalities reversed (Buyst, 2011).

1.3 Thesis structure

This is a paper-based thesis which consists of three distinct articles (chapters 3, 4 and 5) within the topic of regional economic development in the field of economic history. Chapter 1 introduces the general topic of the thesis, highlights the articles' thematic overlaps and provides summaries of the articles. In chapter 2 various strands of literature are discussed which are connected to the thesis in general but are not tied to one particular article. More specific literature, which is only relevant for a particular article, is discussed within each article separately. Chapter 2 is followed by the main body of the thesis. Chapter 3, *Spatial effects of Trade Liberalisation: Cobden-Chevalier and the Economic Geography of 19th century France*, analyses the spatial effects of the Cobden-Chevalier treaty of 1860 on the French economy. Chapter 4, *Technological Choice and Urban Agglomeration: Steam vs Water power in French industrialisation*, asks the research question whether French adherence to water power contributed to its slow urbanisation, limited gains from urban agglomeration and through this mechanism constrained economic development. And chapter 5, *Market Access, Coal and the Second Industrial Nation: Belgium 1846-1896*, studies the importance of access to coal and markets for the regional patterns of Belgium's industrialisation. The last chapter of the thesis, chapter 6, gives a summary of the main findings and outlines the contributions to the existing literature.

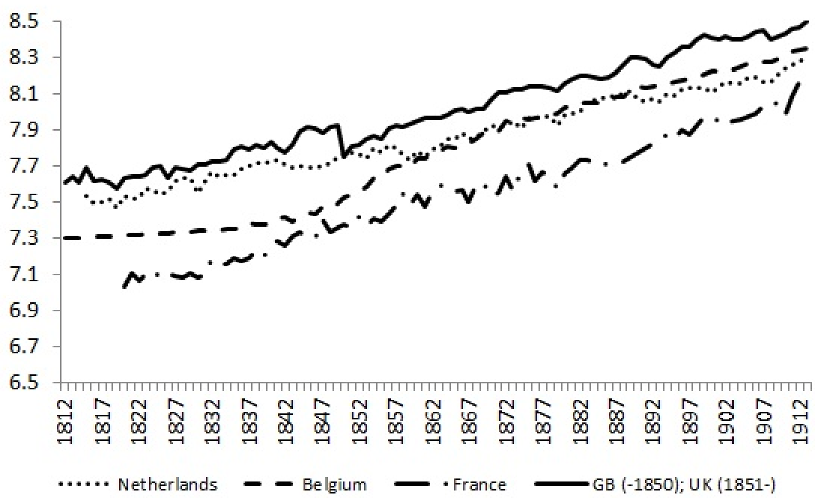
Chapter 2

Related literature

2.1 Nineteenth century economic development

This section is not intended to be a comprehensive review of 19$^{\text{th}}$ century economic development including all its dimensions. Instead, it presents an overview of the main aspects which the literature has discussed with respect to the economic development of France and Belgium between the Napoleonic Wars and World War I. However, before discussing each country separately, a wider comparison is needed to put the two economies into a broader perspective.

Figure 2.1: GDP per capita (*log*) among Western European economies (1812-1913)



Notes: *log GDP per capita* is measured in 1990 international Geary-Khamis-Dollar for the economies of Belgium, France, Great Britain (1812-1850)/United Kingdom (1851-1913) and the Netherlands. In the case of Belgium, GDP per capita is not available between 1812 and 1835 and has been approximated by constant growth rates during this period.
Sources: The Maddison-Project, http://www.ggdc.net/maddison/maddison-project/home.htm, 2013 version. The GDP series for the individual economies are based on Smits et al. (2009) for Belgium, Toutain (1987) for France, Broadberry et al. (2015) for Great Britain and the UK, and van Zanden et al. (2000) for the Netherlands.

A comparison of gross domestic product (GDP) per capita seems to be an appropriate starting point when discussing economic development during this period. Figure 2.1 shows the development of GDP per capita (log transformed) in the Western European economies of Belgium, France, Great Britain/United Kingdom and the Netherlands during the period 1812 to 1913. Based on this indicator, or component of economic development, the 19th century was a period of continuous economic progress, particularly during the second half of the century. If a more holistic measure of economic development is used which also incorporates health and human capital, the Human Development Index (HDI), all of the above economies show substantial improvements in living standards between the benchmark years 1870 and 1913 (Crafts, 1997).[1] At the beginning of the century and after the Napoleonic Wars, Great Britain and the Netherlands were the wealthiest societies in Europe. Being on very different long-run trends, Britain, however, showed more economic dynamic and secured its economic dominance throughout the period.[2] Belgium and France started at much lower levels with catch-up growth being more pronounced in Belgium than in France. By 1860 Belgium closed the GDP per capita gap to the Netherlands.

Economic development during the 19th century is traditionally associated with industrialisation. The sectoral transformation of Western European economies is, therefore, ascribed crucial importance in order to understand their economic success. Broadberry (2008) emphasises the importance of moving labour out of agriculture into industry and services, finding a strong negative relationship between the share of the agricultural labour force and the level of GDP per capita. As labour productivity levels differed across the various sectors of the economy, higher labour shares in high productivity sectors like industry and services result in higher aggregate productivity levels and, thus, higher GDP per capita. In 1870 the United Kingdom (22.2%) had the lowest share of the labour force working in the agricultural sector among a sample of 14 European economies with the Netherlands coming second (39.4%), Switzerland third (42.3%) and Belgium fourth (44.4%). Even though Belgium (23.2% in 1913) almost reached the UK level of 1870 in 1913, the catch-up was limited as in the UK only 11.8% of the working population worked in the agricultural sector by 1913. With levels close to 50% in 1870 and close to 40% in 1913, the French economy shows a stronger dependence on the agricultural sector (Broadberry et al., 2010, p.61). A sectoral transformation from agriculture to industry and services is, therefore, seen as a crucial element of economic development during the 19th century. Nevertheless, as Crafts (1984b, p.451) states *"the most striking feature of the British Industrial Revolution is the very rapid and early change in the share of the labour force in the primary sector which took place whilst income per head grew only slowly"*.

Britain was clearly ahead of her European neighbours when it comes to the sectoral distribution of the labour force. Does this imply that Continental European economies had to follow the British example in order to achieve economic prosperity? Pollard (1981) makes it very clear that he sees the British model of industrialisation as the basis for

[1] Crafts (1997) calculates Human Development Indices for a large number of economies for the benchmark years 1870, 1913, 1950, 1973 and 1992. For Belgium the HDI increases from 0.429 to 0.621, in the case of France from 0.400 to 0.611, for the Netherlands from 0.450 to 0.676 and in the United Kingdom from 0.496 to 0.735 (Crafts, 1997, p.310).

[2] Even though van Zanden and van Leeuwen (2012) have shown that the Dutch economy was not in stagnation during the 18th century, as has previously been thought, high levels of GDP per capita were based on a structural transformation between the middle of the 16th and the middle of the 17th centuries. Britain, on the other hand, experienced a very transformative 18th century which laid the foundations for becoming the manufacturer of the world in the following century.

economic success on the European Continent.[3] That the industrial revolution started in Britain is relatively undisputed.[4] Why the First industrial revolution was British is, however, subject to much debate. Currently, the two competing perspectives on the British origin of the industrial revolution are Allen (2009) and Mokyr (2009). Allen (2009) focuses on directed technological change based on favourable relative factor prices of coal and labour, while Mokyr (2009) argues that the favourable supply of and interplay between various levels of human capital were crucial.[5] In spite of their many differences both authors share the same objective to explain technological progress. Whether Continental European economies followed the British model should, therefore, be focused on explaining technological diffusion. Based on a comparison of the British, French, Belgian and German iron industries Fremdling (2000) shows evidence of a co-existence of modern (British) and traditional techniques, at least until 1860. British technologies were, thus, not always superior to existing traditional techniques. British technologies were adapted when profitable and innovated to local needs when necessary. Applying the ideas of Abramovitz (1986) to the 19$^{\text{th}}$ century, suggests that technological diffusion should be seen as conditional on social capabilities. Adapting British technologies to local needs required the necessary skill set as well as an institutional environment which was open to change.[6] The economies of Belgium and France show quite some heterogeneity when it comes to the success of copying Britain. While Belgian industrialisation is seen as being very closely linked to the British model, French industrialisation is often used as an example to argue for the existence of multiple paths to economic prosperity with applying local ingenuity to overcome domestic constraints.

The objective of this short introduction to the industrialisation of Europe was to put the French and Belgian example into the broader perspective of European industrialisation. Based on the existing literature the next two sections will outline the characteristics and identify the driving or constraining factors of French and Belgian industrialisation.

2.1.1 France

The historiography of 19$^{\text{th}}$ century French economic development has been dominated by a comparison with the British path to economic prosperity. Early analyses of French economic development have drawn a rather pessimistic view of France during the long 19$^{\text{th}}$ century. France as the leading political and economic power of the 18$^{\text{th}}$ century has lost its world status to Britain and experienced relative economic decline, or as Grantham

[3] *'The process started in Britain and the industrialization of Europe took place on the British model; it was, as far as the Continent was concerned, a purely and deliberately imitative process. Even after the 1860s, when technological and organizational innovations came increasingly from other advanced countries also [...] it was still a development from the base of the British model. [...] Europe's industrialization occurred as an outgrowth of a single root with mutations caused by varying circumstances.'*(Pollard, 1981, p.v)

[4] Whether Britain was the first economy to experience modern economic growth is less clear (De Vries and Van der Woude, 1997).

[5] A rather concise comparative summary of the two explanations by Allen (2009) and Mokyr (2009) is presented by Crafts (2010).

[6] The role of formal education during 19$^{\text{th}}$ century industrialisation is much debated. A recent contribution to this literature, Becker et al. (2011), finds that formal education was positively associated with non-textile industrialisation in Prussia. With respect to the importance of institutions for economic development during the 19$^{\text{th}}$ century, Acemoglu et al. (2011) have shown that institutional change brought by the Napoleonic reforms stimulated urbanisation in Germany.

(1997, p.369) states it: *"a long decline from the cultural and political grandeur of Louis XIV to the humiliation of Vichy"*. This view, which Crouzet (2003) has summarised as the 'retardation-stagnation' thesis does not state that economic progress was absent during the 19th century. It states that compared to Britain, but also Germany, French modernisation was incomplete. Clapham (1936) was the first to argue in favour of this pessimistic interpretation of France's relative economic development during the 19th century and his view prevailed until the 1960s.[7] Landes (1949) contributed to this interpretation by attributing French relative decline to entrepreneurial failure, conservatism and adherence to a small scale family firm structure. An extensive discussion of potential retarding factors using a comparative framework between France and Britain has been performed by Kindleberger (1964). For the period 1851-1875 he lists Napoleon III's diversion of government attention from economic motives to foreign adventures and the resource limitations in coal as the two most important retarding factors (Kindleberger, 1964, p.328).[8] Railroad investment, the expansion of the national market, expanding exports, import competition and government expenditures on cities as well as expenditures on communication are identified as drivers of economic development during this period. Until the start of WWI the resource limitations in coal continue to act as a burden. Studying French economic development through the British lens, the retardationists' view has identified France's low population growth with slow urbanisation and the scarcity and high cost of coal with adherence to water power and the small scale structure of enterprises as important differences to the British path to economic maturity and, thus, French economic backwardness (Cameron, 1985, pp.13-14).

During the 1960s and 1970s a 'revisionist' interpretation of 19th century French industrialisation emerged and reached broad acceptance from the 1980s onwards. Estimates of output, employment and productivity did not support the French backwardness and motivated a reinterpretation. In per capita terms the rate of economic growth was quite similar to that of Britain.[9] A comparison between economic growth in Britain and France has been performed by O'Brien and Keyder (1978) and Crafts (1984a). O'Brien and Keyder (1978) argue that French labour productivity was higher than British labour productivity in the industrial sector but lower in the agricultural sector. Crafts (1984a, p.67) confirms the non-failure thesis but is less optimistic in stating that *"French economic growth was respectable but certainly not outstanding during the nineteenth century"*. The general consensus reached by the revisionists is the existence of various paths of economic development and that using the British path as a norm is misleading.[10] The French economy did not perform worse than the British economy but their paths to economic prosperity

[7]Clapham (1936, p.53) summarises France's economic development as follows: *"In the course of the nineteenth century most French industries were remodelled but it might be said that France never went through an industrial revolution. There was a gradual transformation, a slow shifting of her economic centre of gravity from the side of agriculture to that of industry, and a slow change in the methods of industrial organisation. The transformation accomplished in a century was in many ways less complete than that which Germany experienced in the forty years after 1871."*

[8]Further *'force and frictions resisting economic growth'*, though of less economic significance, Kindleberger (1964, p.328) lists the immobility of the agricultural labour force and bankers' quarrels.

[9]Marczewski (1965) produced commodity output per capita estimates showing that growth rates did not differ between France and Britain. Estimates of national accounts by Toutain (1987) have supported this interpretation. Alternative estimates which reach similar conclusions have been presented by Lévy-Leboyer (1968) and Crouzet (1970).

[10]O'Brien and Keyder (1978, p.196), for instance, state that *"[France's] development reminds us that there is more than one way of transition from an agricultural to an industrial economy and from rural to urban society"*.

were structurally different. Lévy-Leboyer (1964) was the first to frame this interpretation. France did not follow the British path of coal, steam and urbanisation but developed a distinct model of economic development which was not inferior to the British model. This interpretation was also shared by Cameron and Freedeman (1983). Cameron (1985, p.13) even states *"that the French pattern may have been more 'typical' than the British"*. In search of British exceptionalism Crafts (1984b) highlights Britain's commitment to free trade, reflected by a high share of manufactures in her exports, and the early release of labour by agriculture.

The major contribution of the revisionists was to provide a more profound empirical basis for arguments about France's 19$^{\text{th}}$ century economic development. The new evidence revealed that the French economy did not stagnate and even grew at a similar rate as Britain when compared in per capita terms. The revisionists' critique is valid but French economic growth should not be glorified. Crouzet (1974, p.171) frames this point quite accurately: *"the legitimate reaction against the excessive pessimism which was fashionable some years ago, must not be carried so far as to overlook the weak points in French nineteenth-century economic development."* He further supports the assessment by Lévy-Leboyer (1964) of a late and incomplete industrial revolution and ascribes the French nineteenth century economy a creditable but not brilliant performance. Moreover, recent comparative estimates of labour productivity indicate a narrowing of the labour productivity gap with the UK only for the period 1850 to 1870 and lost competitiveness with respect to the UK and Germany between 1871 and 1911 (Dormois, 2006c,a). Interestingly, the sectoral results for the mid-19$^{\text{th}}$ century show that the labour productivity gap was rather small in the leading sectors of the first industrial revolution, textiles and metalworking, such that Dormois (2006c, p.5) concludes *"French industry followed in the steps of the British pioneer rather than break an alternative path"*. The debate is, thus, far from closed. Nevertheless, even if French economic development was better than we previously thought this does not imply that the French economy grew at full potential and that the structural weaknesses, which have been identified by the retardationists, did not limit growth. Therefore, a new group of cliometric revisionists analysed specific arguments of French retardation. The research agenda of this cliometric approach is to analyse whether French entrepreneurs acted rationally within their given circumstances. There are three main areas of cliometric research: a focus on small family firms, low sectoral labour mobility between agriculture and industry, protective trade policy.

The first widely discussed aspect of French economic structures is the dominance of small family firms. Landes (1949), famously, argued that the French economy performed badly because of poor entrepreneurship and small family firms. That economic development can but does not have to follow the British model has been argued by O'Brien and Keyder (1978). They argue that *"the techniques of production and the scale and form of industrial organisation found operating in French industry for much of the nineteenth century were in most cases well adapted to the demands that confronted industrialists in that country"* (O'Brien and Keyder, 1978, p.178). Nye (1987) supports the argument of O'Brien and Keyder (1978) by finding only low estimates of returns to scale in France during the 1860s. Increasing firm size would not have been rational for the majority of French industries. This finding has been challenged by Sicsic (1994) who finds evidence of increasing returns to scale in small scale industries as well as the woolen industry, cotton spinning and glass and paper mills. A more recent contribution to this debate is Doraszelski (2004) who finds less support for increasing returns to scale for the 1860s and so supports Nye's (1987) findings. However, for the first half of the 19$^{\text{th}}$ century, using the industrial census of the 1840s, Doraszelski (2004) identifies increasing returns to scale for some industries. Based on increasing return to scale estimates for the 1840s and constant return to scale estimates for the 1860s, Doraszelski (2004, p.280) concludes that French industries faced unexploited scale economies during the first half of the 19$^{\text{th}}$ century but that there was *"little to gain from scale economies in the second half of the 19th century"*. Hence, small firms should not be seen as a source of slower growth during the second half of the 19$^{\text{th}}$ century.

A second structural explanation for the pattern of French economic development is the existence of small peasant farms which limited the growth of agricultural productivity, through a rather slow introduction of labour-saving technologies, and limited sectoral labour mobility (O'Brien, 1996). That insufficient inter-sectoral labour mobility between agriculture and industry impeded French economic growth was also argued by Lévy-Leboyer (1974). The agricultural sector released insufficient labour for the industrial sector, so the argument. This contrasts the argument by Kindleberger (1964) that labour scarcity was no impediment to the growth of industry. An interesting contribution to this debate is Sicsic (1992) who analyses rural-urban wage gaps to test if the agricultural sector failed to release labour to industry. He finds negligibly low rural-urban wage gaps in the middle of the century which grew by 25% until 1890. This finding supports Kindleberger's (1964) argument. If industry's labour supply was substantially undermined by the agricultural sector's limited inter-sectoral mobility we would expect a large and rising rural-urban wage gap. Hence, if French agricultural labour was reluctant to move to the industrial sector industry's demand for this labour was small as, in this case, the wage gap would have increased more substantially. That the agricultural sector could not have slowed down growth in industry is further supported by Magnac and Postel-Vinay (1997) who analyse the degree of seasonal employment in the agricultural and industrial sector. They find elasticities of labour supply to industry of approximately 0.5 which is further evidence against the hypothesis of an inter-sectoral immobile labour force. Hence, as Grantham (1997, p.390) concludes: *'the preception that nineteenth-century French industrialisation was significantly retarded by the agrarian structure has not been cliometrically confirmed.'*

The third focus of the cliometric revisionists is trade policy. The protectionist agenda of French trade policy before the Cobden-Chevalier treaty of 1860 could have been an impediment to economic development in France.[11] In particular, because Britain has been perceived as a free-trading economy. This comparison of France as a protectionist economy and Britain as a free trade economy has been challenged by Nye (1991b). He found that French tariffs were lower than British tariffs until the mid 1870s and that during the period between 1840 to 1860 differences in tariff policies could not have had explained differences between the economic development of Britain and France. Based on Nye's (1991b) analysis, Grantham (1997) concludes that French economic development was not

[11] A more detailed discussion of French trade policy and the importance of the Cobden-Chevalier treaty of 1860 is presented in section 3.3.1.

distorted by barriers to trade. Nye's (1991b) finding that French tariff levels were below the British rates has been questioned by Irwin (1993). He argues that British tariffs were designed to avoid protecting producers but raise revenues for fiscal purposes while French tariffs were designed to protect domestic producers. Tena-Junguito (2006) supports this argument empirically by showing that the French non-fiscal average tariff rate was, indeed, higher than the British non-fiscal average tariff rate.

An aspect which has received less attention among cliometric revisionists is the less favourable resource endowment, coal in particular. Reviewing various factors of French backwardness Kindleberger (1964, p.17) attributes the 'coal factor' ancient origin. Also Clapham (1936) refers to the contemporary view of a less favourable coal position by citing Chaptal (1828) who sees the lack of applying machinery in cheap labour and high coal prices. France lacked sufficient domestic coal resources and imported 20% of its coal consumption in 1820 and 43% in 1860 (Crouzet, 1996, p.40). Coal deposits were small except for the fields in the department Loire and the region Nord-Pas-de-Calais. Besides the modest size in coal deposits Crouzet (1974, p.173) refers to the location of coalfields with respect to the lacking proximity to other resources, such as iron ore, and industrial districts as features of the 'coal argument'. In spite of the long tradition the 'coal factor' has become unfashionable. Nevertheless, Crouzet (1974, p.174) himself acknowledges that *"after all, nearly all the large industrial districts of the nineteenth century developed on coal-fields, and France's bad luck was to have only a couple of such vital growth areas"*. Given the dependency on imports and the disadvantageous location of coal deposits, a more nuanced interpretation of the 'coal factor' has emerged with respect to tariff policy and transport infrastructure. Kindleberger (1964) argues that lower import tariffs and a faster expansion of the transport network would have supported French growth during the first half of the 19$^{\text{th}}$ century. The French railroad boom did not start before the 1840s and the coal as well as charcoal producers were protected from foreign competition by import tariffs at least until 1830. To what extent a more liberal trade policy towards coal and an earlier expansion of the transport infrastructure would have fueled French economic growth has not yet been empirically examined. Even if the 'coal factor' is subject to much debate it is rather undisputed by the literature that the relative scarcity of coal has led to the slow penetration of the steam engine and the dominance of water power (Crouzet, 1996). The existing literature identifies three key features of French industrialisation which are related to the dominance of water power: small firm size; geographical dispersion of industry; slow urbanisation (Cameron, 1985; Crouzet, 1996).[12] Up to my knowledge there is no empirical research which studies the interlinkages between power technologies and the geographical dispersion of industry and slow urbanisation in the French economy. Therefore, chapter 4 of this thesis is the first attempt to quantify the importance of power technology for the rural location of French industry during the 19$^{\text{th}}$ century.

A further aspect which is still subject to much debate is the importance of market integration for 19$^{\text{th}}$ century industrialisation. Comparing the total population of Britain with France, the extent of the French market cannot be seen as a major constraint to economic development.[13] However, if the larger French market was less integrated it could

[12] See section 4.2.1 for a more detailed discussion of arguments related to the diffusion of steam and water power.

[13] In 1820 the population of Britain was 20.9 million while France was inhabited by 30.5 million people

be the case that market size played an important role. By comparing the British and French transport system during the 18th century, Szostak (1991, p.232-233) argues that *'the small-scale, geographically dispersed nature of French industry made it difficult not only to develop new technology but also to borrow technology developed elsewhere'.* High degrees of market fragmentation did, thus, impede French economic development. This is contrasted by Daudin (2010) who shows that French markets were not smaller than British ones at the end of the 18th century by estimating the extent of the French market size at the product level based on the *Tableaux du Maximum.*[14] The early 19th century saw an expansion of the road and canal network.[15] The construction of railroads, however, did only speed up during the second half of the century. In 1848 France operated only 1,860 kilometers of railroad while 5,900 kilometers were in operation in Britain and 5,200 kilometers in Germany (Smith, 2006, p.65). By 1883 the French railroad network connected all regions of France with 25,000 kilometers in length achieving a cost reduction of 75% of merchandise freight between 1840 and 1870 (Smith, 2006, p.87). Hence, even if markets were less fragmented as previously thought, technological change in the transport sector contributed to a substantial increase in market integration.

The section on 19th century French economic development has, so far, outlined the main themes discussed by the literature. There is surprisingly little research on regional economic inequalities during this period.[16] Notable contributions are Toutain (1981), Combes et al. (2011) and Caruana-Galizia (2013). Toutain (1981) estimates the regional gross internal product for 21 regions while Combes et al. (2011) and Caruana-Galizia (2013) estimate gross value added (GVA) per capita for French departments. They reveal a concentration of income in the North and North-East with more localised concentrations around the cities of Bordeaux, Lyon and Marseilles. Caruana-Galizia (2013) hypothesises that the regional patterns in GVA per capita were driven by access to natural resources, coal in particular, rather than access to export markets, and poor transport infrastructure prevented the successful integration of the French market. Combes et al. (2011) empirically identify drivers of regional disparities and find that in 1860 access to a larger domestic market and higher sectoral diversity was associated with higher labour productivity. Given the limited empirical research on spatial inequalities, there is a clear need to empirically investigate the spatial dimension of French 19th century economic development in more detail.

2.1.2 Belgium

Belgium was the first economy to follow Britain through the industrial revolution developing a similar set of industries (Wee, 1996) and showing GDP per capita growth driven by the industrial sector already during the first half of the 19th century (Buyst, 2002).[17]

(Mitchell, 1980). At the turn of the century, Britain had overtaken France in terms of total population.

[14] *'The Tableaux [du Maximum] give information on trade links between 552 districts in France for fifteen different goods categories' (Daudin, 2010, p.717).*

[15] Between 1815 and 1848 2,900 kilometers of canals were built which extended the French canal network to 4,000 kilometers (Milward and Saul, 1973, p.335-336).

[16] This is particularly striking as following the book by Gravier (1947) the French government became very active to diminish the regional dominance of Paris. Moreover, during the second half of the 19th century France experienced progressive rural depopulation and internal migration known as the *rural exodus* (Merlin, 1971; White, 1989).

[17] In 1846 36% of the labour force was employed in the manufacturing sector, 43% in the agricultural sector and 22% in the service sector (Buyst, 2007).

National account estimates of 19th century Belgian GDP per capita, however, show that Belgium experienced very fast industrialisation not before 1850. Between 1850 and 1870 Belgian industrial real value added increased by 5.5% per annum and GDP per capita gained 2.7% per annum (Horlings and Smits, 1997, p.86). Compared to the periods before 1850 and after 1870 the twenty years between 1850 and 1870 are clearly unprecedented and can be described as a *growth spurt*.[18] Moreover, during this period the Belgian economy closed its GDP per capita gap to the Netherlands and narrowed its gap to the UK.[19] Horlings and Smits (1997) show that the catch-up to the Netherlands was based on a sharp rise in the investment ratio between 1850 and 1870.[20]

According to Allen (2011, p.373) Belgium was the only region outside of Britain where British technologies could be adopted profitably. The rich coal deposits in the Southern Belgian region of Wallonia can be found at the centre of many explanations for the early success of Belgian industry. This is true for Allen's argument but also Pollard (1981, p.87) writes on Belgium that *"the basis, as always, was coal"* and Wrigley (1961, p.4) sees the Austrasian coalfield as *"by far the most important industrial region in continental Europe"*.[21] The relative importance of coal for Belgium's early economic success is, however, far from clear and various authors emphasise alternative factors. In his seminal work on explaining the different growth trajectories of Belgium and the Netherlands during the 19th century, Mokyr (1976) identifies low wages as giving Belgian producers the key comparative advantage. He further discredits the importance of coal by emphasising, on the one hand, the limited importance of coal for the textile industry during the early 19th century and, on the other hand, the transportability of coal to coal-scarce locations (Mokyr, 1976, p.205). This is in line with the more recent argument for the British industrial revolution by Clark and Jacks (2007, p.69) who come to the conclusion that *"England gained little advantage from actually possessing the coal reserves"*. As the textile industry was the main contributor to aggregate productivity and energy intensity was low in this sector, they deny coal a pivotal role for the British industrial revolution. Mixed results on this matter have been identified by Crafts and Wolf (2014) who show that low coal prices were not associated with a higher probability for the location of cotton textile mills in the UK in 1838. However, lower coal price were positively associated with the total size of the industry in terms of employment and firm size.

Besides rich coal endowments, the fate of the Belgian economy has been linked to demand-side explanations. Gaining political independence from the United Kingdom of the Netherlands in 1830 and being separated from the French Empire by the Congress of Vienna in 1814-1815, the Belgian domestic market was in decline during the first half of the 19th century. The first population census post Belgian independence states a total

[18]The term *growth spurt* refers to ideas of Gerschenkron (1962) who argued that economically backward countries can experience a spurt in industrialisation once disadvantageous initial conditions have been overcome.

[19]In 1850 Belgian GDP per capita was 79% of the UK level and 78% of the Dutch level. In 1870 relative GDP per capita increased to 84% of the UK level and 98% of the Dutch level - see the Maddison-Project - see http://www.ggdc.net/maddison/maddison-project/home.htm, 2013 version.

[20]Due to their geographical proximity and similarity in size, the economic development of Belgium and the Netherlands is often studied in a comparative framework.

[21]That coal played a key role in the British industrial revolution is associated with the seminal contributions by Wrigley (1988) and Pomeranz (2000), but also Allen (2009). Fernihough and O'Rourke (2014) further show that access to coal was an important factor for the growth of European cities by using a difference-in-difference identification strategy for a sample of European cities from 1750 to 1900.

population of 4.1 million in 1831. In the same year France reports a population of 32.6 million and in 1829 the Netherlands was inhabited by 2.6 million people (Mitchell, 1980, p.29-32). Given the relatively small domestic market it is at no surprise that economic historians have linked market size to economic development. In their seminal study of the economic development of Continental Europe, Milward and Saul (1973) see Belgian economic development conditional on the international situation with a specific focus on the demand from industrialising Germany and France.[22] Having gone through the early stages of the industrial revolution under socio-economic changes of the French period with protection from British competition (Juhász, 2014), growth enhancing institutional reforms (Acemoglu et al., 2011) and access to a large homogenous market (Wee, 1996), the decline of its market confronted Belgian industry with major challenges. The various governments, however, became active to mitigate these negative demand effects. King William I of the United Kingdom of the Netherlands supported Belgian industry by providing loans through government institutions like the Société Générale, introducing moderate tariffs against the free-trade interests of the Northern Netherlands and providing a protected colonial market of the Dutch East Indies (Kossmann, 1978, p.129-136). This policy was continued after Belgian independence with the *"foundation of the Banque de Belgique in 1835 and the highly protective tariff of 1834"* (Mokyr, 1976, p.229). It was only after the 1850s that Belgium became oriented towards free-trade (Milward and Saul, 1973, p.453). The feature of Belgium as a small and open economy only developed during the second half of the 19th century. The ratio of total trade ($imports + exports$) and GDP, as a proxy for economic openness, was at 21% in 1835, 23% in 1850 and 56% in 1910.[23] There was a rise in openness during the period of rapid industrialisation between 1850 and 1870 after which the ratio remained at 40% until 1900. This period was followed by an equally significant increase in openness of 20%-points until the eve of World War I. In contrast to the earlier period, the short period between 1900 and 1913 was not characterised by equally significant gains in GDP per capita. Analysing this phenomenon Huberman et al. (2017) argue that the increase in trade openness was due to a more diversified range of exported products and served markets. The comparatively limited growth in GDP per capita stems from the fact that lower productivity firms were able to serve these new markets as entry fixed costs declined. The earlier period of 1850 to 1870 is associated with substantial trade liberalisation among Belgium's neighbours. Britain abolished its Corn Laws in 1846 and signed a trade agreement with Belgium in 1850. A commercial treaty was signed with France in 1854 as well as in 1862 following the Cobden-Chevalier treaty between Britain and France in 1860. A first trade treaty was negotiated with the German Customs Union, which included the Duchy of Luxembourg from 1842 onwards, as early as 1844 and 1852. And Belgium's northern neighbour, the Netherlands, is seen as one of the most liberal economies throughout the 19th century. Additionally, Belgium abolished most of its export prohibitions in 1853 and the port of Antwerp was freed from Dutch tolls in 1863 (Milward and Saul, 1973; Bairoch, 1989).

[22] They argue that *"until the construction of a European railway network and the lowering of tariffs in the 1860s Belgium's trade problems were always critical"* (Milward and Saul, 1973, p.441).

[23] Openness is measured as the sum of imports and exports in current prices as a percentage of GDP in current prices. Trade values are derived from Horlings (1997) and GDP is based on Smits et al. (2009). A comparison of GDP per capita and openness between 1835 and 1913 is shown in figure 5.1 of chapter 5.

Besides the provision of loans and protective tariffs, another field of government activity which the literature has associated with Belgian economic development is transport infrastructure. The main focus lies on railroad building post independence. On the one hand, the Belgian government intended to compensate industries for operating in an even smaller domestic market by providing better access to international markets. On the other hand, the railroad was intended to divert transit trade from Rotterdam to Antwerp by connecting the latter to Cologne. At the start of WWI Belgium had the densest railroad network in the world with 1/3 km of railroads per square km (Milward and Saul, 1973, p.442). From a demand perspective, the Belgian railroad construction did not only connect locations to international markets but also served as a source of demand for the domestic iron industry. Fremdling (1986, p.258) shows that the demand of railroads over total production in the iron industry was between 8.1% in 1835 and 13.7% in 1844. Railroad construction was, thus, an important stimulus for the Belgian iron industry, however, it can hardly be seen as the sole driver of the Belgian iron industry. From a supply perspective, it is argued that Belgian railroads, light railroads in particular, had a significant influence on the supply of cheap rural labour to urban industries (Rowntree, 1911; De Block and Polasky, 2011). The dense Belgian transport network with the possibility of cheap commuting tickets also prevented the depopulation of the countryside.[24] Huberman (2008) highlights the train network's importance not only for the regional but also sectoral and political integration of the economy. While guaranteeing a supply of cheap labour, the train system stimulated the political formation of a Beligan working class.

So far multiple factors have been introduced which the literature has identified as important to understand Belgium's 19$^{\text{th}}$ century economic development: favourable resource endowments, low labour costs, beneficial institutional reforms during the Napoleonic era, variations in domestic and international market access and a dense transport network. Additional factors which are important to mention are innovations in providing capital to industry as well as the long tradition in manufacturing activity. The previous paragraphs have already introduced the initiatives to provide capital to industry by establishing the Société Générale in 1822/23 and the Banque de Belgique in 1835. By combining commercial banking with long-term investment, these so called *mixed banks* provided capital to basic and capital goods producing industries to finance their mechanisation and expansion. Cameron (1967) ascribes the new format of mixed banks vital importance for Belgium's industrialisation post 1830. By focusing on long-term investment and neglecting short-term commercial credit, these new financial intermediaries favoured large establishments, between 1830 and 1850.[25] The mixed banking system has even been described as *"the main engine driving industrialisation in Belgium"* by Wee and Goossens (1991, p.113), not only focusing on domestic investment in its early stages but also presenting evidence on foreign engagement whenever Belgian industrial interests were supported.[26] Apart from these innovations to provide Belgian industry with sufficient funds, the early economic success of Belgian industry is further ascribed to proto-industrialisation. Flanders has a long

[24] This is in stark contrast to France where urban regions grew at the expense of rural regions, which is known as the *rural exodus* (Merlin, 1971; White, 1989).

[25] Between 1850 and 1870 seven new joint-stock banks were created which spread banking facilities more broadly (Cameron, 1967, p.136).

[26] A key example is the financial engagement in foreign railroad companies which derived their inputs from Belgian heavy industry.

tradition in textile production under the putting-out system, see Mendels (1971) and Vandenbroeke (1996), and the metal industry was well established in Wallonia already before the 19th century (Wee, 1996, p.64-65). Early industrialisation could, therefore, draw on a skilled labour force with tacit knowledge in industries of the first industrial revolution.

In contrast to France, the regional perspective is much more prominent in the economic history literature of Belgium. As this literature is reviewed more extensively in section 5.2, only a concise summary is presented here. Belgium is characterised by a distinct regional divide between the Flemish-speaking Northern region of Flanders and the French-speaking Southern region of Wallonia. During the last 200 years the economic dimension of this divide has changed dramatically. While Wallonia was at the centre of 19th century industrialisation it fell into relative decline during the 20th century. By estimating GDP per capita at the province level from 1896 to 2000, Buyst (2011, p.337) shows that the richest province in 1896, which was Hainaut, had the lowest relative GDP per capita among Belgian provinces in 2000. Explaining the different paths of economic development between Flanders and Wallonia stimulated research on the 19th century. With the exception of Ronsse and Rayp (2016), the literature consists of mainly descriptive comparisons of the economic development of these regions. The seminal contribution in this literature is the book by De Brabander (1981). Analysing the spatial concentration of industrial employment based on industrial censuses between 1846 and 1970, he identifies the Walloon provinces of Hainaut and Liège as leaders in the industrialisation process and attributes the province of Antwerp, as the only Flemish province, signs of economic success during the 19th century. Besides De Brabander (1981), also Riley (1976), Boschma (1994) and Vandermotten (1997) perform descriptive regional analyses based on industrial employment census data. The sole study which tries to empirically identify determinants of industrial location is Ronsse and Rayp (2016). However, by focusing on the period 1896-1961, their contribution to explain the regional patterns of the 19th century remains limited. For the 20th century they emphasise the role of market access for the relative success of Flanders.

2.2 Spatial Inequalities and Economic Development

This section reviews the literature on the relationship between spatial inequalities and economic development. The first part surveys theories of economic geography with an emphasis on *New Economic Geography* (NEG) theory and outlines empirical frameworks which have been used to analyse their predictions. The second part discusses the influence of the theoretical and empirical NEG literature on the discipline of economic history.

2.2.1 Theoretical frameworks

The interest in understanding the relationship between regional inequality and economic development is not new and has been stimulated by existing spatial patterns of economic activity. Among the first scholars to analyse this relationship was Jeffrey Williamson in 1965. Inspired by the work of Kuznets (1955), who argued for an inverted U-shaped relationship between income inequality and economic development, and motivated by existing regional inequalities in France, Italy, Brazil and the United States, Williamson (1965, p.44) argued that *"increasing regional inequality is generated during the early development stages, while* *mature growth has produced regional convergence or a reduction in differentials"*. Hence, Williamson (1965) suggests the existence of what we can call a regional *Kuznets curve*. His analysis is mainly descriptive and leads to further research questions regarding the underlying mechanisms. Nevertheless, he suggests that regional inequalities first increase because of the unequal distribution of capacities for economic growth as well as high barriers to trade which prevent the diffusion of economic growth to less favourable regions. Only once these barriers have been diminished, regional inequality declined.[27] Theories of spatial inequality which follow this reasoning are based on a neoclassical growth model with constant returns to scale and regional inequality has their origin in regional comparative advantages.

The interpretation of the relationship between regional inequality and economic development has changed with the emergence of the so called *New Economic Geography* (NEG) literature. By combining the research fields of international trade and economic geography Paul Krugman is regarded as the founder of this strand of literature.[28] *"For his analysis of trade patterns and location of economic activity"* he was awarded the Nobel Price in Economic Sciences by the Royal Swedish Academy of Sciences in 2008.[29] In Krugman's tradition the NEG literature explains the existence of spatial agglomeration of economic activity within a general equilibrium framework using monopolistic competition. Applying this analytical framework to questions of economic geography has been pioneered by Fujita (1988), Krugman (1991b,c) and Venables (1996). NEG-models combine transport costs and increasing returns to scale at the firm level, which lead to a market structure of imperfect competition following Dixit and Stiglitz (1977). Additional components of NEG models which distinguish them from alternative modeling aproaches are *endogenous firm location* and *endogenous location of demand* (Head and Mayer, 2004). Transportation costs, which are usually modelled in the form of ice-berg transportation costs following Samuelson (1952), are decisive to make location matter.

In the seminal article of Krugman and Venables (1995), they show that an inverted U-shaped relationship between income inequality and economic development can also be predicted within the NEG tradition. Depending on the level of transport costs spatial concentration occurs in order to profit from intermediary goods and lower production costs of final goods. At the early stages of economic development high transportation costs prohibit the spatial concentration of production but as transportation costs decline producers have an incentive to concentrate in regions of large demand and low costs. If transportation costs, however, become even cheaper, then the advantages to locate closer to markets disappear and production disperses again as previously disadvantaged regions benefit from low wage costs. This results in a bell-shaped, or inverted U-shaped, relationship between transport costs and the spatial concentration of economic activity. The same structure emerges when specifying an NEG type model with adding agglomeration costs, like land rents (Ottaviano and Thisse, 2004).

The mechanisms through which benefits of agglomeration emerge are manifold. The

[27] *"As long as the barriers to trade and factor flows (as well as communication of technological change) persist, regional inequality will clearly increase"*(Williamson, 1965, p.5).

[28] The underlying ideas of NEG models have long existed among economic geographers and location theorists but were at the periphery of mainstream economic theory (Ottaviano and Thisse, 2004, p.2566).

[29] "Paul Krugman - Facts". Nobelprize.org. Nobel Media AB 2014. Web. 23 Jun 2017. <http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2008/krugman-facts.html>

traditional NEG theories by Krugman (1991b,c) model agglomeration through internal economies of scale and transportation costs creating a *home market effect*. Large firms, exploiting internal economies of scale, form large markets and create demand incentives for other firms to locate in the same region. A variation of the traditional Krugman model introduces scale economies through forward and backward linkages. Firms concentrate in the same region in order to benefit from cheaper intermediary inputs which are produced under scale economies. This aspect is also known as *input sharing*, one of three Marshallian agglomeration externalities. Marshall (1890) is still the seminal reference with respect to mechanisms of benefits of agglomeration. Besides *input sharing*, Marshall (1890) emphasises *knowledge spillovers* and *labour-market pooling*. Firms in close spatial proximity benefit from each other by sharing knowledge and technologies. At least since Lucas (1988), human capital externalities are seen as crucial for economic development. That knowledge spillovers are not confined to one industry but may benefit a broader group of sectors has been suggested by Jacobs (1970). The third Marshallian externality, *labour-market pooling*, suggests that industries concentrate in order to benefit from more efficient labour matching. More recently, a new analytical framework to classify agglomeration economies has been proposed by Duranton and Puga (2004) who argue that Marshallian agglomeration externalities are often theoretically not distinguishable. The classification proposed by Duranton and Puga (2004) distinguishes between three mechanisms: *sharing*; *matching*; *learning*.[30]

Apart from various forms of agglomeration benefits, location fundamentals can explain the location of firms and industries. Krugman's New Trade Theory, which entered his NEG models, should be seen as a response to Ricardian comparative advantage theories of trade. The Heckscher-Ohlin (H-O) model, which is the most prominent example for Ricardian comparative advantage theories of trade, predicts that countries specialise in industries in which they face a comparative advantage given their factor endowments.[31] International trade and the distribution of production is, thus, determined by the differences in regional factor endowments, or what Williamson (1965) called regional capacities for economic growth. That locational fundamentals can be a source for the spatial concentration of economic activity has been emphasised by Ellison and Glaeser (1997, 1999) and further empirically verified by Davis and Weinstein (2002) and Kim (1995, 1999). In contrast to H-O based explanations, predictions from NEG theories emphasise the importance of internal and external economies of scales, transportation and agglomeration costs which determine the location of production. However, it should be stressed that these two lines of arguments are not mutually exclusive. An important theoretical contribution in combining NEG and H-O type forces is the article by Epifani (2005) who incorporates endowment-based comparative advantages within a NEG framework. The model's predictions differ with respect to industry diversification in a free trade equilibrium. In the case of a diversified free trade equilibrium, agglomeration economies cause an overshooting of industry specialisation and factor prices. At first, lowering trade costs results in specialisation according to comparative advantages. Due to positive agglomeration externalities

[30] Potential sources of urban agglomeration benefits based on the framework proposed by Duranton and Puga (2004) are discussed more extensively in section 4.3.

[31] The original article on which the H-O model is based has been published in English in 1991 - see Heckscher (1991). For a text-book summary of the H-O model see Feenstra (2004, chapter 2).

the degree of specialisation exceeds the free trade equilibrium once trade costs become sufficiently small. However, at even lower trade costs agglomeration economies weaken such that specialisation decreases to its free trade equilibrium. In the case of complete specialisation there is no overshooting. Nevertheless, agglomeration economies strengthen comparative advantages such that full specialisation can be reached at higher trade costs. In both scenarios the combination of agglomeration economies and comparative advantages adds valuable insights and clear-cut theoretical predictions. It should be stressed that the contribution of NEG models lies in the explanation of spatial agglomeration even in the absence of regional differences in factor prices. NEG models are, therefore, not intended to overthrow H-O based explanations but rather to complement them.

Within the economic geography literature the neoclassical renaissance, which is associated with the models of the NEG literture, covers only one of three approaches. Before economists became increasingly interested into economic geography in the early 1990s, which is known as the *Geographical Turn*, the discipline of economic geography made an *Institutional Turn* starting in the 1980s.[32] The institutional approach to economic geography, or Institutional Economic Geography (IEG), seeks to explain regional differences in economic development by institutional, or cultural, differences. During the last two decades Evolutionary Economic Geography (EEG) has gained importance as a third approach to economic geography. This approach's main focus lies in explaining different regional economic trajectories and spatial agglomeration as a path dependent process of firm specific locational behaviour.

The evolutionary approach to economic geography emphasises synergies with both the NEG and the IEG literature without loosing its distinct focus, which is to emphasize the evolution of the economic landscape over time (Boschma and Martin, 2010). According to Boschma and Frenken (2006) evolutionary economic geography (EEG) is unique in its core assumptions, units of analysis and type of explanations. From a methodological perspective EEG values methodological pluralims applying formal modelling and statistical testing of theoretical propositions alongside case study approaches. Key assumptions a more closely shared with the IEG literature which assumes *"economic action to be contextual rather than driven by maximisation calculus."* (Boschma and Frenken, 2006, p. 292). EEG focuses mainly on organizational routines determining economic behaviour and firm or industry location. Organizational routines are shaped by path dependencies, or put differently by organizational routines acquired in the past, innovation as well as relocation. Following Nelson and Winter (1982) the unit of analysis is organizational routines at the firm level. Firms are studied from a historical perspective in which entry, exit and spinoffs are attributed special attention. For instance, Klepper (2007, 2010) highlights the importance of spinoffs for the forming of successful clusters like the automobile industry around Detroit and the semiconductor industry in Silicon Valley. As spinoffs are more likely to locate close to their parent firms in order to exploit location specific economic and social knowledge, spatial clusters emerge. Thus, clusters are persistent and self-reproducing, even if localization economies are absent (Boschma and Frenken, 2011), and the location of the cluster is determined by the location of the initial successful parent (Klepper, 1996). Apart

[32] The terms *Geographical Turn* and *Institutional Turn* are borrowed from Boschma and Frenken (2006, p.274).

from spatial clusters economic network and networks of knowledge spillovers are a prime interest within the research field of EEG. Boschma and Frenken (2010, p.101) argue that proximity in knowledge networks is *"required on some (but not necessarily all) dimensions to make firms connected, and to enable interactive learning and innovation"*. Labour mobility and social ties between moving individuals have been identified as important channels of knowledge spillovers Boschma and Frenken (2011, p.301). However, at the moment *"the mechanisms transmitting knowledge spillovers remain relatively unexplored and unknown"* (Audretsch and Feldmann, 2004).

The institutional approach to economic geography assumes that differences in economic behaviour are primarily due to differences in institutions (Hodgson, 1988). Institutional Economic Geography (IEG) studies place specific institutions and how those affect local economic development. In contrast, NEG shows how uneven spatial patterns can emerge even when starting from neutral space. Boschma and Frenken (2006, p.274) describes the dialogue between IEG and NEG as a *"dialogue between the deaf"*. The methodological approaches are fundamentally different, IEG follows a case study approach assuming that agents are bounded rationally and rely heavily on the institutional framework. Institutions are embedded in geographically localized practices. While institutions do not play an active part in NEG, they can be an important factor in EEG. Routines are at the centre of EEG and even though EEG neglects that routines are primarily determined by the prevailing institutional environment, routines might well have a political dimension and be transformed by major institutional disruptions (Boschma and Frenken, 2011). Additionally, as EEG sees institutions as co-evolving with technologies and markets. Regions can adapt their institutional setting in order to seize opportunities from new industries and technologies, or put differently to increase their local capacities. Institutions should definitely not be overlooked in assessing spatial patterns of economic development, not at least due to the increasing evidence in favour of institutional explanations (Hall and Jones, 1990; Acemoglu et al., 2001, 2006). It is more about the question what type of institutions matter rather than that institutions matter. Institutionalists believe that both formal and information institutions, such as culture, history, religion or identity, are crucial for regional economic development (Rodriguez-Pose, 2013, p.1038). Informal institutions lower uncertainty and information costs, smooth the process of knowledge and innovation transfer, shape incentives and disincentives to balance coordination and competition, facilitate the learning process and generate a degree of adaptive efficiency to adopt new knowledge and to engage in innovative and creative activities (North, 1990; Rodriguez-Pose, 2013). Hence, according to advocates of IEG local institutional capital determines to a large extent a region's development potential. According to Gertler (2010), the importance of institutions for local and regional economic change is still underrepresented within economic geography.

The Economic Geography literature is closely associated with the innovation and technical change literature as spatial concentration is not only a feature of economic activity but is even more pronounced for innovative activity.(Audretsch and Feldmann, 2004) Institutional Economic Geography can be linked to the concept of Local Innovation Systems (LIS), which is a sub-concept of National Innovation Systems (NIS) being used in the technical change and innovation literature.(Nelson, 1993; Lundvall, 1992; Freeman, 1987) Local Innovation Systems can be interpreted as a conceptual approach to analyse innovation and diffusion processes within a specific geographical boundary which is characterized by well defined historical, social, cultural, or productive features (Edquist, 1997, p.130). Abramovitz's concept of *social capability*, which refers to the capabilities backward countries possess in order to catch up, can be seen within the tradition of innovation systems.(Abramovitz, 1986) Investment in education, infrastructure or more generally technological capabilities such as public and private sector R& D can accelerate innovative activity and technological diffusion. The regional perspective within the broader *systems of innovation* approach is usually focused on the distribution of knowledge within the region also known as regional knowledge spillovers. Knowledge externalities may be spatially bounded particularly when *tacit* knowledge, which is difficult to codify, is an important component in the knowledge production function. Audretsch and Feldmann (2004, p.2734), for instance, conclude on this subject that *'the model of the knowledge production has been found to hold better for spatial units of observation than for enterprises in isolation of spatial context'*. That knowledge spillovers matter for spatial agglomeration and cluster building has been confirmed, the mechanisms, though, remain largely unexplored.

The discussion has outlined a variety of approaches to study the uneven distribution of economic activities in space. Hence, there is no clear consensus why spacial inequalities emerge and persist over time. Different strands of literature highlight alternative factors, why it is important to consider a variety of possible explanations in empirical investigations.

2.2.2 Empirical frameworks

The discussion of various theoretical frameworks and approaches to economic geography has shown that alternative explanations for the existence of the spatial inequalities do exist. This turns the question about the location and concentration of economic activity into an empirical exercise.

One objective is to disentangle demand driven NEG determinants from supply based H-O type effects. Among the first attempts to do so was the article by Davis and Weinstein (1996) which was followed by Davis and Weinstein (1999, 2003) using a similar methodology. They set up an empirical model of NEG and H-O type components with the objective to test for the existence of *home market effects*. The main NEG type factor is a measure of idiosyncratic demand differences, for which the reference group are *rest of the world* patterns of demand (*IDIODEM*). Moreover, they consider a variable which accounts for *rest of the world* patterns in production (*SHARE*). Additionally, their empirical model includes controls for factor endowments of land, capital and labour by education. A *home market effect* is identified if the coefficient estimate for *IDIODEM* is statistically significantly greater than 1, showing *"idiosyncratic demand patterns [...] have magnified effects on production"* (Davis and Weinstein, 1996, p.36). On the one hand, they find only little empirical support for the existence of a *home market effect* in their 1996 article. In those models which detect a statistically significant coefficient for *IDIODEM* of greater than 1 the economic significance of this effect is minor. Davis and Weinstein (1999, 2003), on the other hand, support the existence of a *home market effect*. The coefficient for *IDIODEM* is statistically significantly greater than 1 as a mean across disaggregated industries as well as for a sizeable number of within-industry regressions.[33]

[33]The differences between the three studies can be explained by a change in the sample and unit of

The determinants of the spatial distribution of economic activity have further been analysed by Midelfart-Knarvik et al. (2000) within a general equilibrium model which combines comparative advantage and NEG factors. The strength of this model is its focus on empirical applicability. Market demand effects and factor endowment effects are combined through interaction terms between regional characteristics and industry characteristics. This approach can be applied for various interaction terms covering factor endowment effects and market potential effects. The market potential effects which have been considered by Midelfart-Knarvik et al. (2000) are the interaction between the elasticity of market potential and transport intensity as well as the interaction between relative market potential and the share of output to industry. In a subsequent article, in which Midelfart-Knarvik et al. (2001) have studied the location of European industry, three interaction terms covering economic geography effects have been considered: market potential & sales to industry, market potential & intermediate goods, market potential & economies of scale. The interaction between market potential and the share of sales to industry reflects backward linkage, as firms can benefit from being close to their customers. Forwards linkages are captured by the second interaction term, which follows the idea that industries being highly dependent on intermediate goods will prefer to locate in regions with higher market potential. Finally, the interaction term between market potential and economies of scale captures the idea that industries with increasing returns to scale may tend to concentrate in locations with good market access (Midelfart-Knarvik et al., 2001, p.32).

The two empirical approaches which have been introduced so far study the determinants of employment and firm location decisions. An equally important strand of literature focuses on local productivity and wages rather than the location of employment and firms.[34] The seminal article by Ciccone and Hall (1996) show that the concentration of economic activity can explain more than half of the variance in labour productivity across U.S. states in 1988. Following the approach by Ciccone and Hall (1996), this literature relates local indicators of productivity (total factor productivity (TFP), labour productivity, wages) to local agglomeration characteristics, such as employment density. Besides employment density important local agglomeration characteristics are the total size of the local economy, industry specialisation and diversity, firm size as a measure for internal economies of scale, and human capital externalities.[35] As Combes and Gobillon (2015) highlight, studies following this approach estimate the total net impact of agglomeration economies rather than the magnitude of agglomeration channels. Empirical analyses which try to identify and estimate the magnitude of channels of agglomeration are rare and should be seen as an important field of further empirical research.

One key element in empirical applications of NEG theory is the measurement of market potential. As it is reasonable to assume that local agglomeration spillovers go beyond the boundaries of the chosen local unit, measures of market potential need to account for demand from markets in distant places. There are two concepts which are frequently applied. Most often, market potential is measured based on the seminal contribution by

observation in the case of Davis and Weinstein (1999), which studies Japanese regions instead of OECD countries, and a methodological improvement with respect to the idiosyncratic demand component in the case of Davis and Weinstein (2003).

[34] Combes and Gobillon (2015) presents a detailed survey of the *Empirics of Agglomeration Economics* literature.

[35] Within the field of economic history, a recent contribution is the article by Combes et al. (2011).

Harris (1954) who has suggested to approximate market potential as an inverse distance weighted sum of neighbouring regions' incomes. Market potential, MP, of region i, is a weighted sum of GDPs across j regions, where j includes i. The market accessibility, ϕ, is measured by distance and η is assumed to be -1, such that GDP is weighted by the distance to market i. Regions which are closer to a set of regions with large GDP, therefore, face a higher market potential. This assumes the accessibility of markets to be positively correlated with inverse distances. Variations of the Harris type market potential measure use density, population or employment instead of GDP and actual transport costs can be used as the measure for market accessibility ϕ. Moreover, MP can either include or exclude the own location i. If region i is included the distance weight for region i follows the idea that market accessibility decreases with area size. The distance measure for the region pair ii is then given by $\phi_{ii} = 2/3 * (area_i/\pi)^{0.5}$. If region i is excluded own location market potential is added as a separate determinant.

$$MP_i = \sum_j GDP_j * \phi_{ij}^{\eta} \tag{2.1}$$

A shortcoming of the Harris (1954) type market potential is that it does not include local price effects, why it can be interpreted as *nominal market potential* (Head and Mayer, 2004). Redding and Venables (2004) derive *real market potential* based on a standard gravity model of trade. This approach, however, is much more data demanding as it requires information on internal trade flows. Therefore, most historical research refers to the original approach by Harris (1954). Wolf (2005) and Daudin (2010) are noticeable exceptions applying a gravity approach to estimate market potential in the field of economic history.

The theories and arguments which have been presented so far reflect only a relatively small part of the NEG and EEG literature and an even smaller part of the regional and urban economics literature.[36] This specific selection has been included because of its importance in empirical applications within the field of economic history. The next and last part of this literature review will survey how these ideas have diffused to the discipline of economic history.

2.2.3 The historical perspective

Similar to the question to what degree the ideas from NEG are actually new within the field of *Urban and Regional Economics*, it should be emphasised that the regional perspective has a long tradition in the field of economic history. Emphasizing the importance of regions in 19$^{\text{th}}$ century industrialisation goes back to the seminal contributions by Pollard (1981) and Hudson (1989). These authors have challenged the use of the nation state as the standard unit of comparison and suggested to compare regions instead, arguing that *"each country was made up of a number of regional economies"* (Pollard, 1981, p.41). The regional focus has recently experienced a renaissance. Concepts and ideas from the *New Economic Geography* (NEG) literature have found broad acceptance and applications

[36]For more detailed surveys on various aspects of the regional and urban economics literature see the *Handbook of Regional and Urban Economics* by Henderson and Thisse (2004, Vol.4) and Duranton et al. (2015, Vol.5).

within quantitative economic history. Explaining industrial location and the degree of concentration is at the centre of these articles. Even though, Pollard (1981) was undoubtedly a forerunner in emphasising the regional perspective in economic history, and has not remained unnoticed in the regional economics literature (Ottaviano and Thisse, 2004), his approach deviates from NEG theory. He writes *"the methodology of this book is to study the supply factors, and over-all (though not necessarily localized) demand is taken for granted"* (Pollard, 1981, p.112). This being said, it should also be emphasised that Pollard (1981) remains an indispensable source for our understanding of regional economic development in 19$^{\text{th}}$ century Europe.

Among the first applications of NEG theories within historical context was Rosés (2003) who has analysed the industrial structure, intensity and distribution of industrialisation across Spanish regions during the long 19$^{\text{th}}$ century. Methodologically his approach follows Davis and Weinstein (1999, 2003) which incorporates increasing returns to scale (IRS) effects into a H-O model (see section 2.2.1). NEG effects are found to be relevant for industries producing more than half of industrial output in 1861. These IRS-industries are: cotton spinning, flour mills, metal industry, textiles and wool spinning. Hence, it was among the first articles to empirically show that NEG mechanisms can be an important component of regional divergences during the 19$^{\text{th}}$ century. Following, Rosés (2003) the explanatory power of NEG theories for the regional pattern of 19$^{\text{th}}$ century industrialisation was analysed for other economies. However, the majority of these empirical application used an alternative methodological framework, the Midelfart-Knarvik et al. (2000)-approach.[37]

Based on a reduced form equation of the general equilibrium model of Midelfart-Knarvik et al. (2000), economic historians have performed regression analyses in order to assess the statistical and economic significance of various H-O type and NEG type explanations for the location of industries. Among the first empirical applications of this model were Crafts and Mulatu (2005, 2006). Both articles, which differ from each other only slightly, study the effect of H-O and NEG effects on the spatial distribution of British manufacturing employment from 1871 to 1931. This is a period of falling transportation costs when steam power revolutionised shipping and rail transportation (Harley, 1988; Jacks et al., 2010; Jacks and Pendakur, 2010). As the seminal paper by Krugman and Venables (1995) argues for a bell-shaped relationship between transportation costs and the spatial concentration of economic activity this period is of particular interest. Crafts and Mulatu (2005, 2006) conclude that the spatial distribution of manufacturing activity was quite persistent during the sample period. The effects of falling transportation costs on changes in industry's/region's employment shares via market potential are marginal. A counterfactual analysis holding market potential at its 1871 level throughout the whole time period has delivered only marginal differences. Overall, they find that factor endowments are stronger determinants of Britain's regional distribution. The sole NEG effect which turned out to be statistically significant is the interaction term between market po-

[37] Midelfart-Knarvik et al. (2000) have developed a general equilibrium model which combines comparative advantage and geographical forces. In contrast to NEG type models, however, they assume a competitive environment. Their model can thus be interpreted as an H-O model with more trade frictions through which geography matters. The strength of the model is its focus on empirical applicability. For a more detailed discussion see section 2.2.1.

tential and the size of the establishment. Its economic significance is, however, below the effect of H-O factors of which the interaction term between the region's educated population and the industry's white collar workers is the single most important factor. Despite the dominance of H-O factors Crafts and Mulatu (2005, p.513) hypothesise that pure H-O factors sometimes have NEG overtones. Positive location externalities can emerge as a result of H-O driven industrial concentration.

From a methodological perspective these rather early articles within the historical NEG literature are lacking robustness checks, in particular, addressing the endogeneity problem of market potential. The empirical strategy is to run OLS regressions, pooled over industries, for a selection of benchmark years. The endogeneity problem is addressed in a rather crude way by using lagged values of time-varying regional characteristics. A much more nuanced approach has been applied by Klein and Crafts (2012) who use instrumental variable estimation techniques. From a methodological point of view this article on the manufacturing belt in the United States during the time period from 1880 to 1920 can be seen as an extension to the articles by Crafts and Mulatu (2005, 2006). Klein and Crafts (2012) build their empirical strategy on the same model but refine the estimation by accounting for endogeneity, heterosketasticity and the problem of constant parameters when pooling data within a panel setting. Empirically investigating the United States' manufacturing belt with respect to NEG effects is important not at least because Paul Krugman motivated his early New Economic Growth theories with the manufacturing belt (Krugman, 1991c,a).[38] Klein and Crafts (2012) find an almost always significant interaction between the size of the establishment and market potential and statistically significant forward-linkages in 1890, 1910 and 1920. The NEG effects are also of economic significance and their importance increases over time. Thus, scale economies and forward linkages were important determinants of industrial concentration in the US economy. These are very interesting findings, especially compared to the articles on the British economy during the same period (Crafts and Mulatu, 2005, 2006). While in Britain factor endowments were the decisive factors, in the United States industrial location was more strongly determined by NEG effects.

Following the empirical strategy of Klein and Crafts (2012) very closely Martinez-Galarraga (2012) applies the Midelfart-Knarvik et al. (2000)-approach to Spanish NUTS3 regions from 1856 to 1929. He finds a dual economic significance of H-O type and NEG type explanations. While the interaction term between agricultural land abundance and agricultural input use was among the main determinants of industrial concentration in 1856, market potential interacted with the size of the establishment is the most important explanatory variable in 1893, 1913 and 1929. Martinez-Galarraga (2012), therefore, concludes that increased market integration during the second half of the 19th century, has led to the gaining importance of scale economies until WWI. Although its influence weakened during the interwar period the effects of increasing returns to scale remained the main force determining industrial location in Spain. Labour abundance, as an H-O type effect, also arises as an important explanation in the years 1893 and 1913. That market potential effects are important to understand the spatial distribution of economic activity in Spain

[38]The US manufacturing belt is about one-sixth of the US land area where a little above half the US population lived in 1900 producing four-fifth of its manufacturing output.

is further supported by Martinez-Galarraga et al. (2015). They assess the relationship between regional estimates of market potential and GDP per capita in a nonparametric framework. Their findings show that in the beginning of their observation period (1860) the explanatory power of the variation in the market potential is rather limited. In 1930, however, the relationship between regional GDP per capita and regional market potential turns positive. They interpret their finding as such that the completion of the railway system and Spain's shift to protectionist trade policy caused market potential forces to gain importance in shaping regional disparities.

Following the Midelfart-Knarvik et al. (2000)-approach, Missiaia (2013) finds no evidence of NEG type effects which are related to the market potential in Italy between 1871 and 1911. The Italian South which is traditionally less industrialized faces higher market potential due to its access to less costly sea transportation. The richer Northern regions, on the other hand, are mostly land-locked and due to their more costly land transportation face also lower market potential. Despite the counter-intuitive results of market potential for Italian regions, human capital stands out as an important determinant of industrial location in Italy during the Liberal period (1871-1911). A further study on the Italian North-South divide by Missiaia (2016) relates market potential to regional GDP per capita estimates for the same period. Constructing market potential based on a transport mode specific approximation of transport costs, Missiaia (2016) finds that access to foreign markets cannot explain the economic disadvantage of the South. Only domestic market potential and not total market potential, which includes foreign market potential, is statistically significantly associated with GDP per capita among Italian regions.

For the the Italian neighbour of Austria-Hungary, Schulze (2007) presents new estimates on regional GDP which he then uses to compute Harris type market potential estimates. These market potential estimates show a high sensitivity to the selection of partner countries. Similar to the finding of Missiaia (2013, 2016) poor regions, like Dalmatia, face high values of market potential due to their coastal position. As sea transportation became cheaper relative to transportation by rail during the sample period of 1870 to 1914, the relative market potential of coastal regions increased. Despite this fact regional GDP estimates show only limited intra-empire catching-up of poor regions, which should be the case if market potential plays a decisive role in the relative economic development of regions within the Austro-Hungarian Empire. Apart from the poor coastal regions market potential is lower for poorer regions among a sample of landlocked regions, such as Bukovina and Galicia. Schulze (2007, p.15), therefore, concludes that *"there is no clear-cut relationship between changes in regions' relative GDP (or GDP per capita) position and market potential"* among the 22 regions of the Austro-Hungarian Empire.

One important contribution to the NEG literature within the field of economic history is the study of industrial location in interwar Poland by Wolf (2007). This study is of particular interest because of two aspects. On the one hand, it deals with the endogeneity problem by exploiting WWI as an exogenous shock to potential determinants of industrial location. In this perspective, the Polish case is an interesting case study, as interwar Poland was formed of regions which, before the war, belonged to Germany, the Austro-Hungarian Empire and Russia. Polish reunification exogenously changed political borders and delinked regions' strong economic ties to their partition powers. Moreover, institutional differences were removed by 1925 and an industrial policy did not exist until 1936. The sample period from 1926 to 1934 should, therefore, be subject to industrial relocation being caused by exogenously affected location determinants. On the other hand, Wolf (2007) uses a market potential measure from an earlier study (Wolf, 2005) in which he applies a gravity approach to calculate market potential rather than using a Harris type market potential measure.[39] Turing to the findings, Wolf (2007) concludes that human capital and forward linkages are both statistically and economically significant determinants of industrial location. Changes in market potential explain approximately 0.34% of the variation in the location index, the skill endowments 50% and patent announcements about 15% of the variation. Hence, both NEG and H-O effects are considered as being important for industrial location in interwar Poland. Interestingly, the size of the establishment is not considered as an interaction term, despite its importance in similar studies on industrial location.

Among the most recent empirical studies within the historical NEG literature which follow the approach of Midelfart-Knarvik et al. (2000) is the article by Ronsse and Rayp (2016). Studying industrial location in Belgium between 1896 and 1961 they find that access to markets was important for industries to change location from the Walloon region to the Flemish region mainly after 1896, depending on the specification. Coal as a location factor was only important in 1896 losing its significance in later periods. Combining these two findings Ronsse and Rayp (2016, p.415) state that *"the reductions in transportation costs led industries to locate away from regions with natural resources and near regions with high market potential"*. During their entire sample period both NEG and H-O type factors were important, however, their relative importance has changed over time. This contribution is motivated by the changing regional disparities of modern day Belgium between the 19th and 20th centuries. To quantify the magnitude of these regional disparities has been achieved by Buyst (2011) who estimated GDP per capita at the province level from 1896 to 2000. Buyst (2011) shows that the richest province in 1896 had the lowest relative GDP per capita among Belgian provinces in 2000.

The empirical literature which has been discussed so far was very much focused on the Midelfart-Knarvik et al. (2000)-approach, which has also dominated the historiacl NEG literature. Alternative approaches have been used by Rosés (2003), as well as Missiaia (2016) and Schulze (2007). The latter relate a measure of market potential to regional estimates of GDP per capita. A similar approach has been chosen by Combes et al. (2011) who study the evolution of regional inequalities in France between 1860 and 2000. Instead of GDP per capita, they identify agglomeration effects on sectoral labour productivity in the manufacturing and service sectors. Even though, market potential is one of their key explanatory variables, the focus is broader as they are also interested in the effects of employment density, industry specialisation, industry diversity and human capital externalities. They find support for a bell-shaped evolution of spatial inequalities in France. Employment density, market potential and industry diversity were the main determinants of regional labour productivity differences in the period between 1860 and 1930. While human capital has not been identified as an important determinant in this period it became the most important factor of regional labour productivity by 2000.

[39] See section 2.2.1 for a discussion of various types of market potential measures.

Other empirical contributions within the field, which do not follow the Midelfart-Knarvik et al. (2000)-approach, provide detailed estimates of market potential. Instead of estimating market potential following Harris (1954), Wolf (2005) and Daudin (2010) construct market potential based on a gravity model of trade. The implications of Wolf (2005) have already been discussed as part of its application in Wolf (2007). Daudin (2010) provides one of the earliest estimates of market potentials at the product level based on the *Tableaux du Maximum* of 1794. Contributing to the debate of market size for the emergence of the first industrial revolution, Daudin (2010) shows that French markets were not smaller than British markets, particularly in hardware and textiles.

All in all, it can be concluded that despite of the differences in the findings, interpretations and conclusions of the selection of articles, industrial location and regional differences in economic activity are subject to both endowment and NEG-type effects during the 19$^{\text{th}}$ century. The H-O and NEG theories of industrial location are not that conflicting after all.

Chapter 3

Cobden-Chevalier and the Economic Geography of nineteenth century France

3.1 Introduction

This chapter studies spatial effects of trade liberalisation. In particular, it analyses the effects of the Cobden-Chevalier treaty on the spatial distribution of economic activity in 19^{th} century France. The Cobden-Chevalier treaty was a bilateral trade agreement between Britain and France which was signed in January 1860 and resulted in a substantial reduction of French import tariffs for manufactured products. So far, the literature analysing the Cobden-Chevalier treaty has focused on its trade flow effects as well as its institutional implications.[1] Regional effects have not yet been examined even though it provides a rich case study which enables us to shed further light on the debate of how regions adjust to trade liberalisation.

There is no straightforward response of regions to trade liberalisation but trade as well as agglomeration theories provide helpful hypotheses. The *New Economic Geography* (NEG) literature highlights a variety of factors shaping industrial location. Transportation costs, agglomeration economies and backward- and forward linkages are probably the most prominent. Firstly, transport cost considerations incentivise firms to locate closer to large markets (Krugman, 1991b,c). One regional response to trade liberalisation should therefore be a shift towards regions with low-cost access to foreign markets. Secondly, agglomeration economies act reinforcing such that pre trade industrial clusters gain in size as Marshallian and Jacobian externalities ensure productivity enhancing effects from clustering (Marshall, 1890; Jacobs, 1970). And lastly, backward and forward linkages suggest that firms locate near their buyers and suppliers on an intermediary goods market (Krugman and Venables, 1995; Venables, 1996). Trade liberalisation, however, means not only a larger trading area but also increased competition from foreign producers. Pre trade liberalisation comparative advantages at the national level might not coincide with comparative advantages at the level of the new trading area which results in a spatial shift in the distribution of economic activity (Haaparanta, 1998). Regions which have specialised in industries that

[1] See Lampe (2008, 2009) and Marsh (1999).

have benefited from high tariff walls but remained uncompetitive internationally will face falling demand post trade liberalisation unless they can find a new regional comparative advantage. Regions which are protected from import competition by transportation costs may therefore benefit in terms of relative industrial location.[2]

The empirical evidence on the effects of trade liberalisation on industrial location supports these theoretical predictions. Hanson (1996, 1997, 1998) finds positive effects of export market access on regional employment and wages for Mexico in 1985. Overman and Winters (2006) confirm the positive stimulus of export market access but find additional effects of import-competition and access to intermediary goods. Applying the framework of Midelfart-Knarvik et al. (2000), Wolf (2007) finds a positive effect through forward linkages shaping the industrial geography of Poland after the Unification resulting from WWI. The same methodology is used by Sanguinetti and Volpe Martincus (2009) to study the effects of tariff protection on industrial concentration in Argentina from 1974 to 1994. They find that low tariffs have led to less concentration. Martincus (2010) argues that access to export markets shaped industrial location in Brazil in the 1990s. By using a difference-in-difference approach, Brülhart et al. (2012) find a positive effect on wages and employment for Austrian regions after the fall of the Iron Curtain within a narrow band of locations 25km from the border. Another natural experiment, the Continental Blockade during the Napoleonic Wars, was studied by Juhász (2014). Protection from British competition in the cotton spinning industry caused industrial concentration and technological diffusion in early 19th century France.

The empirical evidence on the industrial geography of France is quite distinct and scholars have frequently highlighted its regional imbalances during the 19th century (Crouzet, 2003). Industrialisation was concentrated in the regions eastwards of an imagined line connecting Le Havre and Marseilles. Westwards of this line deindustrialisation prevailed. Significant industrial districts were Nord-Pas-de-Calais, Lyons-Saint-Etienne, Alsace and Paris. Normandy as an important early industrial district, particularly in cotton textiles, lost ground and was not able to develop as a hub of modern economic growth (Teich and Porter, 1996, p.53). Industrial concentration further intensified until 1930 due to economies of agglomeration in manufacturing and services (Combes et al., 2011). Market potential and industry diversity were the main determinants of regional labour productivity differences in 1860. Although they did not test the effect of declining transportation costs and international trade directly, they suggest that the relatively high transport costs during the period between 1860 and 1930 have caused the positive market potential effect. Within a 19th century perspective transport costs were considerably lower during the second half than during the first half of the century (Toutain, 1967). The effects of trade liberalisation and declines in transport costs on the industrial location and concentration, however, still remain to be examined.

The primary data sources for this analysis are two industrial censuses. The first completed French industrial census, which was collected during the period 1839-47, provides information on an industry-regional level prior to the Cobden-Chevalier treaty of 1860. The census of 1861-1865 supplies comparable industry-regional information after the trade treaty was implemented. The regional effects of the treaty are identified by estimating

[2]For a review of the theoretical literature on the topic see section 3.2.

a model of relative labour demand. This follows the methodology proposed by Hanson (1998). However, some important extensions are introduced to allow distance to matter according to market access and import-competition (Overman and Winters, 2006). The analysis shows that Britain's increased import competition has led to relative shifts of employment and output towards regions with higher relative access costs. Export market access, on the other hand, has not been identified as an important location determinant during mid 19$^{\text{th}}$ century France. Overall, industries which did benefit in terms of exports towards Britain did not locate closer to British ports while industries which experienced a rise in British import shares did respond by locating away from British competition. In contrast to many other studies which highlight the export market access mechanism, this case study is, therefore, an important piece of evidence showing displacement effects of trade liberalisation.

The rest of the chapter is organised as follows. First, a theoretical background is provided based on which testable hypotheses are formed. Then a literature review surveys the literature on the Cobden-Chevalier treaty and the empirical literature on spatial effects of trade liberalisation. After that I discuss the data and outline the estimation strategy. This is followed by presenting the estimation results and a discussion of the findings. The article is closed by some concluding remarks.

3.2 Theoretical background

Theoretical models on adjustments to trade are plentiful. The seminal contributions by Krugman (1991b,c) establishing the *New Economic Geography* (NEG) literature marks the start of a boom in modelling regional adjustments to trade. Within this literature, however, the spatial effects of intra-national trade adjustments have been studied much less intensively than firm or sectoral adjustments (Brülhart, 2011). We can, nevertheless, draw on a considerably large pool of model-based predictions. Models focusing on the effects of trade liberalisation on regional spatial adjustment can be distinguished with respect to their 'model tradition' - neoclassical vs NEG - and their prediction - concentration vs dispersion. The theoretical literature has not yet reached a finite conclusion and we see a broad range of model predictions with respect to the location choice of production and regional wage inequality. The key difference between neoclassical and NEG models of intra-national adjustments to trade liberalisation lies with respect to their predictions for regional disparities in real wages. While in neoclassical models real wages equalise across regions due to a fully mobile labour market this is not the case in NEG models in which part of the labour force is assumed to be immobile. Both neoclassical and NEG models, however, give mixed predictions if trade liberalisation leads to intra-national concentration. We should therefore be interested not only in the effects on the location of production but also the effect on wages.

The seminal contribution within the neoclassical literature is Henderson (1982). He develops a constant returns to scale model with homogenous goods and perfectly mobile workers. In his model on city size, firms in larger cities benefit from city-level scale economies. It, therefore, assumes internal constant returns to scale but external increasing returns to scale. These productivity advantages of larger cities are being offset by demand-side disadvantages. Whether trade liberalisation leads to urban concentration depends on relative factor endowments and on capital intensity in particular. Rauch (1989) builds on Henderson (1982) and incorporates firm-level increasing returns to scale. Industries which are characterised by increasing returns to scale operate most efficiently in large cities. In a comparative advantage framework countries with lower commuting costs will have a comparative advantage in increasing returns to scale industries. If trade liberalisation leads to urban concentration, therefore, depends on relative commuting costs. Urban concentration will be the result when large cities are cheaper to sustain. Allowing for within-country geographical differences Rauch (1991) finds that locations with cheaper access to foreign markets will benefit. At unchanged internal trade costs trade liberalisation results in a monotonic decrease in city size with distance to the foreign market. We can conclude from these models that distance to foreign markets (Rauch, 1991), relative factor endowments - capital intensity in particular (Henderson, 1982), and industry characteristics with respect to returns to scale are important factors to be considered (Rauch, 1989).

With the shift from neoclassical trade models to NEG models of trade comes the micro-foundation of external economies. Predictions on the intra-national adjustments to trade liberalisation are mixed. Depending on the specific model assumption one can find predictions of internal dispersion as well as agglomeration. The first NEG model on intra-national effects of trade liberalisation was Krugman and Elizondo (1996). Forward and backward linkages are the key determinants of agglomeration. Forward linkages state that consumers benefit from locating close to a large number of producers. This agglomeration force is ensured by positive interregional iceberg transport costs and a preference for variety. Backward linkages describe the preference for firms to locate close to their consumers in order to economise on transport costs and fixed costs. As national backward and forward linkages become less important as a location determinant with trade liberalisation we should see a dispersion of economic activity. Apart from Krugman and Elizondo (1996), also Behrens et al. (2007) come to the same result, though through different channels. At unchanged internal transport costs trade liberalisation results in internal dispersion. This result comes from two dispersion forces: (1) some workers are immobile; (2) larger competition in industrial clusters results in smaller mark-ups. Similar models, which are, however, closer to the original Krugman (1991b) model result in the opposite prediction. Trade liberalisation leads to agglomeration and not dispersion. Models in this tradition are Monfort and Nicolini (2000), Monfort and Van Ypersele (2003) and Paluzie (2001). In these NEG-models the intensity of the dispersion forces (implied by the demand of the spatially immobile part of workers) falls faster with trade liberalisation than agglomeration forces.

All NEG-models above have assumed homogenous intra-national space. However, in reality some regions offer cheaper access to foreign markets than others. Alonso Villar (1999), for instance, finds that border regions have a locational advantage over interior regions. A more diversified picture is modelled by Brülhart et al. (2004) and Crozet and Koenig Soubeyran (2004). They do not only account for the locational advantage of border regions through access to foreign demand. Additionally, they argue that foreign supply weakens domestic dispersion forces due to more intensive foreign competition in border regions. A model with unequal regional factor endowments has been developed by

Haaparanta (1998). If trade liberalisation leads to spatial concentration in a particular region depends on the region's ability to produce goods for which the country as a whole enjoys a comparative advantage.

We have seen that trade liberalisation can affect the spatial distribution of industrial activity through multiple channels. In this historical case study about the effects of mid-19th century trade liberalisation on the spatial distribution of economic activity in France, the first channel an historically-informed reader would suggest is British competition. Britain was the industrial super power of the time and reducing import tariffs on British manufactured goods should have had an effect on industrial production in France. Contemporary manufacturers were not very fond of the new competition and blamed the commercial treaty for destroying French industry (Dunham, 1930). If contemporary unrest was valid we should see evidence for the channels of weakening dispersion forces due to more intensive foreign competition as has been proposed by Brülhart et al. (2004) and Crozet and Koenig Soubeyran (2004). Non-border regions have a locational advantage as higher trade costs shield them from foreign competition. We would, however, also expect the effects to differ among industries. For industries which had a comparative advantage over Britain we expect increased foreign demand from trade liberalisation to be a key locational advantage for border regions. Access to foreign markets was a key force for dispersion in all of the above models. From our discussion on the theories of spatial trade effects two hypotheses are constructed.

Hypothesis 1:

Industries which were exposed to increased British competition experienced relative economic decline in regions with cheaper access costs for British manufacturers.

Hypothesis 2:

Industries which could benefit from exporting to the British market experienced relative economic gains in regions with cheaper access costs for British manufacturers.

3.3 Related literature

3.3.1 French trade policy and the Cobden-Chevalier treaty

Nineteenth century economic development of France has traditionally been interpreted as a period of stagnation during which France did not manage to keep up with the fast growing industrialising economy of Britain.[3] With the increased attempts of quantification and the building of historic national accounts this stagnation-thesis has been challenged by the *revisionists* reaching the consensus that the French path of economic development was different though not inferior to the British experience. Estimates of economic growth per capita by Lévy-Leboyer (1968), Crouzet (1970) and Toutain (1987) have shown that the French economy grew at a similar pace as Britain in per capita terms. Crouzet (2003, p.239) summarized the recent consensus on French economic development during the 19th century as follows: *"recent syntheses stress both the strong and the weak points in the French economy, the positive and negative aspects of French development"*. Recent comparative

[3]Clapham (1936) argues for a slow and incomplete transformation of the French economy during the 19th century, not experiencing industrialisation before 1895. This interpretation of the stagnation thesis is based on Crouzet's 2003 review of the historiography of French economic growth. For a more detailed discussion of the historiography of 19th century French economic development see section 2.1.1.

estimates of labour productivity indicate a narrowing of the labour productivity gap with the UK between 1850 and 1870, though, a decline of competitiveness with respect to the UK and Germany between 1871 and 1911 (Dormois, 2006c,a). The French share of world exports was in decline during the late 19$^{\text{th}}$ century while Germany and the United States could expand their position in global trade (Bairoch, 1993).

One aspect which is often discussed as one of the French economy's structural weaknesses is trade policy. The protectionist agenda of French trade policy before the Cobden-Chevalier treaty of 1860 could have been an impediment to economic development in France. In particular, because Britain has been perceived as a free-trading economy. This comparison of France as a protectionist economy and Britain as a free trade economy has been challenged by Nye (1991b). He finds that French tariffs were lower than British tariffs until the mid 1870s and that during the period between 1840 to 1860 differences in tariff policies cannot explain differences in the economic development between Britain and France. Based on Nye's (1991b) analysis Grantham (1997) concludes that French economic development was not distorted by barriers to trade. Nye's (1991b) finding that French tariff levels were below the British rates has, however, been questioned by Irwin (1993). He argues that British tariffs were designed to raise revenues for fiscal purposes while French tariffs were designed to protect domestic producers. Tena-Junguito (2006) supports this argument empirically by showing that the French non-fiscal average tariff rate was, indeed, higher than the British non-fiscal average tariff rate. Therefore, the debate about the consequences of protection in France has not yet been settled. The following discussion of the Cobden-Chevalier treaty of 1860 which abolished all French import prohibitions will shed further light on this debate.

The history of French trade policy during the 19$^{\text{th}}$ century has traditionally been told as a history of protectionism with a relatively short period of free trade. A system of protectionism was introduced after the Napoleonic Wars in order to support industries which grew during the blockade of the Continental System. France kept a protectionist agenda until 1860. In 1860 a bilateral treaty between Britain and France was signed - the Cobden-Chevalier treaty - which abolished all trade prohibitions for British manufactures and capped import tariffs. Through MFN (Most Favoured Nation) clauses and bilateral tariff agreements with all major European economies this trade liberalisation spread across Europe. The slowing down of economic growth with the beginning of the 1870s brought protectionist ideas back on the agenda. France returned to protectionism in 1892 when the Méline tariff was signed. Becuwe et al. (2015) argue that increased industry protection and not being exposed to international competition slowed down the diversification of French exports. As a consequence, the main export industries in 1913 were still those of the Second Empire. The time between the Cobden-Chevalier treaty of 1860 and the Méline tariff of 1892 is known as the free trade interlude (Bairoch et al., 1988).

More recent research has challenged this interpretation arguing that French trade policy was much more nuanced. In particular, the sharp contrast between protectionism before 1860 and free trade after Cobden-Chevalier is doubted. Accominotti and Flandreau (2008), for instance, argue that trade liberalisation was well under way when Cobden-Chevalier was signed. What we see is a shift from unilateral to bilateral trade deals but not a shift from protectionism to free trade. Trade legislations show a move towards liberalisation from the

Table 3.1: French manufacturers tariffs: 1846-1880

	1846	1859	1863	1870	1880
Level	89.9%	70.6%	17%	21.1%	24.5%
% change	-	-21.4%	-75.9%	24.1%	16.2%

Source: Tena-Junguito et al. (2012) online appendix A.2;
Notes: Unweighted Manufactures Average Tariffs France; changes to the previous benchmark year are in % not in %-points.

1840s and tariff rates, measured in 'tariff revenue divided by total import value', started to decrease substantially at least from 1850 onwards - see Accominotti and Flandreau (2008, p.163-164). That overall trade was not significantly increased by Cobden-Chevalier was further supported by Lampe (2009). However, he denies that Cobden-Chevalier was inefficient. If the effects on trade are studied at the product level, and not at the aggregate level, we can see that Cobden-Chevalier was effective. Tariff rates for agricultural goods, raw materials and semi-manufactured goods were already reduced before 1860 but import tariffs for manufactured goods were not. In this commodity group the effect of Cobden-Chevalier is strong and significant as tariff rates for manufactured goods were high well into the 1850s (Lampe, 2008, 2009).

Evidence of French tariff rates on manufacturers by Tena-Junguito et al. (2012) show that in certain respect both Accominotti and Flandreau (2008) and Lampe (2009) made some fair points. On the one hand, it is true that tariff rates, even for manufacturers, already decreased before 1860. The average French tariff on manufacturers decreased by 21% between 1846 and 1859. On the other hand, the effect of the Cobden-Chevalier treaty was very significant. The same average tariff went down by 76% between 1859 and 1863. Table 3.1 gives us a clear indication that the period between the mid-1840s and early 1860s was a period of trade liberalisation in France. This implies that the changes which we observe due to trade liberalisation between the two industrial censuses (1839-47 and 1861-65), which will be used in the empirical analysis, cover not only the trade liberalisation associated with the Cobden-Chevalier treaty but also effects from unilateral trade liberalisation before 1860. Manufacturers average tariff levels did decrease by 81.1% between 1846 and 1863 which implies a gain in price competition of 38.4% for goods being imported into France.

On a commodity basis we can also see how significant the differences between industries must have been regarding the effects of Cobden-Chevalier. The most substantial tariff reduction were felt in the woollen, cotton and ironware industries - see Lampe (2008, p.54-58). In other industries such as silk, leather or wine tariff rates were already low before the treaty. Britain reduced its import duties on silk textiles and wines from France as part of the trade deal. Given this variation at the commodity level we should also expect to see different effects among a variety of industries. The silk industry, for instance, should be able to benefit from a larger export market. The cotton industry, however, is expected to be affected by British competition and might not be able to benefit from market size effects at the same extent as the silk industry.

The Cobden-Chevalier treaty has not only been discussed with respect to the two signing countries Britain and France but also regarding its spread across Europe. In contrast

Table 3.2: French bilateral trade treaties after Cobden-Chevalier: Bilateral MFN Agreements with France

Year	Country
1860	Britain
1861	Belgium
1862	Prussia and Zollverein (effective in 1865)
1863	Italy
1864	Switzerland
1865	Hanse towns; Netherlands
1866	Austria-Hungary; Portugal

Source: Accominotti and Flandreau (2008, p.163).

to earlier unilateral tariff reductions the Cobden-Chevalier treaty was a bilateral tariff. However, it was a bilateral tariff with MFN clauses. Other countries which also wanted to benefit from the new trade terms and the large market signed bilateral treaties as well. After Cobden-Chevalier bilateral treaties spread all over Europe marking the first great era of free trade in Western Europe. Table 3.2 shows the chronology of bilateral treaties which France signed with other countries. It can be seen that all European economic powers entered the Cobden-Chevalier network in the years following 1860. In this literature the Cobden-Chevalier treaty is seen as a European-wide phenomenon.

The treaty of 1860 has, furthermore, been studied with respect to its effect on the French economy. One of the earliest economists studying this question was Dunham (1930). He took a rather positive position of necessary competition to force French producers to adopt modern technologies. Bairoch (1976) was more critical and assessed a more negative picture. He based his analysis on a comparison of economic growth rates prior and post the trade deal concluding that trade liberalisation harmed the French economy. Nye (1991a) finds contrasting results if periodisation is changed in such a way that trade liberalisation prior to Cobden-Chevalier is covered as well. He declares the full period of trade liberalisation from 1850 to 1870. Moreover, he argues for beneficial effects of trade liberalisation, in particular from abolishing import prohibitions, for the French economy by estimating elasticities of export demand.

Apart from the treaty's effect on economic growth and its significance in terms of reducing import tariffs and stimulating trade, the Cobden-Chevalier treaty has been studied from a political economy perspective. The seminal contribution in this respect is Kindleberger (1978). He argues that the bilateral treaty was signed in the absence of strong export interests, though admitting the favourable conditions for French wine from Bordeaux, silk products from Lyon and luxury products from Paris. The French movement to free trade in 1860 has traditionally been interpreted as a decision of a few. The treaty was negotiated secretly and Napoleon III used his constitutional power to bypass the Chamber for treaties of trade (Kindleberger, 1978). In order to limit economic and political resistance the trade treaty was announced within a reform plan of increased infrastructural investment as well as a system of governmental loans to support the industry's transition to the lower tariff system. The new trade deal was not very well received in the textile centres of the North as well as within the iron industry. However, their protests were not effective and their political influence was limited as the treaty was not brought before the Chamber. This is further emphasided by the decision to set import tariffs well below the agreed maximum rates of 30% ad valorem (Dunham, 1930). Most tariffs for textiles were set at 15% ad valorem being reduced to 10% in 1864. Other commodities were set below the 30% threshold as well: 20% for cutlery, 10% for glassware, china and earthenware, 10% to 12% for tools and between 10% and 15% for chemicals (Marsh, 1999, p.22). Even though, the Cobden-Chevalier treaty of 1860 can be seen within a longer trend of increased trade liberalisation in France, the treaty still remains a substantial policy shift in commodities which faced prohibitive tariffs until 1860. Even though French manufacturers were supported by governmental loans to adjust to British competition it is very clear from the discussion of Dunham (1930) that French manufacturers were very much concerned by lowering import tariffs.

Let's assume that Bairoch (1976) and Kindleberger (1978) are right that the Cobden-Chevalier treaty harmed French economic growth as only few sectors were able to benefit. Why was Napoleon III so eager to sign a trade deal with Britain in the absence of strong export interest? Napoleon III's preference for a trade deal with Britain can best be explained with respect to the emperor's ambitions to re-establish French political and economic dominance on the Continent. French annexation of the provinces Nice and Savoy awoke old fears of French expansionism and the Anglo-French treaty ensured British acceptance of these new French possessions. Moreover, though ascribed lesser importance by Marsh (1999), Napoleon III was also motivated by the trade deal's competitive stimulus for French producers and the lowering of consumer prices implied by reducing import tariffs. The British initiative for a bilateral treaty with France followed political rather than economic interests as well. Richard Cobden, who was the British representative, thought that only a trade deal can bring *'any permanent improvements in the political relations of France and England'*. He writes further that *'there is no other way of counteracting the antagonism of language and race'*(Marsh, 1999, p.10). British concerns were related to government revenues as the import duty on French wines and spirits were an important source of revenue for the treasury. This shows that neither on the British nor on the French side economic interests of domestic producers were dominant in the negotiation process of the treaty.

With respect to the effects of the treaty on industrial location there is hardly any recent literature. Dunham (1930) discusses some aspects. He argues that French industry benefited from the Cobden-Chevalier treaty as the British competition as well as cheaper machinery imports incentivised technological upgrades. With respect to geographical diversity he writes that *"the crisis was clearly worse in Normandy than elsewhere because her manufacturing centres were nearer England than any others in France, except a few in the North, and goods could reach Rouen by cheap means of direct water transportation"* (Dunham, 1930, p.195). Moreover, he argues that it reinforced the tendency towards industrial concentration and large-scale industrial production (Dunham, 1930, p.364). The historical literature on the spatial effects of Cobden-Chevalier is rather limited. This article is, therefore, a first step to fill this gap.

3.3.2 Spatial effects of trade liberalisation

The empirical evidence on the spatial effect of trade liberalisation, as being surveyed by Brülhart (2011), concludes that regions with less costly access to foreign markets reap the largest benefits from trade liberalisation. Whether this leads to spatial concentration or divergence depends on the pre-trade liberalisation distribution of economic activity. If economic activity was already concentrated in regions with lower access costs to foreign markets before trade liberalisation we see spatial concentration. If the opposite is the case we see spatial divergence. Overall, empirical studies have, so far, supported the positive effects of market access.

The seminal empirical contributions in this literature is Hanson (1997, 1998). Studying the spatial effects of trade liberalisation in Mexico during the 1980s on wages (Hanson, 1997) and employment (Hanson, 1998), he finds that wages decrease with distance to the industrial centres and employment growth was stronger in regions which were located closer to the US border. As economic activity was concentrated around Mexico City during the period before trade liberalisation, we observe spatial divergence. The example of Mexico shows how trade reforms can lead to a break-up of existing location structures and agglomeration externalities by changing the reference market. That the response differed among industries has been shown by Faber (2007). In the case of Mexico, import-competing industries benefited in regions of 'natural protection' while industries with a revealed comparative advantage benefit in regions with better access to foreign markets.

The literature on the effects of trade liberalisation on the spatial distribution of economic activity is not particularly large and most of the work has analysed the case of Mexico. Apart from Mexico, spatial responses to trade liberalisation have also been studied for Argentina and Brazil. Sanguinetti and Volpe Martincus (2009) have found that industries with a lower protection from tariffs de-concentrated in Argentina from 1974 to 1994. Employment was located away from the industrial centre of Buenos Aires. However, this was not a shift to border regions of Brazil or Uruguay. The authors interpret their results as evidence for the reduction of agglomeration effects due to trade openness. For Brazil, Martincus (2010) finds positive effects from trade openness in Brazilian regions closer to Buenos Aires during the 1990s.[4]

As Faber (2007) has shown for Mexico that trade effects differ with respect to industries, Overman and Winters (2006) acknowledge industry diversity studying the UK accession to the EEC in 1973. Linking import and export data by UK port to manufacturing employment at the establishment level by industry, they confirm the positive stimulus from export market access but find additional effects of import-competition and access to intermediary goods. Moreover, they highlight that the effects are quite heterogeneous across industries. About one quarter of the industries responded as predicted and for the majority of industries no significant employment effect from the UK's accession to the EEC was found.

The importance of market access has, furthermore, been studied by using natural experiments as identification strategies. In their important article about the effects of the division of Germany after WWII, Redding and Sturm (2008) find that cities closer to the new border between West and East Germany grew more slowly compared to other cities

[4] Both of these studies use the empirical framework of Midelfart-Knarvik et al. (2000).

in West-Germany which they link to a loss in market access. Using a similar methodology Brülhart et al. (2012) study the effects of the fall of the Iron Curtain on wages and employment in Austrian regions and find a positive effect for a narrow band of locations within 25km of the border. Exploiting the Polish unification after WWI, Wolf (2007) finds a positive effect through forward linkages. Apart from forward linkages also human capital is found to be an important location determinant in interwar Poland.

The literature on the spatial effects of trade liberalisation has, for most cases, found empirical support for the export market access hypothesis. Regions with better access to trading partners benefit. The only, but important, exception is Argentina for which a deconcentration pattern has been identified which is not consistent with the export market access hypothesis. To reach a finite conclusion on this topic, more economies need to be studied in order to be able to assess if Argentina can be seen as an outlier. Moreover, we still know relatively little about the mechanisms through which trade liberalisation shapes the spatial distribution of economic activity. Attempts like Faber (2007) and Overman and Winters (2006) go into the right direction to identify industry heterogeneity. Sectoral and spatial effects cannot be studied in isolation.

3.4 Data & Descriptives

3.4.1 Industrial location

Sources

Information on industrial location can be drawn from two type of data sources in 19$^{\text{th}}$ century France: industrial censuses and population censuses. Industrial censuses present us with detailed information on the French industrial sector. As the aim of this research is to assess the effects of the Cobden-Chevalier treaty on the industrial location in France we need at least one census before and after the date when the treaty became effective. The first industrial census which has ever been published in France was conducted during the period of 1839 to 1847 (France, 1847). A second census was started in 1861, which was one year after Cobden-Chevalier was signed, and finished in 1865 (France, 1873). Population censuses have been published more regularly. The most relevant ones for this time period are the censuses of 1856, 1861 and 1866 (France, 1859, 1864, 1869). The industrial censuses have some major advantages in contrast to the population censuses. Firstly, they cover employment at the level of the establishment while population censuses report profession by residence. Secondly, they report a lot of supplementary information on production, salary and motive power. Thirdly, the population censuses do report professions on a less detailed level of disaggregation.[5] Fourthly, population censuses do cover both industrial and commercial profession within the same industry, making it very difficult to match them consistently with industry censuses. For reasons of consistency I choose to not combine population and industrial censuses and work with industrial censuses.

The first industrial census of 1839-1847 was originally intended to cover only establishments with more than 20 employees (Gille, 1964, p.200-204) which was later reduced

[5] The population census of 1856 is the most detailed one giving employment figures and firm counts for 126 different industries. The 1866 census, however, reports information on the number of employees for 18 industries.

to 10 employees (Chanut et al., 2000, p.15-21). This information is reported at the individual enterprise level. However, we do also find a lot of aggregate ('collective') entries. These entries are assumed to contain a lot of establishments with less than 10 employees. This aspect is of crucial importance as it makes the first census more comparable with the second one which aimed to cover all of French industry. Chanut et al. (2000) ascribe these two early industrial censuses a fairly good quality, especially for that time, and show that they are consistent enough for comparative analyses. Table A.3 shows the entries, number of firms, number of workers and average firm size by firm size category for the first census period. This supports the view that the industrial census of 1839-47 has a much broader range than only establishments with more than 10 workers. About 40% of entries cover firms with less than 10 workers. Moreover, 84% of all firms fall in this category which accounts for 19.4% of all workers. Apart from the number of establishments and the total number of workers, the industrial census of 1839-47 collected information on the gender of employees (male, female and children), their salaries, the value of output, the tax base, material input and the number of engines driven by water, steam, wind and animate power. This information is provided by department and arrondissement although the city of Paris which was part of the department Seine is not covered. One problem of these early industrial censuses is, however, that they were collected over a long period of time. For the first industrial census, the census was started in September of 1839 interrupted and only resumed in 1845.

The second French industrial census was collected during the period from 1861 to 1865. It was intended to cover all of French industry. As in the earlier census information is provided by industry, department and arrondissement. In contrast to the earlier census firm level entries are much rarer and collective entries are the norm. The information required is similar to the first census. Firms were asked to report on their number of employees by gender (male, female, children), their salaries, the value and quantity of production, a measure of the capital stock, material and fuel input and the number and horse power of engines driven by water, steam, wind and animate power. It covers 89 departments and the city of Paris, which was not covered in 1839-47, but excludes the city of Lyon. Moreover, in 1860 France annexed three new departments (Haute-Savoie, Savoie, and Alpes Maritimes) which were not included in the 1839-47 censuses as was Corsica.

In order to make the two censuses comparable France is reduced to 85 departments excluding the cities of Paris (department Seine) and Lyon (department Rhone). Table A.4 shows the same information for the census period 1861-65 which table A.3 has shown for the 1839-47 census. The census of 1861-65 is ascribed very good coverage. Comparing both tables supports the argument by Chanut et al. (2000) that the 1839-47 census has a fairly good coverage and comparable studies between both censuses are possible.

Industry classification

The choice of industry classification and aggregation level is crucial. Industrial classification between the two censuses differed markedly. The 1839-47 industrial census classifies industries by products' main input sources: mineral, vegetal, animal. The 1861-65 industrial census uses an aggregation system comprising 16 industries: (1) textiles; (2) mining; (3) metallurgy; (4) metal products; (5) leather; (6) wood; (7) pottery; (8) chemicals; (9)

construction; (10) lighting; (11) furniture; (12) apparel; (13) food and beverages; (14) transport equipment; (15) paper, printing, instruments; (16) luxury. Both censuses have been collected on a much higher level of disaggregation. Chanut et al. (2000) provide a variety of classification schemes which are harmonised across the two censuses. The highest degree of disaggregation is the CODB2000 classification which comprises 82 industries. This is our baseline classification which is used to match industrial census data to trade commodities. Small industries are excluded as are heterogeneous industries and industries for which a match with the commodity classification of the French trade statistics was not possible. This leaves us with 32 industries which cover approximately 80% of total industrial employment in both censuses. These 32 industries cover 8 textile industries (cotton spinning, cotton textiles, woolen yarn, woolen textiles, linen spinning, linen textiles, silk spinning, silk textiles), 1 leather industry, 3 apparel industries (hats, shoes, gloves), 3 mining and quarry industries (fuel, iron mines, soil and stones), 5 metal industries (ferrous metallurgy, nails, cutlery, locks and hardware, machines), 4 ceramics and building materials industries (pottery, glass, binding materials, tiles and bricks), 5 food and beverages industries (brewery, distillery, flour mills, oil mills, sugar products) and 3 paper, printing and instruments industries (paper, printing, watches). Table A.7 gives an overview over the industries and presents some descriptive statistics for each industry for both censuses. It reports a productivity weighted labour measure and output values for 1839-47 and 1861-65, as well as each industry's labour and output shares across all 32 industries for both census years. Moreover, I report the regional dispersion of the industries by reporting the number of French departments in which each industry employed any kind of labour.

Descriptives

The empirical evidence on the industrial geography of France during the 19$^{\text{th}}$ century is quite distinct and scholars have frequently highlighted the regional imbalances of 19$^{\text{th}}$ century French economic development (Crouzet, 2003). Industrialisation was strongly concentrated in the regions eastwards of an imagined line connecting Le Havre and Marseilles. Westwards of this line deindustrialisation prevailed. Significant industrial districts were Nord-Pas-de-Calais, Lyons-Saint-Etienne, Alsace and Paris. Normandy as an important early industrial district, particularly in cotton textiles, lost ground and was not able to develop as a hub of modern economic growth (Crouzet, 2003, p.53).[6]

The two industrial censuses of 1839-47 and 1861-65 partly support the view described by the literature of a shift from the South-West to the North-East. Comparing industrial regional employment shares among five macro-regions between the early 1840s and early

[6]There are various theories which aim to explain the regional pattern of industrialisation in 19$^{\text{th}}$ century France. Firstly, it is argued that the collapse of traditional industries and the entrepôt commercial system in the coastal regions during the Napoleonic Wars was due to the loss of overseas markets which contributed to the deindustrialisation of these regions (Crouzet, 1964). Secondly, the 'self-blockade' during the Napoleonic Wars acted as a shield to British competition and therefore enabled modern industries, the mechanisation of cotton spinning in particular, to prosper in regions which were least accessible by smugglers (Crouzet, 1964; Juhász, 2014). A consequence of this shift from coastal regions to inward regions was that, in contrast to Britain, Continental European industries worked mostly for their national markets and neighbouring regions. Thirdly, it is argued that the location, co-location and transportation costs of coal and iron were a key determinant of shaping the industrial landscape of France (Pollard, 1981). Crouzet (1990, p.440) argues in a similar tradition that the role of access to cheap coal was non-negligible in understanding the lack of industrialisation in Western France.

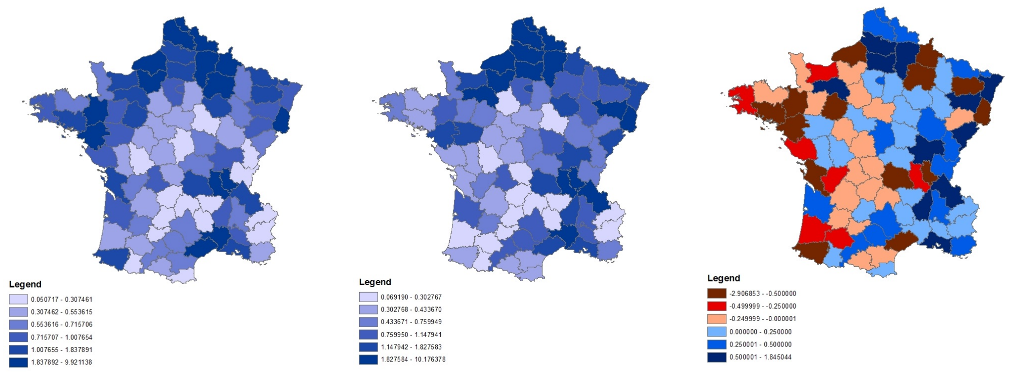
1860s reveals a similar pattern.[7] The Western and the Central regions lost in terms of relative industrial employment while the Northern, Eastern and Southern regions were able to gain in importance - see table 3.3.

Table 3.3: Changes in French regional industrial employment shares

	1839-47	1861-65	Change
North	40.1%	41.9%	1.8%
Centre	13.5%	11.7%	-1.8%
East	19.1%	22.6%	3.5%
South	11.3%	14.2%	3.0%
West	16.1%	9.6%	-6.5%

Source: Industrial censuses of 1839-47 and 1861-65.
Notes: Industrial employment as a share of total French industrial employment. Calculations are based on constant departments between the two industrial censuses. This excludes Paris, Lyon and all departments which have been annexed in 1860.

On a more detailed level of regional disaggregation we can see that regions in the centre of France are, in general, less developed with respect to industrial employment in the early 1840s. Regions at the Channel, the Atlantic and Mediterranean coasts and regions to the Belgian and German border face higher relative employment than central regions. The partial exception is the industrial district around Lyon and St. Etienne. This picture has changed by the early 1860s such that Atlantic coastal regions have lost employment shares while Central regions were unable to benefit. The only exception is the department of Gironde. Departments to the East have mostly gained. Those regions with lower industrial employment shares in 1861-65 in the East were, nevertheless, among regions with high levels of employment in both periods - see figures 3.1a and 3.1b. That changes in regional employment shares follow a spatial West-East pattern can be seen in figure 3.1c which shows positive changes (blue) and negative changes (red) at a departmental level.



(a) 1839-47 (b) 1861-65 (c) Δ

Figure 3.1: French employment shares by department in 1839-47 and 1861-65

In order to better understand the patterns of regional economic development we also need to analyse the industrial structure of French regions. Table 3.4 shows French national employment shares by 7 broad industry aggregates and one 'other manufacturing' category. We can see that industrial employment was highly concentrated in textiles, leather and

[7] Map A.1 shows the location of these 5 macro-regions at the departmental level.

Table 3.4: French employment shares by industry in 1839-47 and 1861-65

	1839-47	1861-65	Change
(I) Textile, Leather and Apparel	58.1%	51.6%	-6.5%
(II) Mining	6.2%	7.5%	1.3%
(III) Metallurgy and Metal Products	11.2%	12.9%	1.7%
(IV) Wood, Wood products and Furniture	1.4%	2.4%	1.0%
(V) Pottery, Construction, Chemicals	6.4	9.7%	3.3%
(VI) Food and Beverages	14.1%	11.7%	-2.4%
(VII) Paper, Science, Arts	2.5%	3.8%	1.3%
(VIII) Other Manufacturing	0.1%	0.4%	0.3%

Source: Industrial censuses of 1839-47 and 1861-65.

apparel industries. Other big industrial employers were metal industries as well as food and beverage industries. The industrial landscape, however, got more diversified with big industries loosing and smaller industries gaining employment shares.

In a next step it is investigated which industries drive the result of changing regional employment shares among the 5 macro-regions. Table 3.5 shows the contribution by eight broad industry aggregates. We see that the decline in the textile, leather and apparel sector (I) had substantial negative employment effects in the Northern, Central and Western regions and thus contributed substantially to the observed pattern. In contrast to the Western and Central region the Northern region was, however, able to compensate for this loss by increased engagement in the Pottery, Construction and Chemicals industries (V) as well as the Food and Beverages industries (VI). The shift of relative employment from the Western but also Central region to the Northern region meant that Western regions were even worse off. In the Eastern and Southern regions we see a much more balanced development across industries accumulating to significant gains in the industrial sector as a whole. The metal industry (III) has been identified as the single most important contributor for these two regions.

The estimates in table 3.5 can be driven by two forces. On the one hand, the change in the region's within-industry employment share across all other regions can drive the result. On the other hand, the development at the national industry level can be responsible for the change at the regional level. For instance, the 6.5%-point decrease in employment share of the textile, leather and apparel industry - see table 3.4 - may explain the negative contribution of 1.8%-points of this industry to the overall decline in the Western region of 6.5% - table 3.5. The purpose of table A.8 is to calculate the contribution of these two forces. For the particular case of the textile, leather and apparel industry in the Western region we can see that it is not the overall decline of the national textile, leather and apparel industry which drives the result in the western region. Reallocation from Western and Central regions to Eastern and Southern regions is the driving factor.

The key finding from table A.8 is that the development of regional industrial employment which has been identified in table 3.3 is the primarily factor explaining the decline in the Western and Central regions. French de-industrialisation in the West and Centre is a story of inter-regional relocation and only to a lesser extent a story of sectoral reallocation between industries. In the Northern region, on the other hand, sectoral reallocation seems

Table 3.5: Industries' contributions to regional %-point changes in employment and output shares

Employment	I	II	III	IV	V	VI	VII	VIII	sum
North	-3.2%	0.3%	0.4%	0.3%	1.8%	1.9%	0.2%	0.1%	1.8%
Centre	-1.8%	1.1%	-0.8%	0.0%	0.4%	-0.9%	0.0%	0.1%	-1.8%
East	-0.1%	0.2%	1.2%	0.2%	0.5%	0.4%	1.0%	0.1%	3.5%
South	0.5%	0.6%	0.9%	0.9%	0.4%	-0.3%	0.1%	0.0%	3.0%
West	-1.8%	-0.9%	0.0%	-0.5%	0.2%	-3.5%	0.1%	0.0%	-6.5%

Source: Industrial censuses of 1839-47 and 1861-65.

to be the dominant factor. In Eastern and Southern regions the picture is more diversified and both factors matter. It is very interesting to see that in contrast to the Northern region Eastern and Southern regions were able to compensate for the losing market share of the textile, leather and apparel industry by inter-regional relocation. In the Southern region national industry development contribute -0.9%-points to the change in its total industry regional share but regional relocation from Central and Western regions contributed positively by 1.3%-points resulting in a positive net effect of 0.5%-points. A similar effect can be observed in the Eastern region although the net effect is slightly negative. The overall picture shows that industries relocate away from Central and Western regions. With the only exception of the mining industry in the Central region, the region-industry effect for these two regions is either zero or negative. In contrast to that, Eastern and Southern regions show positive effects for all industries with the exception of the pottery, chemical and construction material industry in the Southern region. For the Northern region we see mixed results across industries. The region/industry effect of the food and beverage industry and the national industry effect of the textile, leather and apparel industry have been identified as main drivers.

We can conclude that the industrial geography of 19$^{\text{th}}$ century France is shaped by a regional relocation from the West and Centre to the East and South rather than sectoral reallocation at the national level. The Northern region sees larger effects from sectoral reallocation across a large number of industries and regional relocation effects matter only from a small number of industries, though being sizeable. Moreover, it can be seen that the most important industries with respect to their quantitative impact from regional relocation are textiles, leather and apparel (I), metallurgy and metal products (III), and food and beverages (VI).

3.4.2 Trade

Data sources

Data on trade and tariff rates are collected from the official annual publication of foreign trade, *Tableau général du commerce de la France avec ses colonies et les puissances étrangères*, which has been published annually between 1825 and 1895 (France, 1825-1895).[8] This source is very detailed and reports the quantity of trade per commodity

[8] For the empirical anaylsis product level trade data has been digitalized for the years 1839, 1858 and 1861.

and country of destination. For each commodity the quantities of either imports/exports are then aggregated across destination countries and multiplied by a fixed price per unit. This presents us with estimated bilateral import/export values.[9] Furthermore, they report the import/export duty which was paid per commodity. We can match the commodities to the industry classification from the industrial censuses which allows us to compute British export shares, British import shares and ad valorem tariff rates for 32 industry. Table A.5 shows the selected industries along their import tariffs, UK import and export shares as well as their balance of trade.

$$Tr_{it} = \sum_{s} \frac{IMPDUTY_{st}}{IMP_{st}} * \frac{IMP_{s,1861}}{IMP_{i,1861}}$$
$$\text{if } s \text{ prohibited } \frac{IMPDUTY_{st}}{IMP_{st}} = 200\%$$

$$UKIMPsh_{it} = \sum_{s} \frac{IMP_{UK,st}}{IMP_{st}} * \frac{IMP_{s,1861}}{IMP_{i,1861}}$$
$$\text{if } s \text{ prohibited } \frac{IMP_{UK,st}}{IMP_{st}} = 0\%$$

One problem when studying pre-1860 trade statistics in France is the handling of import prohibitions. Firstly, we need to assign a protective tariff rate. One practice is to use the first tariff rate after trade liberalisation. As the Cobden-Chevalier abolished import prohibitions and set tariffs rates at a maximum of 30%, in reality a lot of tariffs were set to 15%, we can not follow this approach. In our dataset import prohibitions are set at a value of 200% which is among the highest tariffs rates in 1839 and very close to the 99% percentile which is at 195%. Secondly, most industries include protected and not protected commodities. Calculating ad valorem tariff rates with using 1839 weights would assign 0% to the protective tariff rate of 200%. Cotton yarn, for instance, was importable below a thread count of 143 at an ad valorem tariff rate of 35% but prohibited above this thread count. In order to avoid this problem we use 1861 weights instead of 1839 weights. Industry sub-commodities are, therefore, weighted by their respective shares after trade liberalisation.[10] The same problem occurs with import shares. Hence, we also use the 1861 sub-commodity shares for the respective industry to calculate UK import and export shares in 1839, where each industry i consists of several sub-commodities s. For the cotton spinning industry this approach results in a 1839 tariff rate of 190% instead of 35%. The British import share alters from 99% using 1839 weights and 6% using 1861 weights. Hence, the chosen weights can influence the results quite significantly.

[9] Prices were fixed at their 1826 level until 1847 when so called 'actual' prices were introduced. However, the commission to determine annual average market prices did not function regularly until 1854 such that figures between 1847 and 1849 reflect a combination of 'official' and 'actual' values.

[10] An alternative option would be to take simple averages among sub-commodities. However, this leads to different results given the level of disaggregation which is also changing between our observation periods.

Descriptives

The empirical strategy will draw on the change in the British share of imports and exports over total imports and exports. Figure A.5a shows the development of these shares. Comparing our census period we can see a clear level shift. The share of French imports from Britain over total French imports has increased about 15%-points while the export share shows an increase of a similar magnitude. With regard to the Cobden-Chevalier treaty we can observe a level shift in the import share at the time when the treaty became effective. For the export share this is less clear. It seems as if the period in the early 1860s continues a trend of increased British export shares which started around 1855. The development of the French import tariff against Britain compared to the French import tariff against all destinations shows a similar level effect - see figure A.5b. Import tariffs start to fall significantly just after the first French industrial census was taken and show little movement during the period of the second industrial census. These trade shares and tariff rates are, however, based on total trade and not on the industrial sector.

For the manufacturing sector, based on the selection of 32 industries, we see a more substantial shift in French trade. While the total ad valorem import tariff decreased from 16% in 1839 to 5.2% in 1861, which implies a price reduction of 9%, we see a drop in the average manufacturing import tariff from 68% in 1839 to 12% in 1861, which implies a price reduction of 33%.[11] Although, these two tariffs are not fully comparable as the total tariff uses 1839 weights and the average manufacturing tariff uses 1861 weights, it supports previous findings that this period is characterised by substantial trade liberalisation in the manufacturing sector.[12]

With respect to the variation among industries we can see that import trade was much more exposed to Britain than export trade. French manufacturing export trade was more diversified than its imports. In 1839 22% of imports within the average product category associated to specific industries came from Britain. In 1861 the average import share increased to 47%. Within half of the industries the share of imports from Britain increased by more than 23%-points while this number is only 3%-points for exports. Moreover, the differences with respect to the third quartile is even more astounding. For 25% of the industries Britain was the main source of import competition with almost more than 80% of imports coming from Britain in 1861. The British import shares for these industries has increased by 50%-points or more. During our period Britain gained in importance as a source of imports and only to a lesser extent increased its importance as an export market - see table 3.6.

Among the industries which gained in import shares of more than 50%-points are metal processing industries such as 'hardware and locks', 'cutlery' and 'nails' along with textile industries such as 'cotton textiles', 'cotton spinning', 'woolen textiles' and 'silk spinning' but also apparel industries such as 'shoes' and 'gloves'. It would, however, be wrong to suggest that these industries did all suffer enormously from British competition as a result of trade liberalisation. Some of these industries such as 'woolen textiles', 'shoes', 'gloves' and 'nails' show even a bilateral trade surplus with Britain. Looking on import

[11] Tariff induced price reductions are calculated as $(1 + Tr_{1861})/(1 + Tr_{1839}) - 1$.

[12] For a review of the literature on French trade policy during the 19$^{\text{th}}$ century and the Cobden-Chevalier treaty in particular see section 3.3.1.

Table 3.6: Distribution of UK import and export shares among 32 industries

	1839 UK IMPsh	1861 UK IMPsh	1839 UK EXPsh	1861 UK EXPsh	Δ UK IMPsh	Δ UK EXPsh
avg	22%	47%	8%	15%	26%	7%
min	0%	0%	0%	0%	-58%	-10%
25th	0%	24%	1%	3%	0%	1%
50th	6%	37%	5%	10%	23%	3%
75th	33%	79%	12%	19%	50%	8%
max	89%	97%	32%	76%	97%	61%

Notes: calculated based on the figures presented in table A.5.

trade alone without considering the export situation would lead to wrong conclusions. The glove industry, for instance, has such high exports relative to imports that the balance of trade surplus as a share of total trade is still at 99.9% even though the British import share increased by 50%-points. This also shows that industries which were protected from foreign imports by import prohibitions did not always suffer from a flood of imports when lifting the prohibitions. The 'cotton spinning' industry, on the other hand, shows a strong shift towards British imports alongside a large deficit in its bilateral and total balance of trade - see table A.6.

Table 3.7: Cobden-Chevalier: top 25% industries affected by imports from and exports to Britain.

	IMP $\Delta\frac{UKIMP}{IMP+EXP}$		EXP $\Delta\frac{UKEXP}{IMP+EXP}$
Silk spinning	42%	Gloves	61%
Cotton spinning	40%	Leather	22%
Flour mill	26%	Silk textiles	21%
Ferrous metallurgy	23%	Binding materials	15%
Oil	16%	Woolen textiles	13%
Cotton textiles	12%	Distillery	13%
Locks and hardware	10%		
Cutlery	10%		

Notes: See table A.6 for a full list of levels and differences across 32 industries.

By looking at the French imports from Britain as a share of total French trade per industry ($IMP_{UK,it}/(IMP_{it}+EXP_{it})$) we can see more easily for which industries British imports gained in importance overall. Table 3.7 lists the top movers for imports and exports. Apart from textile industries and metal industries we see that food processing industries are also among the top 25% percent of industries being confronted with British imports. Looking at exports we can see that some industries with import prohibitions like 'gloves' and 'leather' lead this group. Also French silk and woolen textile producers increase their relative exports to Britain. One important take-away from table 3.7 is that industry disaggregation matters. The silk industry, for instance, benefits from exports in its weaving sector but sees a strong inflow of British imports in its spinning sector. Moreover, the disaggregation of the overall textile sector is important as the trade effects in cotton, wool and silk show. However, also in the food and beverage industries we see a heterogeneous pattern with vegetable oils and flour mills as industries experiencing stronger relative imports from Britain but distilleries benefiting from gains in relative exports.

Overall, this short discussion of French trade statistics shows that the industries covered show sufficient extent of variation with respect to exports and imports. Import effects have been identified to be particularly large and strongly focused on Britain while the export market of French producers is more diversified. For a majority of industries Britain is the primary import destination and this development intensified strongly during our observation period. The last remaining piece of information for our analysis of regional trade liberalisation effects is transport cost to Britain.

3.4.3 Transport costs

The hypothesis states that industries which were more exposed to British competition will relocate to regions with higher relative access costs from Britain, while industries which benefited from having access to the British market should locate to regions with better relative access to Britain. The most important British ports during the mid-19$^{\text{th}}$ century are Liverpool and London which account for more than 70% of British exports in 1861.[13] The first approach in studying regional location is to look at 'great circle distances' (GCD) as an approximation for transport costs. Figure A.2 shows the relative distances from each departmental capital to the ports of London and Liverpool. We see that for both destinations a strong North-South pattern emerges.

Table 3.8: French absolute and relative freight rates by transport mode

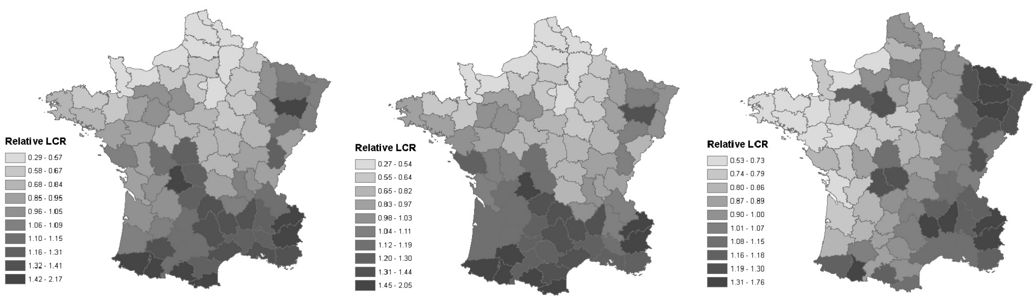
	Road	Canal		Railway		Sea (coastal)		Sea	
			rel.		rel.		rel.		rel.
1815-1824	33	-	-	-	-	-	-	-	-
1825-1834	25	4.1	0.16	-	-	3.3	0.13	1.92	0.08
1841-1844	25	4.1	0.16	14.5	0.58	3.3	0.13	1.92	0.08
1845-1854	25	3.8	0.15	10.6	0.42	3	0.12	1.74	0.07
1855-1865	25	3.2	0.13	8.7	0.35	2.6	0.10	1.51	0.06
1865-1874	25	2.4	0.10	7.5	0.30	2.6	0.10	1.51	0.06
1885-1894	25	1.8	0.07	6.8	0.27	1.5	0.06	0.87	0.03

Source: Toutain (1967); Daudin (2010) and own calculations.
Note: Freight rates are measured as centimes per ton and kilometre. Relative freight rates show the costs of transporting one ton per kilometre on canals, railways or the sea relative to the cost of transporting one ton per kilometre on road. For instance, the cost of transporting one ton of freight on canals is 16% of the cost of transporting the same amount on road in 1825-1834. I also differentiate between up-stream and down-stream costs on rivers. Following Daudin (2010), I assume that up-stream river costs are 114% and down-stream river costs are 43% of the freight rate of canals.

[13] BPP, Annual statement of the trade and navigation of the United Kingdom with foreign countries and British possessions in the year 1861 (London, 1862).

This approach is far from ideal as regions are not equally well endowed with transportation infrastructure such as direct access to the sea or navigable rivers. Canals, railroads and roads are built to mitigate disadvantageous transport links. However, hardly any railroads have been built when the first census was taken and these different modes of transportation show large differences in freight rates. In order to account for these differences in transport costs to Britain I measure distance by using a least cost route algorithm. This algorithm is applied based on a multimodal transport network which differentiates between five different modes of transportation: roads; canals and navigable rivers; railroads; coastal sea-routes; sea-route from the Mediterranean Sea. For this purpose transportation maps with information on roads, canals, railroads and sea-routes around the benchmark years 1840 and 1860 have been geo-referenced and the respective transportation infrastructure has been digitalised.[14] Different modes of transportation have then been linked to freight rates from Toutain (1967). Table 3.8 shows the absolute and relative freight rates for road, canal, railway and sea routes. These freight rates reflect internal transportation.

Figure 3.2: Relative lowest cost routes per French departmental capital to London and Liverpool in 1842



(a) London or Liverpool (b) London (c) Liverpool

We see that water transportation is considerably cheaper than transport on roads and by railway in both periods of interest (1841-45 and 1855-65). Relative costs of transportation did decrease considerably during our observation period. While the cost of transport by road stayed constant over the period between 1841 and 1865 we see substantial relative decreases in freight rates for canals, railways and sea routes. Railroads show the most substantial gain in relative price competitiveness. While the cost of transporting one ton per kilometre was 58% compared to road transportation, railways cost only 30% of road transportation in the period 1865-1874. The results of the least cost analysis for the years 1842 and 1861 show that access to and from Britain via London and Liverpool was quite heterogeneous and does only partly fit a North-South or West-East pattern - see figure 3.2. Among coastal regions we find cheaper access at the North-Western Atlantic coast than at the Western Atlantic cost when measuring distance to London. Access costs decline along the border to the South. The coastal regions at the Mediterranean Sea show high costs no matter which destination is chosen. This was all expected. The overall pattern of access costs in non-border regions is mostly determined by inland waterways, particularly in 1842 when the French railroad network was rarely developed. Also the pattern in the South of

[14] The network of French internal waterways in 1842 is shown by map A.4a and map A.4b shows the extent of the railroad network in 1842. The maps by Perrot (1841), Levasseur (1842) and France, Ministère de l'Agriculture du Commerce et des Travaux Publics (1861) have been used as the main points of reference.

France is driven by canals. On the one hand, the 'Canal du Midi' which connected Bordeaux to the Mediterranean Sea through Toulouse and, on the other hand, the river Rhone and the vast Canal system linking the Rhone and the Loire to the Seine shaped the access cost pattern in the South of France. Comparing access to Liverpool with access to London shows that the Western Atlantic coast regions were highly exposed to access to and from Liverpool. We see a clear West-East pattern. Access to London is characterised by cheap access costs in the North-Western Channel regions. Moving land-inwards the Seine shapes the pattern towards the South. For both destinations the South-East is clearly the least accessible region.

3.5 Empirical Analysis

3.5.1 Empirical framework

The spatial effects of trade liberalisation are tested within a model of industrial location using a 'difference-in-difference' (DD) specification. Inspired by the ideas of Hanson (1998) spatial trade effects are identified by relative distances to trading partners and controls include dynamic agglomeration externalities. Based on Overman and Winters (2006), this framework is extended by allowing for different effects of trade liberalisation stemming from import competition and export market access. The spatial distribution of economic activity is measured by regional employment and output shares and these indicators are then regressed on the lowest cost distance to Britain within a region-industry-year panel. The dataset consists of 85 French departments (r) and 32 industries (i) prior to ($t-1$) and post (t) trade liberalisation. The first French industrial census of 1839-47 is used as pre trade liberalisation observations and the second French industrial census of 1861-65 as post trade liberalisation observations. The distance measure is allowed to differ among import and export industries as we would expect opposing distance responses depending on whether a specific industry was exposed to greater import competition or could benefit from better export market access. By interacting the relative trade cost measure with the change in import and export shares we are able to identify these opposing forces.

Equation 3.1 shows the baseline DD specification in logarithmic terms. The dependent variable is the logarithm of regional labor share by industry, region and time period. On the right hand side of equation 3.1, the primary variables of interest are the triple interaction terms of either $\Delta IMPsh_i$ or $\Delta EXPsh_i$, the distance measure $ln(DIST_r)$ and a year dummy $POST_t$ which is assigned a value of 1 for the post trade liberalisation period and 0 otherwise. The coefficients β_1 and β_2 estimate the extent to which the treatment group deviates from the common trend with untreated observation. The treatment consists of being located in a region with relatively high access costs to Britain AND having experienced a stronger increase in British imports or exports to Britain. Note that in contrast to the usual binary DD specification this is a continuous treatment, however, results will also be presented using binary treatments. Apart from distance related variables we add a set of control variables. Most of them are dynamic agglomeration externalities such as within-industry agglomeration, backward and forward linkages, industry diversity and internal economies of scale but we also control for differences in wages. Moreover, industry-region pair fixed effects η_{ir} control for any time invariant confounders. The model has been specified as a fixed effects model in contrast to using random effects based on a Hausman test.

$$
\begin{aligned}
ln(Lsh_{irt}) = \alpha + \lambda * POST_t + \sigma * ln(DIST_r) * POST_t + \gamma_1 * \Delta IMPsh_i * POST \\
+ \gamma_1 * \Delta EXPsh_i * POST + \beta_1 * \Delta IMPsh_i * ln(DIST_r) * POST_t \\
+ \beta_2 * \Delta EXPsh_i * ln(DIST_r) * POST_t + \sigma * ln(X_{ir}) * POST_t + \eta_{ir} + \epsilon_{irt}
\end{aligned}
\tag{3.1}
$$

The identification strategy of the DD model is based on the standard assumption that treated and non-treated groups would follow the same trend in the absence of the treatment. For our specific case study this implies that industries in regions with a similar relative distance to Britain would all follow the same trend independent of their sensitivity to trade liberalisation. This counterfactual situation is hard to verify. The usual approach to use pre-treatment trends is not possible as the pre-treatment industrial census used is the first of its existence. This identification problem is, at least, partly bypassed by adding potential confounders. It would be, anyway, wrong to assume that during the 20 years between our two observations only trade liberalisation affected the spatial distribution of economic activity in France.

Using a logarithmic specification has several advantages and disadvantages. The main advantage is to account for non-linearities between the independent and dependent variables. Moreover, coefficient estimates can be interpreted as elasticities. A severe disadvantage, however, is that observations without employment within a given industry, region and time period are excluded from the sample. This is also true for import and export shares, why those differences are incorporated in non-logarithmic form. With respect to employment shares, there are two possibilities to deal with zero-observations. On the one hand, a constant value can be added to each observation before taken the logarithm. On the other hand, a Poisson model can be used, which can incorporate zero-observations. Both approaches are applied, and as the empirical results below show, the qualitative results are very similar.

3.5.2 Variable specification

As dependent variables industry specific regional employment and output shares are used. The industrial censuses present employment figures and wages for male and female employees as well as child work. Instead of using total employment as the sum over males, females and children, a productivity weighted employment index is calculated. This follows Doraszelski (2004), using relative wages as proxies for relative productivity. Based on this productivity adjusted labour index regional labour shares per industry (i) are calculated. Output shares are calculated based on the output figures presented in the censuses.

$$L_{irt} = EMP_{m;irt} + EMP_{f;irt} * \frac{w_{f;irt}}{w_{m;irt}} + EMP_{ch;irt} * \frac{w_{ch;irt}}{w_{m;irt}}$$

The primary independent variable is the relative distance to Britain. Distances are calculated from each departmental capital to London and Liverpool which account for more than 70% of British exports in 1861. Instead of using great circle distances the actual transport costs are estimated based on multi-modal transport networks in 1840 and 1860 which account for relative freight rates among roads, canals, rivers, sea-routes and railroads. Relative distance to Britain is estimated as the shortest road equivalent distance among the ports of Liverpool and London divided by the average distance to Britain across all departments. The pre trade liberalisation distance measure is used as the benchmark estimate.[15]

In order to differentiate between distance effects stemming from a response to import competition rather than market access, the distance measure is interacted with the change in import and export shares. By matching industries from the industrial censuses to commodities from the French trade records I calculate the imports from Britain as a share of total French import and export trade per industry (i) and take the difference between 1839 and 1861. Imports and exports are weighted by total trade by industry and not on imports and exports separately in order to account for the importance of imports and exports in overall trade.

$$
\begin{aligned}
ln(DIST_r) &= ln(DIST_{rUK}) - ln(\overline{DIST_{UK}}) \\
\Delta IMPsh_{it} &= \frac{IMP_{UKit}}{IMP_{it} + EXP_{it}} - \frac{IMP_{UKi,t-1}}{IMP_{i,t-1} + EXP_{i,t-1}} \\
\Delta EXPsh_{it} &= \frac{EXP_{UKit}}{IMP_{it} + EXP_{it}} - \frac{EXP_{UKi,t-1}}{IMP_{i,t-1} + EXP_{i,t-1}}
\end{aligned}
$$

While it makes sense to hypothesis relative distance to the UK to be an important location determinant in a period of strong bilateral and unilateral trade liberalisation, it would be wrong to neglect other potential determinants of industrial location. Industry-region fixed effects control for industry and regional specificities such as regional differences in factor endowments and industry differences in market structure, competition and productivity. What we need to worry about are region-industry specific confounders which change over time. Such potential determinants of industrial location are agglomeration externalities. I follow the model specification proposed by Hanson (1998) and control for external economies of scale like proximity to buyers and suppliers, benefits from within industry agglomeration and industrial diversity as well as internal economies of scale, firm size, and differences in wages. These indicators are introduced at the pre-trade liberalisation level and interacted with the POST dummy in order to capture dynamic effects and do not introduce any simultaneity bias.

Backward and Forward Linkages are measured by matching industries to five broad aggregates (k) which have been designed to share buyer and supplier relationships: (1) Textile; Leather; Apparel; (2) Metal mines; Metallurgy; Metal Products; (3) Clay and Stone; Pottery and Glass; Chemicals; Construction Materials; (4) Food and Beverages; (5) Paper; Printing; Instruments. We expect backward and forward linkages to be positively associated with industrial employment if firms benefit from locating closer to upstream and downstream firms. The idea of backward and forward linkages has been formalised by Krugman and Venables (1995) and Venables (1996).

[15] For a detailed discussion of distance measures see subsection 3.4.3.

$$ln(BFL)_{irt} = ln\left(\frac{EMP_{krt}/EMP_{irt}}{EMP_{kt}/EMP_{it}}\right)$$

Specialisation measures the degree of relative within-industry agglomeration. In contrast to agglomeration along upstream and downstream firms, industrial location might be determined by agglomeration forces within the same industry. The idea of within-industry agglomeration is based on the seminal contribution by Marshall (1890) who formed a theory of industrial agglomeration based on three components: (1) forward and backward linkages; (2) labour market pooling; (3) knowledge spillovers. Forward and backward linkages have been discussed above. Labour market pooling refers to firms' access to a large labour pool and the associated scale advantages. Knowledge spillovers refer to the distance related flow of knowledge. These have been usually modeled as within-industry externalities of localised learning (Arrow, 1962; Romer, 1986; Glaeser et al., 1992).

$$ln(spec)_{irt} = ln\left(\frac{EMP_{irt}/EMP_{rt}}{EMP_{it}/EMP_{t}}\right)$$

Diversity refers to the idea of externalities stemming from the diversity of industries being located within the same department (Jacobs, 1970). Industry diversity is computed using a Herfindhal index. A smaller index implies a higher degree of industry diversity. We should therefore expect a negative coefficient.

$$ln(div)_{r,t-1} = ln\left(\frac{\sum_i(EMP_{ir,t-1}/EMP_{r,t-1})^2}{\sum_i(EMP_{i,t-1}/EMP_{t-1})^2}\right)$$

Firm size and wage: Following Hanson (1998), relative firm size and wages are included as additional control variables. Firm size is meant to measure internal economies of scale, differences in technology and competition. Including wages might be problematic for two reasons. Firstly, wages might not reflect unit labour costs very well if labour productivity differences are large. Hence, the expected negative sign of the wage coefficient due to cheaper input costs might be compensated by the positive effect of labour productivity. Secondly, trade liberalisation might have affected wages directly creating an endogeneity bias. Therefore, results will be presented with and without wages as an independent variable.

$$ln(size)_{irt} = ln\left(\frac{EMP_{irt}/EST_{irt}}{EMP_{it}/EST_{it}}\right)$$

$$ln(wage)_{irt} = ln\left(\frac{maleWage_{irt}}{maleWage_{it}}\right)$$

3.5.3 Estimation results

As a first step in analysing the spatial effects of trade liberalisation we evaluate the relationship between French departmental employment shares and distance to the UK. It is hypothesised that trade liberalisation affects the spatial distribution of employment and output which should be observable in the effect of distance as a location determinant. More specifically, economic theory suggests a positive distance coefficient with respect to increased import competition and a negative distance coefficient with respect to increased export market access. The regression is based on two industrial censuses which are used to measure the spatial distribution of economic activity pre and post trade liberalisation. Between these two census periods the total French ad valorem import tariff decreased from 16% (avg. 1839-47) to 5.8% (avg. 1861-65) and the unweighted manufactures average import tariff decreased from 90% (1846) to 17% (1863).[16] In the sample of 32 industries we see a drop in the average manufacturing import tariff from 68% in 1839 to 12% in 1861.[17] Moreover, relative trade between France and the UK doubled as a share of total trade both for exports and imports. We find that changes in the direction of trade did shape the spatial distribution of employment and output through the import competition mechanism. Increased exposure to British imports did result in a spatial employment shift to regions with higher access costs to British competition.

Table 3.9 shows the results from estimating variations of equation 3.1. We find strong support for the import competition channel of distance. Increased exposure to British imports did result in a spatial employment shift to regions with relatively higher access costs to British competition. There is no evidence that the export mechanism has shaped the economic geography of France, at least with respect to Britain. The negative distance coefficient in specification (1) of table 3.9 shows that on average industrial employment shifted to regions which were located closer to Britain. Specification (2) adds the import competition channel and we find a positive coefficient at the 10% significance level. Adding the export channel shows no significant effect for export industries locating closer to the British market and the import effect just turns statistically insignificant. Once the controls of external and internal economies of scale are added, the import competition coefficient increases and becomes statistically significant at the 1% level. Internal and external agglomeration effects are detected as strong determinants of regional employment. Dispersion (negative within industry agglomeration) effects, a tendency to locate closer to upstream and downstream industries, gains from industrial diversity and a concentration in large establishments shape the spatial distribution of industrial employment in 19th century France, see specification (4). Adding the wage control in specification (5) does not affect the import competition coefficient. Among the control variables only the within industry agglomeration variable stays statistically significant indicating the expected multicollinearity with the wage level. A further robustness test includes a set of time interacted industry and departmental dummies. This restrictive dummy variable specification, specification (6) of table 3.9, does not affect the industry-region-time variant coefficients. The specified model explains 18% (R^2) of the variance in labour shares, which comparable with goodness of fit measures from Hanson (1998), but should also re-emphasize that only one aspect of many driving regional labour markets is covered. In additional to the log-linear OLS specifications, which add a constant of 1 to labour shares in order to account for zero-observations, a Poisson model specification has been applied which can account for

[16] Total ad valorem tariff rates are calculated based on total duty paid and import values as reported in the 'Tableau decennal du commerce de la France' (various years). Unweighted manufactures average tariffs are taken from Tena-Junguito et al. (2012). For a more detailed discussion of the degree of trade liberalisation during 19th century France see section 3.3.1.

[17] This is slightly below the figures estimated by Tena-Junguito et al. (2012) but the figures are very similar in terms of percentage change (-81% for Tena-Junguito et al. (2012) figures and -82% for our sample of 32 industries.

Table 3.9: FE panel estimation results: labour shares

	(1) OLS ln(Lsh)	(2) OLS ln(Lsh)	(3) OLS ln(Lsh)	(4) OLS ln(Lsh)	(5) OLS ln(Lsh)	(6) OLS ln(Lsh)	(7) Poisson Lsh
POST	-0.000	-0.000	-0.000	0.009***	0.008**		
	(0.001)	(0.000)	(0.001)	(0.003)	(0.003)		
ln(DIST)	-0.003*	-0.003**	-0.003	-0.003*	-0.003		
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)		
Δ IMPsh		0.002	0.002	0.003	0.003		
		(0.003)	(0.003)	(0.003)	(0.003)		
Δ IMPsh*ln(DIST)		0.014*	0.013	0.023***	0.023***	0.024***	1.614***
		(0.008)	(0.008)	(0.009)	(0.009)	(0.008)	(0.458)
Δ EXPsh			-0.001	-0.001	0.000		
			(0.007)	(0.007)	(0.007)		
Δ EXPsh*ln(DIST)			-0.010	0.001	-0.000	0.001	-0.804
			(0.012)	(0.010)	(0.010)	(0.010)	(1.024)
ln(aggl)				-0.016***	-0.019***	-0.017***	-0.788***
				(0.003)	(0.003)	(0.003)	(0.066)
ln(BF)				0.002**	-0.001	0.002***	0.069
				(0.001)	(0.001)	(0.001)	(0.075)
ln(div)				-0.003*	-0.003		
				(0.002)	(0.002)		
ln(size)				0.004*	0.002	0.004*	-0.081
				(0.002)	(0.003)	(0.002)	(0.079)
ln(wage)					0.011***		
					(0.003)		
Constant	0.011***	0.011***	0.011***	0.011***	0.011***	0.012***	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	
IND*POST	no	no	no	no	no	yes	yes
DEP*POST	no	no	no	no	no	yes	yes
R2 within	0.00	0.00	0.00	0.13	0.14	0.18	-
N	5,440	5,440	5,440	5,440	5,440	5,440	3,700

Clustered standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Distance is measured based on a cheapest route algorithm within the French transport network of 1842. All control variables refer to the $t-1$ period and all variables are interacted with a time dummy.

zero-observations without the necessity to transform input variables. Specification (7) in table 3.9 shows that the main results of an import competition effect on regional labour markets is well supported.[18] Using gross output shares instead of labour shares as a dependent variable - see table 3.10 - shows very similar results. The import competition mechanism is identified as a statistically significant determinant of changes in output shares while the coefficient measuring export market access does not show statistical significance. The import competition coefficient is slightly lower in size and among the control variables we do not find evidence of gains from industry diversity and the result on firm size seems to be less consistent.

Apart from statistical significance we should also be interested in the economic significance. Relative economic significance is measured in terms of beta coefficients which normalise coefficient estimates by standard deviations. Beta coefficients of specification (4)

[18]The number of observations decreases in the Poisson model specification as those industry-region pairs which have no observations in both periods are excluded. Log-linear fixed effects OLS results are in-variant when applying the same sample.

Table 3.10: FE panel estimation results: output shares

	(1) OLS ln(Ysh)	(2) OLS ln(Ysh)	(3) OLS ln(Ysh)	(4) OLS ln(Ysh)	(5) OLS ln(Ysh)	(6) OLS ln(Ysh)	(7) Poisson Ysh
POST	-0.000	-0.000	-0.000	0.006***	0.006***		
	(0.000)	(0.001)	(0.001)	(0.002)	(0.002)		
ln(DIST)	-0.003	-0.003*	-0.003	-0.003	-0.003		
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)		
Δ IMPsh		0.001	0.001	0.002	0.002		
		(0.002)	(0.002)	(0.002)	(0.002)		
Δ IMPsh*ln(DIST)		0.010	0.009	0.017**	0.017**	0.018**	1.169**
		(0.007)	(0.007)	(0.008)	(0.008)	(0.007)	(0.499)
Δ EXPsh			-0.001	-0.001	-0.001		
			(0.007)	(0.007)	(0.007)		
Δ EXPsh*ln(DIST)			-0.011	-0.001	-0.001	-0.001	-1.949
			(0.012)	(0.011)	(0.011)	(0.011)	(1.238)
ln(aggl)				-0.014***	-0.014***	-0.015***	-0.651***
				(0.002)	(0.002)	(0.002)	(1.238)
ln(BF)				0.001*	0.001	0.002**	0.04
				(0.001)	(0.001)	(0.001)	(0.088)
ln(div)				-0.002	-0.002		
				(0.002)	(0.002)		
ln(size)				0.003*	0.003*	0.003	-0.151
				(0.002)	(0.002)	(0.002)	(0.092)
ln(wage)					0.001		
					(0.003)		
Constant	0.011***	0.011***	0.011***	0.011***	0.011***	0.011***	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	
IND*POST	no	no	no	no	no	yes	yes
DEP*POST	no	no	no	no	no	yes	yes
R2 within	0.00	0.00	0.00	0.10	0.10	0.14	
N	5,440	5,440	5,440	5,440	5,440	5,440	3,714

Clustered standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Distance is measured based on a cheapest route algorithm within the French transport network of 1842. All control variables refer to the $t-1$ period and all variables are interacted with a time dummy.

from table 3.9 are by order of relative magnitude as follows: -0.397 ln(aggl)*POST, 0.09 ln(size)*POST, 0.059 Δ IMPsh*ln(DIST)*POST, 0.047 ln(BF)*POST, -0.047 ln(div)*POST. It can be seen that the single most important factor is within-industry dispersion. The remaining external and internal agglomeration controls are of a similar economic magnitude as the import competition mechanism. A similar relative order of the economic significance of coefficients results when studying output shares instead of labour shares: -0.341 ln(aggl)*POST, 0.073 ln(size)*POST, 0.044 Δ IMPsh*ln(DIST)*POST, 0.039 ln(BF)*POST, -0.023 ln(div)*POST.[19]

As a next step we look at binary treatments. Table 3.11 shows estimation results for the same model as above but uses dummy variables for distance and the change in import/export shares. The same confounders are considered. A value of 1 is assigned to

[19]It should be noted that the fixed effects specifications of tables 3.9 and 3.10 are computational equivalent to estimating first differences. Hence, the presented beta coefficients indicate by how much of a standard deviation the difference of labour or output shares responded due to a one standard deviation difference in the respective independent variable.

import/export industries which are among the top 25% in terms of trade effect. Relative distance dummies have been assigned a value of 1 if the region is among the lowest third. For all specifications we find evidence for the import mechanism to be active.[20] Regions with lower relative access costs to Britain did perform worse in industries which faced substantial import competition from Britain. Specification (1), for instance, shows a net regional treatment effect of $0.002 - 0.005 * IMPq4$ for regions close to Britain ($DISTq1 = 1$). Depending on the type of industry, departments close to Britain have either gained or lost relative labour shares. If being exposed to British competition ($IMPq4 = 1$) the average effect is 0.3%. Given that ln(Lsh) has a mean of 0.011 and a standard deviation of 0.036, the average treatment effect explains around 8% of the standard deviation.[21] Moreover, we can see that import industries gain employment shares relative to non-import industries in areas less accessible from Britain but loose relative employment in regions closer to the UK.[22] The magnitude of these effects is similar for both employment and output shares such that we can conclude that the import competition effect was quite substantial, though as expected not the only factor driving differences in regional employment shares. It should also be noted that, as the post-treatment observations are very close to the treatment, probably not the full effect has materialized yet and the magnitude of the identified mechanisms are downward biased.[23]

The results are robust against various specifications. Firstly, it should be noted that all estimation results presented report heteroscedasticity robust standard errors which are clustered in the industry-region fixed effects (Stock and Watson, 2008). Secondly, table A.1 presents results from weighting regression by industry labour or output shares in period $t-1$. So far only unweighted regression results have been presented. As all variables are normalised by their national mean or aggregate, the regressions do not account for differences in the importance of industries. Once, regressions are weighted by industry labour shares in specification (2) of table A.1 and by industry output shares in specification (4) of table A.1 general conclusions regarding the aggregate importance of the effects can be drawn. In comparison to unweighted regressions, the coefficient for the spatial effect of import competition decreases slightly and in the case of labour slightly looses statistical significance. Hence, it can be concluded that the identified import mechanism is less significant once the industries are weighted by their respective importance in the French economy in the period $t-1$. Thirdly, additional control variables are introduced. Table A.2 shows the benchmark specification (1) including regional and industry dummies. Step by step additional control variables are added. Non of the identified mechanisms are violated by adding more controls. In specification (2) the relative female and child labour shares are included. They are not identified as being of statistically significant importance, however, once within-industry agglomeration is dropped, their coefficients turn negative and statistically significant. As additional controls, firm level factor intensities of capital, material input and labour are considered.[24] We can see that labour concentrates in material

[20] This finding is robust against variations of combining binary and continuous treatments.

[21] In order to also include observations with no employment or output the number 1 is added to the shares before taking the logarithm.

[22] For import industries ($IMPq4 = 1$) the net effect ($\gamma_1 + \beta_1 * DISTq1$) is negative for regions close to Britain ($DISTq1 = 1$) and positive for regions facing higher relative access costs ($DISTq1 = 0$).

[23] This factor is discussed in more detailed in section 3.6.

[24] Capital and material input are taken from the industrial census of 1839-47. Labour input is approxi-

Table 3.11: Binary DD results

	(1) ln(Lsh)	(2) ln(Lsh)	(3) ln(Ysh)	(4) ln(Ysh)
POST	0.009***	0.009***	0.006**	0.006**
	(0.003)	(0.003)	(0.002)	(0.002)
DISTq1*POST	0.002	0.000	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.002)
IMPq4*POST	0.001	0.001	0.001	0.002
	(0.002)	(0.002)	(0.001)	(0.001)
IMPq4*DISTq1*POST	-0.005**	-0.004*	-0.006**	-0.005*
	(0.002)	(0.002)	(0.002)	(0.003)
EXPq4*POST		-0.000		0.000
		(0.001)		(0.002)
EXPq4*DISTq1*POST		0.003		0.002
		(0.002)		(0.003)
ln(aggl)*POST	-0.016***	-0.016***	-0.014***	-0.014***
	(0.003)	(0.003)	(0.002)	(0.002)
ln(BF)*POST	0.002**	0.002**	0.001*	0.001*
	(0.001)	(0.001)	(0.001)	(0.001)
ln(div)*POST	-0.004*	-0.004*	-0.002	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)
ln(size)*POST	0.004*	0.004*	0.004*	0.004*
	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.011***	0.011***	0.011***	0.011***
	(0.000)	(0.000)	(0.000)	(0.000)
R2 within	0.13	0.13	0.10	0.10
N	5,440	5,440	5,440	5,440

Clustered standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Distance is measured based on a cheapest route algorithm within the French transport network of 1842. All control variables refer to the $t-1$ period and are interacted with a time dummy.

intensive industry-region pairs.[25] The coefficient of capital intensity is positive but just above the 10% statistical significance threshold. Once, all control variables are considered simultaneously, the labour intensity measure shows a negative and statistical significant coefficient.

Our baseline empirical analysis of the effects of trade liberalisation on the spatial distribution of economic activity during 19$^{\text{th}}$ century France has shown that French industries moved away from increased British competition. Industries which faced increased imports from Britain relative to their total trade experienced relative gains in regions with higher relative access costs from Britain. This holds for industry employment and output shares. Moreover, we find evidence for within-industry regional dispersion, shifts towards down- and upstream industries, benefits from industry diversification and benefits from internal economies of scale.

mated by multiplying daily wages with employment figures assuming a work year of 300 days.

[25] Once material intensity is added our measure of backward and forward linkages loses statistical significance, which supports the accuracy of our backward and forward linkages measure. It should also be noted that fuel, coal in particular, is an important component of material input.

3.5.4 The effect of Cobden-Chevalier

So far the analysis has shown that French industries which increased their relative imports from the UK shifted employment and output to regions with higher relative access costs from British ports. Given the 20 year interval between the two observations on which our results are based on, it would be wrong to assume that the shift towards British imports was solely due to the effects of the Cobden-Chevalier treaty. As our discussion of trade liberalisation during 19$^{\text{th}}$ century France has shown, some barriers to trade have already been lifted before the treaty in 1860. Moreover, declining transport costs increased the competitiveness of British imports relative to domestically produced commodities. Inspite of these alternative factors influencing our chosen treatment we can assess the quantitative effect of the Cobden-Chevalier treaty by limiting our time interval. The smaller the time interval around the Cobden-Chevalier treaty the less likely it is that other factors influence relative trade shares. Using the coefficient estimates from our baseline specification, we calculate the effects of Cobden-Chevalier by applying UK trade shares between the period 1858 to 1861.

Before presenting out of sample model predictions we situate the 1858 trade shares into the trade pattern which we observe between our two census benchmark years of 1839 and 1861 - see table A.6. As expected we see the most diversified pattern among textile industries. The cotton and woolen industries which were under import prohibitions before the Cobden-Chevalier treaty experience a rise in import trade shares during the period 1858 to 1861. The linen and silk industries on the other hand, did experience their movement in trade patterns already in the period before 1858. As import tariffs were already at low levels before Cobden-Chevalier in the linen and silk industries this observation fits nicely with the historical evidence. Also the ferrous metallurgy industry experiences little movement in import shares during the period 1839-1858 but is subject to an import trade rise between 1858 and 1861. With respect to export shares we see less industry variety. The general picture is one of prolonged growth in the UK as an export market across the whole period. Hence, the picture, which we have identified for overall trade is also supported for manufacturing sub-industries.

Table 3.12 shows labour share predictions based on specification (6) of table 3.9 - for different trade patterns. While column (1) shows the actual change in labour shares for 12 regions, column (2) shows the model predictions for the entire trade shock on which the coefficient estimates are based on, including the effect from changes in trade patterns between 1839 and 1861. Column (3) displays out of sample predictions applying the 1858 trade pattern to split the sample based on region-industry weights from the 1839-47 industrial census. We can interpret these columns as approximations for the aggregated spatial effect of Cobden-Chevalier. When comparing column (1) and (2) we can see that the overall predictions are plausible, yet not very precise for some regions. Even though the aggregate residuals are non-negligibly large the overall trend has been predicted very well.

The regional effects of Cobden-Chevalier - column (3) in table 3.12 - have been estimated as the difference between the model predictions for 1861 and 1858. The figures should, thus, be interpreted as the deviation in predictions if trade patterns would not have changed between 1858 and 1861. Our predictions show that Cobden-Chevalier has con-

Table 3.12: Quantifying the aggregate spatial effects of the Cobden-Chevalier treaty

		(1)	(2)	(3)
		ΔLsh_{39-61}	$\Delta \widehat{Lsh}_{39-61}$	$\Delta \widehat{Lsh}_{58-61}$
(I)	Nord-Pas-de-Calais-Picardy	4.1%	5.0%	-1.3%
(II)	Normandy	-1.6%	-3.0%	-0.7%
(III)	Île-de-France	0.1%	1.1%	-0.5%
(IV)	Brittany	-1.7%	-1.7%	-0.4%
(V)	Centre-Val de Loire	-0.3%	-0.2%	-0.2%
(VI)	Bourgogne-Franche-Comté	1.2%	2.5%	-0.3%
(VII)	Pays de la Loire	-4.1%	-4.3%	-0.1%
(VIII)	Aquitaine-Limousin-Poitou-Charentes	-2.3%	-1.9%	0.4%
(IX)	Auvergne-Rhône-Alpes	1.8%	1.6%	0.1%
(X)	Alsace-Champagne-Ardenne-Lorraine	1.0%	0.6%	-0.2%
(XI)	Languedoc-Roussillon-Midi-Pyrénées	1.1%	0.4%	1.0%
(XII)	Provence-Alpes-Côte d'Azur	0.6%	1.5%	0.6%

Notes: This table presents model predictions for differences in labour shares based on specification (6) from table 3.9. The overall trade effect between 1839 and 1861 is split into a prediction based on the change in trade patterns up to the Cobden-Chevalier treaty (1858) and from 1858 until the first year of the second census (1861). Predictions are performed at the department-industry level and have been aggregated into 12 regions using industry labour weights from the first census. Regions: (I) Nord-Pas-de-Calais-Picardy; (II) Normandy; (III) Île-de-France; (IV) Brittany; (V) Centre-Val de Loire; (VI) Bourgogne-Franche-Comté; (VII) Pays de la Loire; (VIII) Aquitaine-Limousin-Poitou-Charentes; (IX) Auvergne-Rhône-Alpes; (X) Alsace-Champagne-Ardenne-Lorraine; (XI) Languedoc-Roussillon-Midi-Pyrénées; (XII) Provence-Alpes-Côte d'Azur.

tributed to the decline in Nord-Pas-de-Calais-Picardy and Normandy. In spite of this similarity these two regions differ substantially as the negative effect from Cobden-Chevalier is part of a general downward trend in Normandy but mitigates positive gains in labour shares in Nord-Pas-de-Calais-Picardy. Cobden-Chevalier, however, cannot be seen as a general explanation for the 'decline of the West'. For the regions at the Atlantic coast (Britanny, Pays de la Loire, Aquitaine-Limousin-Poitou-Charentes) pre-Cobden Chevalier patterns are responsible for most of the relative decline. Positive effects are identified in the Southern regions of Languedoc-Roussillon-Midi-Pyrénées and Provence-Alpes-Côte d'Azur. Overall, we can conclude that the spatial net effects from Cobden-Chevalier are sizeable but do not dominate the overall trend.

3.6 Discussion

3.6.1 The role of British import competitions

French manufacturers were not very amused when the bilateral treaty between France and Britain was signed on the 23rd of January 1860. This article shows that for specific industries their concern was valid for producers in regions which were easily accessible from Britain. Regions being located closer to Britain lost employment and output shares relative to the rest of France in industries which experienced a rising importance of UK imports. This effect has, furthermore, been found to be of economic significance when reduced to the short interval around the bilateral treaty. Hence, we have found support that British competition has led to smaller industries in those regions closer to Britain, both in terms of output and employment. Comparing the employment and output effects we see that coefficients for labour are stonger than for output shares suggesting a positive labour productivity effect. This supports Dunham's (1930) assessment of the treaty's positive impact on French industry by forcing them to introduce more productive machinery and production processes. Given the fact that the industrial census was taken not long after the trade treaty became effective it might well be the case that British competition has resulted in smaller, but more efficient, shares in regions more strongly affected by British competition. Implementing more efficient technologies is associated with learning and it takes time to see positive effects. This is further amplified by the fact that the treaty was not expected by French producers such that upgradings, as a response to the treaty, have not been implemented before 1860.

The short time span between the treatment and the post-treatment period might also introduce a downward bias to our coefficient estimates. Employment, in particular, might not respond immediately after a tariff shock but is subject to a time lag. Besides other factors, this might explain the relatively small effect when compared to the estimates for Mexico by Hanson (1998). It should, however, also be noted that the Hanson (1998) effect is based on the export market access mechanism, while our study identifies the import-competition mechanism as the main channel, which limits comparability. In addition to the potential downward bias from the timing of the industrial censuses, the regional coverage of the censuses might bias our results. In order to achieve comparability between the pre and post treatment censuses the cities of Paris and Lyon had to be removed from the sample. During our observation period the cities of Paris and Lyon grew much faster than the rest of France.[26] Given the fast growth of Paris and Lyon, omitting these cities should not violate our results. If the regional shift of employment and output away from coastal border regions dis-proportionally relocated to large cities, then the exclusion of Paris and Lyon should downward bias the results. The bias should, however, be mitigated by the fact that only the cities were excluded from the sample but the regions within which the cities are located are covered.[27]

Trade liberalisation influences not only the spatial distribution of economic activity but has effects on the sectoral distribution as well. Lévy-Leboyer and Bourguignon (1989, p.159-171) have argued that effects of trade liberalisation with respect to the economic development of nineteenth century France were mainly felt at the sectoral distribution. By studying regional employment and output shares on the industry level we have explicitly focused on the spatial distribution. Is this sufficient to rule out sectoral effects? In order to identify the effects of trade liberalisation a high-level of industry disaggregation is preferable in order to account for heterogeneity within the manufacturing sector. This, however, also implies that labour is more mobile between industries. Dunham (1930), for instance, gives examples of cotton producers switching to the linen industry as a result of the treaty. This does not affect our finding of spatial effects from trade liberalisation, however, it is interesting with respect to the mechanisms. An industry, which is not directly affected by trade liberalisation can be indirectly affected through sectoral redistribution. And this

[26]The population of Lyon increased from 177,976 in 1846 to 323,954 in 1866 (+82%) and the population of Paris increased from 1,053,897 in 1846 to 1,825,274 in 1866 (+73.2%). The average population growth of French arrondissements during the same period is 1.75% (Le Mée, 1989; France, 1869).

[27]Besides the potential biases of the distance coefficients, omitting Paris and Lyon might also bias the agglomeration coefficient hypothesising weaker dispersion forces in a sample which would include the two cities.

mechanism would then also be spatially clustered. Depending on the direction of labour mobility this makes the identification of the export channel more difficult. Following the example of Dunham (1930) with comparing the linen and the cotton industry we see inter-sectoral migration from an industry which is highly affected by British import competition to an industry which is not characterised by the UK's importance as an export market. Hence, we observe gains in a sector which, in our model, is not treated as being affected. How much this effect of inter-sectoral migration matters for the identification of the export market is difficult to assess. However, as our descriptive analysis of the patterns of French external trade has shown, the French export sector was much more diversified compared to its import sector. Britain played a much smaller role with respect to exports in the industrial sector. Hence, we do not think that the export mechanisms would be detected as particularly strong if we could adjust for inter-sectoral mobility. This holds for the industrial sector. Main beneficiaries of trade liberalisation with respect to the export channel should be expected in the agricultural sector. Hence, for the case of 19$^{\text{th}}$ century France it is not entirely surprising that we do not find strong location effects from export industries.

3.6.2 The industrial decline of the West and the role of agriculture

Our analysis of the two industrial censuses has confirmed Crouzet's (2003) observation that Western France - South of Le Havre - has lost ground in terms of relative industrial employment as well as output. The exposed location at the Atlantic coast made it more easily accessible for foreign products. Hence, we might think that import-competition may have contributed to the 'decline of the West'. However, in our sample of industries we do find only limited support for the hypothesis that increased British competition as a consequence of the Cobden-Chevalier treaty is associated with the de-industrialisation of these western regions. The regions of Brittany, Pays-de-la-Loire and Aquitaine-Limousin-Poitou-Charentes experience only small effects from Cobden-Chevalier relative to their overall decline. In Normandy, British competition was felt much more severely and bilateral trade liberalisation with Britain contributed substantially to the region's relative decline. The differences between the responses is not only because of the Normandy's closer distance to the UK but more importantly the regions' industry composition. In Normandy, the cotton textile industry was prevalent while the linen textile industry was mainly concentrated in the regions of Brittany and Pays-de-la-Loire. The decline of the linen industry is seen as an European phenomenon and caused by the competition from other textiles such as cotton. Imports of linen goods were neither prohibited nor were they protected by very high import tariffs. The direct effect of the Cobden-Chevalier treaty was, therefore, limited. The effects were felt much more severely in the cotton textile industry.

Hence, the results have shown that the decline of Western France was not associated with British import competition. Regions at the Western Atlantic coast did loose industrial employment shares most heavily in industries which were not exposed to increased British competition, like linen textiles. This finding should, however, not be generalised to the extent that trade liberalisation did not play a role in the decline of the West. Western France located France's most advanced agricultural regions. Our analysis has only covered the industrial sector and does not account for inter-sectoral labour mobility. If Western

France's comparative advantage lied in the production of agricultural commodities, like wine, we should expect a growing importance of this sector as a result of trade liberalisation. The lowering of British import tariffs on French wine and spirits was an important component of the Cobden-Chevalier treaty. British duties on lighter wines were reduced by about 80% and *"high British tariffs on wines and spirits were the central target"* for French negotiators (Lampe, 2009, p.1016). Nevertheless, it is important to note that the share of wine in total exports to Britain has remained comparably stable, averaging 4.2% between 1857 and 1866 with a standard deviation of 0.8% and a maximum at 6.1% in 1861 (France,1857-1866). According to the agricultural census of 1852, which has been made available by Marin and Marraud (2011), the department Girdonde produced 9.1% of the total value of French wine, 7.4% of total hectolitre and 13.5% of total wine exports (hectolitre). The second most important wine exporting region was the department of Herault producing 5.6 % of total French wine exports (hectolitre). It, therefore, seems plausible that the dominant wine producing region at the Atlantic coast, as well as its hinterland, profited from lower British import tariffs. A comparison of the agricultural censuses of 1852 and 1862 shows that the regional share of wine production has increased most substantially in the department Charente-Maritime but also in other regions close to the Atlantic coast like Charente, Loire-Atlantique and Vendée. However, also regions close to the Mediterranean Sea, like Hérault, increased their regional share in wine production substantially.[28] Inter-sectoral labour mobility between the agricultural and industrial sectors would imply that agriculture increases in importance at the expense of industry. That 19$^{\text{th}}$ century French labour responded to market signals of the labour market and did indeed move between industry and agriculture has been shown by Magnac and Postel-Vinay (1997) for seasonal labour. However, if specialisation in the production of agricultural commodities did contribute to the de-industrialisation of Western regions remains to be evaluated. What this analysis shows is that the contribution of the Cobden-Chevalier treaty within the industrial sector was limited with respect to British import competition and export market access. This holds for Western regions south of Normandy and can be attributed to the decline of the linen textile industry which was heavily concentrated in the regions of Britanny and Pays-de-la-Loire.

3.6.3 The role of agglomeration externalities

Apart from the identification of the importance of British competition during the mid-19$^{\text{th}}$ century our analysis has shown that industrial employment and output responded to a variety of externalities of scale. Across all specifications negative within-industry agglomeration effects, backward and forward linkages, benefits from industry diversity and some evidence for internal economies of scale have been identified as important determinants of industrial location. Interestingly, we find strong support for within-industry dispersion forces. Our approximation of agglomeration measures relative industry specialisation within a given region. A negative effect from this measure implies that regions became more diversified, or put differently less concentrated, in one particular industry. This is further emphasised by the positive effect from industry diversity. Regions with a more

[28] Data for the 1862 agricultural census are derived from the original publication (Statistique de la France, 1870, p.108-109).

diversified industrial structure benefit in terms of employment and output shares. This supports the hypothesis that Jacobian externalities are crucial during French industrialisation. This holds true for relative shares. Interestingly, when we look at labour productivity we see opposite effects. Regions which experienced higher levels of within-industry concentration increased their labour productivity relative to less concentrated regions. From the first industrial census we have also seen that more concentrated industries had lower levels of labour productivity. Hence, similar to the findings of Combes et al. (2011) for a later period, we find support for a convergence in labour productivity with respect to specialisation. Combes et al. (2011), however, show that labour productivity dispersed while employment concentrated.

In this respect it is important to note that Paris, the French capital, has not been included in the industrial surveys used. The arrondissements Sceaux and Saint-Denis, which were also part of the department Seine have, however, been covered by both surveys. In 1821, after the Napoleonic Wars, Paris had 657,172 inhabitants, which was 2.2% of the total French population. During the second half of the 19th century the capital grew much faster than the total population such that in 1911 already 7.3 % of the total population, close to 2.9 million people, lived in the capital city.[29] Paris was, however, not the only big French city gathering growth momentum during the second half of the 19th century. The cities of Lyon, Marseilles, Toulouse, Lille, Strasbourg and Nantes followed the example of Paris. In general, large towns with more than 10,000 inhabitants grew most rapidly between 1851 and 1911, at 300%. At the same time, rural municipalities with less than 2,000 inhabitants declined by 8% between 1806 and 1911 (Talandier et al., 2016). It, therefore, seems plausible that large cities increasingly became the backbone of the French economy suggesting that external, rather than internal, agglomeration externalities were important. Nevertheless, the level of urbanisation was lagging behind other advanced economies like Britain, Germany or the United States.[30]

Apart from industry specialisation and diversity we have found positive effects from backward and forward linkages. This is consistent with NEG hypotheses of firms locating closer to their input and output markets (Krugman and Venables, 1995). Moreover, it emphasises the importance of having access to a large industrial base. As we have studied a period of increased trade liberalisation as well as improvements in the internal transport network it is worth noting that backward and forward linkages still matter. Employment and output shares increased in regions with a higher density of their suppliers and buyer industries, even though inputs became more easily accessible from more distant destinations and products could be shipped to more distant customers. Moreover, this research contributes to the discussion of the role of firm size in French development. Internal economies of scale did play a role in shaping the economic geography during the mid-19th century. That firm size matters is also consistent with Doraszelski (2004) who found that firms benefited from increasing returns to scale during this period. These findings show that region-industry pairs with larger firms did, on the one hand, attract relative output shares and, on the other hand, increased their relative labour productivity.

[29]The Parisian population increased to 1,053,262 in 1851 (2.9%), 2,269,023 in 1881 (6.0%) and 2,888,110 in 1911 (7.3%). Population figures for Paris are taken from the Cassini project Motte and Vouloir (2007).

[30]See chapter 4 for comparative statistics of urbanisation rates.

3.7 Concluding remarks

The mid 19th century was a period of substantial trade liberalisation. France was among the first economies to shift trade policy towards a free-trade agenda which peaked in the bilateral treaty between France and Britain in 1860. The Cobden-Chevalier treaty lifted all import prohibitions on British manufacturers and reduced overall import tariffs. As Britain was the leading export-oriented manufacturing economy, French producers faced increased competition on their domestic markets. The Cobden-Chevalier treaty has mainly been studied with respect to trade flow effects (Lampe, 2008, 2009) as well as its institutional implications (Marsh, 1999). Spatial effects of trade liberalisation have not yet been examined even though it provides a rich case study which enables us to shed further light on the debate of how regions adjust to trade liberalisation.

The research presented in this chapter has shown that increased British competition has led to a shift in the spatial distribution of French production and employment. Regions being located closer to Britain lost employment and output shares relative to the rest of France in industries which experienced a rising importance of UK imports. Within the industrial sector the relocation effects of export industries were limited such that the effects of import competition dominated the overall trade effects. This, however, excludes the agricultural sector which covers a potential beneficiary of reduced British import tariffs on French wine. The results are based on an analysis of industrial census data before and after trade liberalisation which are linked to bilateral product-level export and import data as well as a multi-modal transport network analysis. Identification is based on a region-industry-time difference-in-difference strategy which also accounts for agglomeration externalities, following Hanson (1998) and Overman and Winters (2006). Apart from the spatial effects of trade liberalisation French industries responded positively to backward and forward linkages, a more diversified industrial structure and exploited internal economies of scale. Moreover, we find evidence for within-industry dispersion effects at a fine level of industry disaggregation suggesting that agglomeration forces were stronger with respect to inter-industry spillovers than within industries.

This research is an important contribution to the existing literature of spatial effects of trade liberalisation. Most studies have found positive effects for border regions as their relative access costs to export markets increased (Brülhart et al., 2012; Hanson, 1998). The evidence presented in this case study has shown that in addition to the export mechanism import competition can be an important factor in shaping the spatial allocation of economic activity. Hence, it is important to acknowledge the diversity within the industrial sector, which has recently been supported by the findings of Autor et al. (2013) for the role of Chinese import competition on US regional labour markets. Thus, spatial and sectoral effects of trade liberalisation should be seen as highly intertwined. Hence, in spite of aggregate beneficial effects of globally integrated trade patterns, variation in the effects on regional economies should not be overlooked. The 19th century can help to improve our understanding of effects of trade policy on regional economies with France being an important example. The empirical evidence is, however, much more broad-based and additional research on other case studies is needed to build a coherent picture. The shift to protectionism in France associated with the Méline tariff in 1892 would be an important addition to this research agenda, for example by building on the work by Dormois (2006b).

Chapter 4

Steam vs Water power in French industrialisation

4.1 Introduction

The industrialisation of 19^{th} century Europe and the United States was associated with a strong movement towards urban locations. Industrialisation and urbanisation are, therefore, seen as interdependent processes of modern economic growth. Besides urbanisation another key feature of 19^{th} century industrialisation is the growing importance of steam as the dominant power source overtaking water. In spite of the prominent role of steam power and urbanisation in economic histories of 19^{th} century industrialisation, the linkages between urbanisation, power-choice and industrialisation lack empirical investigations. Economic historians have only recently started to analyse the effect of power-choice on industrial location. Rosenberg and Trajtenberg (2004) and Kim (2005) have studied the effects of steam power on urbanisation for the United States and Gutberlet (2014) has investigated the effects of steam on the spatial concentration of industry in Germany. The underlying idea behind these studies is that a switch from water power to steam power frees industries from a land constraint as the source of power is not tied to fast flowing streams but to coal which can be transported more easily. Rosenberg and Trajtenberg (2004) find that the diffusion of steam power stimulated urban growth while Kim (2005) finds the effect of steam power on urbanisation to be negligible. Gutberlet (2014) shows evidence for positive effects of steam for the spatial concentration of industries. I contribute to this evolving literature by adding a very important case in the debate about the interrelatedness between power-choice, urbanisation and industrialisation: the case of France. This article analyses the question whether French adherence to water power and its delayed diffusion of steam power contributed to its slow urbanisation, limited gains from urban agglomeration and through this mechanism constrained economic development.

Why is France such an important case study? In contrast to the industrialisation of Britain, Germany and the United States which experienced fast urbanisation along with intense use of steam power, the French path to economic development was characterised by slow urbanisation and adherence to water power. Moreover, economic historians like Crouzet (1996) and Cameron (1985) have hypothesised a causal relationship between power choice and urbanisation arguing that French adherence to water power has led to small firms, geographical dispersion and a rural location of French industry. This article is the first to empirically investigate the relationship between the French focus on water power and its slow urbanisation. I use two early industrial censuses which were collected in the 1840s and 1860s and give detailed information on the type of industrial power use at the regional and industry level. Following Kim (2005) a discrete choice model of urban-rural location is applied to identify power-source specific differences in urban-rural location preferences both at the city (commune) and regional (arrondissement) level. The high quality of the French industrial census data allows to extend this approach to a fully continuous specification. For the 1840s, which is the only period for which commune level data is available, I find very strong support that water powered firms were more likely to be located in rural communes rather than cities. The urban preference of steam powered firms, relative to non-water and non-steam powered firms, is less clear. Extending the analysis to the 1860s, which is only possible using regions as the unit of analysis, shows that the urban preference of steam powered firms is much stronger at the regional level than it is at the commune level. I find strong evidence that steam-powered firms were more likely to choose urban regions, while water-powered firms were only marginally, though statistically significantly, more likely to locate in rural regions. Moreover, the urban preference of steam-powered firms increased substantially between the 1840s and 1860s. Similar to the findings of Kim (2005) for the United States, the high explanatory power of firm size for a firm's urban location is also identified to be important for the French economy. The results indicate that water power was, indeed, associated with a more rural character of French industry. However, it should be highlighted that the rural-urban differences with respect to power source changes with the unit of observation.

In a next step it is necessary to relate rural preferences of water power and urban preferences of steam power to differences in economic success. French economic development during the 19$^{\text{th}}$ century has traditionally been interpreted as a failure as France lost political and economic influence. Since the 1970s, however, French historiography has emphasised the distinct pattern of French economic development arguing that the French path to modern economic growth was different, though, not less successful.[1] One potential mechanism through which power-source related location choices can be linked to economic development is through the existence of benefits of urban agglomeration. The rationale behind this idea is that if benefits of urban agglomeration were present in the French economy then a faster diffusion of steam power would have fostered economic growth through its positive effect on urbanisation. The existence of benefits of urban agglomeration is empirically analysed by estimating urban premiums in wages and labour productivity. After adjusting for endogeneity biases by instrumenting urbanisation with lagged urbanisation ratios, I find that urban firms paid 13-14% higher wages and were 16-22% more productive than their rural counterparts, depending on the census period. These results are statistically and economically significant and control among other potential confounders for urban-rural differences in capital intensity. Hence, the results suggest that French economic growth was indeed constrained by its adherence to water power and low urbanisation.

This article is structured as follows. The next section discusses the relative importance

[1] Clapham (1936), Landes (1969) and Kindleberger (1964) are key contributions to this debate. See section 2.1.1 as well as Crouzet (2003) and Grantham (1997) for a review of the literature.

of steam and water power in French industrialisation and reviews its urbanisation pattern. Then a section on the benefits of urbanisation outlines potential mechanisms through which urbanisation can stimulate economic development. These two background sections are followed by a discussion of sources, variables and a descriptive summary of the dataset. The empirical analysis is structured in two sections. At first, the relationship between power choice and urbanisation is analysed. Then I test for the existence of benefits of urban agglomeration. A discussion section combines these two parts and links them to the existing literature. The article is closed by some concluding remarks.

4.2 Historical background

4.2.1 Industrial power choice and the 'coal factor'

One prominent feature of the French path of industrialisation is the importance of water as the primary source of industrial power.[2] Compared to Britain, where water and steam power reached parity in 1830 the French economy still used more water power than steam power during the 1860s. The industrial census of 1861-65 shows that steam contributed 32% (35%) and water 59% (65%) to total power use (power use from steam and water) of the French economy. Although steam reached dominance by 1901, the role of water power never decreased below 20% in France while the share of water power was at 10% in Britain as early as 1870.[3] The technological diffusion of steam power was delayed if the economies of France and Britain are compared, at least at the intensive margin.[4]

While the 'retardation' view interprets French adherence to water power as a sign of French backwardness and entrepreneurial failure, the 'revisionist' view emphasises the less favourable factor endowments for the adoption of steam technologies. The decision to prefer water power over steam power was rational, given the French geographic constraints. Reviewing various factors of French backwardness Kindleberger (1964, p.17) attributes the 'coal factor' ancient origin. Also Clapham (1936) refers to the contemporary view of a less favourable coal position by citing Chaptal (1828) who sees the lack of applying machinery in cheap labour and high coal prices. France lacked sufficient domestic coal resources and imported 20% of its coal consumption in 1820 and 43% in 1860 (Crouzet, 1996, p.40). Coal deposits were small except for the fields in the department Loire and the region Nord-Pas-de-Calais. Besides the modest size in coal deposits Crouzet (1974, p.173) refers to the location of coalfields with respect to the lacking proximity to other resources, such as iron ore, and industrial districts as features of the 'coal argument'. In spite of its long tradition, the 'coal factor' has become unfashionable. Nevertheless, Crouzet (1974, p.174) himself acknowledges that *"after all, nearly all the large industrial districts of the nineteenth century developed on coal-fields, and France's bad luck was to have only a couple of such vital growth areas"*. Given the dependency on imports and the disadvantageous

[2] Cameron (1985, p.14), for instance, lists the low rate of urbanisation, the scale and structure of enterprise, and the source of industrial power as key features of the French pattern of industrialisation.

[3] Table B.12 shows the distribution of power by power source measured in horsepower from the 1860s until 1931 while table B.11 shows the development of water and steam power in Britain from 1760 to 1907.

[4] The technological diffusion literature specifies the intensive margin of technological diffusion as the intensity with which a specific technology is used. The extensive margin, on the other hand, refers to whether a specific technology has, or has not been adopted, independent of the intensity this technology is used. See Comin and Mestieri (2014) for a survey on measuring technological diffusion.

location of coal deposits, a more nuanced interpretation of the 'coal factor' has emerged with respect to tariff policy and transport infrastructure. Kindleberger (1964) argues that lower import tariffs and a faster expansion of the transport network would have supported French growth during the first half of the 19th century. The French railroad boom did not start before the 1840s and the coal as well as charcoal producers were protected from foreign competition by import tariffs at least until 1830. To what extent a more liberal trade policy towards coal and an earlier expansion of the transport infrastructure would have fueled French economic growth is open to debate. A quantitative examination remains to be performed for the French case.

Even for the British industrial revolution the role of coal is subject to much debate in the literature. Clark and Jacks (2007, p.69) even come to the conclusion that *"England gained little advantage from actually possessing the coal reserves"*. This is in stark contrast to the seminal contributions by Wrigley (1988) and Pomeranz (2000) who attribute coal a key role in their explanations of the British industrial revolution. The role of coal is also central in the explanation proposed by Allen (2009). That access to coal was an important factor for the growth of European cities has recently been confirmed by Fernihough and O'Rourke (2014) using a difference-in-difference identification strategy for a sample of European cities from 1750 to 1900. Other empirical studies which relate the factor endowment of coal to the location of coal intensive industries, using the approach proposed by Midelfart-Knarvik et al. (2000), find mixed results. Crafts and Mulatu (2005) find a strong positive relationship between coal supply and the location of energy intensive industries for late 19th century Britain while Klein and Crafts (2012) find no such evidence for 19th century United States.[5] The importance of coal as a location factor has, furthermore, been supported on the industry level for late 19th century Germany by Gutberlet (2012).

Even if the 'coal factor' is subject to much debate, both for the French as well as the British example, it is rather undisputed by the literature that the relative scarcity of coal has led to the slow penetration of the steam engine and the dominance of water power (Crouzet, 1996). The negative relationship between coal prices and the diffusion of steam engines as well as a wider diffusion within coal mining regions has quantitatively been supported for the English case by Nuvolari et al. (2011). It would, however, be wrong to see French producers as passive adopters of existing technologies. France took the lead in improving water technologies in the early 19th century. J.V. Poncelet who invented an undershot water-wheel with curved vanes in the 1820s and B. Fourneyron who patented the prototype of modern turbines in 1832 are prominent examples for the active role France played in technological improvements of power technologies (Mokyr, 1990, p.92). This in mind it is unconvincing to interpret French entrepreneurs as technologically inactive and conservative as it is argued by the retardation view. By solely focusing on rational behaviour of economic agents the debate between 'retardationists' and 'revisionists' misses a key aspect of understanding French economic development. Even if economic agents act rationally within their *exogenously given* economic environment it is still important to understand the constraints and discuss to what extent they can be seen as exogenous. Applying this thought to the dominance of water technology in French industrialisation we

[5] Applications of the Midelfart-Knarvik et al. (2000)-approach have become quite numerous so it should be noted that this only represents a small selection. See section 2.2.3 for a more comprehensive review of the literature.

need to understand the consequences of this choice of power technology for French economic development. The existing literature identifies three key features of French industrialisation which are related to the choice of water power: small firm size; geographical dispersion of industry; slow urbanisation. Crouzet (1996, p.41) states: *"Water power contributed to the small size of firms, geographical dispersion and rural location in French industry."* And Cameron (1985, p.14) argues that *"the characteristics of water as a source of power imposed constraints upon its use. The best locations were generally remote from centres of population; the number of users at any given location was limited to one or a very few; the size of the installations was similarly limited. Thus, important though water power was for French industrialization, the resulting pattern included small firm size, geographical dispersion of industry and slow urbanisation, characteristics displayed also by other coal-poor industrial nations."*[6] To what extent power choice contributed to these features of French industrialisation has not yet been investigated empirically.

The first power source related feature, firm size, is a key argument in the 'retardation' literature and is most often linked to Landes (1949). His argument, however, was criticised by O'Brien and Keyder (1978, p.178) arguing that *"the techniques of production and the scale and form of industrial organisation found operating in French industry for much of the nineteenth century were in most cases well adapted to the demands that confronted industrialists in that country"*. Nye (1987) supports the argument of O'Brien and Keyder (1978) by finding only low estimates of returns to scale in 1860 France. Increasing firm size would not have been rational for the majority of French industries. This finding has been challenged by Sicsic (1994) who finds evidence of increasing returns to scale in small scale industries as well as the woolen industry, cotton spinning and glass and paper mills. A more recent contribution to this debate, Doraszelski (2004), finds less support for increasing returns to scale for the 1860s and so supports Nye's (1987) findings. However, for the first half of the 19th century, using the industrial census of the 1840s, Doraszelski (2004) identifies increasing returns to scale for some industries. He concludes that French industries faced unexploited scale economies during the first half of the 19th century but that these benefits from increasing firm size have vanished by 1860. Even though this literature is not focused on the relationship between power choice and firm size it can be concluded that even if water-powered firms were smaller they would not have benefited from expansion at least in 1860.[7] The relationship between small firms and power choice has been investigated more directly for the US economy during the second half of the 19th century. Atack et al. (2008) finds that the productivity of steam power increased with firm size both in absolute terms and relative to water power. Hence, firms' incentives to prefer steam power over water power increased when they ought to increase the scale of production. They hypothesise that this relative productivity decline of water power with increased firm size is due to lower relative gains from division of labour.[8]

[6]The comment by Cameron (1985, p.14) that *"the best locations were generally remote from centres of population"* refers to the fact that the best locations for water power had access to fast flowing streams of mountainous regions which are usually rather remote areas.

[7]Nye (1987) presents some of his returns-to-scale coefficients for steam and water powered firms separately finding no evidence of returns to scale for water-powered firms.

[8] *"Economies of scale arising through an enhanced division of labor as a consequent of the application of powered machinery were difficult to capture through traditional waterpower which was not as reliable as steam and which faced significant rising marginal costs of use as output increased compared with steam."* (Atack et al., 2008, p.197).

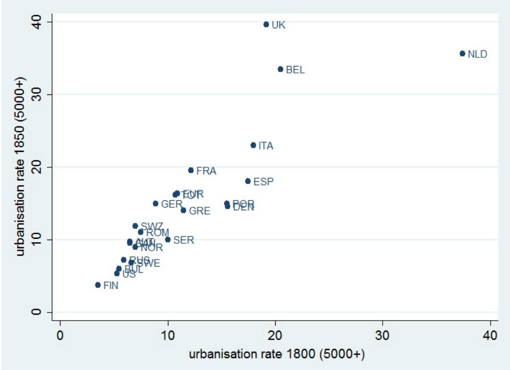
Besides firm size water power can also affect economic development through alternative mechanisms. Crouzet (1996) and Cameron (1985) relate geographical dispersion of industry and slow urbanisation/rural location as distinct features of French industrialisation which can be devoted to the dominance of water power. There is no empirical research for France which links geographical dispersion and urbanisation to power choice. For late 19th century Germany Gutberlet (2014) investigates the relationship between power choice and the spatial concentration of industry. She finds evidence that the transition from water power to steam power was associated with the building of spatial industrial clusters. In the period 1875-1895 a more intense use of water power was associated with a decrease in the spatial concentration of industry while an increase in the intensity of steam power use was associated with increased spatial concentration for the whole period of 1875 to 1907. That the increase in spatial concentration stimulated economic development through exploiting agglomeration externalities has been suggested but not empirically investigated. With respect to the relationship between power choice and rural/urban location an important empirical contribution is Kim (2005). He investigates the preferences of urban and rural location for steam, water and animate-powered firms for the late 19th century US economy. The main motivation is whether the rise of urbanisation can be attributed to the growing importance of steam power relative to alternative power sources. This can be seen as a response to Rosenberg and Trajtenberg (2004) who argue that the Corliss steam engine freed industrial production from the land and fueled urbanisation. Kim (2005) finds that steam-powered firms were between 8.7 (1850) and 4.3 (1860-1880) times more likely to locate in cities than water-powered firms but steam-powered firms were more likely to locate in rural regions than hand-powered firms. In spite of this urban preference of steam relative to water the net overall contribution of steam to urbanisation was negligible. Urbanisation in the US during the second half of the 19th century was fueled by a shift from artisan to factory production and only to a lesser extent by a shift from water power to steam power.

Based on the discussion of the academic literature and quite closely derived from Crouzet's (1996) and Cameron's (1985) hypotheses this article empirically investigates the following research questions: *"Is water power associated with rural locations while steam power is associated with urban locations? Did the dominance of water power over steam power in French industrialisation act as a constraint for economic development through its limits to form urban agglomerates?"*

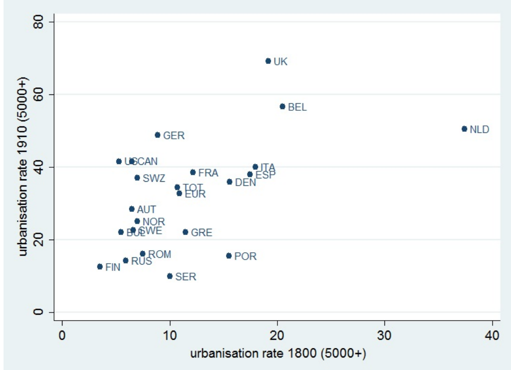
After having reviewed the historiography of French 19th century economic development as well as the role of power generating technologies, the next part of this section reviews the relationship between urbanisation and industrialisation. As the above hypothesis suggests a link between power choice, urbanisation and industrialisation it is important to understand the patterns of French urbanisation during its period of industrialisation.

4.2.2 Urbanisation & Industrialisation

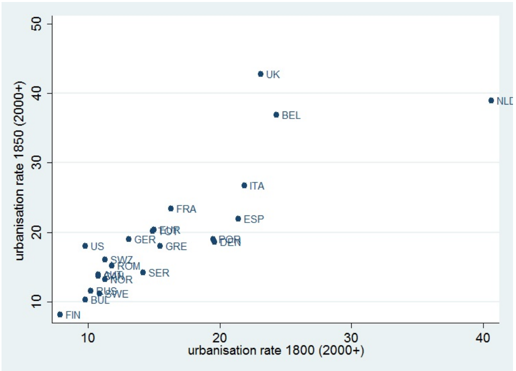
The low degree of urbanisation is a key feature of the French economy and is traditionally contrasted with the high degree of urban development in Britain. Kindleberger (1964, p.248) emphasises the economic importance of urbanisation and asks if French economic growth was held back by a lack of urbanisation. Already at the start of the 19th century



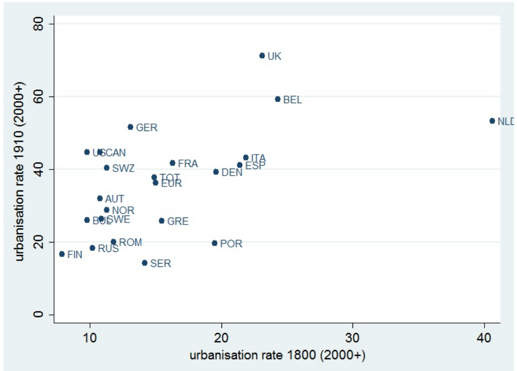
(a) 1800-1850 (5,000+)



(b) 1800-1910 (5,000+)



(c) 1800-1850 (2,000+)



(d) 1800-1910 (2,000+)

Figure 4.1: Urbanisation rates in 1800, 1850 and 1910

Notes: Urban population is specified as cities with more than 5,000 inhabitants in figures (a) and (b) and more than 2,000 inhabitants in figures (c) and (d).
Source: Bairoch and Goertz (1986).

the differences between France and Britain were substantial and the gap increased rather than declined during the 19th century. According to Kindleberger (1964, p.248) 9.5% of the French population lived in cities with more than 10,000 inhabitants in 1801 while it was 23.3% in Britain. In 1851 the gap increased as 10.6% (14.5% according to Le Mée (1989)) of the population lived in cities with more than 10,000 inhabitants in France while it was 39.5% in Britain. Assessing the French 19th century urbanisation within a broader sample of economies, based on the dataset of Bairoch and Goertz (1986), it can be seen that independent of the urban classification (2,000+ or 5,000+ inhabitants) French urbanisation levels stayed close to the sample mean throughout the 19th century - see figures 4.1b and 4.1d. In 1800 the French economy was less urbanised than the North Western economies of the UK, Belgium and the Netherlands as well as the Mediterranean economies of Portugal, Spain and Italy. By 1850 France overtook Portugal as well as Spain and remained only narrowly behind Italy. However, urbanisation rates of more than 30% like in North-Western Europe could not be achieved by quite a substantial margin - see figures 4.1a and 4.1c. When extending the comparison from 1850 to 1910 it can be seen that a couple of economies which were well behind France in 1800 as well as in 1850 either overtook French urbanisation levels (Germany, US and Canada) or closed the gap (Switzerland)- see figures 4.1b and 4.1d. Hence, even if France went through a period of urbanisation during the second half of the 19th century it could not close the gap to North-Western Europe or follow economies like Germany and North America.

Table 4.1: French urbanisation rates between 1806 and 1901

Le Mée (1989)		Kindleberger (1964)	
1806	18.6%	1851	25.5%
1831	20.5%	1861	28.9%
1836	21.4%	1872	31.1%
1841	22.5%	1881	34.8%
1846	24.4%	1891	37.4%
1851	25.5%	1901	40.9%

Notes: Urbanisation is defined as communes with populations of more than 2,000 inhabitants.
Sources: 1806-1851 (Le Mée, 1989, p.328); 1851-1901 (Kindleberger, 1964, p.253).

Looking at French 19^{th} century urbanisation in more detail, table 4.1 shows the development of urbanisation rates with a 2,000 inhabitant criterion of urbanisation from 1806 to 1901. France underwent a continuous process of urbanisation more than doubling its urban share of the population from 18.6% in 1806 to 40.9% in 1901. Urban growth during the 19^{th} century is described as being fundamentally different comparing the first and the second half of the century. Clout (1977, p.528) argues that even though the urban population grew faster than total population between 1801 and 1851 (60% urban population growth vs. 36% total population growth), it probably was slower than before the Revolution. The second half of the century, however, is described as an *urban revolution* with 75% growth in the urban population between 1851 and 1901 but only 9% in the total population. Urban growth was disproportionately stronger in large cities compared to small cities. The period of the *urban revolution* is also associated with the term *rural exodus* which describes a progressive rural depopulation during the second half of the 19^{th} century (Merlin, 1971). The rural population peaked in 1861 at the national level but the pattern of rural depopulation can be traced back to much earlier dates if we look at the regional level. In the Massif Central, for instance, depopulation occurred already during the period 1821-1846 (Planhol, 1994, p.395). Explaining the *rural exodus* is complex and multidimensional and determinants range from effects of the demographic transition, the railroad boom to improvements in agricultural productivity.

During the first half of the 19^{th} century the principal determinant of urbanisation was industrialisation. Planhol (1994, p.402) states that *"out of the thirty largest towns in France, not counting military ports (Brest, Toulon), it was the industrial towns (Saint-Etienne, Limoges, Rheims) which developed the most rapidly - even faster than more complex major cities (Marseilles, Toulouse, Metz)"*. More specifically, textile centres like Roubaix, Mulhouse, Tourcoing or Saint-Quentin were among the fastest growing cities. Also during the second half of the century industrialisation remained a key driver of urbanisation but the industries affected became more diverse including metallurgical industries and coal mining. In spite of emphasising the role of industrialisation as a determinant of urbanisation Planhol (1994) warns from exaggerating its effect as the effect of industrialisation on urbanisation was much less severe than in other countries.

Why was the process of French urbanisation rather slow? A prominent explanation for low levels of urbanisation and also industrialisation is related to the agricultural sector and peasant farming in particular. O'Brien (1996, p.228) argues that *"the institutions* *and culture of peasant agriculture in France operated to restrain the outflow of people from countryside to towns and from agriculture to industry"*. The French agricultural sector had considerable lower levels of labour productivity than the British agricultural system of large-scale, capital-intensive farming (O'Brien and Keyder, 1978). The existence of large sectoral labour productivity differences would suggest a similar gap in wages. Sicsic (1992), however, argues that the farm-city wage gap was not large enough to support the hypothesis that industrialisation was impeded by reluctant farm labour. This suggests that urban-industrial producers did not face labour shortages from peasants' resistance to migrate. An alternative explanation has been suggested by Heywood (1981) who argues that weak industrial demand for agricultural labour can explain the differences between gaps in wages and productivity. This interpretation is in line with Crouzet (1996) who sees the problem in skill mismatch rather than a supply shortage: *"labour from the countryside was not suitable for factory production and there was a chronic shortage for skilled labour"* (Crouzet, 1996, p.53). With respect to sectoral labour productivity, Magnac and Postel-Vinay (1997, p.24) further show that the French labour market was quite mobile between the agricultural and industrial sector with *"about 25% of the industrial labor force moving from one sector to another during the summer in the middle of the nineteenth century"*. Overall, it is not clear to what extent the structure of the agricultural sector was an obstacle to French economic growth or limited urbanisation. To isolate effects on urbanisation is not always easy as the literature does not differentiate between urban-rural and industrial-agricultural. However, French industrialisation, in particular, shows a strong component of rural industrialisation which, as we have hypothesised, can be related to the dominance of water power. If water power is bounded to rural locations and steam is assumed to be more mobile, low levels of urbanisation might also be driven by the French focus on water power as Crouzet (1996) and Cameron (1985) have argued.

This section has clarified that French industrialisation was characterised by slow urbanisation. This holds, in particular, if Crouzet's (1996) timing that France industrialised before 1860 is accepted. The previous section has shown that in 1860 water power was still the dominant power source in the French economy. The subject of the next section is to give some theoretical background of how urbanisation can stimulate economic development.

4.3 Potential mechanisms of Benefits of Urbanisation

The idea that urbanisation can have positive effects for economic development is not new and has already been discussed by Adam Smith (1776) who emphasised positive efficiency gains from increased division of labour. About a century later Marshall (1890) analysed the question of why industries agglomerate in space. Since then a growing literature on agglomeration economies emerged in which Marshall (1890) is still a seminal reference point and Marshallian agglomeration externalities are often used to discuss urban clusters.[9] Based on Marshall (1890) urban agglomeration economies arise from three factors: labour-market interactions, linkages between intermediate- and final-goods suppliers, knowledge spillovers. More recently, a new analytical framework to classify agglomeration economies

[9]See Crafts and Klein (2015) for a recent contribution of using Marshallian agglomeration externalities to explain labour productivity growth in US cities from 1880 to 1930.

has been proposed by Duranton and Puga (2004) who argue that Marshallian agglomeration externalities are often theoretically not distinguishable. The classification proposed by Duranton and Puga (2004) distinguishes between three mechanisms: *sharing*, *matching*, *learning*. These mechanisms describe how urban agglomeration leads to higher levels of productivity which is understood as the underlying cause why firms locate in urban agglomerates in the first place. Locating in cities, however, also comes at a cost, like higher unit labour costs and rents. The existence of cities is, therefore, seen as the outcome of a trade-off between urban congestion cost and urban agglomeration benefits. Firms will only locate in cities if agglomeration benefits outweigh urban congestion costs. In order to understand the interdependence between urbanisation and industrialisation we have to understand agglomeration economies in more detail.

The first mechanism of the classification proposed by Duranton and Puga (2004) is *sharing*. This mechanism is quite multidimensional in itself. Sharing can cause urban agglomeration economies through four channels. Firstly, increasing returns at the city level can emerge due to the sharing of facilities which are characterised by high fixed costs. The larger the population which shares the facility the lower the cost per user will be. This can be related to sharing of local public goods, production facilities or the role of cities as markets of exchange. Secondly, sharing can emerge at the level of intermediary inputs where agglomeration economies emerge through the *"productive advantages of sharing a variety of differentiated intermediate inputs produced by a monopolistically competitive industry a la Chamberlin (1933)"* (Duranton and Puga, 2004, p.2069). Thirdly, gains from urbanisation can stem from *sharing the gains from individual specialisation*. This mechanism is inspired by Adam Smith's (1776) famous pin factory example. Agglomeration economies can be created through a positive specialisation stimulus of a larger market. Fourthly, sharing can occur at the labour market via labour pooling. This mechanism is closely linked to the Marshallian externality of labour-market interactions which emphasises the advantage of having access to a constant market for skill in an urban environment.[10]

The second mechanism is *matching* and argues that matching costs between employers and employees or buyers and suppliers are lower in more densely populated areas. The theoretical literature of matching within an urban environment has identified two mechanisms how matching can cause urban agglomeration. The first mechanism is related to the quality of matches arguing that the expected quality of matches increases with the number of agents trying to match. A second mechanism argues that the probability of matching increases with the number of agents trying to match. These two mechanisms can also be combined such that a higher probability of matching in urban environments allows for a greater flexibility and increases the average quality of matches.

The third mechanism of the three dimensional classification of Duranton and Puga (2004) is *learning*. That learning is a key agglomeration factor in cities has been emphasised by Jacobs (1970). She argued that knowledge is generated within a diversified urban environment which facilitates the search and experimentation process of innovation. This idea has been formalised by Duranton and Puga (2001) showing that young firms tend to locate in more diversified cities compared to more established firms which located in

[10]Based on Marshall's idea of labour market pooling as a source of agglomeration, Krugman (1991c) built a model in which agglomeration emerges because firms can respond to idiosyncratic shocks more efficiently in locations with large concentrations of employment.

specialised cities, as young firms benefit from urban diversity during a trial-and-error phase until they have reached their full potential. Apart from facilitating knowledge generation it is, furthermore, argued that knowledge diffusion is stronger in urban environments. Following the concept of external human capital by Lucas (1988), firms and workers acquire skill and knowledge faster in cities due to greater proximity to greater skill and knowledge.[11]

Based on the theoretical concepts proposed by Marshall (1890) and refined by Duranton and Puga (2004), a large empirical literature with the objective to quantify agglomeration economies has evolved.[12] However, the empirical literature which assesses to distinguish empirically between the various channels through which agglomeration economies emerge is comparably small. Studies range from analysing agglomeration effects on labour mobility (Freedman, 2008; Wheeler, 2008; Bleakley and Lin, 2012), the quality of matches (Andersson et al., 2007; Figueiredo et al., 2014), division of labour (Duranton and Jayet, 2011; Kok, 2014) to knowledge spillovers (Serafinelli, 2015). Historical studies on the 19th century are even rarer and, up to my knowledge, have been mainly focused on the United States. Kim (2006) emphasises the importance of division of labour and matching costs as a mechanism of benefits of urban agglomeration during the 19th century. Also on the United States, Bostic et al. (1997), on the other hand, finds no positive urbanisation effect on productivity growth. Based on a sample of U.S. cities from 1890 to 1920, Crafts and Klein (2015) emphasise the importance of Marshallian externalities while Jacobian externalities only played a significant role in large cities and had a negative effect on productivity growth in smaller cities.

4.4 Data & Descriptives

4.4.1 Sources

The main data source for this analysis are two industrial censuses of mid-19th century French industry which have been harmonised with respect to industry classifications by Chanut et al. (2000). These two censuses have been collected during the periods 1839-47 and 1861-65 on a detailed industry and regional level. The first industrial census of 1839-47 was originally designed to cover only establishments with more than 20 employees which was later reduced to establishments with more than 10 employees (Gille, 1964). Results are reported on the establishment level but additionally the census contains 'collective' entries which cover firms below the 10 worker thresholds. The second industrial census of 1861-65 was intended to cover the whole of French industry and lists results by French arrondissement and industry. Even though the two censuses show differences in their collection strategy they have been assigned good quality and comparability, in particular, for mid-19th century censuses (Chanut et al., 2000; Doraszelski, 2004).

Both censuses report information on the number of establishments, number of male, female and child workers, their respective daily wages, the value of production, the value of inputs, an indication of the capital stock and the motive power used.[13] Additionally, the

[11] The article by Glaeser (1999) which emphasises the interaction between skill acquiring workers and experienced workers is a key contribution to this literature.

[12] See Combes and Gobillon (2015) for a recent survey of the literature.

[13] Following previous empirical research using these two early French censuses the capital stock is measured as the tax base *(valeur locative)* in the first census and a measure of market value *(valeur venale)* in

first industrial census reports information about the commune in which the establishment is located and the second industrial census gives an indication for seasonal employment by reporting the months during which the establishment operated. With respect to the type of motive power it should be noted that the first industrial census reports solely the number of motors differentiating between power from water, wind, steam and animals, while the second industrial census reports also the horse power of these categories. In spite of this shortcoming these two early industrial censuses give unique insights into the power choice of French entrepreneurs at the industry and regional level.

The coverage of the two censuses differs with respect to regions and industries. Industry categories have been harmonised by Chanut et al. (2000) building consistent aggregates of 16, 52 and 82 industries which have been formed based on matching the 1839-47 establishments to the 810 individual industries of the second census. In order to limit the degree of heterogeneity within industry aggregates but still ensuring a sufficient number of observations a sample of 52 industries has been chosen as the baseline classification for this research. Table B.16 gives an overview over the industries which are covered. From this classification all 'other' categories are excluded from the sample in order to ensure within-industry homogeneity.[14] The regional coverage differs with respect to the expansion of the French territory and the cities of Paris and Lyon. While the city of Paris is not covered in the first industrial census, the city of Lyon is not reported in the second industrial census. Moreover, the departments Alpes-Maritimes, Corse, Savoie and Haute-Savoie are only covered in the second industrial census. This reduces the sample to 359 arrondissements within 86 departments. Tabel B.15 lists the departments with the number of arrondissement for each department. The baseline sample consists of 2 time periods, 47 industries and 359 regions. Apart from consistency between industrial censuses with respect to regional coverage and industry classification the sample is reduced due to individual entries as well. Observations on the establishment level (first industrial census) and the arrondissement level (second industrial census) are excluded if they report no information on any of these categories: number of establishments, total number of workers, value of production, material input, capital stock.

The data from the two industrial censuses are augmented by information on urban population. The primary data source is Le Mée (1989) presenting city level population figures from the French population censuses of 1806, 1821, 1831, 1836, 1841, 1846 and 1851 for each department. For the first industrial census firm level entries can be linked to specific cities, while for the second industrial census the differentiation between rural and urban has to be performed at the regional level. Whether a firm is located in a rural or urban region is assessed at the level of the arrondissement. Cities are matched to the boundaries of arrondissements and combined with total population to calculate urbanisation rates. Total population by arrondissement is derived from population censuses.[15] At which size a commune is classified as urban is always subject to debate. I follow the previous literature and use thresholds of 2,000, 5,000 and 10,000 inhabitants to specify urban locations.

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the second census (Doraszelski, 2004).

[14] The excluded industries are 'Other Textiles' (CODB3000: 3901); 'Other iron products' (3904); 'Diverse building materials' (3909); ' Other clothing' (3912); 'Other food products' (3913).

[15] Population figures have been derived from L'Atelier du Centre de recherches historiques (2011b) for the period 1806 to 1836 and from L'Atelier du Centre de recherches historiques (2011a) for the censues between 1836 and 1866.

In the year 1851, for instance, 165 cities with more than 10,000 inhabitants are located in 139 urban regions resulting in 224 remaining rural regions. For the period after 1851, population census publications only report city level population figures for cities above 10,000 inhabitants. However, the project *cassini.ehess.fr* has collected municipality level population figures for the period 1793 to 2006 (Motte and Vouloir, 2007).

4.4.2 Variables

The two industrial censuses of 1839-47 and 1861-65 give the opportunity to differentiate between four types of motive power used by French firms: steam, water, wind, animate power. As it has been outlined above, the two censuses are not necessarily comparable without alterations. With respect to power sources the most important difference is that the first census reports only the number of motors and does not give any information on horsepower. To assess the average horsepower by motive power source two alternative approaches are used. On the one hand, averages can be assessed based on the secondary literature and selected primary sources. Based on the average of the Belgian industrial census of 1846 which reports both the number as well as the horsepower of steam engines - see Belgique (1851, p.X-XIII) - the average horsepower of a steam engine can be assumed to be 24. Unfortunately, the Belgian industrial census only reports the number of water and wind mills but not their horsepower. The average horsepower of a water mill is set at 10 which follows Kanefsky (1979, p.220) who assesses the average for the UK in 1800 between 8 and 12 HP per water mill. Based on the same source the average horsepower of a windmill is assumed to be 5 which already takes into account the shorter work-day of a wind mill compared to water and steam (Kanefsky, 1979, p.227). On the other hand, averages can be assessed based on the second industrial census which lists both the number and horsepower of power sources. The averages from the second census tend to be lower: water 5.6 HP, wind 3.5 HP and steam 16.1 HP (France, 1873, p.XIX-XX). The horsepower per horse mill is set at 1.4 for both scenarios which has been derived from the second French industrial census assuming that the average HP per horse mill stayed constant - see France (1873, p.XIX-XX). Whether results change due to different assumptions with respect to the average HP per power source will be subject to a robustness test. The estimates based on the second industrial census are the baseline scenario for the following analysis as they can be interpreted as lower bound estimates.

After having harmonised the two censuses with respect to power sources, a measure is needed which allows to identify power-choice related urban-rural preferences. The individual observations are grouped into steam-powered, water-powered and a residual category which includes wind-powered, animate powered firms as well as firms which use a combination of different power forms. I differentiate between three specifications. Firstly, a binary dummy variable specification can be used to identify firms which have adopted steam or water power. This specification, however, faces a severe identification problem as firms used multiple power sources simultaneously. A firm might be identified as steam-powered even though the steam engine installed represents only a minor share of total power consumed. Hence, the second approach tries to identify the primary motive power based on the share of each power source. Two cut-off points (τ) are chosen at which an observation is specified as being dominated by a specific type of power: $\tau = 0.5$ and $\tau = 0.75$.[16] Observations which use one specific type of power intensively - relative share greater than 50% or 75% - are assigned a value of 1 for the specific power type and 0 otherwise.[17] This specification is flexible enough to include also those observations not reporting any form of power use which can be understood as hand-powered firms. Alternatively, a continuous framework by measuring power-choice based on horsepower by worker, $steam_{HP}/worker$ and $water_{HP}/worker$, is used.

The specification of urban character of firm locations depends on the census period. In the 1840s the industrial census allows to relate urban or rural status to observations at the sub-arrondissement (commune) level. For each observation, which is covered by the city population register of Le Mée (1989), the population is available. For the second industrial census urbanisation needs to be specified at the regional level of arrondissements. This is also the highest possible level of disaggregation which is consistent across both censuses, as the second industrial census only provides aggregates at the regional level of arrondissements. Nevertheless, the level of regional disaggregation remains fairly high and heterogeneity between urban and rural arrondissements is substantial. An arrondissement (r) is classified as urban if it contains a city (s) of at least 10,000 inhabitants in the population census of 1841, for the first industrial census, and 1861, for the second industrial census.[18] This criterion yields 139 urban arrondissements and 224 rural arrondissements. As a robustness check a 5,000 city size criterion is used based on the 1806 population census. An arrondissement is urban if it contained a city of at least 5,000 inhabitants in 1806.[19] The two criteria complement each other as 95% of cities with more than 10,000 inhabitants in 1841-1851 had more than 5,000 inhabitants in 1806. Hence, by adding those cities which did not reach the 10,000 threshold by 1851 the sample is made more robust as cities are considered which did not grow as quickly during the first half of the 19th century. Along with the 10,000 threshold criterion a 5,000 or 2,000 population criterion is applied at the commune level. Similar to the classification above, urbanisation can either be specified as a dummy variable or as a continuous variable.

Apart from the type of power source and urbanisation, labour productivity across firms and industries as well as the workers' wages are of interest in order to analyse the effects of urbanisation and power choice on French economic development. Labour productivity is measured as nominal value added divided by male equivalent employment. Using male equivalent employment follows Sicsic (1994) and Doraszelski (2004) who have analysed these early industrial censuses to assess economies of scale. Male equivalent employment (L_{irt}) is calculated as a weighted sum of male, female and child employment applying relative male wages as weights. Following Sokoloff (1984, 1986) labour input is adjusted for under-reported entrepreneurial labour by adding 1 to the labour index at the firm level

[16]Identification at 100% of power shares would reduce the observations considerably, especially for steam power during the first industrial census.

[17]$Steam_D = 1$ if $\frac{steam_{HP}}{power_{HP}} > \tau$; 0 otherwise
$Water_D = 1$ if $\frac{steam_{HP}}{power_{HP}} > \tau$; 0 otherwise

[18]Binary specification of urban arrondissements using the 10,000 inhabitants threshold: $urban_{D10,r,t} = 1$ if $POP_{sr,t} > 10,000$; 0 otherwise

[19]Binary specification of urban arrondissements using the 5,000 inhabitants threshold: $urban_{D5,r} = 1$ if $POP_{sr,1806} > 5,000$; 0 otherwise

and the number of establishments at the regional level.[20] As an additional measure of interest the nominal male wage is reported for all specifications.[21] The remaining key variable is firm size which is a simple measure of employees by establishment using either total employment or the above labour input measure as the numerator and the number of establishments as the denominator. Firm size will be used as a continuous variable as well as a dummy variable specifying a firm with more than 15 employees as a factory.[22] In addition to firm size, the main control variables will be a measure of the capital labour ratio ($KL_{irt} = K_{irt}/L_{irt}$) and the share of female and child employment (female $\text{Lsh}_{irt} = EMP_{f,irt}/EMP_{irt}$; child $\text{Lsh}_{irt} = EMP_{ch,irt}/EMP_{irt}$).

4.4.3 Descriptives

The summary statistics are presented in tables B.13 for the period of the first industrial census and table B.14 for the period of the second industrial census (appendix). It shows the richness of the dataset for both periods. The dataset is quite evenly distributed across urban and rural observations. The mean of the urban dummy variable ($urban_{D10}$) is close to 0.56 for both periods. With respect to different power sources the dominance of water power is clearly visible. During the 1840s 30% of all observations used water as their primary source of power while it was only 10% for steam. In the 1860s steam and water power are almost on par within the industrial sector if it comes to primary power source.[23]

With respect to firm size it seems as if the first industrial census was, indeed, less complete than the second industrial census. The mean size of establishments decreased from 59 in the 1840s to 37 in the 1860s. Moreover, while 55% of the observations had more than 15 employees in the 1840s this figure decreased to 33% in the 1860s. Hence, either French industry became more oriented towards small-scale production or the second industrial census was more complete in collecting information on small establishments. The discussion of the industrial censuses in Chanut et al. (2000) and Gille (1964) suggest the latter. As a consequence, all specifications include time fixed effects if the two industrial censuses are pooled, in order to control for differences in collection. Moreover, estimation results will also be reported for the two periods separately. That the two censuses are comparable is supported by looking at the distribution of firm size more closely. The distribution among firms below 20 workers, which was the official cut-off point at the beginning of the first census, is very similar across both censuses - see figure B.1a. When

[20] Male equivalent employment: $L_{irt} = EST_{irt} + EMP_{M,irt} + EMP_{F,irt} * \frac{w_{F,irt}}{w_{M,irt}} + EMP_{CH,irt} * \frac{w_{CH,irt}}{w_{M,irt}}$. Labour productivity: $LP_{irt} = (Y_{irt} - M_{irt})/L_{irt}$

[21] The wage listed in the industrial censuses is the daily wage paid and does not reflect annual labour costs. As employment information reflects the situation at the time the census was taken and does not account for seasonal unemployment the annual labour costs cannot be easily estimated. Seasonal unemployment affects both the wage rate as well as the labour productivity measures. Potential biases from seasonal unemployment are, however, reduced by controlling for industry specific characteristics. Industry fixed effects control for seasonal unemployment at the industry level. The importance of regional differences of within industries can be assessed only for the second industrial census which indicates the months during which the firm operated.

[22] Continuous specification: $size_{irt} = L_{irt}/EST_{irt}$. Dummy variable specification: $factory_{irt} = 1$ if $size_{irt} > 15$; 0 otherwise. Using this factory specification follows the research by Atack et al. (2008) and Kim (2005, 2006) on the US industrial censuses during the second half of the 19$^{\text{th}}$ century. However, it has to be emphasised that a firm with 30 employees can be structurally very different from a firm employing 250 workers.

[23] Primary power source refers to the dummy variable steamD75 or waterD75 which uses $\tau = 0.75$ as the cut-off point - see section 4.4.2.

looking at the distribution of firm size with restricting the sample to observations with less than 100 workers per firm the source for the differences in the mean can be seen - see figure B.1b. As expected, the second industrial census contains much more observations at the lower end of the firm size distribution. Except for this rise in observations below 10 workers the within distribution, however, does not change.[24]

The dataset can be described as appropriate to analyse questions on power source, urbanisation and labour productivity. Observations show a large enough variation in urban vs rural locations and power use. It reveals not only a significant variation in the type of power sources used within each census but also shows a changing pattern across time. Studying effects between water and steam powered observations seems to be valid in particular. It can be concluded that these two early industrial censuses are of remarkable detail and quality given the time and scope they were collected.

4.5 Power choice and urbanisation

4.5.1 Empirical framework

The empirical specification used to answer this research question initially follows Kim (2005) who uses a discrete choice model to analyse whether steam power contributed to urbanisation in the US during the second half of the 19$^{\text{th}}$ century. By doing so, a logit regression model with a binary urban dummy variable as a dependent variable and dummies for steam and water power as independent variables is applied. It identifies the determinants' probabilities to be located in an urban rather than rural commune. The French data allow to further expand Kim's (2005) analysis. Both urbanisation and power choice can be measured as continuous variables. This is a major advantage, of the first census in particular, as the assumption of conditional homogeneity among observations can be lifted. The nature of the underlying dataset allows for analyses at different levels of disaggregation. For the first industrial census it is possible to identify urbanisation at the commune level. Unfortunately, the second industrial census does not report observations at this detailed spatial level such that differences between urban and rural locations have to be identified at the regional level of arrondissements.

Equation 4.1 shows the main binary specification with the probability P_i for a representative firm in industry (i) to be located in an urban area. In order to control for unobserved location effects the specification includes departmental fixed effects which are allowed to vary across time (π_{dt}) if both censuses are pooled. For the identification of location choice this implies that only within departmental variation is exploited. Hence, the firm's location choice is whether to locate in an urban or rural arrondissement within the same department. The same specification is also applied to the commune level for the first census. This limits the effects from factor-endowment related determinants across departments. Moreover, industry fixed effects, which are allowed to vary across time as well (η_{it}), control for unobserved industry specific preferences for urban/rural locations. This limits

[24] Given the fact that small firms might be less likely to adopt steam engines it is important to discuss potential biases stemming from the census collection procedure. If there is additionally a rural preference of small firms, then the results might be upward biased in the 1840s sample. However, biases from firm size should be mitigated by including firm size as well as interaction terms between firm size and power source among the list of potential confounders.

identification to location choices within industries and within departments. Apart from time varying location and industry fixed effects we control for the share of female employment ($ln(EMP_{female,irt}/EMP_{irt})$), the share of child labour ($ln(EMP_{child,irt}/EMP_{irt})$) and firm size ($EMP_{irt}/EST_{irt}$, or $factory_{irt}$).

$$ln(P_{it}/(1-P_{it})) = \alpha + \beta_1 * steam_{irt} + \beta_2 * water_{irt} + \sigma * X_{irt} + \eta_{st} + \pi_{dt} + \epsilon_{irt} \quad (4.1)$$

$$ln(UR_{10}) = \alpha + \beta_1 * steam_{irt} + \beta_2 * water_{irt} + \sigma * X_{irt} + \eta_{st} + \pi_{dt} + \epsilon_{irt} \quad (4.2)$$

The next section will present estimation results from variations of equations 4.1 and 4.2 shedding light on the question whether water power was indeed associated with a more rural character of French industry. The analysis starts with studying the first census at the commune level after which the arrondissment becomes the main regional unit of analysis allowing a comparison between both census periods.

4.5.2 Results

Analysing firm level data from the 1840s

We start our analysis by focusing on the first industrial census which has the advantage of presenting firm level observations and stating the commune in which the firm was located. The disadvantage of the 1840s census is that motive power has been collected by the number of engines rather than their horsepower. Hence, assumptions regarding the relative horsepower intensity of different types of motive power are necessary - see section 4.4.2. The empirical strategy starts with replicating Kim's (2005) approach based on which a continuous specification will be developed. Table 4.2 shows the results of the first part of the exercise, estimating logit regression models based on the 2,000+ inhabitants definition of urbanisation. The specifications vary with respect to the measurement of motive power as well as the modeling of the relationship between firm size and power choice. Before interpreting the coefficients it should be noted that the omitted category includes firms which use any other form of power generation (wind power, animate power, hand power or a combination of various power sources). Specifications (1) and (2) of table 4.2 identify the primary power source at a 50% threshold level while specifications (3) and (4) use a 75% threshold level. Specifications (5) and (6) measure power by horsepower intensity using employment as the denominator. The coefficients of the logit regression models are presented in odd-ratios. An odd-ratio greater than 1 (smaller than 1) is evidence for a firm being more likely to be located in an urban (rural) rather than rural (urban) commune.

Table 4.2 reveals a clear rural location preference of water powered firms in all specifications. Compared to firms which are not primarily powered by steam or water, water powered firms are between 2 (specification 3) and 2.5 (specification 1) times more likely to locate in communes with less than 2,000 inhabitants. Also in the logit framework which uses continuous independent variables (specification 5 and 6), the rural preference of water power is identified. A firm which uses water power more intensively is more likely to have a rural location. With respect to steam power, the results are not as clear. However, there is a tendency for urban locations. Both in the 75% threshold specification and the steam-power-per-worker specification, steam power has a statistically significant urban preference. Moreover, changing the reference category to water power and reducing the sample to observations which have either been primarily powered by water power or steam power shows clear statistically significance for the urban preference of steam powered firms compared to water powered firms.[25] Apart from power source, the results also show a strong urban preference of factories and a strong rural preference of non-male employment (measured as female and child labour shares). A shift to the factory production system seems to be a dominant feature of urban production. Interestingly, the interaction terms between factory or firm size and power choice do not reveal a lot of additional insight. In the binary specifications (2) and (4) neither the factory interaction with steam nor with water power are detected as being statistically significant. Please note that both steam and water power remain jointly significant, at least for specification (4). Only in the continuous specification (6) the interaction with firm size indicates that the rural preference of water power increases with firm size. The argument that large steam powered firms drive urbanisation can not be supported from this evidence. One could argue that the definition of urbanisation is set too low and that communes with 2,000 inhabitants do not show enough urban characteristics. Therefore, a robustness test which uses a higher threshold of 5,000 inhabitants as the preferred criteria of urbanisation is applied. Table B.1 shows the results for this analysis in which, compared to table 4.2, only the definition of urbanisation is changed. The strong rural preference of water-powered firms and the strong urban preference for factory production is well supported. With respect to steam powered firms, changing the urban specification shows no clear indication, but if anything, the urban preference of steam is most likely associated with smaller rather than larger firms.

In a further step the binary specification of urbanisation is changed to a continuous specification using urban population. Table 4.3 shows the results for the fully continuous specification both from an OLS model (specifications 1 to 4) and a poisson model (specifications 5 and 6).[26] All specifications include industry and regional fixed effects. The findings that water power is associated with a more rural location as well as the positive association of firm size with urbanisation is again well supported, at least in the OLS specifications. The non-significance of firm size in the poisson specifications (5) and (6) is driven by very large firms. Once, the sample is reduced to firms with less than 500 employees, which is a reduction by only 1% of the sample (126 firms), the firm size coefficient increases to 0.069 and is statistically significant at the 1% level. In contrast to the binary specification, the continuous specification offers more support for the idea that steam power is directly linked to urbanisation. The interlinkages with firm size are again only relevant for water power but not for steam.

With respect to the quantitative significance of these factors, table B.2 shows the models' beta coefficients for the OLS specifications. It is clear that firm size and water power can explain much more of the variation in urban population than steam power. A one standard deviation difference in $ln(steam/L)$ is associated with a 0.03 standard

[25] In this specification the number of observations is reduced to 4,793 and shows an odd ratio for steam power in the 75% threshold specification of 2.91 which is statistically significant at the 1 % level. Adding an interaction term of firm size and steam power increases the non-interacted steam power coefficient to 3.24 at 5% statistical significance. The coefficient of the interaction term is again not statistically significantly different from zero.

[26] A poisson model is used to account for the count variable character of the dependent variable: urban population.

Table 4.2: Urban location (2,000+) and power choice (1840s; firm level)

	(1)	(2)	(3)	(4)	(5)	(6)
urban	2,000+	2,000+	2,000+	2,000+	2,000+	2,000+
power	D50	D50	D75	D75	HP/L	HP/L
size	factory	factory	factory	factory	L/EST	L/EST
steam	0.826	1.547	1.350*	1.911	2.786***	1.125
	(0.112)	(0.741)	(0.218)	(0.989)	(0.814)	(1.135)
water	0.404***	0.456***	0.499***	0.496**	0.145***	1.041
	(0.053)	(0.136)	(0.067)	(0.159)	(0.054)	(0.639)
steam × size		0.530		0.704		1.289
		(0.262)		(0.376)		(0.408)
water × size		0.878		1.007		0.376***
		(0.271)		(0.335)		(0.107)
size	3.446***	3.608***	3.210***	3.240***	1.407***	1.411***
	(0.716)	(0.880)	(0.665)	(0.771)	(0.082)	(0.085)
women/L	0.055***	0.055***	0.049***	0.049***	0.038***	0.042***
	(0.024)	(0.024)	(0.021)	(0.021)	(0.016)	(0.017)
children/L	0.034***	0.034***	0.029***	0.029***	0.022***	0.025***
	(0.017)	(0.017)	(0.015)	(0.015)	(0.011)	(0.012)
constant	6.207	6.143	5.852	5.854	4.472	4.473
	(9.108)	(9.069)	(8.543)	(8.552)	(6.242)	(6.310)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2	0.33	0.33	0.32	0.32	0.33	0.33
N	12,138	12,138	12,138	12,138	12,138	12,138

robust standard errors in parentheses; weighted by employment.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

deviation higher urban population and a one standard deviate difference in $ln(firmsize)$ is associated with a 0.16 standard deviation increase of the urban population, while a one standard deviation difference in $ln(water/L)$ is associated with a 0.094 standard deviation in lower urban population - based on specification (3). What is interesting, however, is that steam power is not associated, especially large steam powered factories, with larger urban populations - as can be seen in specification (5) and (6) which exclude rural communes from the sample. Reducing the sample shows that the main results from the previous exercises are driven by the rural urban divide rather than variation within urban communes. This is true for firm size but not for water power. Also among urban communes smaller cities are more associated with water power than larger cities. However, this is also true, though to a lesser extent, for steam power. Large water or steam powered firms are associated with smaller cities rather than larger cities. Apart from motive power and firm size determinants, table B.2 shows that the gender and age composition of the labour force is strongly connected to the urban-rural location of firms. Holding all the other factors constant, a firm is substantially less likely to be located in a city if a large fraction of its work force consists of women and children.[27] On the one hand, this effect might stem from gender and age differences in human capital, a mechanism which is discussed in the next paragraph. On the other hand, the gender and age composition effect might cover

[27] It should be noted that all specifications include industry fixed effects such that this effect is not merely an industry composition effect.

Table 4.3: Urban location (continuous) and power choice (1840s; firm level)

	(1) OLS ln(urban)	(2) OLS ln(urban)	(3) OLS ln(urban)	(4) OLS ln(urban)	(5) poisson urban	(6) poisson urban
steam	0.482	0.881**	1.391***	1.178	0.283**	0.060
	(0.428)	(0.426)	(0.431)	(1.528)	(0.113)	(0.388)
water	-3.479***	-2.452***	-2.195***	0.762	-1.177***	0.993**
	(0.441)	(0.467)	(0.477)	(0.843)	(0.314)	(0.391)
size		0.448***	0.549***	0.567***	0.032	0.038
		(0.084)	(0.087)	(0.089)	(0.024)	(0.024)
women/L			-5.111***	-5.026***	-1.263***	-1.168***
			(0.632)	(0.629)	(0.175)	(0.172)
children/L			-6.745***	-6.634***	-2.729***	-2.601***
			(0.811)	(0.812)	(0.264)	(0.264)
steam × size				0.065		0.068
				(0.479)		(0.128)
water × size				-1.406***		-1.688***
				(0.313)		(0.228)
constant	3.606***	2.799*	5.527***	5.529***	7.177***	7.309***
	(1.383)	(1.455)	(1.769)	(1.807)	(0.459)	(0.459)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2	0.37	0.38	0.40	0.41	-	-
N	12,034	12,034	12,034	12,034	12,034	12,034

robust standard errors in parentheses; weighted by employment.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: independent variables are log transformed. *steam* refers to the HP of steam engines per worker, *water* refers to the HP of water mills per worker and *size* refers to the number of workers per firm.

differences in the organisation of production such as the putting out system.

The specifications which have been presented so far use highly disaggregated fixed effects at the regional and industry level in order to control for omitted variable biases along with controls for firm size, female and children employment shares. One potential source for omitted variable biases, especially for steam technology, is human capital. Urban preferences of steam technologies could be due to the larger supply of skill in urban communes rather than rural communes. In order to control for this effect, table B.3 adds a measure for skill premiums to the logit, OLS and poisson benchmark specifications. Skill premium is measured as the wage premium of males over children working in the same firm. As not every firm employed children, so that no wage is available, the sample is reduced by half. Measuring human capital in terms of skill premiums incorporates not only formal education but also skills which have been acquired informally.[28] For each specification, the model which adds the measure of human capital is compared to the same specification without the human capital measure, but holding the sample constant. It can be seen that the effects on power technologies and firm size are minimal. Moreover, the hypothesised positive relationship between urban location and skill premium is found in the poisson

[28] See Rosés (1998) as an example for using earning differentials as a measure of human capital in analysing the development of the Catalan factory system during the 19$^{\text{th}}$ century.

specification. It is, however, important to note that the skill premium might be a *bad control* (Angrist and Pischke, 2008) due to the technology-skill complementarity of steam power. Franck and Galor (2017) argue that steam power, as a technology of early industrialisation, was conducive to human capital formation. Hence, the non-significance of the skill premium coefficient should be interpreted with caution.

So far, it has been identified that water power shows strong rural tendencies while large firms, irrespective of their source of power, are most likely to be located in cities. Steam powered firms are also associated with an urban tendency, though, steam as an urban location factor shows less economic significance and less consistency across model specifications. To gain insights whether these results, which hold at the aggregate level, also hold at the sub-industry level, I estimate model 3 from table 4.3 at the industry level. The approach is identical to the aggregate level as industries are sufficiently large and even sub-industry fixed effects can be considered to control for urban preferences of particular industries. Table B.4 shows the results for this exercise, in terms of standardised beta coefficients, for the following industries: textiles, metals (metallurgy and metal products), leather, ceramics, chemicals, building materials, food and beverages, paper and printing.[29] There are four industries which show urban preferences of steam powered firms. The rural preference of water powered firms, however, is more widespread (6 industries). An urban preference of large firms is shown in textiles, metals, leather and food industries. What is important to note here is that the textile industry as well as the food processing industry show the highest number of employees, why these two industries are very powerful in all employment weighted regressions. The textile industry shows the hypothesised pattern of a positive steam coefficient and a negative water coefficient. This pattern is also shared by the metals industry. The leather, ceramics and chemicals industries show a clear rural preference of water but no steam effect. With respect to relative strength of the explanatory variables it is quite clear that the aggregate picture is very well resembled by the textile industry. In the metals industries steam power is a more powerful explanatory factor than water power. What should also be emphasised is the firm size as a location factor which shows strong economic significance in the textile, metal and food processing industries. From the industry disaggregation it should be concluded that the rural preference of water power is a more widespread phenomenon than the urban preference of steam power. However, depending on the industry, steam power can also dominate water power as a location determinant. Therefore, the industrial composition and regional comparative advantages influence the urbanisation effects of power technologies.

To conclude the firm level analysis for the 1840s industrial census, the findings are used to estimate out-of-sample predictions. The advantage of this approach is to gain insights into the dependent variable's predicted change which is associated with particular independent variables. It should, however, be noted that this counter factual exercise assumes a constant relationship between urbanisation and the specific location factors. Being aware of this shortcoming, the partial equilibrium framework is, nevertheless, a useful exercise to understand the independent variable's explanatory power. Predicted probabilities are estimated based on the coefficient estimates of specifications (3) and

[29] This analysis is based on the traditional French census 16 industry classification. Only industries are considered which show a large enough number of observations in order to be able to include departmental fixed effects.

(5) in tables 4.2 and B.1. As starting points, employment sample means of urban firms (60% for the 2,000+ urban definition and 50% for the 5,000+ urban definition) are used as probabilities. The effect of steam power, water power and firm size is assessed by estimating predicted probabilities changing only one factor and holding all the other constant at their means. From these predicted probabilities the employment sample mean, as the starting probability, is then deducted in order to achieve the independent variable's effect on urbanisation.

Table 4.4: Predicted probabilities minus urban employment sample mean (1840s; firm level)

	(1)	(2)	(3)	(4)
urban	2000+	2000+	5000+	5000+
power	D75	HP/L	D75	HP/L
size	factory	L/EST	factory	L/EST
L sample mean	60%	60%	50%	50%
steam	+7%	+4%	+5%	+2%
water	-17%	-16%	-18%	-21%
size	+22%	+11%	+23%	+9%

Notes: Out-of-sample predictions based on coefficient estimates of specifications (3) and (5) in tables 4.2 and B.1.

Table 4.4 shows the results for this exercise based on the 2,000+ urban definition, the 5,000+ urban definition as well as for variations in the specification of independent variables (binary vs continuous). The out-of-sample predictions suggest that steam power increased urbanisation by 7% for the 2,000+ urban definition and by 5% for the 5,000+ urban specification. Water power, on the other hand, was associated with a 17% to 18% lower urbanisation of French industry and factory production increased urbanisation by between 22% and 23%. The specifications using continuous independent variables support this relative pattern. It is, therefore, clear that with respect to the aggregate impact water power and firm size had the strongest association with urban-rural locational preferences while the aggregate effect of steam power was comparably small during the 1840s.

Analysing both censuses: arrondissement level

The last section has analysed urban location at the firm level. As this detailed information is not available for the second industrial census, a comparative approach between both censuses needs to analyse urban location at the level of French arrondissements. This changes the definition of urbanisation. The last section was interested in whether a firm located within an urban or a rural commune. This section, however, is interested in whether a firm is located within an urban or rural region (arrondissement). Urbanisation at the regional level is defined whether the region includes a city of at least 10,000 inhabitants and in a continuous framework the urban population of all cities within that particular region is aggregated - see section 4.4.2 for more details. Methodologically we follow the previous section by first analysing a logit model - see equation 4.1 - which is then extended to a continuous specification using urbanisation rates as a dependent variable - equation

4.2. The benchmark results from estimating equation 4.1 are presented in table 4.5 for the 1840s industrial census and in table 4.6 for the 1860s industrial census. All results are represented as odds-ratios which have to be interpreted relative to the omitted category.[30] Odds ratios are the ratio of odds which are themselves ratios of the probability of being located in an urban region and the probability of being located in a rural region. Hence, an odds-ratio of greater (smaller) than 1 should be interpreted as being more (less) likely to be located in an urban region than the omitted category. The specifications presented in tables 4.5 and 4.6 differ with respect to the definition of steam and water power as well as with respect to weighting regressions by employment.[31]

Table 4.5: Urban-Rural preferences at the regional level (1840s)

	(1)	(2)	(3)	(4)	(5)	(6)
	urban10	urban10	urban10	urban10	urban10	urban10
period	1840s	1840s	1840s	1840s	1840s	1840s
weighted	w		w		w	
power	D50	D50	D75	D75	HP/L	HP/L
size	factory	factory	factory	factory	L/EST	L/EST
steam	1.363**	1.362***	1.828***	1.651***	3.149***	1.473***
	(0.201)	(0.112)	(0.314)	(0.153)	(0.956)	(0.196)
water	0.993	0.821***	0.920	0.829***	0.941	0.737***
	(0.153)	(0.055)	(0.140)	(0.054)	(0.347)	(0.075)
size	1.546**	1.576***	1.502*	1.557***	0.970	1.249***
	(0.327)	(0.114)	(0.316)	(0.112)	(0.058)	(0.033)
women/L	1.119	1.021	1.140	1.025	1.331	1.002
	(0.321)	(0.152)	(0.319)	(0.153)	(0.380)	(0.146)
children/L	0.250***	0.485***	0.259***	0.493***	0.279***	0.502***
	(0.090)	(0.082)	(0.093)	(0.083)	(0.097)	(0.083)
constant	0.066*	0.377	0.069*	0.371	0.115	0.127
	(0.106)	(0.495)	(0.107)	(0.485)	(0.182)	(0.173)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2	0.29	0.20	0.29	0.20	0.28	0.20
N	10,565	10,565	10,565	10,565	10,565	10,565

robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages. Specifications which are marked as w have been weighted by employment.

The results for the 1840s industrial census - table 4.5 - show support for the positive urban preference of steam powered firms across all specifications, irrespective of weighting

[30] Similar to the last section the omitted category are all observations which are not covered by the steam and water power variable specification.

[31] Employment weighted regressions are marked with a w at the top of the table.

and measuring steam power. Steam powered firms are between 1.4 to 3.2 times more likely to be located in an urban region than a non-steam and non-water powered firm. The rural preference of water power, which was very dominant at the city level, is only observable in the unweighted regressions and even there the effect is much smaller than in the previous analysis. Water powered firms are approximately 1.3 times more likely to be located in rural regions compared to non-steam and non-water powered firms. These results suggest that the rural location preference of water power is more pronounced at the city level than at the regional level. On the other hand, the urban preference for steam powered firms is stronger at the regional level than at the city level. Apart from the strong urban preferences of steam and the indication of rural preferences of water power, factory production shows a strong urban relationship and firms which employ more child labour are more likely to be located in rural regions. What is also important to note, is that the weighting has a very strong effect on the specification using continuous explanatory variables. Urban preferences of steam are clearly more pronounced in the weighted specification 5 than in the unweighted specification 6, while the rural preference of water power and the urban preferences of firm size only becomes statistically significant in the unweighted specification. Similar to the firm level analysis, once the sample is reduced to cover only steam and water powered observations, such that water power becomes the reference category, the steam coefficient remains highly statistically significant.[32]

Applying the same methodology to the 1860s industrial census, shows an increasing urban preference of steam powered firms and industries - see table 4.6. The rural preference of water power stays at the same magnitude compared to the 1840s industrial census and again is only statistically significant for unweighted regressions. The same holds for the factory, or firm size, coefficient. However, this should be interpreted with caution as the second industrial census covers more small scale establishments compared to the first industrial census - see section 4.4.3. Another important difference between the two censuses is the reporting of seasonal economic activity, which is measured by the variable *shut*. As seasonal inactivity was tied to the harvest, the rural preference of the variable is expected. What stands out in table 4.6 is the high value of the steam-per-worker coefficient in specification (5). The unweighted specification (6) presents us with a more reasonable estimate. This is why unweighted specifications are treated as the new benchmark specification for further analyses, at least for continuous specifications.

Robustness tests for adding interaction terms between power source and firm size do not change the overall results - see table B.5. The indications are quite mixed. With respect to the 1840s specifications (1) and (2) show a decreasing urban preference for steam powered firms with factory production. This tendency decreases once a higher cut-off point is chosen and even vanishes in the steam per worker specification. There is also no indication that the rural preference of water powered firms changes with firm size. For the 1860s adding firm size interactions shows a tendency of increased urban preferences for steam powered factories. This result, however, is not consistent across all specifications. Neither is the result that the rural preference of water powered firms increases with firm size, which is quite strong in specifications using continuous independent variables. Consistent across all

[32]For instance, for the specification 1 of table 4.5 the reduced sample steam coefficient is 1.79 with a standard deviation of 0.392 being statistically significant at the 1 % significance level. The same holds for the remaining specifications of table 4.5.

specification remains the increased urban preference if firm size is increased independent of the power source.

Table 4.6: Urban-Rural preferences at the regional level (1860s)

	(1)	(2)	(3)	(4)	(5)	(6)
	urban10	urban10	urban10	urban10	urban10	urban10
period	1860s	1860s	1860s	1860s	1860s	1860s
weighted	w		w		w	
power	D50	D50	D75	D75	HP/L	HP/L
size	factory	factory	factory	factory	L/EST	L/EST
steam	2.421***	1.923***	3.116***	2.125***	40.460***	2.451***
	(0.644)	(0.180)	(0.915)	(0.203)	(41.108)	(0.564)
water	1.183	0.862	0.882	0.744***	0.588	0.725**
	(0.292)	(0.079)	(0.183)	(0.068)	(0.209)	(0.091)
size	0.852	1.286***	0.867	1.291***	0.832**	1.188***
	(0.275)	(0.114)	(0.275)	(0.113)	(0.078)	(0.040)
shut	0.237*	0.756	0.184**	0.755	0.199*	0.823
	(0.197)	(0.163)	(0.149)	(0.163)	(0.175)	(0.177)
women/L	0.837	1.013	0.883	1.033	0.762	0.955
	(0.421)	(0.209)	(0.448)	(0.213)	(0.383)	(0.195)
children/L	0.393	1.491	0.547	1.538	0.185**	1.518
	(0.350)	(0.447)	(0.510)	(0.461)	(0.157)	(0.452)
constant	0.397	0.490*	0.362	0.481*	0.960	0.382**
	(0.352)	(0.184)	(0.325)	(0.182)	(0.895)	(0.146)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2	0.28	0.13	0.29	0.14	0.28	0.13
N	5,676	5,676	5,676	5,676	5,676	5,676

robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages. Specifications which are marked as *w* have been weighted by employment.

In a next step, the semi-continuous specification, which uses continuous independent variables within a logit model framework, is compared to fully-continuous log-linear OLS specifications and generalised-linear model (GLM) specifications, using urbanisation rates as the dependent variable.[33] Table 4.7 presents the results for all three models in both census periods. All specifications reveal the same results. Firms which use steam power more intensively are associated with urban regions while firms which use water power more intensively are associated with rural regions. Moreover, larger firms are associated with

[33]A glm specification is chosen to account for the distributional characteristics of urbanisation rates which are bound between 0 and 1.

Table 4.7: Urban-Rural preferences at the regional level (1840s, 1860s; unweighted)

	(1) urban10 logit (OR) 1840s	(2) urban10 logit (OR) 1860s	(3) ln(UR10) OLS 1840s	(4) ln(UR10) OLS 1860s	(5) UR10 GLM 1840s	(6) UR10 GLM 1860s
steam	1.473***	2.451***	0.015***	0.057***	0.163***	0.501***
	(0.196)	(0.564)	(0.006)	(0.011)	(0.050)	(0.095)
water	0.737***	0.725**	-0.009*	-0.019***	-0.142**	-0.299***
	(0.075)	(0.091)	(0.005)	(0.006)	(0.057)	(0.080)
size	1.249***	1.188***	0.012***	0.012***	0.110***	0.113***
	(0.033)	(0.040)	(0.001)	(0.002)	(0.011)	(0.016)
shut		0.823		-0.030***		-0.337***
		(0.177)		(0.012)		(0.126)
women/L	1.002	0.955	-0.027***	-0.012	-0.267***	-0.093
	(0.146)	(0.195)	(0.007)	(0.011)	(0.066)	(0.108)
children/L	0.502***	1.518	-0.044***	0.014	-0.481***	0.162
	(0.083)	(0.452)	(0.008)	(0.016)	(0.079)	(0.149)
constant	0.127	0.382**	0.041	0.029	-3.797***	-3.450***
	(0.173)	(0.146)	(0.058)	(0.038)	(0.417)	(0.300)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2	0.20	0.13	0.37	0.28	-	-
N	10,565	5,676	10,605	5,801	10,605	5,801

robust standard errors in parentheses; unweighted.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages. All independent variables are log transformed. *steam* refers to the HP of steam engines per worker, *water* refers to the HP of water mills per worker and *size* refers to the number of workers per firm.

urban locations. Introducing interaction terms between firm size and power-choice shows that any additional urban preference of larger steam-powered firms has been lost by the 1860s. Water-powered firms, however, reveal a growing rural preference with increased firm size during the 1860s. The latter result is consistent with the previous findings from table B.5. What the fully-continuous specifications (3)-(6) show, compared to the semi-continuous specifications (1) and (2), is that the relationships between power source or firm size and urban-rural location also hold once urbanisation is not treated as homogeneous.

Further, the temporal dynamics of the power related location preferences as well as their relative economic significance is investigated. So far the two censuses have been analysed separately and the models from table 4.7 have revealed some common patterns. The increase in the steam power per worker coefficient from the first to the second census is the most obvious finding. The results for the temporal analysis are represented in table B.6. The pooled regressions (specifications 1, 3 and 5) confirm the overall findings on steam power, water power and firm size. What we are interested in now, is whether the differences in the size of the coefficients, which have been identified in table 4.7, are statistically significant. This is performed by interacting steam power, water power and firm size with a time dummy which covers the second census period (specifications 2, 4 and 6). This exercise shows that indeed the increase in the steam per worker coefficient is statistically significantly higher in the 1860s compared to the 1840s irrespective of the model specification. In the OLS specification (4), for instance, the relationship between steam power and urbanisation triples between 1840s and 1860s. The other factors which have been found to be associated with either urban or rural regions, however, do not show any temporal dynamics, even though the water power coefficient is close to the 10% significance level. Reporting the same results in beta coefficients shows that the increase in the steam coefficient is also associated with an increase in the economic significance.[34] Starting at comparable economic magnitudes between steam and water power during the 1840s (one standard deviation difference in steam or water power was associated with a 0.02 standard deviation difference in urban population), this shift implies that steam became the dominant power source related location factor by the 1860s. However, what should be emphasised is the economic significance of firm size. In both census periods the explanatory power of firm size is much greater than steam or water power. Even after the relative catch-up of steam power, firm size is still twice as important as steam power. One standard deviation difference in firm size is associated with an approximately 0.12 standard deviation difference in urban population during both census periods. Therefore, I want to close this paragraph by arguing that, yes, power related factors are important and indeed steam power shows an urban preference while water power shows a rural preference, however, firm size remains to be much more closely associated with urbanisation than power source. The importance of firm size is in line with the findings for the United States during the second half of the 19$^{\text{th}}$ century by Kim (2005).

A key assumption in the performed regression models is that location determinants which are not available at the highly disaggregated industrial census level, are not correlated with the use of steam power and a firm's urban location. In order to mitigate these potential endogeneity biases, very tight fixed effects specifications have been chosen as the benchmark.[35] Apart from the concern about omitted variable biases, an important aspect of the studied relationship, which has not been addressed to a sufficient extent so far, is causality. The presented results have shown correlations or associations between power source and urbanisation without making any claims about the direction of the causal effect. There are two potential channels which need to be discussed. On the one hand, steam-powered firms might locate close to already existing urban centres in order to gain from agglomeration benefits like the supply of skilled labour, access to consumer markets or intermediary suppliers or knowledge spillovers. On the other hand, the correlation between steam power and urbanisation might come from the fact that higher wages and labour productivity of steam powered firms attracted labour and, through this mechanism, caused the forming of industrial cities. In order to shed light on this relationship, the continuous benchmark specification is compared with coefficient estimates which have been derived from regressing regional urbanisation in 1806 on firm characteristics during the 1840s and 1860s - see table 4.8. The idea behind this exercise is that the coefficient estimates are expected to decrease in order to capture the effects of emerging industrial cities. If power related coefficients do not change significantly, it can be concluded that the urban location preference of steam powered firms stems from locating in established urban centres. Spec-

[34]Standardised beta coefficients in 1840s: $steam = 0.021$, $water = -0.023$, $size = 0.127$
Standardised beta coefficients in 1860s: $steam = 0.067$, $water = -0.052$, $size = 0.119$

[35]Removing regional fixed effects increases the power related coefficient estimates by a factor of two.

ifications 1 to 4 in table 4.8 show the results for this exercise. As expected the coefficient estimates for steam power are lower when the 1806 urbanisation rates are used. The magnitude of the effect is not substantial for both periods - coefficients are expressed as beta coefficients. The change in coefficients is, however, greater during the 1860s than during the 1840s. As the importance of steam power increased in the French aggregate economy, it is also economically meaningful that the association of steam power with pre-industrial urbanisation rates weakens. Overall, it can be concluded that the relationship between steam power and urbanisation was mainly driven by steam-powered firms locating in regions with already existing urban characteristics. This is further supported when adding urbanisation rates in 1806 as an additional explanatory factor for urbanisation rates in 1841 and 1861 - specifications 5 and 6. While the water power coefficient remains important, the relationship between steam power and urbanisation disappears for the 1840s. Steam power was, therefore, not associated with the change in urbanisation during the first half of the 19$^{\text{th}}$ century. Extending the period to the 1860s, however, shows that steam power regains statistical significance. This supports the idea that the importance of steam power as a factor for contributing to the growth of industrial cities only emerges during the second half of the 19$^{\text{th}}$ century. Fernihough and O'Rourke (2014), for instance, only find a positive effect of access to coal on city population by 1900 once the UK is excluded from the sample.

Table 4.8: Urban-Rural preferences at the regional level (1840s, 1860s; unweighted; beta coefficients)

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(UR10)	ln(UR10)	ln(UR10)	ln(UR10)	ln(UR10)	ln(UR10)
UR10	1806	1841	1806	1861	1841	1861
period	1840s	1840s	1860s	1860s	1840s	1860s
UR10 1806					0.947***	0.857***
					(0.003)	(0.008)
steam	0.015*	0.018**	0.054***	0.064***	0.004	0.018***
	(0.006)	(0.006)	(0.009)	(0.012)	(0.002)	(0.006)
water	-0.011	-0.030**	-0.034**	-0.052***	-0.020***	-0.023***
	(0.004)	(0.005)	(0.005)	(0.006)	(0.002)	(0.003)
R2	0.40	0.38	0.28	0.28	0.92	0.81
N	10,375	10,375	5,718	5,718	10,375	5,718

Controls: *size*, *shut*, *women/L*, *children/L*, *INDFE*, *DEPFE*.
robust standard errors in parentheses; specifications are not weighted.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages. All independent variables are log transformed. *steam* refers to the HP of steam engines per worker, *water* refers to the HP of water mills per worker and *size* refers to the number of workers per firm.

Given the potential sources of endogeneity, results need to be interpreted with caution. The idea that steam power freed firms from the locational constraints of water power, enabling them to choose urban locations to benefit from advantages of agglomeration economies, implies firms to relocate from rural to urban locations. The available data, however, only allow us to take one snapshot in time. The empirical analysis has convincingly shown that water powered firms are more likely to be found in rural locations compared to non-water powered firms, including steam powered firms. By including a set of control variables and by setting tight regional and industry specific fixed effects, potential alternative sources for industrial location have been considered. In light of the evolutionary economic geography literature, the importance of path dependency and the persistence of spatial networks also needs to be stressed (Boschma and Frenken, 2006). French urban networks go back to the Roman Empire which has led to suboptimal locations and a slower subsequent growth of urban centres (Michaels and Rauch, 2018). It should, therefore, also be considered that persistence in urban networks determines organizational routines and, in this sense, the adoption of technological routines. The empirical results might, thus, also be interpreted such that urbanization was low in France and, therefore, the adoption of steam power within an urban environment was limited. However, also within the evolutionary economic geography, the successful implementation of new routines should then have led to agglomeration based on successful spin-offs (Klepper, 1996). Hence, combining the empirical evidence on the rural preference of water-powered firms with the limited cost effectiveness of steam power compared to water power (Nuvolari, 2010), suggests that water power was associated with a rural orientation of French industry and, thus, more limited benefits from economies of agglomeration.

4.6 Benefits of urban agglomeration

The last section has empirically validated the hypothesis that French focus on water power in contrast to steam power was associated with a lower degree of urban location of industrial production. The French path to economic development was relatively water intensive which contributed to the fact that industrialisation was less associated with urbanisation. The implications of these findings for French economic development are analysed in this part. More specifically, the research question asks if mid-19$^{\text{th}}$ century France shows benefits of urbanisation. Was the French path just a different, though equally successful, path of economic development or was the more rural character of French industry associated with unexploited benefits of urban agglomeration? In order to shed light on this question the existence of urban premiums in wages and labour productivity is investigated.

4.6.1 Empirical framework

The empirical framework used to analyse these questions follows Kim (2006) and Atack et al. (2008). Both studies analyse late 19$^{\text{th}}$ century US censuses focusing on the relationship between power-choice, firm size and urban wage/productivity premiums. I use the arrondissement level dataset from the last section.[36] Urban-premiums of wage and

[36] The unit of observation is at the region-industry-time level where regions are French arrondissements, industries/firms at the original census level and time variation stems from the two industrial censuses of 1839-47 and 1861-65. The census periods are studied separately as well as in a pooled framework. The variation of urban vs rural location stems from being located in an urban arrondissement vs a rural arrondissement within French departments.

labour productivity are differences between urban and rural arrondissements which are located within the same department as departmental fixed effects are used. Wages refer to daily adult male wages. Controls added are wage and labour productivity differences from power technologies, firm size, interactions between power technologies and firm size, capital intensity, the share of non-male employment, industry specific effects, departmental fixed effects and differences between the two census periods. Moreover, time specific industry and departmental fixed effects are considered in order to capture changing patterns in departmental and industry characteristics. For the second industrial census only, it is also possible to control for the share of months during which the firm was not in operation (*shut*). Equations 4.3 and 4.4 show the baseline specifications for the analysis of urban-premiums.

$$\begin{aligned} ln(wage_{irt}) = \alpha &+ \phi * urban_r + \beta_1 * steam_{D,irt} + \beta_2 * water_{D,irt} + \beta_3 * factory_{irt} \\ &+ \gamma_1 * steam_{D,irt} * factory_{irt} + \gamma_2 * water_{D,irt} * factory_{irt} \\ &+ \sigma * X_{irt} + \eta_{it} + \pi_{dt} + \epsilon_{irt} \end{aligned} \tag{4.3}$$

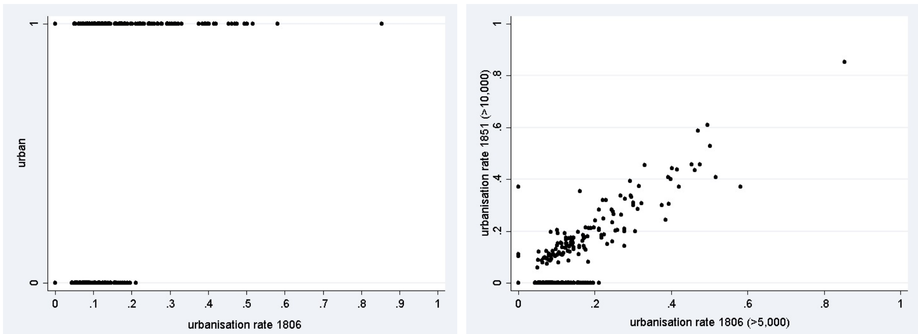
$$\begin{aligned} ln(LP_{irt}) = \alpha &+ \phi * urban_r + \beta_1 * steam_{D,irt} + \beta_2 * water_{D,irt} + \beta_3 * factory_{irt} \\ &+ \gamma_1 * steam_{D,irt} * factory_{irt} + \gamma_2 * water_{D,irt} * factory_{irt} \\ &+ \sigma * X_{irt} + \eta_{it} + \pi_{dt} + \epsilon_{irt} \end{aligned} \tag{4.4}$$

The main variable of interest is whether an industry is located in an urban or rural arrondissement. The dummy variable *urban* takes a value of 1 if the arrondissement had a city of at least 10,000 inhabitants in 1841 (first census) and 1861 (second census). This is the same specification which has been used in section 4.5. The coefficient ϕ in equations 4.3 and 4.4 identifies urban premiums in wages and labour productivity and is expected to be positive in the existence of urban premiums.[37] Apart from using this binary dummy variable specification, urbanisation is also measured continuously by measuring urbanisation rates at the arrondissement level $UR10$ which define urban population at the 10,000 population threshold.

This identification of urban-premiums has severe identification problems due to the existence of potential endogeneity biases. The correlation between urban-premiums in wages and productivity might not stem from benefits of agglomeration. Urban regions might have reached the 10,000 inhabitants threshold because they paid higher wages and were more productive due to unobserved characteristics which are not covered by the control variables. In order to mitigate these effects an instrumental variable approach, using lagged urbanisation rates as instruments, is used. It is argued that urban-rural wage and labour productivity differences in the 1840s and 1860s were not responsible for the status of urbanisation in 1806. To strengthen this identification strategy, urbanisation in 1806 is measured at a lower cut-off point including urban regions which had no urban

[37] In the existence of urban premiums the interpretation would be that industries located in arrondissements which contain a city of at least 10,000 inhabitants in its territory pay higher wages and produce more productively than industries in arrondissements with urban populations below the 10,000 city population criterion.

Figure 4.2: French urbanisation rate ($> 5{,}000$) in 1806 compared to



(a) urban dummy in 1851 (b) urbanisation rate in 1851

status during the mid-19th century. Urbanisation rates in 1806 are measured as the sum of cities with at least 5,000 inhabitants in 1806 over the total population per arrondissement.[38] Figure 4.2 shows the relationship between urbanisation rates in 1806 and the urban dummy in the baseline specifications (*urban*) - figure 4.2a - as well as the urbanisation rates in 1851 using the 10,000 city criterion - figure 4.2b. The graphs show a strong positive correlation between urbanisation in 1806 and urbanisation in 1851. Urban places in 1806 (cities with more than 5,000 inhabitants) which did not meet the criterion in 1851 (cities with more than 10,000 inhabitants) show a maximum urbanisation rate of 21% in 1806. This is below the mean urbanisation rate of 22% in 1806 for urban places in 1841-51. Hence, as expected urban places at the start of the 19th century were clearly more likely to be urban during the mid 19th century as well. The next section will present the results of the discussed empirical specifications. First the OLS results on urban premiums of wage and productivity will be presented which is followed by a discussion of the instrumental variable (IV) results.

4.6.2 Results

OLS results

The OLS results from estimating equations 4.3 (wages) and 4.4 (productivity) are presented in tables 4.9 (wages) and 4.10 (productivity).[39] They show a clear indications for the existence of urban premiums in both wages and labour productivity. Urban producers pay 6-7% higher wages than rural producers and labour is used 7-11% more productively in urban regions than in rural regions. The urban premiums are highly significant and very robust against adding controls. Potential confounders like the effects from steam or water power, capital intensity, the share of non-male employment and firm size do not alter the statistical significance of urban agglomeration benefits, though they decrease the magnitude of the effect. Adding capital intensity has the strongest effect on urban premiums for both wages and labour productivity. If the urban dummy variable, which is used in specifications 1,2,4 and 5 of tables 4.9 and 4.10 is regressed on wages or labour

[38] The 5,000 inhabitants criterion is used as more than 95% of cities in the 1841-61 10,000 city population criterion had at least 5,000 inhabitants in 1806. Hence, urbanisation in 1806 covers the pool of potentially urban arrondissements in 1841-61. As a lot of regions identified as urban in 1806 did not maintain this status until 1841-61, urban premiums in wages and labour productivity during the 1840s and 1860s should not be responsible for urban status in 1806.

[39] The specifications presented in tables 4.9 and 4.10 exclude interaction terms between firm size and power source.

Table 4.9: Urban wage premiums at the regional level (1840s, 1860s; unweighted)

	(1)	(2)	(3)	(4)	(5)	(6)
	wage	wage	wage	wage	wage	wage
period	1840s	1840s	1840s	1860s	1860s	1860s
urban	$urban_D$	$urban_D$	$ln(UR)$	$urban_D$	$urban_D$	$ln(UR)$
power	D75	HP/L	HP/L	D75	HP/L	HP/L
size	factory	L/EST	L/EST	factory	L/EST	L/EST
urban	0.069***	0.064***	0.364***	0.063***	0.065***	0.356***
	(0.006)	(0.006)	(0.027)	(0.006)	(0.006)	(0.023)
steam	0.151***	0.112***	0.114***	0.028***	0.044*	0.040*
	(0.010)	(0.018)	(0.018)	(0.008)	(0.023)	(0.023)
water	0.062***	0.033***	0.033***	-0.037***	-0.022**	-0.017
	(0.008)	(0.012)	(0.012)	(0.008)	(0.011)	(0.011)
size	0.069***	0.054***	0.053***	0.041***	0.027***	0.026***
	(0.009)	(0.004)	(0.004)	(0.008)	(0.004)	(0.004)
K/L	0.077***	0.092***	0.089***	0.045***	0.044***	0.041***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)
1-(men/L)	-0.048***	-0.034***	-0.030***	-0.022***	-0.011	-0.008
	(0.005)	(0.005)	(0.005)	(0.006)	(0.007)	(0.006)
shut				-0.008	-0.002	0.003
				(0.019)	(0.019)	(0.019)
constant	4.490***	4.368***	4.380***	5.336***	5.255***	5.295***
	(0.087)	(0.077)	(0.079)	(0.075)	(0.084)	(0.086)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2	0.40	0.39	0.40	0.46	0.46	0.48
N	10,644	10,644	10,605	5,801	5,801	5,801

robust standard errors in parentheses; unweighted
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages. All specifications are log transformed.

productivity with only adding a constant, industry fixed effects and regional fixed effects the urban wage premium is 10% in the 1840s and 8% in the 1860s while the urban labour productivity premium is 17% in the 1840s and 19% in the 1860s. It is, therefore, clear that urban-rural differences in wages and labour productivity are not only an agglomeration effect but might be driven by other structural differences. Hence, all the specifications are presented with a full set of control variables.

Table 4.9 presents the results for urban agglomeration benefits of male wages for the 1840s and 1860s censuses using a variety of specifications. The wage premium in specifications 1, 2, 4 and 5, which use a binary urban definition, should be interpreted as follows: within the same industry and the same department firms which are located in an arrondissement which contains at least one city of at least 10,000 inhabitants in 1841 (1840s census) or 1861 (1860s census) pay 6-7% higher male wages than producers which are located in an arrondissement with no city of at least 10,000 inhabitants. In specifications 3 and 6, which treat urbanisation as a continuous variable by using urbanisation rates, a 10% higher urbanisation rate is associated with a 3.6% higher male wage. In terms of beta coefficients, a one standard deviation change in urbanisation is associated with a 0.14 standard deviation higher wage during the 1840s and a 0.18 standard deviation higher wage during the 1860s - see table B.7. Comparing both census periods, the urban wage premium is quite stable. Besides the positive urban-premium the wage regressions reveal some interesting results among the control variables. Steam-powered firms pay higher wages than non-steam and non-water powered firms. So do water-powered firms during the 1840s, even though, to a lower extent and during the 1860s water-powered firms even pay lower wages than non-steam and non-water powered firms. This implies an even larger wage gap between steam and water power for the second census period. Factories and larger firms, in general, also pay higher wages. At least for the 1840s the factory wage premium shows a similar magnitude than the urban wage premium - see specification 1. Besides the effects from firm size and power choice, wages differ with respect to capital intensity and the share of non-male employment. Unsurprisingly, firms which use capital more intensively relative to labour pay higher salaries. Moreover, a higher share of male employment is associated with higher wages.

Table 4.10 shows the same model specifications as before only using labour productivity as the dependent variable instead of male wages. The coefficient identifying the urban premium in terms of labour productivity is more substantial than for wages.[40] The higher urban premium in labour productivity was more pronounced during the 1860s than during the 1840s. For the first industrial census period firms which were located in urban regions were 7-8% more productive than firms and industries in rural regions. During the 1860s, when the second industrial census was taken, urban regions were associated with 11% higher labour productivity. Among the control variables we see some differences compared to the wage regressions. There is no substantial difference in labour productivity between steam and water power with respect to the dummy variable specifications 1 and 4. Once the intensity of power use is introduced, a marked difference emerges in the 1860s but not in the 1840s. With respect to firm size it is interesting to note that not only does the productivity advantage of larger firms, which existed in the 1840s, decrease, as it was the case with respect to wages, but the coefficient even turns statistically insignificant. This is partly, but not entirely, due to controlling for seasonal inactivity during the 1860s for which no information is available in the 1840s. Apart from urbanisation, power source and firm size, firms which use capital more intensively have a higher level of labour productivity and firms which employ a larger share of non-male workers are less productive in the 1840s but not in the 1860s.

In order to analyse the relative explanatory power of wage and labour productivity determinants, coefficients are normalised by their standard deviation, called beta coefficients. Table B.7 presents beta coefficients for all fully continuous specifications. The explanatory power of urban premiums is stronger for wages than for labour productivity. During the 1860s the explanatory power of the urban premium in wages was even similar to that of capital intensity which is the single most important factor in all other specifications. On average, the relative explanatory power of urbanisation for wages is similar, or slightly, below that of firm size but clearly above power technologies. Firm size is very impor-

[40] It should, however, be noted that standardized (beta) coefficients are larger for wage regressions than for labour productivity regressions. This is shown in the next paragraph. The variance of labour productivity is thus more pronounced than the variance of wages.

Table 4.10: Urban labour productivity premiums at the regional level (1840s, 1860s; unweighted)

	(1)	(2)	(3)	(4)	(5)	(6)
	LP	LP	LP	LP	LP	LP
period	1840s	1840s	1840s	1860s	1860s	1860s
urban	$urban_D$	$urban_D$	$ln(UR)$	$urban_D$	$urban_D$	$ln(UR)$
power	D75	HP/L	HP/L	D75	HP/L	HP/L
size	factory	L/EST	L/EST	factory	L/EST	L/EST
urban	0.081***	0.069***	0.364***	0.111***	0.111***	0.574***
	(0.019)	(0.019)	(0.080)	(0.023)	(0.023)	(0.091)
steam	0.169***	0.240***	0.240***	0.012	0.371***	0.365***
	(0.031)	(0.053)	(0.053)	(0.034)	(0.087)	(0.087)
water	0.158***	0.271***	0.271***	0.007	0.088*	0.097*
	(0.024)	(0.042)	(0.042)	(0.034)	(0.051)	(0.051)
size	0.261***	0.151***	0.150***	0.048	0.007	0.006
	(0.029)	(0.011)	(0.011)	(0.032)	(0.013)	(0.013)
K/L	0.256***	0.281***	0.279***	0.366***	0.343***	0.338***
	(0.009)	(0.009)	(0.009)	(0.014)	(0.015)	(0.015)
1-(men/L)	-0.117***	-0.086***	-0.083***	-0.010	-0.011	-0.007
	(0.014)	(0.014)	(0.014)	(0.018)	(0.019)	(0.019)
shut				-1.071***	-1.085***	-1.078***
				(0.085)	(0.085)	(0.085)
constant	5.171***	4.808***	4.824***	3.907***	4.063***	4.129***
	(0.208)	(0.291)	(0.284)	(0.285)	(0.289)	(0.276)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2	0.32	0.33	0.33	0.40	0.40	0.40
N	10,643	10,643	10,604	5,739	5,739	5,739

robust standard errors in parentheses; unweighted
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages. All specifications are log transformed.

tant for labour productivity during the 1840s but less so during the 1860s. So far, urban premiums in wages and labour productivity have been analysed in a reduced form of the specifications stated in equations 4.3 and 4.4. Adding interaction terms between firm size and power source, as being presented in table B.8, does not affect urban premiums. There is, however, a tendency that the productivity and wage advantages of water power as well as steam power increase with firm size.

Overall the OLS results have revealed strong empirical support for the existence of urban premiums in both wages and labour productivity. Industrial producers in urban regions pay higher wages and use labour more productively compared to their rural counterparts. Relative to other determinants, urban premiums explain an economically meaningful fraction of the variance in wages and labour productivity. The single most important factor, however, is capital intensity.

IV results

The OLS results in the last section have shown that urbanisation was associated with higher wages and higher levels of labour productivity in mid-19$^{\text{th}}$ century France. Until now it is unclear if this association is *just* a correlation or reveals information about causality as well. It might be the case that unobserved region-industry characteristics are correlated with the error term leading to biased results. High wages and high labour productivity might cause urbanisation as more productive firms pay higher wages which attracts workers. This mechanism turns the explanation of benefits of urban agglomeration upside down. In order to shed light on the causality between urbanisation and urban premiums an instrumental variable approach is used. Following the previous literature lagged urbanisation rates are used to instrument urban location.[41] I use urbanisation rates from the population census of 1806 assuming that urbanisation rates in 1806 are unrelated to wage and labour productivity differences in the 1840s and 1860s except for their impact through persistence in urbanisation. Given multiple exogenous shocks during the First French Empire such as the Continental Blockade as well as the pre-industrial state of French industry at this early stage of French economic development makes this assumption plausible. This is further confirmed by the first stage results which are shown in table 4.11. A high F-statistic and a very strong relationship between urbanisation rates in 1806 and mid-19$^{\text{th}}$ century urbanisation are revealed.

The remaining columns of table 4.11 show the second stage regression results from instrumenting the urban identifier with urbanisation rates in 1806. It is clear that accounting for potential endogeneity biases does not affect the existence of urban premiums in wages and labour productivity. Urban firms still pay higher wages and produce more productively than rural firms. It is even the case that IV coefficients are larger than the OLS estimates which indicates that OLS results were downward biased. The coefficients on wages and labour productivity are about twice as large after instrumenting urbanisation. The adult wages paid by urban firms are between 13% and 14% higher than the wage paid by rural firms and urban firms are 16% to 22% more productive than their rural counterparts. Both for wages and labour productivity the instrumented coefficients are higher for the second census period than for the first census period. The difference, though, is much more pronounced in terms of labour productivity than wages. Moving from the binary definition of urbanisation to a continuous specification further supports the downward bias of the OLS results - see table 4.11. A 10% increase in the urbanisation rate results in a 4% to 5% increase in wages and a 4% to 6% increase in labour productivity. The covariates' coefficients from the IV estimations differ only marginally from their OLS coefficients. It can be concluded that the empirical support from IV estimates for the existence of urban premiums in wages and labour productivity is even stronger than from OLS estimates. Moreover, alternative measures of urban agglomeration do not change the results. Table B.10 shows first and second stage IV results when using population density or total population as measures for agglomeration effects. Both specifications identify agglomeration effects for wage and labour productivity during the 1840s and 1860s.[42] Overall, it can

[41] Instrumenting current measures of agglomeration with historic agglomeration measures has been proposed by Ciccone and Hall (1996), found broad acceptance and has also been used by Kim (2006).

[42] Population density is instrumented by using population density in 1806 while total population is instrumented by using total population in 1806.

be concluded that the results from instrumenting urbanisation support the OLS results. Urban premiums in wages and labour productivity were not driven by endogeneity biases supporting the hypothesis that firms did indeed benefit from producing in urban regions rather than rural regions and workers did earn higher wages.

Table 4.11: IV: Urban wage and labour productivity premiums at the regional level (1840s, 1860s; unweighted; urban dummy)

	(1)	(2)	(3)	(4)	(5)	(6)
	$urban_D$	wage	LP	$urban_D$	wage	LP
stage	first	second	second	first	second	second
period	1840s	1840s	1840s	1860s	1860s	1860s
urban		$urban_D$	$urban_D$		$urban_D$	$urban_D$
UR 1806	3.492***			3.215***		
	(0.027)			(0.045)		
urban		0.125***	0.156***		0.136***	0.216***
		(0.009)	(0.027)		(0.009)	(0.036)
steam	0.015	0.106***	0.237***	0.013	0.038	0.372***
	(0.018)	(0.018)	(0.054)	(0.032)	(0.023)	(0.087)
water	-0.070***	0.047***	0.299***	-0.042**	-0.012	0.111**
	(0.014)	(0.012)	(0.043)	(0.020)	(0.011)	(0.051)
firm size	0.012***	0.053***	0.143***	0.015**	0.025***	0.005
	(0.004)	(0.004)	(0.011)	(0.006)	(0.004)	(0.013)
K/L	0.011***	0.088***	0.274***	0.013**	0.039***	0.336***
	(0.003)	(0.003)	(0.009)	(0.006)	(0.004)	(0.015)
1-(men/L)	0.006	-0.032***	-0.087***	0.010	-0.009	-0.011
	(0.005)	(0.005)	(0.015)	(0.008)	(0.007)	(0.019)
shut				0.050	-0.004	-1.085***
				(0.034)	(0.019)	(0.085)
constant	-0.103	4.349***	4.847***	0.371***	5.252***	4.082***
	(0.123)	(0.084)	(0.280)	(0.128)	(0.083)	(0.286)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2		0.39	0.33		0.45	0.40
N	10,375	10,376	10,375	5,657	5,718	5,657
K-P Wald F statistic	16387.53			5112.32		
K-P LM statistic	3254.21			2061.59		

robust standard errors in parentheses; unweighted
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages. *steam* refers to the HP of steam engines per worker, *water* refers to the HP of water mills per worker and *size* refers to the number of workers per firm. K-P refers to Kleibergen-Paap rank statistics (Kleibergen and Paap, 2006).

4.7 Discussion

The results from section 4.5 show that the type of power technology was associated with differences in urban-rural location during 19$^{\text{th}}$ century France. There is a clear urban preference of steam powered firms relative to water powered firms for all specifications. This is in line with the findings by Kim (2005) for the United States. However, in contrast to his findings the French data reveal an urban preference of steam power also with reference to non-steam and non-water powered firms. This is most pronounced at the regional level but also true, though at a lower magnitude, at the commune level. The increased urban preference of steam powered firms at the regional level suggests that steam was also more associated with close proximity to urban centres. Agglomeration effects do not stop at the border of urban communes. Apart from some differences to the findings of Kim (2005) there are also important similarities. Most importantly, his main conclusion that the shift from artisan to factory production was associated with urbanisation also holds for France. Firm size is a very strong explanatory factor of urban location both at the commune and the regional level. Of further interest is the comparison with the findings of Crafts and Wolf (2014) on the location of British cotton textile mills. They argue that sunk costs related to the installation of water power equipment has reduced the incentives to locate away from the Lancashire region. Firms have remained at a specific location due to acquired advantages like cheap coal and market access even though first nature advantages have already disappeared. This line of reasoning would suggest that steam powered firms in urban regions benefited from previous agglomeration of water powered firms.

Besides the power-choice related location preferences the analysis shows that urban producers were significantly more productive and paid higher wages. Linking the existence of urban agglomeration economies to power choice, therefore, suggests that economic development might indeed have been impeded by the French focus on water power through its negative effects on urbanisation. Steam power stimulated urbanisation and urban regions were more productive and paid higher wages compared to rural regions. However, this does not imply that French producers acted irrationally and failed to adopt steam powered technology within their economic and geographical constraints, particularly given the technological complementarity of coal endowments and steam technology. However, if France could have overcome its geographical constraints more quickly, urbanisation would have been faster and as urban firms were more productive than their rural counterparts aggregate productivity would have been higher. The French historiography contains two mechanisms through which the diffusion of steam technologies could have been accelerated: an earlier expansion of the transport network and cheaper coal imports through lower import tariffs.

France was rather slow in building a national railway network. The first plan for a system of national rail trunk lines was developed in 1832 by Victor Legrand. However, it took the French parliament 10 years to form the Railroad Law of 1842 which developed a system of public-private partnerships to implement the Legrand plan. However, the Railroad Law was badly designed such that the anticipated rapid completion of the national railway network did not follow. Smith (2006, pp.82-83) argues that this was mainly a problem of railroad finance. Initiatives to railroad building were disincentivized by high technical specifications, a short duration of concessions and uncertainty about the legal status between railroad companies and the state due to a fear of nationalisation. This resulted in high costs of railroad building[43] and a slow implementation of the Legrand plan. In 1848 France operated only 1,860 kilometers of railroad while 5,900 kilometers

[43] Building one kilometre of railroad in France was 1.4 times more expensive than in Belgium, 1.6 times more expensive than in Germany and cost 3.9 times more francs per km than in the US (Ribeill, 1993, p.434-435).

were in operation in Britain and 5,200 kilometers in Germany (Smith, 2006, p.65). Hence, with respect to a systematic national transport network France was clearly disadvantaged during the first half of the 19th century. It was not before the reform of the Railroad Law after the *Coup d'État* of 1851 that France experienced its transport revolution. By 1883 the French railroad network connected all regions of France with 25,000 kilometers in length achieving a cost reduction of 75% of merchandise freight between 1840 and 1870 (Smith, 2006, p.87). Even if the precise quantitative contribution of a national transport network remains to be evaluated it is fair to assume that the politically delayed building of a French railroad network limited the cost efficient diffusion of steam technologies and contributed to the French adherence to water power.

Geographical constraints can be reduced by increasing the efficiency in resource allocation. An alternative mechanism is to import scarce resources from abroad. France was a major importer of coal but, nevertheless, artificially increased coal prices by imposing a tariff on the import of coal. Table 4.12 shows that ad valorem import tariffs on coal were above 20% in the period from 1827 to 1836 and declined continuously until 1876. Moreover, it can be seen that import tariffs on coal follow a common trend in tariff decline. The high tariffs on coal in an economy which is dependent on coal imports had a political motive. Kindleberger (1964, pp.18-19) argues that high tariffs on coal were designed to favour landowners who benefited from a high price on charcoal as well as to protect the coal mining industry from foreign competition on the home market. In 1832 the coal mining industry was, however, not able to convincingly support their demand for protection such that duties on coal were cut as part of the Act of 1836 (Dunham, 1955, pp.101-102). The import tariff on coke, however, was not decreased and even increased until 1848 reaching 35%. The political motive of keeping a tariff of above 20% ad valorem until 1836 (effectively: 1837) and introducing only stepwise reductions throughout the century was a further disadvantage for coal consuming industries. Dunham (1955), for instance, argues that the tariff reduction on coal in 1836 was a belated response to the fact that France was a major importer of this important raw material.[44] An earlier reduction of the tariff on coal but, probably more importantly, the extension of the transport network would have contributed to a lower coal price and a faster diffusion of steam power.

Table 4.12: French ad valorem import tariffs on coal (1827-1876)

	coal	total
1827-1836	21.2%	20.8%
1837-1846	16.5%	16.8%
1847-1856	10.2%	13.0%
1857-1866	8.7%	6.9%
1867-1876	5.5%	4.9%

Notes: Ad valorem import tariffs: import duties as a share of current import values.
Source: Nye (1991b, p.44) based on *Tableau decennal du Commerce, 1867-76*

It has been hypothesised that the delayed completion of a national transport network

[44] *"The tariff, then, merely injured French industrial growth by raising the price of the fuel, which it must then obtain in part from abroad, as it has done ever since. Reductions of duties on coal in 1836 was a belated and inadequate recognition of this fact."*(Dunham, 1955, p.395)

and the unfavourable tariff policies contributed to the rural character of French industrialisation through their effect on the relative competitiveness of water power over steam power. However, besides the effects of government policy on power choice, the mechanisms of urban agglomeration economies need to be understood in more detail. Section 4.6 has revealed the existence of urban agglomeration economies but the black box has not been opened such that little is known about the mechanisms through which urban producers benefited from locating in urban rather than rural regions. This is done by applying the analytical framework of Duranton and Puga (2004) who distinguishes between the mechanisms of *sharing*, *matching* and *learning*.[45] In a similar exercise covering the late 19th century US economy Kim (2006) emphasises the importance of division of labour and matching costs as a mechanism of benefits of urban agglomeration. He uses a city-industrial diversity index as a measure of division of labour and matching costs and finds that a higher degree of industrial diversity was associated with larger urban populations. Total manufacturing employment, however, was associated with lower levels of industrial diversity. That matching might also play a role for productivity advantages of French cities is suggested by Crouzet (1996, p.53) who argues that migrants from the countryside were not suited for factory work and that there was a chronic shortage of skill. Following the idea of Marshall (1890, p.271) that *"a localized industry gains a great advantage from the fact that it offers a constant market for skill"* it can be hypothesised that French cities were more productive due to lower costs from skill mismatches between employees and employers. To empirically investigate the various channels of urban agglomeration economies would, however, go beyond the scope of this article.

I would like to close this discussion section by emphasising the importance to investigate the interrelatedness of various features of 19th century industrialisation. This article shows that by combining the features of power-choice and urbanisation we can reach new insights into an old debate about the success of French 19th century economic development. However, it also has to be clear that power choice is only one part of a more complex puzzle and alternative factors need to be studied in more detail.

4.8 Concluding remarks

The diffusion of steam power and accelerated urbanisation are seen as central elements of modern economic development during the 19th century. In spite of the simultaneous occurrence of these two processes their interrelatedness has only recently led to empirical investigations for the United States (Kim, 2005) and Germany (Gutberlet, 2014). This article contributes to this evolving literature by adding a very important case to the debate regarding the interrelatedness between power-choice, urbanisation and industrialisation: the case of France. The French case is of central importance as its industrialisation is characterised by slow urbanisation and adherence to water power. Economic historians like Crouzet (1996) and Cameron (1985) have already pointed towards a relationship between power-choice and urbanisation. Besides testing this relationship, the article goes one step further and links the urbanisation effect of steam to economic development through

[45] The potential mechanisms of urban agglomeration benefits, including the classification of Duranton and Puga (2004) has been discussed in section 4.3.

urban agglomeration economies. This article is the first attempt to empirically investigate whether French adherence to water power was associated with slow urbanisation, limited gains from urban agglomeration and through this mechanism constrained economic development.

Applying various models of urban location, from a discrete choice model following Kim (2005) to a fully continuous specification, I find strong evidence that French adherence to water power was associated with lower levels of urbanisation. The analysis is based on two mid-19th century industrial censuses which provide detailed information on the source of power at a high level of regional, even firm level in the 1840s, and industry disaggregation. This information is linked to city level urban population derived from 19th century population censuses. Depending on the exact specification and the time period, I find that steam-powered firms were between 1.3 and 2.5 times more likely to be located in urban regions compared to non-steam and non-water powered firms. On the other hand, water powered firms were marginally, though, statistically significantly more likely to locate in rural regions (1.2-1.3 times). Looking at cities instead of regions, water powered firms are much more likely to be located in rural communes (2-2.8 times). The urban preference of steam powered firms is less clear on the commune level than it is on the regional level. Larger firms or factories, irrespective of their power source, are both statistically and economically highly significantly associated with urbanisation. It is further highlighted that during the 1840s, the urban preference of steam power is still most closely related to pre-industrial urban centres, while this focus weakens such that by 1860 steam power is positively associated with urban regions even after controlling for urbanisation in 1806. This suggests a dual causal relationship, as, on the one hand, steam powered firms are more likely to locate in existing urban regions and, on the other hand, regions become more urban where steam powered firms are located.

The findings of power-specific location choice are then linked to the economic success of the French economy by testing for the existence of benefits of urban agglomeration. If benefits of urban agglomeration existed in the French 19th century economy, a faster diffusion of steam power, substituting water power, would have fostered economic growth through its positive effect on urbanisation. The existence of benefits of urban agglomeration is empirically analysed by estimating urban premiums in wages and labour productivity. After adjusting for endogeneity biases by instrumenting urbanisation with urbanisation ratios in 1806, I find that urban firms paid 13-14% higher wages and were 16-22% more productive than their rural counterparts, depending on the census period. Hence, it is concluded that French economic growth was indeed constrained by its adherence to water power and slow diffusion of steam power.

Fruitful avenues for further research are found at both ends of the argument. Firstly, it remains to be investigated to what extent the diffusion of steam power could have been accelerated by an earlier completion of a national transport network or by abolishing tariffs on coal import. Secondly, it remains to be investigated through which mechanisms urban agglomeration economies operated. In light of this chapter's importance of technological change, the role of knowledge spillovers in 19th century urban centres would be an important focus. The discussion of human capital and economic development is, so far, mainly focused on formal education (Franck and Galor, 2017). To what extent knowledge spillovers fostered technological diffusion during the 19$^{\text{th}}$ century's industrial revolution and whether urbanization has played an intermediary role remains to be evaluated. The findings of this chapter can undoubtedly be seen as an indication that technological progress has an important spatial dimension.

Chapter 5

Market Access, Coal and the Second Industrial Nation: Belgium 1846-1896

5.1 Introduction

The role of demand in industrialisation is subject to much debate. Gilboy's (1932) emphasis that both supply and demand factors are important to understand the first industrial revolution has been challenged by Mokyr (1985) arguing that demand-side explanations of the industrial revolution are based on circular reasoning.[1] Since then, however, a variety of growth models have been developed which see market size as being essential for economic development.[2] In particular, insights from 'New Economic Geography' (NEG) following Krugman (1991b,c) have formed new perspectives on the importance of demand factors during the 19th century. Several case studies, like Kim (1995) for the United States and Rosés (2003) for Spain, to name two early contributions to this literature, have shown that both supply and demand factors mattered.[3] This article contributes to this wider debate by analysing 19th century Belgian industrialisation. The case of Belgium is of crucial importance to understand the spread of modern economic growth from Britain to the European Continent, as it was the first economy after Britain to experience an industrial revolution. The small domestic market of the Belgian economy contributed to the limited importance economic historians have ascribed to demand side explanations of industrialisation. Mokyr (1976), for instance, sees demand factors as not being crucial in order to explain the different growth trajectories between Belgium and the Netherlands.[4] Among the supply factors, access to coal is attributed crucial importance and can be found

[1] A good example for this line of reasoning is the debate about the importance of foreign trade for the British industrial revolution. In their article *"Overseas trade and empire 1700-1860"*, Thomas and McCloskey (1981, p.102) dismiss the role of trade for industrialisation by concluding: *"trade was the child of industry"*.

[2] The most seminal theoretical contributions are Galor (2011), Grossman and Helpman (1991), Krugman (1991c) and Romer (1990).

[3] Section 2.2.3 reviews the influence of the *New Economic Geography* literature on the discipline of quantitative economic history.

[4] Based on an analysis of Dutch manufacturing productivity Smits (2000), however, argues that demand factors were crucial in explaining why the Dutch economy experienced modern economic growth not before the 1860s. High indirect taxes, which dampened real wages and limited domestic demand, impeded the diffusion of modern (steam) technologies and TFP growth.

at the centre of many explanations for the early success of Belgian industry. Pollard (1981, p.87), for instance, writes on Belgium that *"the basis, as always, was coal"*.[5] The relative importance of coal for Belgium's early economic success is, however, far from clear and neglecting the importance of demand-side explanations for Belgian industrialisation can be questioned when confronted with the historical evidence.

Firstly, Belgium shows the first signs of industrialisation during the Napoleonic period when Belgium was part of the First French Empire from 1795 to 1814. The annexation by France is seen as a stimulus for investing in the industrial sector, textiles in particular, and increased mechanisation. Besides institutional reforms such as abolishing the guilds, Belgian producers had access to a large homogeneous market (Wee, 1996). In 1806 the French Empire reported 29.1 million inhabitants compared to a Belgian population of 4.2 million in 1816 (Mitchell, 1980). Besides their improved access to consumer markets, Belgian producers were also protected from British competition under the Continental Blockade, which has led to accelerated mechanisation in the cotton spinning sector (Juhász, 2014). Under French control the Belgian economy developed three modern industrial growth centres: Verviers-Liège, Mons-Charleroi, Ghent. Moreover, the cities of Antwerp and Brussels developed as important centres providing tertiary services. The woolen industry was mechanised at Verviers and machinery construction took place at Liège which developed a large metallurgy industry. Coal mining was the main economic activity at Mons which accelerated by improving the transport link to the French market. Nearby Charleroi pushed its metallurgy industry which was supported by modern coal mining. Ghent developed as the Belgian cotton textile centre with early mechanisation in cotton-spinning and a concentration of calico printing.[6]

Secondly, national account estimates of 19th century Belgian GDP per capita show that Belgium experienced very fast industrialisation not before 1850. Between 1850 and 1870 Belgian industrial real value added increased by 5.5% per annum and GDP per capita gained 2.7% per annum (Horlings and Smits, 1997, p.86). Compared to the periods before 1850 and after 1870 the twenty years between 1850 and 1870 are clearly unprecedented.[7] Moreover, during this period the Belgian economy closed its GDP per capita gap to the Netherlands and narrowed its gap to the UK.[8] Which role demand side explanations played during this period of fast economic growth is not obvious. On the one hand, the Belgian secession from the Netherlands in 1830 resulted in an even smaller domestic market compared to the period of French control and under the United Kingdom of the Netherlands. On the other hand, adding an international dimension reveals that Belgium experienced a substantial increase in its trade openness exactly during the time when industrialisation was fastest. Figure 5.1 shows the development of GDP per capita and trade openness

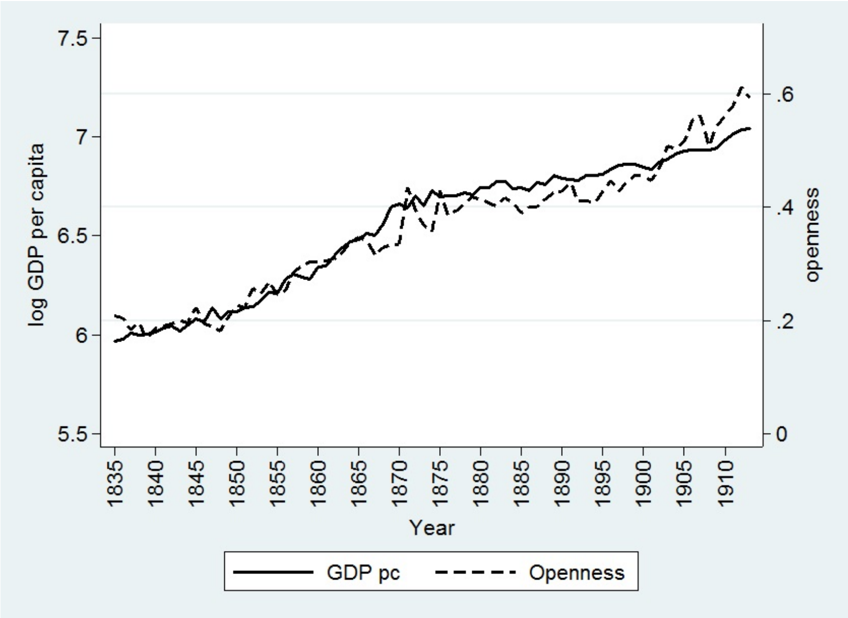
[5] See section 2.1.2 for a discussion of the historiography of 19th century Belgian economic development.

[6] See Wee (1996) for a concise summary of Belgian industrialisation before 1830 and Milward and Saul (1973) and Pollard (1981) for a more detailed discussion of Belgian industrialisation. Section 2.1.2 presents a review of the literature of Belgian 19th century economic development.

[7] Horlings and Smits (1997, p.100) write on the Belgian performance during the first half of the 19th century: *'The dynamic industries made up only a modest part of the Belgian economy and could neither exert decisive influence on the performance of the economy at large nor make up for the bad performance of agriculture'.*

[8] In 1850 Belgian GDP per capita was 79% of the UK level and 78% of the Dutch level. In 1870 relative GDP per capita increased to 84% of the UK level and 98% of the Dutch level. These comparisons are based on the Maddison-Project - see http://www.ggdc.net/maddison/maddison-project/home.htm, 2013 version.

Figure 5.1: Belgian GDP per capita and trade openness: 1835-1913



Notes: *log GDP per capita* (left) is measured in constant 1910 prices (Smits et al., 2009); *openness* (right) is measured as the sum of imports and exports in current prices as a percentage of GDP in current prices (Horlings (1997) for trade values and Smits et al. (2009) for GDP).

which is measured as the share of total nominal trade (sum of imports and exports) over nominal GDP. It shows that the period of fast economic growth is also associated with a substantial increase in trade openness from 20% to 40%. It is not before 1890 that trade openness starts to increase again. After 1870 the Belgian economy can be described as small and open.[9]

The last two paragraphs have developed two stylised facts about the relationship between industrialisation and demand factors in Belgian economic development. Therefore, it is far from clear that even in a comparably small economy early industrialisation was mainly associated with supply-side explanations. This article investigates 19th century Belgian industrialisation by quantifying the relative importance of coal and market potential. The analysis is based on 19th century industrial censuses (1846 and 1896) and is performed at the regional and industry level. The results show that both accessibility of coal and markets play important roles in understanding Belgian industrialisation during the 19th century and thus, also for the diffusion of the British industrial revolution. The counterfactual results suggest that supply and demand factors should be seen as necessary rather than sufficient conditions supporting Gilboy (1932). Access to domestic markets is the strongest location factor at the aggregate level and is highly statistically significant across all sub-industries. Access to foreign markets play only a limited role, at least at the

[9] The determinants of the increase in trade openness remain to be evaluated but it seems plausible that the intensification of trade can be ascribed, at least partly, to increased trade liberalisation among Belgium's neighbours. Britain abolished its Corn Laws in 1846 and signed a trade agreement with Belgium in 1850. A commercial treaty was signed with France in 1854 as well as in 1862 following the Cobden-Chevalier treaty between Britain and France in 1860. A first trade treaty was negotiated with the German Customs Union, which included the Duchy of Luxembourg from 1842 onwards, as early as 1844 and 1852. Belgium's northern neighbour, the Netherlands, is even seen as one of the most liberal economies during the period 1846 to 1860 when it comes to trade. Additionally, Belgium abolished most of its export prohibitions in 1853 and the port of Antwerp was freed from Dutch tolls in 1863 (Milward and Saul, 1973; Bairoch, 1989).

aggregate level. Besides domestic market potential, proximity to coal is an economically significant location determinant. This is mainly driven by the metal, glass and chemical industries. Looking at specific industries, therefore, shows that an economy's relative endowment with supply and demand factors determines the country's sectoral composition. Belgian industrialisation was, indeed, focused on heavy industries, as for these industries coal as a location determinant was strongest. The case of Belgium, therefore, supports the findings for the German Empire by Gutberlet (2012) that access to coal was an important factor in 19$^{\text{th}}$ century industrialisation.

The article is structured as follows. The next section reviews the existing literature on the regional dynamics of 19$^{\text{th}}$ century Belgian economic development.[10] Then, data sources and variable construction will be discussed, which is followed by a descriptive analysis. This is followed by identifying the determinants of Belgian industrialisation within a regression framework using an instrumental variable approach to establish causality. The last section summarises the findings and links them to the previous literature.

5.2 The regional dimension of Belgian economic development

Belgium, today, is characterised by a distinct regional divide between the Flemish-speaking Northern region of Flanders and the French-speaking Southern region of Wallonia. The regional differences are observed politically, culturally and socio-economically.[11] In 2010, GDP per capita in Wallonia was 0.74 times the Belgian average while the region of Flanders was equal to the national average (0.99).[12] From a historical perspective, the spatial pattern of economic inequality is particularly striking as the Walloon region was significantly better off at the end of the 19$^{\text{th}}$ century. By estimating GDP per capita at the province level from 1896 to 2000, Buyst (2011, p.337) shows that the richest province in 1896, which was Hainaut, had the lowest relative GDP per capita among Belgian provinces in 2000. This *reversal of fortune* can also be observed for the remaining Walloon provinces.[13] Except for Luxembourg, all Walloon provinces show above average GDP per capita in 1896 while their GDP per capita was not only below the national average in 2000 but the richest Walloon province, Liège, was poorer than the poorest province of Flanders, Limburg. This raises the question how these differences in regional growth paths can be explained. With the exception of Ronsse and Rayp (2016), the literature consists of mainly descriptive comparisons of the economic development of these regions.

A rather early study on the industrial geography of Belgium by Riley (1976) analyses this exact question. Writing in the 1970s, he experienced the shift from Wallonia to Flanders, stating that *"the Brussels-Antwerp axial belt has replaced the Haine-Sambre-Meuse coalfield as the economic core of the country"* (Riley, 1976, p.178). Even though, his analy-

[10] A more general review of economic development in Belgium during the 19$^{\text{th}}$ century is presented in section 2.1.2.

[11] The focus of this article lies at the historical origins of economic differences. See Deprez and Vos (1998) for a broader approach discussing linguistic, religious, social, economic, political and institutional factors.

[12] Source: Eurostat - *Gross domestic product (GDP) at current market prices by NUTS2 regions.* Belgium consists of three NUTS1 regions which are Wallonia, Flanders and the capital region of Brussels. The underlying GDP per capita estimates in current prices are: Wallonia (24,100), Flanders (32,400), Brussels (61,200).

[13] A previous title of Buyst's (2011) article was *Reversal of Fortune in a Small, Open Economy: Regional GDP in Belgium, 1896-2000.*

sis is mainly based on data from the 1950s to the 1970s, he presents a discussion of economic pre-conditions from the 19th century. In his opinion, coal was a main locational factor as a source for power rather than being a raw material. A dense transportation system, waterways in particular, however, ensured that industries like cotton and linen textiles could emerge outside of coalfields based on local skills (Riley, 1976, p.28). A seminal study in analysing the spatial economic patterns in Belgium is De Brabander (1981). In contrast to Riley (1976), De Brabander (1981) focuses on a longer time period by analysing the spatial concentration of industrial employment based on industrial censuses between 1846 and 1970. For the pre-WWI period, Antwerp was the only Flemish province which showed signs of economic success. Starting as an important tertiary centre, Antwerp expanded its industrial position by attracting the diamond, food, and paper-printing-publishing industries. Even for East Flanders with the early modern industrial centre of Ghent, De Brabander (1981) identifies a non growth-oriented sectoral profile. Among the Walloon provinces, Hainaut and Liège are identified as leaders in the industrialisation process, at least until 1896. Based on the coal-metal complex, the two provinces loose attractiveness as an industrial region at the end of the 19th century. Brabant, on the other hand, gains importance with complementary effects from the tertiary sector in Brussels and a specialisation in the food, clothing and paper-printing-publishing industries. De Brabander (1981) presents a detailed analysis of the spatial distribution of industrial employment but he gives little insights into why these spatial patterns and dynamics have emerged. Nevertheless, his conclusion that *"today's regional sectoral problems are equal to these a century ago"* presents an interesting perspective (De Brabander, 1981, p.101). Even during the 19th century he emphasises the growing importance of the Brussels-Antwerp centres which Riley (1976) has identified as becoming crucial during the 20th century.[14]

Similar to De Brabander (1981), Boschma (1994) performs a detailed descriptive analysis of the spatial patterns of industrial activity. Boschma (1994) identifies and evaluates technological clusters in the Belgian industrial sector from 1846 to 1990. His technological focus on regional patterns shows how regions have succeeded or failed depending on their ability to adapt to technological change. The clusters of the first industrial revolution were successfully developed, with the exception of the chemical industry, in Ghent & Verviers (textile cluster) and Charleroi & Liège (steam-coal-iron cluster). The new mechanical and electric clusters of the second industrial revolution were mainly based in Antwerp and Brussels and only in the steel cluster two former regions of Charleroi & Liège were able to sustain their leading position. Similar to De Brabander (1981), Boschma (1994) associates the rise of the post WWII Brussels-Antwerp dominance with the late 19th century. Based on a similar database of industrial employment from 1846 onwards, Vandermotten (1997) follows a more narrative approach by focusing on the rationale behind location decision rather than solely documenting the distribution of employment. He emphasises proto-industrial tradition, capital investment and human resource availability. Vandermotten (1997) sees the location within the coal-field based on proto-industrial tradition in the metallurgical industry and relates low wage costs in Flanders as discouraging to mechanisation in the textile industry. Moreover, the interest in heavy industries by Brus-

[14] A good discussion of the Belgian spatial divide is also presented by Thomas (1990) who analyses the declining economic prosperity of the Walloon region in a multifaceted and historically embedded way.

sels' bankers were decisive to shape the spatial pattern of Belgian industry (Vandermotten, 1997, p.173).

Based on these collections of evidence on the spatial patterns of Belgian industrialisation, Buyst (2011) outlines arguments about the driving factors of the dynamics of the Belgian regional pattern to interpret his GDP per capita estimates for Belgian provinces. He relates the differences in economic prosperity in 1896 to the decline of the Flemish rural linen industry during the mid-19th century.[15] A second shock to the Flemish economy was the *grain invasion* which put pressure on grain prices and land values.[16] This is in stark contrast to the industrial centre which stretched from the Borinage to Verviers. Industrialisation in this region was based on coal intensive industries like steel, glass, machine building and zinc. Furthermore, Buyst (2011) argues that Walloon entrepreneurs participated successfully in the first global economy of the late 19th and early 20th centuries. He shows that regional convergence can only be observed by 1937 when low wages in Flanders and increasing dependency on coal imports via the port of Antwerp as well as Ghent led to a catch-up of Flemish provinces. After WWII the Walloon industries continued their relative decline which he associates with the decline of coal and the rise of oil as the main energy source. The most recent contribution to this literature by Ronsse and Rayp (2016) can be understood as an empirical test of the location determinants which have been suggested by the literature. Based on the approach of Midelfart-Knarvik et al. (2000), they find that access to markets was important for industries to change location from the Walloon region to the Flemish Belgian region mainly after 1896, depending on the specification. Coal as a location factor was only important in 1896 loosing its significance in later periods. Combining these two findings Ronsse and Rayp (2016, p.415) state that *"the reductions in transportation costs led industries to locate away from regions with natural resources and near regions with high market potential"*. Their focus on the post 1896 period enables them to contribute to our understanding of the shifts in locational advantages from Southern to Northern regions but fails to shed light on the origins of industrialisation of the world's second industrial nation.

5.3 Empirical strategy & Data

Our empirical strategy is embedded in the location choice literature pioneered by McFadden (1978) and Carlton (1979). This framework has been used to study firm level location decisions based on a firm's profit maximising assessment (Carlton, 1983). By choosing this theoretical framework we follow Crafts and Wolf (2014) and Gutberlet (2012) who have estimated models of location choice for 19th century Britain (Crafts and Wolf, 2014) and the German Empire (Gutberlet, 2012). More specifically, we apply a Poisson model which is observationally equivalent to a conditional logit model, as Guimaraes et al. (2003) has shown and Crafts and Wolf (2014, p.1107) have pointed out. The key location factors of interest are access to coal endowments as well as access to consumer markets. Problems of endogeneity are dealt with by applying an instrumental variable approach. Access to

[15]See Jacquemyns (1929) and Verhaegen (1961) for seminal contributions discussing the fate of the Flemish linen industry.

[16]For the development of the Belgian agricultural sector see Goossens (1993) for the period 1812 to 1846 and Blomme (1992) for the period 1880 to 1980.

coal mines is instrumented by access to the carboniferous rock strata (Asch, 2005). Access to urban markets, both foreign and domestic, is instrumented by constructing market potential estimates based on urban population in 1700 (Bairoch et al., 1988; De Vries, 1984). Using urban population in 1700 addresses the problems of endogeneity which stem from the fact that population growth was faster in cities which were in proximity to coal as Fernihough and O'Rourke (2014) have shown.

5.3.1 Identifying location

Information of location choices is assessed by exploiting two Belgian industrial censuses of 1846 and 1896.[17] Compared to other mid-19th century industrial censuses, the 1846 Belgian census is of excellent quality. It lists the number of firms, the number of workers (by sex and age group), their salaries (by sex and age group), the type and number of motive powers and other machinery for 298 industries by urban and rural municipalities at the regional level of arrondissements. The 1896 industrial census was an even more ambitious project resulting in 18 volumes. The census is mainly focused on employment. It lists the number of firms, number of entrepreneurs and workers as well as the horsepower of motive power for 858 industries and 2,604 municipalities.

Given the fact that 50 years lie between the two sources, they cannot be compared without adjustments. The censuses have to be harmonised with respect to regional and industry aggregation. A consistent dataset at the region-industry level has been constructed. Aggregate statistics in Belgian censuses are usually published at the province level. Therefore, most studies of 19th century regional economic development in Belgium, see section 5.2, use the province level as their regional unit of analysis. The actual census results, however, allow for a finer level of regional disaggregation, why in this study the 41 Belgian arrondissements have been chosen as the regional unit of analysis.[18] With respect to the sectoral coverage of the censuses, it is important to note that the 1896 industrial census collected information on the cottage industry, while the 1846 industrial census covers solely the factory and artisan sector. Following De Brabander (1981), the cottage industry is removed from the 1896 census in order to ensure comparability. Furthermore, the construction and transport sectors are excluded from the 1896 as these service sector industries have not been covered in 1846. After these adjustments have been made, the 1846 census yields a total number of 314,842 industrial workers, while the 1896 census results in 851,020 workers.[19]

To further disaggregate the industrial sector, an industrial classification has been chosen which distinguishes between six key industries: (1) coal mining; (2) textile industries; (3)

[17]After Belgian independence in 1830, four industrial censuses have been collected during the remaining 19th century: 1846, 1866, 1888, 1896. However, only the 1846 and 1896 industrial censuses are of sufficient quality to study the Belgian industrial sector at a detailed regional and industrial level. The results of the 1866 census were of such poor quality that they have not even been published and the 1888 census only covers a fraction of the Belgian industrial sector.

[18]A municipality level analysis, which would be possible for 1896, cannot be performed in 1846 as census results for rural communes have been aggregated at the level of arrondissements.

[19]For this analysis the 1846 industrial census (Belgique, 1851) has been digitalised. Employment information from the 1896 census has been aggregated to the arrondissement level from municipality level data based on *LOKSTAT, the Historical Database of Local Statistics in Belgium. http://www.lokstat.ugent.be.* The high level of disaggregation on the industry level in both censuses allows to build consistent industry aggregates.

food and beverage industries; (4) metallurgy and metal product industries; (5) wood, leather, printing and paper industries; (6) chemical and glass industry.[20] In 1846 the five industries (2-6), excluding coal mining, cover 69% of the total industrial workforce reported in the census, which increases to 81% if coal mining is not included in the denominator. In 1896 the selection of industries (2-6) covers 62% of the census workforce, excluding cottage industries as well as the transport and construction sector. If the coal mining industry is deducted from the denominator, the sample's coverage increases to 72%. It is, therefore, fair to conclude that the harmonised sample covers an economically meaningful fraction of the Belgian industrial sector during the 19th century. Table C.4 shows total industrial employment in 1846 and 1896 for the respective industries at the national level and tables C.5 and C.6 report employment by industry at the regional level.

5.3.2 Access to coal and markets

The two main explanatory variables of interest in this analysis are access to the production factor coal and access to markets. With respect to access to coal we follow the approach of Fernihough and O'Rourke (2014) and identify coal mines based on Châtel and Dollfus (1931) which cover the coal mining areas of Hainaut and Charleroi as well as the mining area around Liège.[21] However, as the location of coal mines is not truly exogenous and might be driven by the demand for coal close to a particular location, we also consider the geological information derived from Asch (2005). Asch (2005) presents a detailed GIS georeferenced geological map of Europe including information on carboniferous rock strata. In both cases access to coal is measured as the inverse distance to either the closest coal mine in the case of Châtel and Dollfus (1931) or the carboniferous rock strata in the case of Asch (2005).[22] Figure 5.2 shows this approximation for the cost of coal at the level of Belgian arrondissements. Figure 5.2b displays the shortest distance to the carboniferous layer and figure 5.2a shows the shortest distance to coal mines. Unsurprisingly the two measures show a very similar spatial pattern. Coal was most accessible along a line between the cities of Liège and Mons which follows part of the rivers Meuse and Sambre. The Northern regions as well as the South-East was most disadvantaged with respect to access to coal endowments.

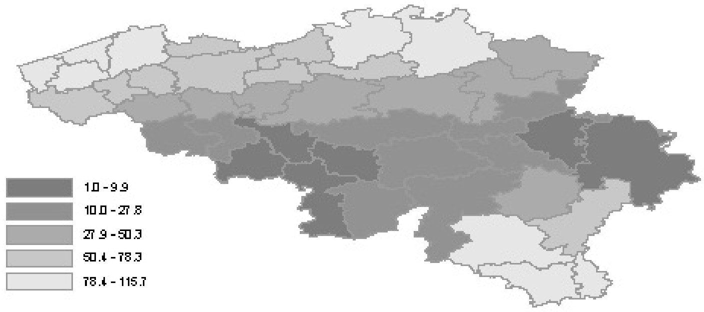
Access to markets is estimated by following Harris (1954) who measures market potential as an inverse distance weighted sum of regional GDPs.[23] In the absence of regional GDP estimates, regional population figures are used instead. More specifically, the maps which are shown in figure 5.3 have been calculated based on regional urban populations. With respect to foreign market potential, which is constrained to Belgium's key trading

[20]This classification scheme is inspired by the work of Gadisseur (1983). Given that one of the objectives of this analysis is to study the determinants of industrial location, the coal mining industry is of less direct interest as location patterns are necessarily tied to the availability of coal. It is also worth noting that the industries like clothing or quarries and pits are not part of the sample.

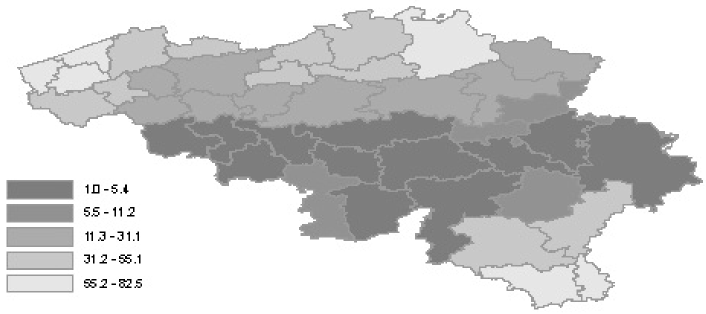
[21]The following locations have been identified as important coal mining centres: Liège, Charleroi, Mons, La Roeulx, Fontaine-l'Évêque, Bernissart, Binche, Hevre, Sambreville.

[22]The inverse distance is normalised by 10,000 following the approach of Fernihough and O'Rourke (2014). Distances are calculated as great circle distances in order to avoid introducing endogeneity biases as transport networks are constructed based on demand considerations and can, therefore, not be seen as exogenous.

[23]Domestic market potential (DMP_r) and foreign market potential (FMP_r) of region r: DMP_r is measured as the sum of a region's own market potential (SP_r) and a distance (d_{rs}) weighted sum of the economic size (M_s) over all other regions. FMP_r is a distance weighted sum of the economic size over



(a) coal mines



(b) carboniferous rock strata

Figure 5.2: Distance to coal by Belgian region

Notes: Distances are based on great circle distances (GCD) applying the Haversin formula. GCD for figure 5.2a are calculated between regional capitals and the following main mining centres Liège, Charleroi, Mons, La Roeulx, Fontaine-l'Évêque, Bernissart, Binche, Hevre, Sambreville.
Sources: own calculations based on information from Châtel and Dollfus (1931) and Asch (2005).

partners (France, the German Customs Union, Netherlands, United Kingdom and Luxembourg), two alterations have been made. Firstly, border crossings are only allowed through key customs stations which have been identified by studying contemporary transport maps.[24] Secondly, foreign market potential has been calculated at the regional level and limited to distances of 300 kilometres from the Belgian border. This alteration has been introduced in order to prevent inflating foreign market potential by the heterogeneous territorial extent of the trading partners. For instance, the foreign market potential with the German Customs Union has been calculated based on a combination of the distance to German regions and those regions' urban population. *Regierungsbezirke* act as the regional

foreign trading partners. This approach follows Martinez-Galarraga et al. (2015).

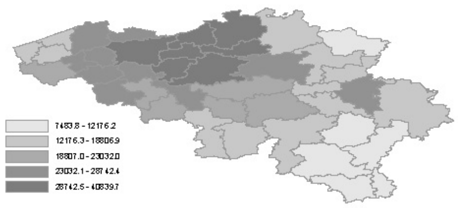
$$DMP_r = \sum^{s} \frac{M_s}{d_{rs}} + SP_r;\ FMP_r = \sum^{f} \frac{M_f}{d_{rf}^{-\delta}}$$

$$SP_r = \frac{M_r}{d_{rr}};\ d_{rr} = \frac{1}{3}\left(\frac{\text{Area of the region}_r}{\pi}\right)^{\frac{1}{2}}$$

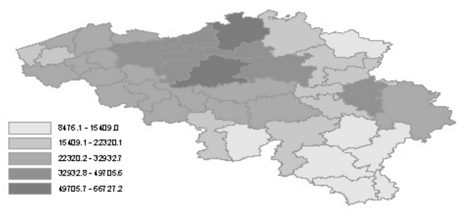
[24]Transport maps have been accessed through the *Bibliothèque nationale de France*. Alphonse Belpaire's map from 1843 *'Carte du mouvement des transports en Belgique pendant l'Année 1843, indiquant l'importance comparative de la circulation sur les voies de communications par terre'* is used for road and railroad transportation while Charles-Joseph Minard's map from 1843-44 *'Mouvement des marchandises en Belgique sur les chemins de fer en 1844 et sur les voies navigables en 1834 et en 1844'* is the main source for transport on waterways.

level for the German Customs Union and distances have been calculated through Verviers. Thus, the contribution of Aachen to the foreign market potential of the Belgian region of Antwerp is based on the urban population of Aachen and the sum of the distances from Antwerp to Verviers and from Verviers to Aachen.[25]

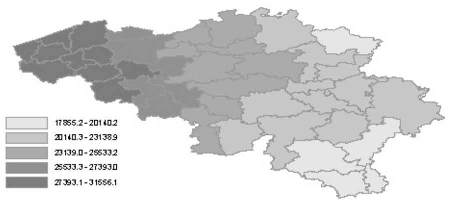
Figure 5.3 shows domestic and foreign market potentials for the years 1846 and 1896. It can be seen that access to domestic urban markets is most beneficial in the Mid-Northern regions and lowest in the South. Foreign market potential is highest in the West with good access to France, the Netherlands and the United Kingdom. Foreign market potential declines along a West-East direction. Access to the German but also the Dutch market through Verviers and Maastricht explain the relatively high value in Verviers and Liège. However, it is quite clear from figures 5.3c and 5.3d that the Eastern part of Belgium is disadvantaged with respect to foreign market access.[26]



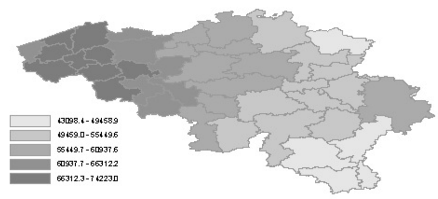
(a) domestic (1846)



(b) domestic (1896)



(c) foreign (1846)



(d) foreign (1896)

Figure 5.3: Belgian domestic and foreign Market Potential in 1846 and 1896

Sources: Great circle distances are calculated based on the Haversin formula; Urban population: Belgium: municipality level population figures for the years 1846 and 1896 have been derived from the 1961 population census which states municipality level population figures for every census between 1831 and 1961. France: municipality level population figures for the years 1846 and 1896 from *Territoires et population, deux siècles d'évolution. Des villages Cassini aux communes d'aujourd'hui (http://cassini.ehess.fr)*. Netherlands: municipality level population figures are based on the population censuses of 1849 and 1899 and have been accessed through *Volkstellingen 1795-1971 (http://www.volkstellingen.nl)*. Britain: municipality level population figures are based on the population censuses of 1851 and 1901 and have been accessed through *Histpop - The Online Historical Population Reports (OHPR), University of Essex (http://histpop.org)*. Germany: city level population figures are from Bairoch et al. (1988) for 1850 and from the *Geographische Zeitschrift (1896)* for 1895.

[25] Other foreign market access has been calculated by using the following border crossings. France (departments): Furnes-Dunkerque, Mouscron-Lille, Tournay-Lille, Tournay-Douai, Tournay-Valenciennes, Mons-Valenciennes, Mons-Mauberge, Charleroi-Mauberge, Philippeville-Givet; Netherlands (provinces): Anvers-Middelburg, Anvers-Bois de Duc, Ghent-Middelburg, Bruges-Middelburg, Maastricht; United Kingdom (counties): Anvers-London, Ostende-London; Luxembourg (one region): Arlon.

[26] Surprisingly, the port region of Antwerp is not identified as the most advantaged region with respect to foreign market potential. This is due to the fact that, based on great circle distances, the port of Ostende is located closer to foreign oversea markets. The British market, for instance, can be accessed through Ostende at shorter distances then it would be possible through Antwerp. It is only the Dutch market for which Antwerp is an important hub of foreign market access.

5.4 Empirical results

5.4.1 Explaining regional industrial employment

We start our empirical analysis by relating coal and market access to the spatial distribution of industrial employment, neglecting any endogeneity problems at this stage. For each industrial classification a poisson model is estimated containing the following key location factors: the inverse distance to coal mines ($ln(coal)$), domestic market potential based on urban population ($ln(domesticMP_t)$) and foreign market potential based on urban population ($ln(foreignMP_t)$). Additionally, the region r's surface area ($ln(area)$), a constant, a dummy for Wallonia and a dummy for the 1896 census period are considered in every benchmark estimation. The results, which are shown in table 5.1, present the models' coefficient estimates with the respective standard errors which have been regionally clustered at the province level. Specifications 1 to 3 study the location of aggregate industrial employment while specifications 4 to 8 analyse sub-industries. The aggregate industrial employment (IND) is the sum of employment in the textile industries (TEX), the food and beverages industries (FOOD), the metallurgy and metal products industries (MET), the wood, leather, paper and printing industries (Group 1) and the chemical products and glass industries (Group 2).

Looking at the industrial sector as a whole, table 5.1 shows clear support for the importance of locating close to coal fields. Furthermore, the expected number of industrial employment is higher in Belgian regions with better access to domestic urban markets. Both coefficients are statistically significant at the 1% level. Access to foreign urban markets is not found to be crucial for regional industrial location. Comparing specifications 1 to 3 shows collinearity between access to coal and access to domestic urban markets. The coal coefficient halves when domestic market potential is added as a location factor. Moreover, the explanatory power of the model increases substantially when adding domestic market potential. Access to foreign urban markets, however, does neither affect the coefficients of coal or domestic market potential, nor does it increase the explanatory power of the model. With respect to individual industries - see specifications 4 to 8 - we find that the aggregate location factor coal is driven by the metallurgy and metal products industry (MET) as well as the chemical products and glass industries (Group 2). Compared to coal, access to urban domestic markets is important for every single industry, most strongly for the textile industries. Also access to foreign urban markets is identified as a location factor at the 1% statistically significant level for the textiles and food industries.[27] It should be concluded from this first analysis, which does not account for potential problems of endogeneity, that both access to coal as well as access to domestic urban markets were associated with Belgian industrialising regions during the second half of the 19$^{\text{th}}$ century. However, these two location factors show crucial differences. While access to urban domestic markets seems to be crucial for a broad selection of industries, access to coal is associated with more specific industries. This implies that access to coal is associated with a sector specific composition of the industrial labour force while market access is a more universal location factor.

[27] Decomposing the textile industries into *linen*, *cotton* and *wool* shows that access to domestic urban markets was of importance for the linen and cotton industries, access to foreign urban markets is detected as statistically significant for the linen and wool industries and access to coal is positively associated with employment in the wool industry.

Table 5.1: Poisson models of regional industrial employment in Belgium 1846-1896

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	IND	IND	IND	TEX	FOOD	MET	Group 1	Group 2
ln(coal)	0.54	0.26	0.26	-0.03	0.08	0.56	0.07	0.75
	(0.11)***	(0.07)***	(0.07)***	(0.14)	(0.11)	(0.05)***	(0.06)	(0.19)***
ln(domestic MP)		1.84	1.84	2.36	1.59	1.90	1.61	1.70
		(0.32)***	(0.31)***	(0.82)***	(0.10)***	(0.23)***	(0.30)***	(0.42)***
ln(foreign MP)			0.81	3.11	1.07	-2.98	0.78	-3.74
			(0.76)	(0.82)***	(0.40)***	(1.68)*	(0.68)	(3.50)
ln(area)	0.75	0.50	0.59	0.01	0.64	1.08	0.93	0.61
	(0.27)***	(0.13)***	(0.13)***	(0.36)	(0.22)***	(0.29)***	(0.19)***	(0.44)
constant	yes	yes	yes	yes	yes	yes	yes	yes
region dummy	yes	yes	yes	yes	yes	yes	yes	yes
time dummy	yes	yes	yes	yes	yes	yes	yes	yes
N	82	82	82	82	82	82	82	82
Pseudo R2	0.52	0.83	0.83	0.42	0.84	0.90	0.88	0.78

Standard errors in parentheses clustered at the province level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Sources: see text.

5.4.2 Establishing causality

The poisson models in table 5.1 are the first steps to analyse the importance of market access and coal in Belgian industrialisation from a spatial location perspective. However, it is likely that the coefficients derived from these models suffer from endogeneity biases stemming either from omitted variables, simultaneity or measurement errors. An instrumental variable strategy is applied to deal with this problem. Based on Asch (2005) and following Fernihough and O'Rourke (2014), the shortest inverse distance to coal mines is instrumented by the shortest inverse distance to the carboniferous rock strata. The rationale behind instrumenting access to coal is that the location of coal mines may depend on the demand for coal and can, therefore, not be treated as truly exogenous. Using the carboniferous layer instead, measures the shortest distance to potential coal mines rather than actual mines and can, therefore, be seen as exogenous to industrial location. Besides access to coal, the market potential coefficients are most likely to suffer from endogeneity biases. Our measure of market potential increases if people move to locations with a higher probability of finding a job in the industrial sector. Market potential is, therefore, measured by using urban population in 1700 assuming it to be exogenous to industrial employment between 150 and 200 years later. Urban population in 1700 is measured by aggregating all cities in the Bairoch et al. (1988)-De Vries (1984) dataset at the regional level both for domestic as well as foreign market potential. The instruments proof to be valid by showing high degrees of conditional correlations and F-statistics well above 10 - see table C.1.

The results from the poisson models with endogenous regressors using two-step GMM are shown in table 5.2.[28] We follow the same approach as in the previous subsection and analyse aggregate industrial employment as well as industrial employment by sector. At the aggregate level, we see the same general pattern as without instrumenting. Both access to coal as well as access to domestic urban markets are highly statistically significant location factors. Comparing both aggregate specifications in tables 5.1 and 5.2 shows that the coal coefficient was downward biased and the domestic market potential coefficient was upward biased. This supports the idea that during industrialisation population grew faster closer to coal fields. Looking at specific industries, the same direction of biases is most pronounced in the metallurgy and metal products industries. The coal coefficient increases from 0.56 to 0.81 and the domestic urban market potential coefficient decreases from 1.9 to 1.38. This pattern is in line with the historiography of Belgian industrialisation during the 19$^{\text{th}}$ century which was largely driven by the coal and metal industries - see section 2.1.2. Market potential again proves to be more consistently important across industries compared to access to coal.[29] The importance of foreign markets is supported for the textiles and food industries, yet, loses its significance once a control-function estimator is applied.[30] In this specification access to coal is identified as a location factor for aggregate

[28] The two-step GMM estimator is used to estimate the parameters of an exponential conditional mean model with endogenous regressors. As the poisson regression is a special exponential conditional mean model, this approach is well suited to model dependent count variables. The exercise is performed by using the *Stata* package *ivpoisson*.

[29] The high standard error for the textile industry is driven by the wool industry such that access to domestic urban markets remains highly statistically significant once linen and cotton textile industries are considered.

[30] The control-function approach follows Wooldridge (2010, sec.18.5) using multiplicative errors. It is a

industrial employment, the metal industries and the chemical products and glass industries. Domestic market potential is a statistically significant location factor for all specifications using the control-function estimator.

Table 5.2: Poisson model of regional industrial employment: instrumenting endogenous regressors

	(1) IND	(2) TEX	(3) FOOD	(4) MET	(5) Group 1	(6) Group 2
ln(coal)	0.43	0.79	-0.18	0.81	-0.03	1.07
	(0.19)**	(0.52)	(0.13)	(0.29)***	(0.09)	(0.89)
ln(domestic MP)	1.56	1.7	1.96	1.38	1.85	0.89
	(0.47)***	(1.29)	(0.25)***	(0.56)**	(0.34)***	(1.28)
ln(foreign MP)	0.83	2.54	1.19	-2.76	0.82	1.46
	(0.55)	(0.99)**	(0.53)**	(2.05)	(0.72)	(2.63)
ln(area)	0.71	0.14	0.52	1.45	0.86	1.41
	(0.17)***	(0.41)	(0.26)**	(0.42)***	(0.18)***	(0.86)
constant	yes	yes	yes	yes	yes	yes
region dummy	yes	yes	yes	yes	yes	yes
time dummy	yes	yes	yes	yes	yes	yes
N	82	82	82	82	82	82

Standard errors in parentheses clustered at the province level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Sources: see text.

5.4.3 Adding controls

In order to further validate our results we add a list of potential confounders as additional regressors. In a step-by-step approach in table 5.3 we control for cultural, geographical, human capital, institutional and labour cost determinants of industrial location. In contrast to the previous results no regional dummies are used in order to gain further insights from the control variables. As a proxy for regional differences in cultural location factors the Belgian language divide is used which is measured as the share of French speaking inhabitants by arrondissement. This information is derived from the population census of 1846. Figure C.2 shows the spatial distribution of the French (figure C.2a) and Dutch (figure C.2b) speaking population as stated in the 1846 population census. Religion as an additional cultural control is not sensible for the Belgian case due to the limited variation in religious affiliation. In the least catholic dominated arrondissement of Antwerp 98.5% of inhabitants affiliated themselves to the roman catholic church in 1846. Therefore, it is not meaningful to exploit any regional variation along religious lines.

two stage estimation process which assumes a structural relationship between endogenous and exogenous regressors using first stage parameter estimates to control for endogeneity in the second stage. The control function estimator is available as an option in the *Stata ivpoisson* package.

Apart from cultural differences regional industrialisation might be affected by the profitability of alternative sectors, agriculture in particular. We, therefore, add a measure of soil quality (FAO/IIASA) to test whether industrial employment concentrates in regions which are less suitable for agricultural production.[31] Figure C.3a displays our indicator of soil quality along a measure of land value, figure C.3b, and the lease rate, figure C.3c, which have been collected from the 1846 Belgian agricultural census. The two measures show a similar pattern indicating that the FAO/IIASA is a reasonable approximation for agricultural suitability.

A further prominent factor for industrial activity is human capital. A higher skilled labour force might be an important determinant of industries to location in a specific region. Measures of human capital in 19th century Belgium are, however, hard to find. From the 1846 population census, school enrolment rates of children between the ages of 5 and 15 are calculated.[32] The 1846 census is the last census to collect information on the number of pupils. From 1866 onwards, the census records the literacy of the Belgian population.[33] Figure C.4 shows both of these measures. School enrolment rates in 1846 (figure C.4a) and literacy rates in 1866 (figure C.4b) show a similar, though not the same, spatial pattern with high levels of human capital in parts of Luxembourg and very low levels in some regions of Flanders. Higher level education is measured by a dummy for universities prior to 1800.[34]

Institutional factors are controlled for by adding dummies for Brussels and provincial capitals as the two levels of legislative power. It should also be noted that the language variable might has an institutional component as the institutional reforms, which were introduced during the period of French rule, might have been easier to implement in the French speaking rather than the Dutch speaking part of the country. A further aspect of institutional capacity is the population's political inclusion. We approximate political inclusion as the share of the population eligible to vote and the share of the population which actual voted in the Belgian elections of 1841 and 1843 (Belgique, 1852, part 3). Figure C.5 shows a similar spatial pattern for both variables with the highest density of voters in the South-East.

As a proxy for proto-industrialisation we further add a dummy variable for proto-industrial regions of Flanders in which participation in the proto industrial textile industry was highest during the 18th century (Vandenbroeke, 1996).[35] In a last step also labour

[31] Soil quality refers to the crop suitability index from the *Global Agro-ecological Zones Data Portal version 3.0 (GAEZ v3.0)* with the following specifications: Crop (Wheat), Water Supply (Rain-fed), Input Level (Intermediate), Year (Baseline period 1961-1990), no CO2 fertilization. The crop suitability index (CSI) has been spatially joined at the level of Belgian arrondissements and transformed (1/CSI) such that a higher value indicates higher suitability.

[32] The census of 1846 states the number of girls and boys who are enrolled in primary school and secondary school at the urban and rural level. The regionally aggregated number of pupils in primary and secondary schools is divided by the region's population between the age of 5 and 15. As the 1846 census does not present information of the age distribution at the arrondissement level, the share of 5 to 15 years old children was approximated. The approximation is based on the urban (rural) share of 5 to 15 years old children at the province level and was weighted by the arronidssement's share of the urban (rural) population.

[33] Literacy rates are constructed by dividing the literate population with the total population for each Belgian arrondissement.

[34] The only university in Belgium prior to 1800 was situated in Leuven. Universities which were founded during the early 19th century in Ghent (1817), Liège (1817), Brussels (1834) and Mechelen (1834) are not considered as they might reflect an industrial demand for human capital.

[35] The selected arrondissements are Courtrai and Thielt in West Flanders and Alost, Audenarde and

costs are added to our main specification. Labour costs are approximated by the male agricultural wage in 1830, with no payment in kind, which is reported in the 1846 agricultural census for the years 1830, 1835, 1840 and 1846. As it is not clear based on which information the wage of 1830 has been collected in 1846, we also use the agricultural wage in 1846. Figure C.6 shows the male agricultural wage in 1830 (figure C.6a) and 1846 (figure C.6b). As wages in 1830 and 1846 are likely to reflect a combination of locational advantages, such as human capital and skills, this is not a perfect control for labour costs and will be collinear to many other location determinants. The full specification which includes all controls is, therefore, presented with and without the agricultural wage.

Looking at the results, which are presented in table 5.3, we find that adding controls does not change our previous findings. Regions with more advantageous access to coal are more likely to have higher employment in the industrial sector as do regions with better access to domestic urban markets. Moreover, the coefficients for access to coal and urban markets stay remarkably stable throughout the various specifications as well as compared to coefficient estimates with only a limited number of controls in table 5.2. Adding all controls simultaneously in specification (8) results in a marginally lower *inverse distance to coal* estimate and a marginally higher *access to domestic urban markets* estimate. It is further supported that access to foreign markets did not play a significant role with respect to the location of industrial employment, at least at the aggregate level. Hence, it can be concluded that adding cultural, geographical, human capital, institutional and proto-industrial controls does not violate the main results on the importance of access to coal and domestic market potential.

Among the control variables we identify some interesting findings of further interest. Starting with specification (2), we find no evidence that cultural differences along the language divide have an effect on industrialisation. Soil quality, on the other hand, shows a strong negative influence on expected industrial employment once the full model with all controls is considered. The validity of this finding is further supported by the fact that the soil quality coefficient turns positive while remaining statistically significant once the sample is reduced to the food and beverage industries. More suitable soil for agricultural production is, therefore, associated with higher expected employment in food related industries while the overall effect remains negative. With respect to indicators of human capital we do not find any significant effects. Neither literacy rates nor being located close to the university is associated with industrial employment.[36] Our institutional variables show a positive association between industrial employment and being located in the capital Brussels. This coefficient is stable across all specifications.[37] Political inclusion, measured as the share of electoral voters over the regional population, is not found to be associated with industrialisation. Proto-industrial tradition, on the other hand, shows a positive and statistically significant link to 19$^{\text{th}}$ century industrialisation.

Gand in East Flanders.

[36] If literacy is replaced by school enrolment the coefficient stays negative and becomes statistically significant. However, once the controls are added schooling turns statistically insignificant and the coefficient becomes positive. Even though literacy is measured in 1866 we believe that this indicator is more reflective of basic human capital endowments as school enrolment in one particular year.

[37] However, it should be remembered that this is only a very crude measure of institutional factors and might even capture multiple aspects including market potential effects. As Brussels is a major urban market, it makes sense that the coefficient of domestic market potential declines once the Brussels dummy is added.

Table 5.3: IV Poisson model of regional industrial employment: adding controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	IND	IND	IND	IND	IND	IND	IND	IND	IND
ln(coal)	0.28	0.44	0.26	0.28	0.32	0.33	0.24	0.40	0.39
	(0.05)***	(0.17)***	(0.05)***	(0.05)***	(0.06)***	(0.07)***	(0.05)***	(0.09)***	(0.09)***
ln(domestic MP)	1.83	1.57	1.86	1.83	1.71	1.74	1.89	1.63	1.64
	(0.18)***	(0.31)***	(0.18)***	(0.18)***	(0.15)***	(0.22)***	(0.18)***	(0.17)***	(0.17)***
ln(foreign MP)	0.38	1.15	0.90	0.35	0.05	-0.17	0.58	0.38	0.39
	(0.59)	(0.6)*	(0.53)*	(0.50)	(0.64)	(0.80)	(0.56)	(0.68)	(0.71)
ln(area)	0.54	0.79	0.54	0.58	0.44	0.60	0.61	0.62	0.67
	(0.16)***	(0.22)***	(0.17)***	(0.21)***	(0.14)***	(0.15)***	(0.16)***	(0.29)**	(0.30)**
ln(sh French)		-1.06						-0.12	-0.24
		(0.87)						(0.59)	(0.59)
ln(soil quality)			-0.98					-2.71	-2.25
			(0.76)					(0.84)***	(0.91)**
ln(literacy)				-0.06				-0.26	-0.21
				(0.72)				(0.67)	(0.65)
D uni pre-1800				-0.31				0.00	0.01
				(0.16)				(0.24)	(0.25)
D Brussels					0.56			1.02	1.06
					(0.25)**			(0.24)***	(0.23)***
D prov capitals					-0.11			-0.42	-0.42
					(0.23)			(0.16)**	(0.16)**
ln(sh voters)					-0.00			0.44	0.38
					(0.42)			(0.16)	(0.30)
D proto-IND						0.42		0.75	0.58
						(0.20)**		(0.17)***	(0.45)***
ln(agr wage 1830)							0.99		0.58
							(0.63)		(0.45)
constant	yes	yes	yes	yes	yes	yes	yes	yes	yes
time dummy	yes	yes	yes	yes	yes	yes	yes	yes	yes
N	82	82	82	82	82	82	82	82	82

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

That Belgian industries benefited from cheap labour is not identified in our analysis, at least Belgian industries did not allocate labour according to its price. In spite of not being statistically significant, the coefficient on wages tends to be positive rather than negative. With the exception of the proto-industrialisation dummy, adding wages as a confounder in specification (9) has hardly any effect on the other determinants' coefficient estimates.

Performing a similar analysis for sub-industries shows more heterogeneity among the location determinants coal, domestic and foreign market potential. Table C.2 applies the same model as specification (9) in table 5.3 for the aggregate industrial sector (1), the textiles industries (2), the food and beverages industries (3), the metal industries (4), the wood, leather, paper and printing industries (5) and the chemicals and glass industries (6). The results confirm the importance of access to domestic markets across all industries. In contrast to the uncontrolled specification, access to coal is also identified as an important location determinant for the textile industries, while confirming its importance for the metal industries as well as chemicals and glass industries. With respect to foreign market access, we find evidence that the non-significance at the aggregate industry level might stem from opposite signs among sub-industries. On the one hand, textile industries are positively associated with foreign market access while, on the other hand, metal industries show a negative locational relationship.

In a further robustness test the sum of domestic and foreign market potential is used as a measure of market access following the approach by Martinez-Galarraga et al. (2015). Table C.3 shows IV regression results based on a full set of control variables, excluding wages, for the coal and market access coefficients. The upper part of the table sums the domestic and foreign market potential measures which have been used before, while the lower part of table introduces a transport cost approach. Firstly, domestic market potential is calculated based on transport cost measures instead of using great circle distances as a denominator. Transport costs between regions are assessed by introducing relative costs by transport mode to a multi-modal transport network model.[38] Secondly, foreign market potential is adjusted to account for import tariffs of manufactured goods based on Tena-Junguito et al. (2012).[39] The results confirm that market potential is a statistically significant location determinant of industrial employment across all sub-industries. Moreover, access to coal is most consistently important for the metal, chemical and glass industries. Once the transport cost measure of market potential is used the coal coefficient almost halves for the textile industries and loses its statistical significance. At the aggregate level, however, coal remains significant, which further highlights the importance of the coal intensive industries. A possible variation of assessing the role of market potential, following Combes and Gobillon (2015), is to differentiate between the region's internal and external market potential. In order to do so, table C.3 introduces own region's urban population as well as the transport and tariff cost adjusted market potential estimate which excludes that particular region. The results show that at the aggregate level coal, localised demand and external demand are statistically significant location determinants. Among the sub-industries the most striking result is the difference between the textile and the metal industries. On the one hand, a region's own internal demand is of less importance for the

[38]Relative costs by transport mode are based on Toutain (1967) for the French transport network during the same period.

[39]Import tariffs are based on the unweighted manufactures average tariffs in 1846 and 1880.

textile industries while it is the main driver for the metal industries. On the other hand, demand external to the region drives the location of textile industries while it is of no importance for the metal industries. Similar to the textiles industries external demand also seems to be the driving factor behind the food industries and both sources of demand are highly statistically significant for the wood, leather, paper and printing industries (Group 1). Overall, it can be concluded that using an aggregate measure of domestic and foreign market potential, substituting great cirlce distances with transport cost measures as well as differentiating between internal and external market potential does not violate the main results at the aggregate level but provides some additional insights at the disaggregated sub-industries level.

5.4.4 Magnitudes and counterfactuals

The previous sections have validated the reliability of the coefficient estimates by discussing problems of endogeneity. So far, however, not a lot has been written about the magnitude of the explanatory variables. In this respect, we are mainly interested whether access to coal or access to urban markets can explain more of the regional variation in industrial employment. Revisiting specification 1 in table 5.2, we have concluded that a unit change in $ln(coal)$ is associated with a 0.43 unit difference in the logs of expected industrial employment. Or put differently, a region which is located 10% closer to coal is associated with 4.3% higher industrial employment, holding all confounders constant. We can further see that the coefficient estimates for market potential estimates tend to be significantly higher. In order to compare the relative significance of the various location determinants, coefficient estimates need to be standardised by the standard deviation. The variable $ln(coal)$ has a standard deviation of 1.21 while the logs of market potential are markedly lower with 0.45 in the case of domestic and 0.44 in the case of foreign market potential. This implies that coefficient estimates of market potential need to be larger than those for coal by a magnitude of around 2.7 in order to explain a larger fraction of the variance in regional industrial employment. Focusing only on industries in which both access to coal and access to urban markets were statistically significant in table 5.2, it can be concluded that for the aggregate industrial sector access to urban domestic markets is economically of more significance than access to coal. A standard deviation change in domestic market potential (MP) is associated with an increase of aggregate industrial employment of 70% (1.56*0.45), while a standard deviation change in access to coal is associated with a 52% (0.43*1.21) higher level of aggregate industrial employment.[40] For the metallurgy and metal products industry, however, access to coal plays the larger role. A standard deviation change in access to coal is associated with an increased employment in the metal industries by 98% (0.81*1.21) while a standard deviation change in access to urban domestic markets is associated with a 62% (1.38*0.45) higher employment in the same sector. Based on the coefficient estimates from the controlled regressions (table C.2), both coal and domestic MP show the same economic magnitude (88%) for the metal industries. At the aggregate level, however, the advantage of domestic MP over coal remains. Also with respect to the textile industries, access to markets is the dominant location factor.

[40]It should be kept in mind that estimated elasticities are only a valid approximation for small changes in the respective variables, why these extrapolations should be interpreted carefully and cautious.

Apart from statistical and economic significance of the coefficients, we are particularly interested in estimating counterfactuals. To what extent can access to coal and access to urban markets explain the regional variation of Belgian industrialisation? To shed more light on this question, we estimate provincial marginal effects. For each of the 9 Belgian provinces we calculate the industrial employment which can be attributed to the various explanatory variables' provincial mean's diversion from the national average.[41] For instance, the province of Antwerp consists of 3 arrondissements. Based on these arrondissements we calculate the provincial mean of each explanatory variable. The poisson model predicts the marginal effects at the provincial means which are then multiplied by the difference from the national average in access to coal and access to domestic urban markets. This results in an estimate to what extent the explanatory variable's diversion from the national average affects industrial employment at the province level. The results are presented in table 5.4 and based on the IV models applied in table 5.2. Table 5.4 gives the provincial and national means of the main explanatory variables of interest: access to coal and access to domestic urban markets. Moreover, it states the total provincial employment at the aggregate industry level in 1846 and 1896. In the lower part of the table the model's predictions are stated at the aggregate and industry level for each of the 9 provinces. For the province of Antwerp, for instance, we see that at the aggregate industry level above average domestic market potential had a substantial positive impact while below average access to coal contributed negatively to industrial employment.

The results from table 5.4 show that the effects of coal and market potential vary substantially between the different provinces. The span between the minimum and maximum contribution is close to 11,000 workers in both cases. The provinces of Hainaut and Liège benefited substantially from their proximity to coal resources, while not being disadvantaged by poor domestic market access. The most advantaged provinces with respect to market access are Antwerp, Brabant and East Flanders. While Antwerp and East Flanders suffered from poor access to coal resources, in the case of Brabant the negative impact of below average coal access was limited. Nevertheless, in all these provinces, the positive market potential effects outweighed the negative impact from coal. This is not the case for West Flanders, where the negative coal effect could not be compensated by positive market access effects. On the other hand, the provinces, which were disadvantaged from a market potential perspective, could not compensate with positive coal effects: Limburg, Luxembourg and Namur. Luxembourg is even characterised by below average access to coal and domestic urban markets. At the aggregate level, it can be concluded that West Flanders, Limburg, Luxembourg and Namur were the most disadvantaged provinces with West Flanders suffering from poor access to coal resources while the latter three provinces were mainly disadvantaged with respect to market access. The locations with the biggest positive effect from a combination of market access and proximity to coal resources were Hainaut, Liège but also Brabant. The situation in Antwerp and East Flanders are more mixed. While the net effect was positive, the high market potential had to compensate for a substantial negative effect from poor access to coal.

[41] Map C.1 shows the location of Belgian provinces as well as their respective arrondissements.

Table 5.4: Counterfactual estimates for 9 Belgian provinces compared to the Belgian average

			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		BEL	ANV	BRA	FLA W	FLA E	HAI	LIE	LIM	LUX	NAM
EMP	1846	222,825	16,653	27,442	39,274	48,881	30,862	37,537	4,679	2,953	9,916
	1896	527,803	47,579	95,183	39,743	94,552	100,647	102,557	9,804	9,446	24,591
mean											
	ln(coal)	5.73	4.87	5.69	4.92	5.15	7.47	7.15	5.77	4.81	6.08
	ln(domestic MP)	10.01	10.38	10.42	10.05	10.41	10.11	10.03	9.73	9.21	9.73
AGGR											
	coal		-3,569	-241	-1,349	-2,040	7,577	4,864	85	-295	683
	domestic MP		5,522	8,859	233	5,037	1,490	243	-2,196	-926	-1,958
TEX											
	coal		-1,362	-57	-1,126	-1,499	2,112	960	47	-15	61
	domestic MP		1,272	1,258	118	2,232	251	29	-740	-28	-106
FOOD											
	coal		260	20	105	149	-450	-321	-3	54	-69
	domestic MP		1,209	2,206	54	1,104	266	48	-221	-504	-592
MET											
	coal		-1,076	-88	-115	-280	2,596	2,285	30	-151	380
	domestic MP		790	1,534	9	327	242	54	-371	-225	-518
Group 1											
	coal		76	5	22	35	-94	-70	-1	10	-46
	domestic MP		2,085	3,460	68	1,528	326	61	-444	-557	2,884
Group 2											
	coal		-350	-24	-109	-164	890	506	22	-12	64
	domestic MP		126	204	4	94	40	6	-133	-9	-43

Sources: see text.

5.5 Discussion

We now want to link the findings of our empirical analysis to the existing literature on the Belgian *regional question*, which has been outlined in section 5.2. Our findings show clear support for the dual importance of coal and market potential throughout Belgian industrialisation. Comparing industrial employment of Belgian provinces with counterfactual estimates at the national average of location determinants made it very clear that provinces benefited differently from access to coal and markets. The importance of coal for the provinces of Hainaut and Liège, which has already been highlighted by Riley (1976), finds strong empirical support. Our results can also give support to the idea that the Brussels-Antwerp centres were already gaining importance during the 19$^{\text{th}}$ century (De Brabander, 1981). Antwerp, Brabant and East Flanders were able to benefit substantially from their market access during the second half of the 19$^{\text{th}}$ century. Their limited access to coal, however, reduced their demand based advantage, at least in the case of Antwerp and East Flanders. Once, the locational advantage of coal weakened, these provinces improved their relative standing. This is well in line with Buyst (2011) who argues that the provinces of Antwerp, East Flanders and West Flanders could only catch-up after 1937 when coal imports became increasingly important. During the 20$^{\text{th}}$ century, these provinces could, therefore, draw on a locational advantage which they have already developed during the 19$^{\text{th}}$ century. Our results show very clearly that regions of industrialisation had a strong advantage in either access to coal (Hainaut and Liège) or market potential (Brabant) without being significantly disadvantaged with respect to the other one. It, therefore, seems to be the case that access to coal and market potential should be seen as a necessary rather than a sufficient condition for 19$^{\text{th}}$ century industrialisation. This, however, is not a contradiction to the findings by Ronsse and Rayp (2016), who emphasise the importance of coal in 1896 and the importance of market potential during the 20$^{\text{th}}$ century.

Looking beyond the Belgian historiography, our results which emphasise the dual importance of access to coal and markets during Belgian industrialisation support Gilboy's (1932) interpretation of industrialisation. Without the necessary demand conditions, coal endowments were not sufficient to spur industrialisation. In spite of many structural differences, Britain, as the first industrial nation, and Belgium, as the second industrial nation, share some similarities with respect to demand and supply factors. On the supply side, it is well known that both economies are well endowed with coal resources. On the demand side, both economies share the characteristics of high degrees of urbanisation already during the pre-modern period. In 1700 Belgium was the second most urbanised economy in Europe, after the Netherlands, with England's degree of urbanisation also being clearly above the European average and reaching the Belgian level by 1750 (Malanima, 2010).[42] At first this might remind us of Mokyr (1976) who argued that the differences in demand conditions between Belgium and the Netherlands are not strong enough to explain the differences in growth trajectories. The dual importance of markets and coal is, however,

[42] Malanima (2010, pp.259-263) calculates urbanisation rates for European economies between 1700 and 1870 using urban definitions of 5,000+ and 10,000+ inhabitants. 1700 (5,000+): Netherlands *45.3%*, Belgium *29%*, England (Wales) *14.6%*, Europe *11.4%*; 1700 (10,000+): Netherlands *32.5%*, Belgium *20.3%*, England (Wales) *13.2%*, Europe *8.2%* ; 1750 (5,000+): Netherlands *39.5%*, Belgium *25.9%*, England (Wales) *22.3%*, Europe *11.7%*; 1750 (10,000+): Netherlands *29.6%*, Belgium *15.8%*, England (Wales) *16.4%*, Europe *8%*.

able to do so. Moreover, Mokyr's (1976) emphasis on cheap labour costs in Belgium is not supported by our results. Even though, Belgium benefited from its high degree of urbanisation it is also clear that the Belgian demand and supply characteristics influenced the sectoral composition of the economy. That Belgium's industrialisation was focused on heavy coal intensive industries is also driven by Belgium's demand constraints. Hence, our results do not go against Clark and Jacks (2007) when they argue that the importance of coal in the British industrial revolution was limited due to its rather limited importance in the textile industry. In Belgium, coal was probably more important than in Britain as the demand side was more constrained and the sectoral composition of industrialisation was, therefore, oriented towards coal-intensive industries while the textile industries only played a secondary role. Nevertheless, it should be stressed again that even in these coal-intensive industries access to urban markets was an important location factor.

The sectoral composition of Belgian industrialisation was not only affected by access to domestic urban markets. Also the external market potential played its role. Not having been identified as a key location factor at the aggregate industry level, access to foreign markets was found to be important for the textile industries. Flanders as a region with good access to foreign markets, due to its proximity to the French market as well as access to the sea via Ostende, nevertheless, struggled to industrialise due to its limited coal availability. At least, based on the chosen specification of Belgian foreign market potential which follows Milward and Saul (1973) by focusing on neighbouring regions, the overall importance of access to foreign markets was not consistently important as a location determinant. Focusing on neighbouring regions is well justified when estimating trade shares by destination. Figure C.7a shows the development of export and import shares of Belgium's most important neighbours: the German Customs Union, France, the Netherlands and the United Kingdom. The aggregated export share of these four economies stayed above 80% until the 1880s and has never decreased substantially below 70%. During the initial period of accelerated trade openness between 1850 and 1870 Belgian export trade was clearly dominated by its neighbours. Import shares follow a similar pattern at a lower level. The limited importance of access to foreign markets is rather surprising and further research needs to be conducted to validate this result. As figure 5.1 has shown, Belgium became a more open economy during the 19th century. Moreover, the trade balance for industrial goods improved significantly between 1840 and 1860 and stayed high until the start of World War I, see figure C.7b. It seems that domestic location determinants limited the importance of access to external markets. The continuous improvement of the Belgian transport infrastructure could have also played its role in limited incentives to locate closer to external trading partners. It should also be noted that distance to the port of Antwerp is highly correlated with domestic market potential. Hence, benefits from domestic market access may have an international component. However, that foreign market access has not always been a decisive location factor during 19th century industrialisation is empirically supported for Italy and the Austrian-Hungarian Empire (Missiaia, 2016; Schulze, 2007). A more nuanced treatment of foreign demand based on input-output table would be an interesting exercise to validate the results.

This also brings us to the limitations of this analysis. Belgium is a very important case study for our understanding of the diffusion of the British industrial revolution. Nevertheless, international research on Belgium in the field of economic history is rather rare. Among other things, the size of the Belgian territory makes empirical research and particularly research on industrial location difficult. With 41 arrondissements as the lowest consistent regional unit of analysis, limitations from degrees of freedoms are faced soon. Therefore, the number of potential confounders, which can be included in empirical location models, is limited. Among other advantages, this is why an instrumental variable approach has been chosen to deal with omitted variable biases. Even though the quality of our instruments is high, the possibility remains that omitted location determinants could be correlated with our instruments. More specifically, the size of urban population in 1700 might be driven by factors which could remain to be important more than 150 years later. Even though, we control for literacy in 1866, pre-modern supply of human capital would be an important control to improve identification. The location of pre-modern urban crafts industries is also likely to be correlated with 19$^{\text{th}}$ century industrial employment and domestic urban market potential. However, analyses using log changes of employment as the dependent variable do not weaken the importance of domestic urban market potential. Moreover, the evidence presented which excludes the region's own internal demand suggest that arguments based on path dependency might only be part of the explanation. Another downside of the limited degree of spatial variation is the limited possibility to identify dynamics in the coefficient estimates. It would be interesting to shed more light on the changes in the importance of various location factors during 19$^{\text{th}}$ century industrialisation.[43]

5.6 Concluding remarks

This analysis contributes to our understanding of the diffusion of the first industrial revolution to the European Continent by studying the second industrial nation, Belgium. We do so by identifying determinants of industrial location for the industrial sector as a whole as well as for selected industries. Belgian arrondissements serve as the regional unit of analysis at which level industrial employment can be aggregated for the second half of the 19$^{\text{th}}$ century by drawing on the 1846 and 1896 industrial censuses. The main explanatory variables of interest are proximity to coal fields and market access. The statistical and economic significance of these determinants is evaluated by applying a poisson regression analysis with an instrumental variable strategy to deal with potential endogeneity biases. Moreover, we calculate counterfactual estimates of industrial employment for 9 Belgian provinces by evaluating the location determinants' employment effects based on the determinants' deviation from the national mean.

The results show that both accessibility to coal and markets play important roles in understanding Belgian industrialisation during the 19$^{\text{th}}$ century. At the aggregate level, access to urban domestic markets is the most important driver of regional industrial employment, followed by proximity to coal. A standard deviation change in domestic market potential is associated with an increase in aggregate industrial employment of 70%, while

[43] Using the instruments for access to coal and urban markets directly as independent variables, interacting those with a time dummy and adding the full set of controls, does not result in statistically significant differences between 1846 and 1896. Among the sub-industries, only the textile industries show dynamics in its location factors as the importance of proximity to coal.

a standard deviation change in access to coal is associated with a 52% higher level of aggregate industrial employment. The importance of domestic market potential holds across all sub-industries. Access to coal, however, is found to be statistically significant mainly for the metal industries but also for the glass and chemical products industries. For the metal industries, proximity to coal tends to be more important than market access. This can also explain the Belgian focus on the heavy industries as Belgium was well endowed with coal relative to the size of her domestic market. This also sheds light on the comparatively limited importance of the textile industries as market access was clearly the more important factor for the textile industries. Foreign market access has been found to be of significant relevance only for the textile industries but, not so, for the aggregate level.

The counterfactual results suggest that supply and demand factors should be seen as necessary rather than sufficient conditions supporting the ideas of Gilboy (1932). Regions of industrialisation had a strong advantage in either access to coal, such as the provinces Hainaut and Liège, or market potential, such as Brabant, without being significantly disadvantaged with respect to the other main location factor. The provinces of Antwerp and East Flanders experienced high level of market potential but these advantages were substantially reduced by their poor position with respect to coal. Regions like Limburg and Luxembourg and to a lesser extent Namur and West Flanders were neither particularly favoured by access to coal nor access to markets.

Previous research has already identified the importance of coal as a main location factor during 19$^{\text{th}}$ century industrialisation. Ronsse and Rayp (2016), for instance, find that coal intensive industries are more likely to locate at coal fields in Belgium in 1896, while Gutberlet (2012) emphasises the importance of coal during the industrialisation of the German Empire. Studying a period of accelerated industrialisation and economic growth, the example of Belgium during the second half of the 19$^{\text{th}}$ century shows that we need to consider both coal as well as access to markets in order to understand how the European Continent managed to follow the British example. Moreover, Belgium's economic geography emphasises that locational advantages based on factor endowments may not be here to stay. With coal deposits exhausting, imported oil becoming the dominant fossil fuel and low wage advantages of poorer regions, coastal regions gained importance during the mid-20$^{\text{th}}$ century even leading to a reversal of regional fortunes in Belgium (Buyst, 2011).

Chapter 6

Conclusion

This PhD thesis contributes to our understanding of the spatial dimension of economic development. Regional inequalities are a central feature of many developed economies today. The North-South divide in the United States, Britain or Italy, the dominance of Paris in France, or the regional differences between Flanders and Wallonia in Belgium, are prominent examples. Regional economic disparities, however, are not a new phenomenon. Already during the 19th century, industrialising economies were experiencing degrees of regional inequality. This period is of particular importance when it comes to the spatial dimension of economic development. Not only was the 19th century a period of unprecedented economic growth among Western European economies, but we also see substantial changes in those factors which *New Economic Geography* (NEG) theory suggests to drive spatial inequalities (Krugman and Venables, 1995; Krugman and Elizondo, 1996). Increased market integration through declining transport costs and reductions of trade barriers should have altered the economic geography of those economies affected. Moreover, rapid technological innovation might have affected regions differently in light of the Regional Systems of Innovation approach (Nelson and Winter, 1982; Lundvall, 1992; Nelson, 1993; Edquist, 1997). The articles presented in this PhD thesis are empirical analyses evaluating the spatial effects of key features of 19th century economic development. By doing so this thesis contributes to our understanding of the spatial dimension of economic development.

The contributions of this PhD thesis are manifold. Studying the 19th century adds important evidence to the empirical NEG literature of assessing the drivers of spatial inequalities. Even though, I am not the first to apply ideas from NEG theory to this period, see section 2.2.3 for a review of the historical NEG literature, relatively little is known for the economies of France and Belgium. Apart from the studies by Combes et al. (2011), which covers the French economy since 1860, and Ronsse and Rayp (2016), which covers Belgium since 1896, the economic geography literature on these two countries is mainly descriptive. I, therefore, contribute to our understanding of French and Belgian economic development during the 19th century. Moreover, the articles, which are presented in this thesis, differ from most historical NEG publications. Instead of following the approach by Midelfart-Knarvik et al. (2000), which has found numerous applications in economic history, I isolate the spatial effects of particular location factors. The first article analyses the spatial effects of trade liberalisation, the second article assesses the spatial effects of power technologies and the third article focuses on the relative importance of coal and market access. The analyses by Donaldson and Hornbeck (2016) and Berger and Enflo (2017) have shown that focusing on particular factors, in their case it is railroad building, can be a powerful methodological approach. Historical analyses of the evolution and drivers of spatial inequalities are, furthermore, vital to our understanding of path dependent processes affecting spatial patterns of economic activity till today (Martin and Sunley, 2012).

The first article of this PhD thesis studies the spatial effects of mid 19^{th} century trade liberalisation. France was among the first economies to shift trade policy towards a free-trade agenda which peaked in the bilateral treaty between France and Britain in 1860. The Cobden-Chevalier treaty lifted all import prohibitions on British manufacturers and reduced overall import tariffs. As Britain was the leading export-oriented manufacturing economy, French producers faced increased competition on their domestic markets. This research has shown that increased British competition has led to a shift in the spatial distribution of French production and employment. Regions being located closer to Britain lost employment and output shares relative to the rest of France in industries which experienced a rising importance of UK imports. Within the industrial sector, thus not considering wine producing regions, the relocation effects of export industries were limited such that the effects of import competition dominated the overall trade effects. This research is an important contribution to the existing literature of spatial effects of trade liberalisation. Most studies have found positive effects for border regions as their relative access costs to export markets increased (Hanson, 1998; Brülhart et al., 2012). The evidence presented in this case study, however, has shown that in addition to the export mechanism import competition can be an important factor in shaping the spatial allocation of economic activity. Spatial and sectoral effects of trade liberalisation are highly intertwined why it is important to also acknowledge the diversity within the industrial sector and inter-sectoral labour mobility. Local effects of import competition have also found empirical support by Autor et al. (2013). Hence, in spite of aggregate beneficial effects of globally integrated trade patterns, variation in the effects on regional economies should not be overlooked.

The second article studies the effects of power technologies on urbanisation and contributes to the evolving literature of analysing the interrelatedness between steam power and spatial concentration during the 19^{th} century (Kim, 2005; Gutberlet, 2014). The French case is an important piece of evidence in this debate as French industrialisation is characterised by slow urbanisation and adherence to water power. Besides testing this relationship, the article goes one step further and links the urbanisation effect of steam to economic development through urban agglomeration economies. This article is, therefore, the first attempt to answer the research question whether French adherence to water power was associated with low urbanisation, limited gains from urban agglomeration and through this mechanism constrained economic development. Based on various models of urban location, from a discrete choice model to a fully continuous specification, I find strong evidence that French adherence to water power was associated with lower levels of urbanisation. The rural preference of water-powered firms is most pronounced at the municipality level and weakens at the regional level. Steam-powered firms, on the other hand, show the highest degree of urban preference at the regional level. Apart from power technologies, firm size is positively associated with urbanisation. This supports the findings by Kim (2005) that the change from artisan to factory production was an important determinant of urbanisation. The findings of power-specific location choice are further linked to the existence of benefits of urban agglomeration. If benefits of urban agglomeration existed in the French 19th century economy, a faster diffusion of steam power, substituting water power, would have fostered economic growth through its positive effect on urbanisation. The existence of benefits of urban agglomeration is empirically analysed by estimating urban premiums in wages and labour productivity, accounting for endogeneity biases by instrumenting urbanity with lagged urbanisation ratios. I find that urban firms paid 13-14% higher wages and were 16-22% more productive than their rural counterparts, depending on the census period. It can, therefore, be concluded that the 19th century French economy would have benefited from the urbanisation effects of a more rapid substitution of water-powered technologies. However, it remains to be investigated through which mechanisms urban agglomeration economies operated. As growth benefits of new knowledge decay most rapidly with distance (Capello and Lenzi, 2014), the interplay between urban agglomeration and knowledge spillovers should be a fruitful area of historical research during a period, which has lately also been associated with the rising importance of knowledge-based industries (Mokyr, 2009).

The third article investigates the relative importance of supply and demand factors for Belgian industrialisation by studying to what extent access to coal and markets can explain the regional variation of industrial employment. The results show that both access to coal and markets play important roles in understanding Belgian industrialisation during the 19th century. At the aggregate level, access to urban domestic markets is the most important driver of regional industrial employment, followed by proximity to coal. The importance of domestic market potential holds across all sub-industries. Access to coal, however, is found to be statistically significant mainly for the metal industries but also glass and chemical products industries. For the metal industries, proximity to coal fields tends to be more important than market access which, however, is the dominant location factor for the textile industries. Counterfactual results for Belgian provinces suggest that supply and demand factors should be seen as necessary rather than sufficient conditions supporting Gilboy (1932). Regions of industrialisation had a strong advantage in either access to coal or market potential without being significantly disadvantaged with respect to the other. Previous research has already identified the importance of coal as a main location factor during 19th century industrialisation. Ronsse and Rayp (2016), for instance, find that in 1896 coal intensive industries are more likely to locate on Belgian coal fields, while Gutberlet (2012) emphasises the importance of coal during the industrialisation of the German Empire. Studying a period of accelerated industrialisation and economic growth, the example of Belgium during the second half of the 19th century shows that we need to consider both coal as well as access to markets in order to understand how the European Continent managed to follow the British example. Moreover, Belgium's economic geography emphasises that locational advantages based on factor endowments may not be here to stay. With coal deposits exhausting, imported oil becoming the dominant fossil fuel and low wage advantages of poorer regions, coastal regions gained importance during the mid-20th century even leading to a reversal of regional fortunes (Buyst, 2011).

6.1 Limitations

The three articles shed light on the spatial dimension of key aspects of 19$^{\text{th}}$ century industrialisation. However, it has to be acknowledged that the chosen focus and empirical approach is not all-encompassing. Hence, it is important to also discuss some general limitations of the presented results.

Conceptually this thesis is mainly influenced by theories associated with the *New Economic Geography* literature. By doing so, it follows most empirical applications of regional analyses in economic history. This being said, it has to be acknowledged that *New Economic Geography* is only one set of ideas within the much broader *Economic Geography* literature. *Evolutionary Economic Geography*, in particular, can be a fruitful additional research agenda for historical analyses. The central role of path dependency within *Evolutionary Economic Geography* makes historical investigations crucial to understand the evolution and existence of spatial economic pattern, which we still observe today. Ideas from *Evolutionary Economic Geography* have been applied in this thesis to interpret and validate the empirical results derived. However, they have not been the basis of the applied research agenda. To what extent evolutionary processes have played a pivotal role during 19$^{\text{th}}$ century Western European industrialisation can be a fruitful research agenda, which would enrich and complement our knowledge of this period.

From a methodological perspective, this PhD thesis has mainly performed quantitative analyses based on regional variation within the boundaries of a nation state. The regional focus, of course, is a pivotal aspect of the chosen research agenda. However, it also limits comparability across nation states within the same framework. In addition to asking the question of how regions within specific institutional and cultural boundaries respond differently to, for instance, technological challenges and opportunities, it would be of crucial importance to additionally know how similar regions in different nations have evolved. The seminal contribution by Pollard (1981) clearly goes in this direction to compare regional economies within a European perspective rather than within the respective nation. Also Wrigley (1961) is a good example of how a transnational comparative approach can be applied. So far, at least for more recent historical analyses, empirical investigations are most often focused on one particular nation state. Consistency of the available empirical information is clearly a reason for this development, as these studies are most often based on national censuses. Comparisons are then made by comparing results of various research publications which use similar methodological approaches. Empirical results derived from the approach pioneered by Midelfart-Knarvik et al. (2000) are good examples. To expand on this country-focused approach, it would be worthwhile to take on the challenge and make regions internationally comparable within a unified methodological framework.

This naturally leads to the question whether the empirical results presented are generalisable to historical trajectories of regions in other European countries. The three articles of this PhD thesis had a clear focus on France and Belgium. However, these countries have not been selected randomly. Particularly on Belgium there is far too little research, given its pivotal importance in economic history as the first industrialising nation in Continental Europe. The regional characteristics of Souther Belgium with favorable resource endowments as well as access to markets is a combination which has also been successful for the industrialisation of parts of Germany and the United States (Gutberlet, 2012; Klein and Crafts, 2012). It should, however, also be stressed that there is not one single path to regional economic success. The economic history of France is a good example for a different path to modern economic growth, which has often been stressed by the economic history literature (Lévy-Leboyer, 1964; O'Brien and Keyder, 1978; Cameron and Freedeman, 1983). The presented PhD thesis has shown that French regional economies have, nevertheless, been influenced substantially by new technologies of 19th century industrialisation. The absorptive capacity of new technologies was pivotal to regional economic success. Positive externalities of urban centres seem to have played an important role. This has been shown for France and has already been suggested as an important aspect of the emergence of modern economic structures in England (Allen, 2009). One should be cautious of making general arguments outside the respective socio-economic context, however, when asked about a generalisable conclusion of the presented PhD thesis I would argue that spatial agglomeration was not only a side-effect of industrialisation but has played an important role in shaping modern economic regions.

What is clearly less well understood are the particular mechanisms through which agglomeration patterns have contributed to modern economic growth. This is also a limitation of the empirical work presented here. The presented articles have identified particular factors shaping regional economies in 19th century Europe. However, there is only suggestive evidence on the mechanisms through which positive spatial externalities operate. This black-box has not been opened and, until now, there is comparatively limited empirical research which identifies through which particular mechanisms spatial agglomeration drives economic development (Combes and Gobillon, 2015). Knowledge spillovers are probably the most prominent mechanisms not at least due to their relevance in endogenous growth theory (Romer, 1986; Lucas, 1988; Grossman and Helpman, 1991). The importance of skilled labor, research oriented universities and social capital within geographically bounded networks has, so far, been the focus when studying spillover mechanisms, even though, *"the literature identifying mechanisms actually transmitting knowledge spillovers is sparse and remains underdeveloped"* (Audretsch and Feldmann, 2004, p.2728). Therefore, it would clearly be a fruitful research agenda to expand on spillover mechanisms also from a historical perspective. Lately, the role of human capital in 19th century economic development had gained attention (Becker et al., 2011) and it would be worthwhile to also consider ideas from spatial knowledge spillovers in this debate.

6.2 Implications

After having outlined some limitations of this PhD thesis, also suggesting fruitful avenues of further research, I would like to close by discussing more general implications of the presented research. The three articles have shown that spatial analyses can reveal additional empirical insights into key factors of 19th century industrialisation. Our perception of the past, however, can also influence our perception of the present. The transformative processes of the 19th century offer rich case studies to investigate questions which have not lost their relevance. What determines patterns of spatial inequality and how have these patterns evolved? How do regions adjust to globalisation and more generally changes in trade patterns? What is the effect of the ICT revolution, Artificial Intelligence (AI) and

Industry 4.0 on industrial location? The evidence presented shows that the main transformative processes of the 19th century, which have been analysed, had substantial spatial effects. It, therefore, seems fair to assume that the spatial dimension of the transformative processes of the 21st century should be carefully considered. The extent of these effects, however, will need to be assessed on a case-by-case basis. What history can do is to raise the awareness of their existence.

Europe shows a substantial degree of regional inequality of economic activity with a pronounced EU-wide core-periphery structure. In spite of convergence between the members states of the European Union, within-country regional inequality has remained rather stable (Combes and Overman, 2004).[1] As Midelfart-Knarvik et al. (2001) have argued, this pattern of industrial location in Europe is determined by factor endowments, in particular access to skilled labour, as well as geography due to the importance of access to intermediate suppliers. The spatial concentration of industrial employment can, furthermore, be associated with differences in labour productivity. Ciccone (2002) finds agglomeration effects in Europe to be only slightly smaller than agglomeration effects in the United States. Hence, spatial inequalities of the recent past can be associated with factor endowments as well as demand-cost linkages. This is also consistent with the evidence from 19th century industrialisation. However, what economic history teaches us is that industry relevant factor endowments as well as demand-cost linkages should not be perceived as constant. The historical evidence, to which also the findings of this PhD thesis contribute, show how regional advantages based on factor endowments depend on particular technologies. The case of Belgium exemplifies this argument very well where coal endowments have played a crucial role in the early development of its Southern region. Once oil has superseded coal as the dominant fossil fuel the region's downfall began. Moreover, the case of France has shown how changes in trade policy can affect spatial industrial location through changes in demand-cost linkages. It is, therefore, likely that a more integrated global economy will have regional side-effects on existing spatial patterns of industrial location. The effect of trade liberalisation on economic geography has further been studied by Hanson (1998),Brülhart et al. (2012) and Autor et al. (2013). To what extent a region benefits or loses from trade liberalisation depends on a region's accessibility, its sectoral specialisation and its absorptive capacity of technological innovation.

This being said regional inequalities seem rather persistent. Paris was the dominant French region during the 19th century and this is still the case today. One reason for the persistence of regional inequalities might be the growing importance of technology-intensive and science-based industries which, on average, tend to be more concentrated (Brülhart, 1998). The positive association between steam power and urbanisation, which has been established as part of this PhD thesis, fits well within this line of reasoning. Innovation might thus contribute to spatial agglomeration. A particular characteristic of regional inequality is the spatial concentration of innovation itself. Empirical evidence shows that innovation is generally more concentrated than general economic activity (Carrincazeaux et al., 2001). This holds for Venture Capital investment, patents and, particularly, new product innovation (Bairoch, 1991; Feldman and Audretsch, 1999; Fornahl and Brenner,

[1]The core-periphery pattern runs *from the South East of the UK through Holland, West Germany and then curving round through Austria and into Northern Italy. Denmark, Sweden and the capital city regions of Paris and Helsinki show up as clear outliers.*(Combes and Overman, 2004, p.2852)

2009). Moreover, growth benefits of new knowledge are spatially concentrated at the most granular level (Capello and Lenzi, 2014). It might, thus, be a reasonable working hypothesis that general purpose technologies of the 21st century, such as ICT, AI and its implementation as Industry 4.0, will be equally associated with intensified agglomeration than it was the case for steam power as the general purpose technology of the 19th century. The idea that the diffusion of Information and Communication Technologies will lead to more agglomeration rather than dispersion of economic activity is also shared by Leamer and Storper (2001).

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Appendix A

to chapter 3

A.1 Maps

Figure A.1: France by 5 macro-regions

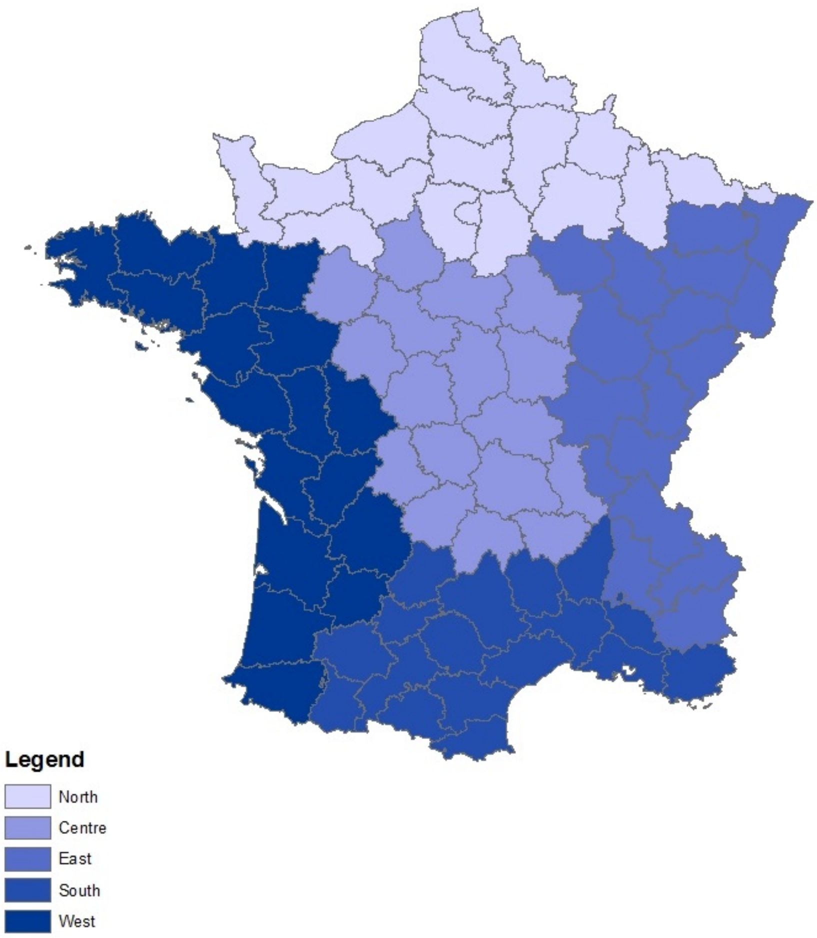
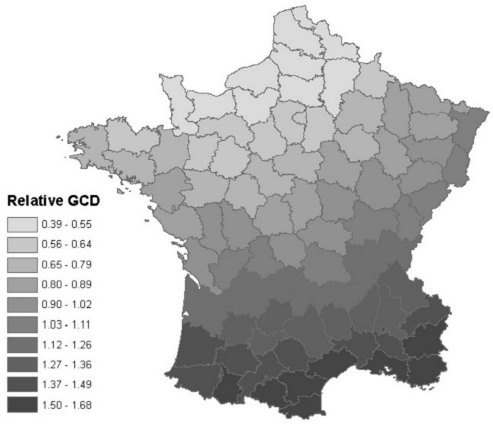
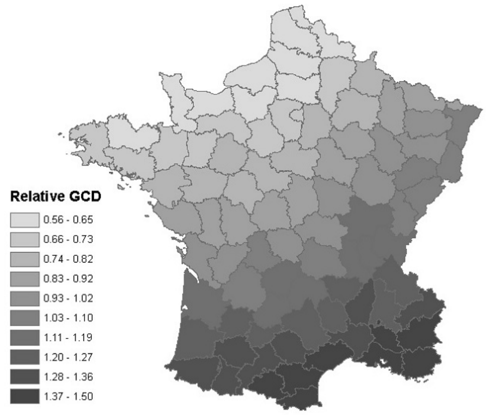


Figure A.2: Relative great circle distances from French departmental capitals to London and Liverpool

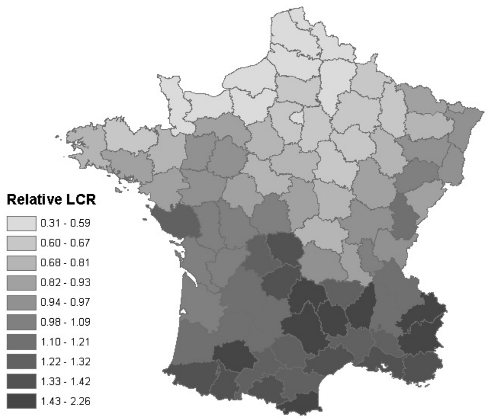


(a) London

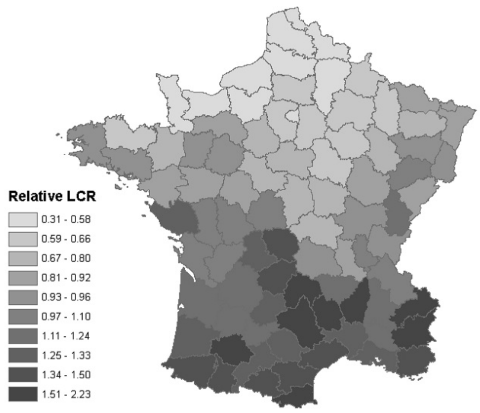


(b) Liverpool

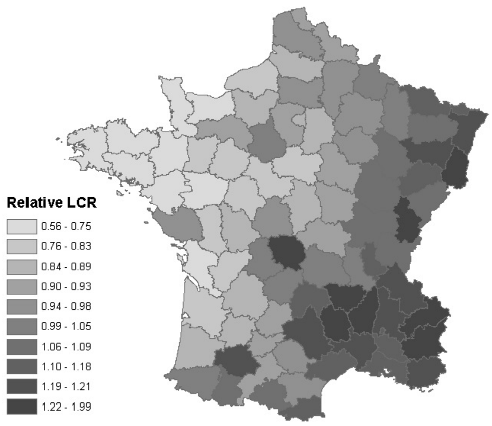
Figure A.3: Relative lowest cost routes per French departmental capital to London and Liverpool in 1861



(a) London or Liverpool

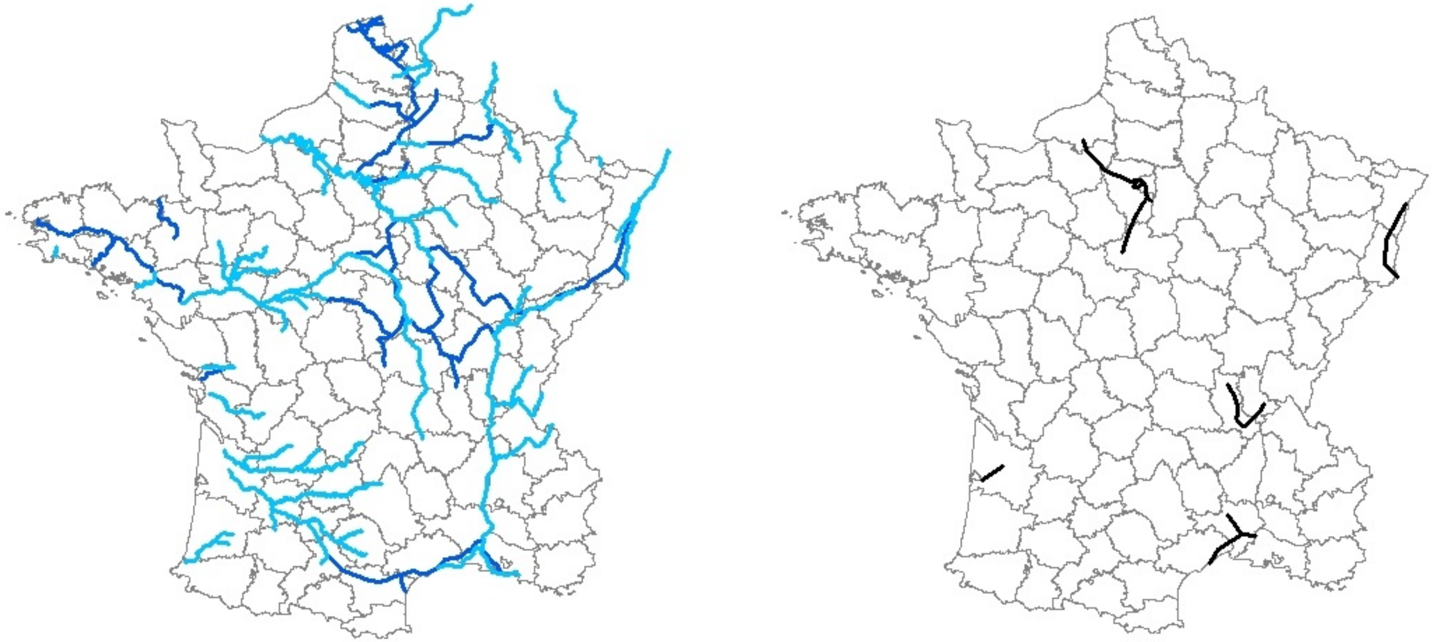


(b) London



(c) Liverpool

Figure A.4: French waterway and railroad network in 1842: canals (dark), rivers (light), railroads



(a) Waterways in 1842

(b) Railroads in 1842

A.2 Regression tables

Table A.1: Weighted Regressions

	(1) Δ ln(Lsh)	(2) Δ ln(Lsh) weighted	(3) Δ ln(Ysh)	(4) Δ ln(Ysh) weighted
Δ IMPsh*ln(DIST)	0.024***	0.022	0.018**	0.014*
	(0.008)	(0.014)	(0.007)	(0.008)
Δ EXPsh*ln(DIST)	0.001	0.012	-0.001	0.015
	(0.010)	(0.013)	(0.011)	(0.014)
ln(aggl)	-0.017***	-0.015***	-0.015***	-0.009***
	(0.003)	(0.004)	(0.002)	(0.001)
ln(BF)	0.002***	0.003***	0.002**	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
ln(size)	0.004	0.004	0.003	0.001
	(0.002)	(0.003)	(0.002)	(0.001)
Constant	0.007***	0.009***	0.006**	0.006***
	(0.002)	(0.003)	(0.003)	(0.002)
IND	yes	yes	yes	yes
DEP	yes	yes	yes	yes
R2	0.18	0.15	0.14	0.18
N	2,720	2,720	2,720	2,720

Heteroskedasticity robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The number of observations is fewer as the regressions are estimated in first differences. Specifications (1) and (3) are, however, computational equivalent to specifications 7 in tables 3.9 and 3.10. Industries are weighted based on labour in 1839 in specification 2 and output in specification 4.

Table A.2: Adding controls

	(1) Δ ln(Lsh)	(2) Δ ln(Lsh)	(3) Δ ln(Lsh)	(4) Δ ln(Lsh)	(5) Δ ln(Lsh)	(6) Δ ln(Lsh)
Δ IMPsh*ln(DIST)	0.024***	0.023***	0.024***	0.023***	0.024***	0.023***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Δ EXPsh*ln(DIST)	0.001	0.001	0.001	0.000	0.001	0.000
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
ln(aggl)	-0.017***	-0.018***	-0.018***	-0.018***	-0.017***	-0.018***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ln(BF)	0.002***	0.002***	0.002**	0.001	0.003***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ln(size)	0.004***	0.004***	0.004***	0.003**	0.004***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ln(female share)		0.001				0.001
		(0.001)				(0.001)
ln(child share)		0.001				0.001
		(0.001)				(0.001)
ln(K/Y)			0.002			0.002
			(0.001)			(0.001)
ln(M/Y)				0.006**		0.005**
				(0.002)		(0.003)
ln(L/Y)					-0.001	-0.004**
					(0.002)	(0.002)
Constant	0.007	0.006	0.007	0.006	0.007	0.006
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
IND	yes	yes	yes	yes	yes	yes
DEP	yes	yes	yes	yes	yes	yes
R2	0.18	0.19	0.19	0.19	0.18	0.19
N	2,720	2,720	2,720	2,720	2,720	2,720

Heteroskedasticity robust standard errors in parenthesess
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The number of observations is fewer as the regressions are estimated in first differences.

A.3 Additional tables & figures

Table A.3: French industrial census 1839-47 by firm size

firm size	#entries	% total	# firms	% total	# workers	% total	firm size
<10	5,608	39.7%	59,181	84.0%	208,654	19.4%	3.5
>=10 - <20	1,710	12.1%	2,507	3.6%	34,670	3.2%	13.8
>=20 - <50	2,958	21.0%	4,303	6.1%	136,556	12.7%	31.7
>=50	3,833	27.2%	4,448	6.3%	697,820	64.8%	156.9
Total	14,109		70,439		1,077,700		15.3

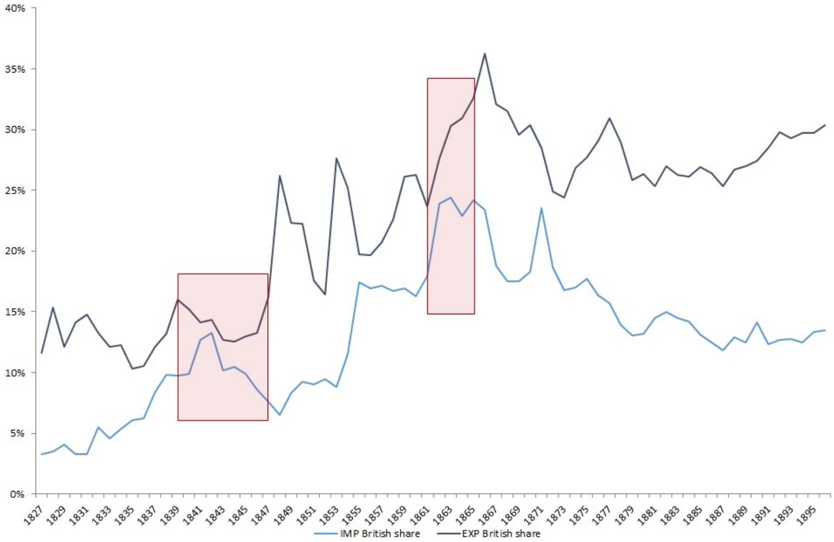
Source: Own calculation based on data from Chanut et al. (2000).
Notes: Covers only entries for which the number of establishments is given (99.3%). Workers are the sum of 'number of employees' and 'number of establishments' as it is not clear if the shop-owner is counted as employee. This might overestimate the total number of workers and firm size - this procedure follows Doraszelski (2004). Table excludes the city of Lyon in order to make the census comparable to the industrial census of 1861-65.

Table A.4: French industrial census 1861-65 by firm size

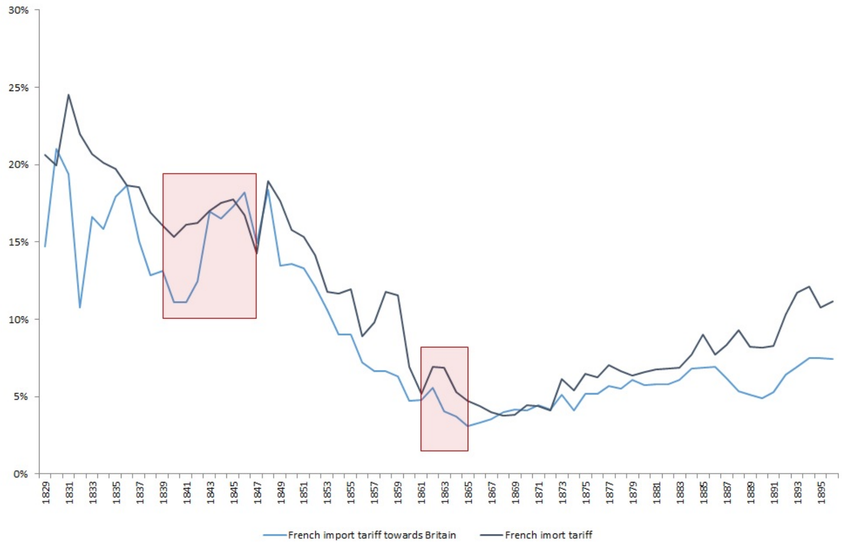
firm size	#entries	% total	# firms	% total	# workers	% total	firm size
<10	4,493	57.1%	77,712	79.4%	283,987	18.0%	3.7
>=10 - <20	1,116	14.2%	5,427	5.5%	76,201	4.8%	14.0
>=20 - <50	1,041	13.2%	7,037	7.2%	229,789	14.6%	32.7
>=50	1,212	15.4%	7,702	7.9%	988,803	62.6%	128.4
Total	7,862		97,878		1,578,780		16.1

Source: Own calculation based on data from Chanut et al. (2000).
Notes: Workers are the sum of 'number of employees' and 'number of establishments' as it is not clear if the shop-owner is counted as employee. This might overestimate the total number of workers and firm size - this procedure follows Doraszelski (2004). Table excludes the city of Paris and the departments Haute-Savoie, Savoie, Alpes Maritimes and Corse) in order to make the census comparable to the industrial census of 1839-47.

Figure A.5: Development of French trade shares towards Britain and ad valorem import tariffs



(a) British export and import shares



(b) Ad valorem tariff

Table A.5: Tariff rates, import shares, export shares for 32 industries

COD2000	Industry	1839 IMP Tr 1861 weights	1861 IMP Tr 1861 weights	Δ IMP Tr 1861 weights	1839 UK IMPsh 1861 weights	1861 UK IMPsh 1861 weights	Δ UK IMPsh 1861 weights	1839 UK EXPsh 1861 weights	1861 UK EXPsh 1861 weights	Δ UK EXPsh 1861 weights
2283	Cotton spinning	189%	11%	-179%	6%	74%	67%	3%	6%	3%
2730	Cotton textiles	200%	15%	-185%	0%	91%	91%	3%	6%	3%
2285	Woolen yarn	119%	4%	-115%	50%	93%	43%	1%	3%	2%
2736	Woolen textiles	198%	15%	-183%	1%	86%	85%	9%	24%	15%
2288	Linin spinning	6%	10%	3%	89%	31%	-58%	3%	2%	0%
2737	Linen textiles	15%	14%	-1%	32%	25%	-6%	3%	7%	3%
2289	Silk spinning	0%	0%	0%	3%	53%	50%	23%	12%	-10%
2740	Silk textiles	11%	9%	-2%	81%	79%	-2%	15%	36%	21%
2510	Leather	114%	8%	-107%	16%	40%	25%	16%	38%	22%
2146	Hats	8%	20%	12%	0%	13%	13%	19%	9%	-10%
2154	Shoes	200%	10%	-190%	0%	81%	81%	9%	14%	6%
2362	Gloves	200%	10%	-190%	0%	50%	50%	16%	76%	61%
2392	Fuel	16%	9%	-7%	23%	23%	0%	0%	2%	2%
2266	Iron mines	2%	0%	-2%	0%	0%	0%	0%	0%	0%
2503	Soil and stones	31%	8%	-22%	11%	15%	3%	1%	0%	-1%
2382	Ferrous metallurgy	49%	22%	-27%	59%	84%	26%	0%	1%	1%
2169	Nails	9%	11%	2%	24%	75%	51%	6%	12%	5%
2192	Cutlery	200%	20%	-180%	0%	96%	96%	1%	1%	0%
2691	Locks and hardware	200%	17%	-183%	0%	97%	97%	0%	3%	3%
2440	Machines	24%	13%	-11%	81%	88%	7%	1%	2%	1%
2260	Pottery	78%	33%	-45%	35%	62%	27%	5%	11%	6%
2797	Glass, mirrors and cristal	52%	41%	-11%	2%	23%	21%	6%	12%	6%
2355	Binding materials	5%	0%	-5%	1%	0%	-1%	2%	35%	33%
2777	Tiles and bricks	16%	8%	-8%	13%	16%	3%	0%	0%	0%
2082	Brewery	15%	17%	2%	65%	34%	-31%	1%	14%	13%
2225	Distillery	111%	13%	-98%	5%	24%	20%	29%	51%	22%
2504	Flour mill	2%	1%	-1%	0%	37%	37%	32%	25%	-7%
2400	Oil	38%	6%	-32%	3%	36%	33%	1%	8%	8%
2703	Sugar products	46%	16%	-30%	4%	29%	25%	8%	6%	-3%
2550	Paper	18%	16%	-2%	64%	31%	-33%	5%	9%	4%
2408	Printing	4%	1%	-3%	21%	26%	5%	10%	18%	8%
2390	Watchmaking	6%	7%	2%	0%	0%	0%	19%	22%	3%

Note: Prohibited commodities have been assigned an ad valorem tariff rate of 200% in 1839 and weighted by their 1861 import share. Import and export shares have been weighted by their 1861 shares as well.

Table A.6: French imports from and exports to Britain as a share of total trade for 32 industries and balance of trade in 1861

COD2000	Industry	1839 $\frac{UKIMP}{IMP+EXP}$ 1861 weights	1861 $\frac{UKIMP}{IMP+EXP}$ 1861 weights	Δ $\frac{UKIMP}{IMP+EXP}$ 1861 weights	1839 $\frac{UKEXP}{IMP+EXP}$ 1861 weights	1861 $\frac{UKEXP}{IMP+EXP}$ 1861 weights	Δ $\frac{UKEXP}{IMP+EXP}$ 1861 weights	1858 $\frac{UKIMP}{IMP+EXP}$ 1861 weights	1858 $\frac{UKEXP}{IMP+EXP}$ 1861 weights
2283	Cotton spinning	16.2%	56.5%	40.3%	2.2%	1.2%	-1.0%	4.8%	7.3%
2730	Cotton textiles	0.0%	12.0%	12.0%	2.9%	3.5%	0.6%	0.0%	4.4%
2285	Woolen yarn	4.2%	8.3%	4.1%	1.1%	0.4%	-0.7%	0.7%	3.0%
2736	Woolen textiles	0.0%	6.9%	6.9%	9.4%	22.6%	13.2%	0.0%	18.2%
2288	Linin spinning	87.3%	24.3%	-63.1%	0.1%	0.4%	0.4%	21.4%	0.0%
2737	Linen textiles	14.0%	7.5%	-6.4%	1.2%	3.7%	2.5%	3.6%	5.1%
2289	Silk spinning	2.8%	45.1%	42.3%	0.2%	1.8%	1.6%	43.1%	2.0%
2740	Silk textiles	1.3%	0.1%	-1.2%	15.1%	36.6%	21.5%	0.1%	25.8%
2510	Leather	0.1%	0.2%	0.1%	15.6%	37.6%	22.0%	0.1%	29.7%
2146	Hats	0.4%	4.8%	4.4%	2.5%	5.7%	3.2%	3.7%	5.1%
2154	Shoes	0.0%	0.3%	0.3%	8.5%	14.2%	5.7%	0.0%	15.3%
2362	Gloves	0.0%	0.0%	0.0%	15.6%	76.2%	60.5%	0.0%	57.0%
2392	Fuel	22.8%	22.4%	-0.4%	0.0%	0.1%	0.1%	21.6%	0.0%
2266	Iron mines	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	1.1%	0.0%
2503	Soil and stones	4.0%	6.2%	2.2%	5.0%	5.2%	0.2%	5.1%	3.6%
2382	Ferrous metallurgy	54.8%	77.8%	23.1%	0.1%	0.1%	0.0%	57.8%	0.2%
2169	Nails	3.0%	4.5%	1.5%	5.7%	11.1%	5.4%	1.4%	8.2%
2192	Cutlery	0.0%	9.5%	9.5%	1.2%	1.3%	0.1%	0.0%	1.0%
2691	Locks and hardware	0.0%	10.1%	10.1%	0.4%	2.7%	2.3%	0.0%	2.7%
2440	Machines	44.8%	49.9%	5.1%	0.5%	0.7%	0.2%	34.5%	1.1%
2260	Pottery	0.6%	2.7%	2.1%	5.9%	12.1%	6.2%	0.7%	8.4%
2797	Glass, mirrors and cristal	0.0%	0.6%	0.6%	4.0%	10.2%	6.2%	0.1%	9.2%
2355	Binding materials	0.8%	0.0%	-0.8%	0.4%	15.8%	15.5%	0.0%	7.1%
2777	Tiles and bricks	3.3%	3.0%	-0.3%	0.1%	0.0%	-0.1%	2.6%	0.0%
2082	Brewery	19.8%	22.0%	2.2%	0.7%	4.9%	4.2%	16.5%	3.9%
2225	Distillery	0.3%	2.6%	2.3%	38.6%	51.8%	13.1%	0.5%	36.9%
2504	Flour mill	0.0%	25.7%	25.6%	28.0%	7.9%	-20.1%	0.0%	62.3%
2400	Oil	0.1%	15.9%	15.8%	0.1%	3.1%	3.1%	6.1%	3.5%
2703	Sugar products	0.4%	2.0%	1.7%	7.5%	5.2%	-2.3%	1.1%	8.1%
2550	Paper	2.7%	1.5%	-1.3%	4.0%	7.9%	3.8%	0.9%	7.2%
2408	Printing	3.1%	3.9%	0.8%	8.9%	14.5%	5.7%	2.4%	13.7%
2390	Watchmaking	0.0%	0.0%	0.0%	9.5%	9.8%	0.2%	0.0%	6.3%

Table A.7: Classification of French industry and industrial census descriptives

CODB2000	Industry	L 39 (in '000)	L 61 (in '000)	Y 39 (in mio)	Y61 (in mio)	Lsh 39	Lsh 61	Ysh 39	Ysh 61	# DEP 39	# DEP 61
2283	Cotton spinning	42.6	50.5	141.2	263.0	6.2%	5.2%	4.8%	4.7%	43	38
2730	Cotton textiles	115.9	142.8	214.6	375.7	16.7%	14.7%	7.2%	6.7%	37	42
2285	Woolen yarn	22.9	33.7	143.7	335.0	3.3%	3.5%	4.8%	5.9%	56	69
2736	Woolen textiles	48.9	56.6	206.6	263.2	7.1%	5.8%	7.0%	4.7%	57	54
2288	Linen spinning	6.9	18.8	36.5	115.5	1.0%	1.9%	1.2%	2.0%	17	14
2737	Linen textiles	33.9	15.9	45.8	42.9	4.9%	1.6%	1.5%	0.8%	37	27
2289	Silk spinning	31.8	34.8	79.7	258.5	4.6%	3.6%	2.7%	4.6%	21	27
2740	Silk textiles	31.8	23.2	75.9	113.9	4.6%	2.4%	2.6%	2.0%	12	17
2510	Leather	8.9	18.0	68.1	198.1	1.3%	1.9%	2.3%	3.5%	66	85
2146	Hats	3.1	8.2	3.4	27.1	0.4%	0.8%	0.1%	0.5%	23	51
2154	Shoes	3.2	9.7	2.4	31.1	0.5%	1.0%	0.1%	0.6%	11	34
2362	Gloves	5.4	10.3	8.9	28.9	0.8%	1.1%	0.3%	0.5%	10	20
2392	Fuel	22.4	60.9	25.3	109.5	3.2%	6.3%	0.9%	1.9%	36	49
2266	Iron mines	4.9	7.6	18.4	10.4	0.7%	0.8%	0.6%	0.2%	29	31
2503	Soil and stones	33.7	31.8	37.0	44.4	4.9%	3.3%	1.2%	0.8%	61	77
2382	Ferrous metallurgy	46.3	94.5	234.5	378.3	6.7%	9.8%	7.9%	6.7%	73	77
2169	Nails	14.9	8.8	20.2	22.2	2.2%	0.9%	0.7%	0.4%	34	40
2192	Cutlery	14.4	12.4	7.6	12.5	2.1%	1.3%	0.3%	0.2%	14	23
2691	Locks and hardware	11.5	13.6	21.3	39.3	1.7%	1.4%	0.7%	0.7%	20	32
2440	Machines	11.1	29.3	41.4	103.1	1.6%	3.0%	1.4%	1.8%	43	72
2260	Pottery	14.7	20.9	22.5	37.0	2.1%	2.2%	0.8%	0.7%	71	79
2797	Glass, mirrors and cristal	15.1	22.7	35.8	63.9	2.2%	2.3%	1.2%	1.1%	48	41
2355	Binding materials	5.9	21.7	12.0	46.3	0.8%	2.2%	0.4%	0.8%	40	83
2777	Tiles and bricks	14.2	38.1	21.2	47.8	2.1%	3.9%	0.7%	0.8%	67	85
2082	Brewery	9.4	8.1	68.2	76.2	1.4%	0.8%	2.3%	1.4%	84	84
2225	Distillery	3.0	15.0	47.4	112.8	0.4%	1.5%	1.6%	2.0%	34	64
2504	Flour mill	74.8	69.1	1,169.5	2,081.2	10.8%	7.1%	39.4%	36.9%	69	85
2400	Oil	5.9	13.0	75.8	179.5	0.9%	1.3%	2.6%	3.2%	49	76
2703	Sugar products	14.4	38.7	23.7	83.3	2.1%	4.0%	0.8%	1.5%	23	11
2550	Paper	11.2	18.5	38.0	79.4	1.6%	1.9%	1.3%	1.4%	66	76
2408	Printing	7.5	9.0	20.4	39.3	1.1%	0.9%	0.7%	0.7%	79	70
2390	Watchmaking	1.7	13.4	1.6	21.3	0.2%	1.4%	0.1%	0.4%	10	11

Table A.8: Sources of industry regional changes in employment shares

		North	Centre	East	South	West	France
(I)		-3.2%	-1.8%	-0.1%	0.5%	-1.8%	
	Nat. Ind.	-3.1%	-0.5%	-1.7%	-0.9%	-0.3%	-6.5%
	Reg. Ind.	-0.1%	-1.2%	1.5%	1.3%	-1.5%	
(II)		0.3%	1.1%	0.2%	0.6%	-0.9%	
	Nat. Ind.	0.4%	0.3%	0.2%	0.2%	0.1%	1.3%
	Reg. Ind.	-0.1%	0.8%	0.0%	0.3%	-1.1%	
(III)		0.4%	-0.8%	1.2%	0.9%	0.0%	
	Nat. Ind.	0.5%	0.4%	0.5%	0.2%	0.2%	1.7%
	Reg. Ind.	-0.1%	-1.1%	0.8%	0.7%	-0.2%	
(IV)		0.3%	0.0%	0.2%	0.9%	-0.5%	
	Nat. Ind.	0.2%	0.0%	0.1%	0.4%	0.2%	1.0%
	Reg. Ind.	0.1%	0.0%	0.1%	0.5%	-0.7%	
(V)		1.8%	0.4%	0.5%	0.4%	0.2%	
	Nat. Ind.	1.3%	0.6%	0.5%	0.4%	0.5%	3.3%
	Reg. Ind.	0.5%	-0.2%	0.0%	-0.1%	-0.2%	
(VI)		1.9%	-0.9%	0.4%	-0.3%	-3.5%	
	Nat. Ind.	-1.1%	-0.2%	-0.2%	-0.4%	-0.5%	-2.4%
	Reg. Ind.	3.1%	-0.7%	0.6%	0.1%	-3.0%	
(VII)		0.2%	0.0%	1.0%	0.1%	0.1%	
	Nat. Ind.	0.3%	0.1%	0.6%	0.1%	0.2%	1.3%
	Reg. Ind.	-0.2%	-0.1%	0.4%	0.0%	-0.1%	
(VIII)		0.1%	0.1%	0.1%	0.0%	0.0%	
	Nat. Ind.	0.1%	0.0%	0.1%	0.0%	0.0%	0.3%
	Reg. Ind.	0.0%	0.0%	0.0%	0.0%	-0.1%	
	Total industry	1.8%	-1.8%	3.5%	3.0%	-6.5%	

Notes: Decomposes industry's contribution to changes in regional employment shares into the contribution which stems from the change in the industry's national employment share and the contribution which stems from the change in the region/industry employment share.
Industry classification: see table 3.4.
Decomposition: $L_{ij61}/L_{i61} * L_{i61}/L_{61} - L_{ij39}/L_{i39} * L_{i39}/L_{39} = L_{i39}/L_{39} * (L_{ij61}/L_{i61} - L_{ij39}/L_{i39}) + L_{ij61}/L_{i61} * (L_{i61}/L_{61} - L_{i39}/L_{39})$ of which $(L_{ij61}/L_{i61} - L_{ij39}/L_{i39})$ is the change in the region/industry employment share and $(L_{i61}/L_{61} - L_{i39}/L_{39})$ the change in industry's national employment share. Note that subcomponents (Nat. Ind. and Reg. Ind. effects) are not additive across industries.

Appendix B

to chapter 4

B.1 Regression tables

Table B.1: Urban location (5,000+) and power choice (1840s; firm level)

	(1)	(2)	(3)	(4)	(5)	(6)
urban	5,000+	5,000+	5,000+	5,000+	5,000+	5,000+
power	D50	D50	D75	D75	HP/L	HP/L
size	factory	factory	factory	factory	L/EST	L/EST
steam	0.629***	2.302*	1.212	2.942**	1.662	6.225*
	(0.087)	(1.041)	(0.189)	(1.427)	(0.520)	(6.843)
water	0.354***	0.431***	0.472***	0.432**	0.075***	1.100
	(0.051)	(0.138)	(0.069)	(0.153)	(0.035)	(0.773)
steam × size		0.269***		0.408*		0.681
		(0.125)		(0.203)		(0.238)
water × size		0.810		1.096		0.238***
		(0.270)		(0.405)		(0.080)
size	3.046***	3.322***	2.759***	2.808***	1.292***	1.308***
	(0.603)	(0.760)	(0.550)	(0.641)	(0.073)	(0.076)
women/L	0.088***	0.089***	0.065***	0.065***	0.053***	0.064***
	(0.039)	(0.039)	(0.029)	(0.029)	(0.023)	(0.028)
children/L	0.018***	0.018***	0.013***	0.013***	0.011***	0.013***
	(0.010)	(0.010)	(0.007)	(0.007)	(0.006)	(0.007)
constant	0.048***	0.044***	0.051***	0.051***	0.028***	0.027***
	(0.038)	(0.035)	(0.040)	(0.039)	(0.023)	(0.023)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2	0.33	0.33	0.33	0.33	0.33	0.33
N	12,113	12,113	12,113	12,113	12,113	12,113

Notes: robust standard errors in parentheses; weighted by employment.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B.2: Urban location (continuous) and power choice (1840s; beta coefficients)

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(urban)	ln(urban)	ln(urban)	ln(urban)	ln(urban)	ln(urban)
sample	whole	whole	whole	whole	urban>0	urban>0
steam	0.010	0.018**	0.029***	0.025	-0.025**	0.080**
	(0.428)	(0.426)	(0.431)	(1.528)	(0.141)	(0.457)
water	-0.148***	-0.105***	-0.094***	0.032	-0.138***	-0.002
	(0.441)	(0.467)	(0.477)	(0.843)	(0.168)	(0.275)
size		0.132***	0.162***	0.167***	-0.013	0.002
		(0.084)	(0.087)	(0.089)	(0.022)	(0.022)
women/L			-0.186***	-0.183***	-0.100***	-0.089***
			(0.632)	(0.629)	(0.175)	(0.174)
children/L			-0.160***	-0.157***	-0.179***	-0.173***
			(0.811)	(0.812)	(0.238)	(0.238)
steam × size				0.005		-0.336**
				(0.479)		(0.151)
water × size				-0.107***		-0.468***
				(0.313)		(0.122)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2	0.37	0.38	0.40	0.41	0.44	0.44
N	12,034	12,034	12,034	12,034	6,026	6,026

standardised beta coefficients; robust standard errors in parentheses; weighted by employment.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: independent variables are log transformed. *steam* refers to the HP of steam engines per worker, *water* refers to the HP of water mills per worker and *size* refers to the number of workers per firm.

Table B.3: Urban location (various) and power choice (1840s; firm level): skill premium

	(1)	(2)	(3)	(4)	(5)	(6)
urban	2000+	2000+	ln(urban)	ln(urban)	urban pop	urban pop
	logit (OR)	logit (OR)	OLS	OLS	Poisson	Poisson
steam	2.718**	2.721**	1.501**	1.514**	0.651***	0.674***
	(1.207)	(1.209)	(0.635)	(0.637)	(0.206)	(0.212)
water	0.006***	0.006***	-5.246***	-5.229***	-5.050***	-4.791***
	(0.005)	(0.005)	(0.738)	(0.736)	(0.881)	(0.849)
size	1.287***	1.287***	0.377***	0.376***	0.010	0.008
	(0.085)	(0.085)	(0.096)	(0.096)	(0.034)	(0.034)
skill premium	1.009		0.202		0.333***	
	(0.189)		(0.293)		(0.099)	
women/L	0.020***	0.020***	-6.515***	-6.483***	-1.780***	-1.761***
	(0.011)	(0.011)	(0.845)	(0.841)	(0.315)	(0.313)
children/L	0.014***	0.014***	-7.238***	-7.168***	-1.612***	-1.515***
	(0.009)	(0.009)	(1.010)	(1.003)	(0.373)	(0.383)
constant	0.330	0.047**	6.995***	6.914***	7.450***	7.348***
	(0.374)	(0.067)	(1.567)	(1.550)	(0.534)	(0.534)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2	0.33	0.33	0.42	0.42	-	-
N	5,772	5,772	5,805	5,805	5,805	5,805

robust standard errors in parentheses; weighted by employment.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: independent variables are log transformed. *steam* refers to the HP of steam engines per worker, *water* refers to the HP of water mills per worker and *size* refers to the number of workers per firm. The skill premium is measures as the natural logarithm of the male wage over the child wage which assumes children to represent the price of unskilled labour.

Table B.4: Urban location (continuous) and power choice by industry (1840s; firm level): beta coefficients

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ln(urban)	ln(urban)	ln(urban)	ln(urban)	ln(urban)	ln(urban)	ln(urban)	ln(urban)
	Textiles	Metals	Leather	Ceramics	Chemicals	Build. Mat.	Food	Paper
steam	0.029^{**}	0.111^{***}	0.017	-0.036	-0.035	0.069^{**}	0.065^{***}	-0.015
	(0.791)	(1.121)	(1.221)	(1.714)	(1.217)	(1.599)	(0.713)	(2.881)
water	-0.103^{***}	-0.053^{**}	-0.280^{***}	-0.086^{*}	-0.089^{**}	-0.064^{**}	-0.048	0.069
	(0.955)	(0.698)	(0.692)	(3.858)	(2.248)	(1.889)	(0.540)	(1.658)
size	0.114^{***}	0.101^{***}	0.154^{*}	0.074	-0.075	0.026	0.242^{***}	0.016
	(0.111)	(0.138)	(0.308)	(0.335)	(0.500)	(0.313)	(0.239)	(0.211)
women/L	-0.224^{***}	-0.090^{**}	0.109	0.025	-0.038	0.006	-0.091^{**}	0.044
	(0.766)	(2.064)	(2.611)	(3.601)	(4.002)	(2.177)	(1.459)	(2.477)
children/L	-0.209^{***}	-0.008	-0.055	-0.001	0.121	-0.183^{***}	-0.074^{**}	0.007
	(0.944)	(1.649)	(2.286)	(4.351)	(4.393)	(1.865)	(2.241)	(1.734)
IND FE	Y	Y	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y	Y	Y
R2	0.38	0.67	0.56	0.56	0.36	0.54	0.59	0.67
N	4,788	1,270	766	473	399	863	2,265	825

standardised beta coefficients; robust standard errors in parentheses; weighted by employment.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All independent variables are log transformed. *steam* refers to the HP of steam engines per worker, *water* refers to the HP of water mills per worker and *size* refers to the number of workers per firm.

Table B.5: Urban-Rural preferences at the regional level (1840s and 1860s; interaction terms)

	(1)	(2)	(3)	(4)	(5)	(6)
	urban10	urban10	urban10	urban10	urban10	urban10
period	1840s	1840s	1840s	1860s	1860s	1860s
power	D50	D75	HP/L	D50	D75	HP/L
size	factory	factory	L/EST	factory	factory	L/EST
steam	2.992***	2.782***	1.036	1.716***	1.655***	2.209
	(0.757)	(0.732)	(0.342)	(0.218)	(0.222)	(1.107)
water	0.876	0.873	0.782	0.958	0.843	1.356
	(0.089)	(0.088)	(0.141)	(0.105)	(0.093)	(0.278)
steam × size	0.404***	0.546**	1.157	1.169	1.517**	1.046
	(0.107)	(0.151)	(0.151)	(0.209)	(0.278)	(0.185)
water × size	0.898	0.920	0.962	0.779	0.731*	0.679***
	(0.110)	(0.111)	(0.095)	(0.134)	(0.127)	(0.070)
size	1.702***	1.633***	1.246***	1.324**	1.268**	1.238***
	(0.140)	(0.133)	(0.035)	(0.155)	(0.134)	(0.048)
shut				0.753	0.748	0.811
				(0.162)	(0.161)	(0.175)
women/L	1.030	1.030	1.001	1.050	1.089	0.983
	(0.154)	(0.153)	(0.147)	(0.218)	(0.226)	(0.201)
children/L	0.491***	0.495***	0.501***	1.527	1.607	1.571
	(0.083)	(0.083)	(0.083)	(0.460)	(0.484)	(0.469)
constant	0.362	0.366	0.129	0.491*	0.486*	0.331***
	(0.475)	(0.478)	(0.177)	(0.185)	(0.185)	(0.128)
R2	0.20	0.20	0.20	0.13	0.14	0.13
N	10,565	10,565	10,565	5,676	5,676	5,676

robust standard errors in parentheses; unweighted.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages.

Table B.6: Urban-Rural preferences at the regional level (pooled; unweighted)

	(1)	(2)	(3)	(4)	(5)	(6)
	urban10	urban10	ln(UR10)	ln(UR10)	UR10	UR10
	logit (OR)	logit (OR)	OLS	OLS	GLM	GLM
steam	0.534***	0.381***	0.026***	0.014**	0.252***	0.154***
	(0.117)	(0.133)	(0.005)	(0.006)	(0.044)	(0.050)
water	-0.315***	-0.309***	-0.013***	-0.009*	-0.201***	-0.146**
	(0.079)	(0.102)	(0.004)	(0.005)	(0.047)	(0.058)
size	0.210***	0.221***	0.013***	0.012***	0.117***	0.107***
	(0.021)	(0.027)	(0.001)	(0.001)	(0.009)	(0.011)
steam × 1860s		0.547**		0.044***		0.372***
		(0.267)		(0.013)		(0.107)
water × 1860s		-0.000		-0.011		-0.155
		(0.162)		(0.008)		(0.099)
size × 1860s		-0.036		0.002		0.020
		(0.042)		(0.002)		(0.019)
women/L	-0.036	-0.028	-0.022***	-0.022***	-0.206***	-0.207***
	(0.118)	(0.118)	(0.006)	(0.006)	(0.057)	(0.057)
children/L	-0.419***	-0.419***	-0.031***	-0.031***	-0.330***	-0.332***
	(0.144)	(0.144)	(0.007)	(0.007)	(0.071)	(0.071)
constant	0.784	0.721	0.201***	0.205***	-1.282***	-1.229***
	(1.371)	(1.379)	(0.059)	(0.059)	(0.383)	(0.379)
IND × YEAR FE	Y	Y	Y	Y	Y	Y
DEP × YEAR FE	Y	Y	Y	Y	Y	Y
R2	0.18	0.18	0.34	0.34	-	-
N	16,222	16,222	16,406	16,406	16,406	16,406

robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages. All independent variables are log transformed. *steam* refers to the HP of steam engines per worker, *water* refers to the HP of water mills per worker and *size* refers to the number of workers per firm.

Table B.7: Urban wage and labour productivity premiums at the regional level (1840s, 1860s; unweighted; beta coefficients)

	(1)	(2)	(3)	(4)
	wage	wage	LP	LP
period	1840s	1860s	1840s	1860s
urban	0.140***	0.184***	0.048***	0.078***
	(0.027)	(0.023)	(0.080)	(0.091)
steam	0.063***	0.024*	0.046***	0.058***
	(0.018)	(0.023)	(0.053)	(0.087)
water	0.034***	-0.022	0.097***	0.034*
	(0.012)	(0.011)	(0.042)	(0.051)
size	0.215***	0.128***	0.210***	0.007
	(0.004)	(0.004)	(0.011)	(0.013)
K/L	0.390***	0.167***	0.422***	0.361***
	(0.003)	(0.004)	(0.009)	(0.015)
1-(men/L)	-0.079***	-0.026	-0.075***	-0.006
	(0.005)	(0.006)	(0.014)	(0.019)
shut		0.002		-0.190***
		(0.019)		(0.085)
IND FE	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y
R2	0.40	0.48	0.33	0.40
N	10,605	5,801	10,604	5,739

standardised beta coefficients

robust standard errors in parentheses; unweighted

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages. All variables are log transformed. *urban* refers to urbanisation rates, *steam* refers to the HP of steam engines per worker, *water* refers to the HP of water mills per worker and *size* refers to the number of workers per firm.

Table B.8: Urban wage and labour productivity premiums at the regional level (1840s, 1860s; unweighted; interactions)

	(1)	(2)	(3)	(4)
	wage	wage	LP	LP
period	1840s	1860s	1840s	1860s
urban	0.373***	0.358***	0.399***	0.594***
	(0.027)	(0.023)	(0.080)	(0.091)
steam	-0.203***	-0.050	-0.292**	0.152
	(0.043)	(0.045)	(0.117)	(0.169)
water	-0.066***	-0.023	-0.118	-0.057
	(0.022)	(0.018)	(0.073)	(0.074)
size	0.043***	0.022***	0.124***	-0.015
	(0.004)	(0.004)	(0.011)	(0.015)
steam × size	0.134***	0.038**	0.229***	0.092
	(0.018)	(0.016)	(0.046)	(0.059)
water × size	0.065***	0.004	0.256***	0.098***
	(0.012)	(0.009)	(0.037)	(0.036)
K/L	0.084***	0.040***	0.263***	0.332***
	(0.003)	(0.004)	(0.009)	(0.016)
1-(men/L)	-0.030***	-0.009	-0.079***	-0.010
	(0.005)	(0.006)	(0.014)	(0.019)
shut		0.003		-1.076***
		(0.019)		(0.085)
constant	4.451***	5.320***	5.019***	4.243***
	(0.078)	(0.087)	(0.270)	(0.282)
IND FE	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y
R2	0.40	0.48	0.33	0.40
N	10,605	5,801	10,604	5,739

robust standard errors in parentheses; unweighted

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages. All variables are log transformed. *urban* refers to urbanisation rates, *steam* refers to the HP of steam engines per worker, *water* refers to the HP of water mills per worker and *size* refers to the number of workers per firm.

Table B.9: IV: Urban wage and labour productivity premiums at the regional level (1840s, 1860s; unweighted; UR)

	(1)	(2)	(3)	(4)	(5)	(6)
	$urban_D$	wage	LP	$urban_D$	wage	LP
stage	first	second	second	first	second	second
period	1840s	1840s	1840s	1860s	1860s	1860s
urban		$ln(UR)$	$ln(UR)$		$ln(UR)$	$ln(UR)$
UR 1806	1.036***			1.078***		
	(0.005)			(0.009)		
urban		0.423***	0.524***		0.405***	0.645***
		(0.030)	(0.090)		(0.026)	(0.107)
steam	-0.002	0.109***	0.240***	0.005	0.038*	0.371***
	(0.003)	(0.018)	(0.054)	(0.006)	(0.023)	(0.087)
water	-0.009***	0.042***	0.293***	-0.009***	-0.014	0.108**
	(0.002)	(0.012)	(0.042)	(0.003)	(0.011)	(0.051)
firm size	0.001***	0.053***	0.144***	0.003***	0.026***	0.006
	(0.001)	(0.004)	(0.011)	(0.001)	(0.004)	(0.013)
K/L	0.003***	0.088***	0.274***	0.003***	0.040***	0.337***
	(0.000)	(0.003)	(0.009)	(0.001)	(0.004)	(0.015)
1-(men/L)	-0.002***	-0.031***	-0.085***	-0.002	-0.007	-0.008
	(0.001)	(0.005)	(0.015)	(0.001)	(0.006)	(0.019)
shut				0.000	0.004	-1.075***
				(0.006)	(0.019)	(0.084)
constant	-0.042	4.354***	4.853***	0.004	5.302***	4.160***
	(0.036)	(0.082)	(0.278)	(0.015)	(0.086)	(0.272)
IND FE	Y	Y	Y	Y	Y	Y
DEP FE	Y	Y	Y	Y	Y	Y
R2		0.40	0.33		0.47	0.40
N	10,375	10,376	10,375	5,657	5,718	5,657
F	36,636.4			16,027.7		

robust standard errors in parentheses; unweighted

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All labour denominated variables use the male equivalent (HC-adjusted) labour index which weights female and child employment by their relative male wages. *steam* refers to the HP of steam engines per worker, *water* refers to the HP of water mills per worker and *size* refers to the number of workers per firm.

Table B.10: IV: Urban wage and labour productivity premiums at the regional level (1840s, 1860s; unweighted; density and total population (pop))

	(1)	(2)	(3)	(4)	(5)	(6)
	$ln(density)$	wage	LP	$ln(density)$	wage	LP
stage	first	second	second	first	second	second
period	1840s	1840s	1840s	1860s	1860s	1860s
urban		$ln(density)$	$ln(density)$		$ln(density)$	$ln(density)$
density 1806	0.963***			1.001***		
	(0.007)			(0.013)		
density		0.089***	0.151***		0.092***	0.159***
		(0.011)	(0.034)		(0.010)	(0.042)
R2		0.39	0.33		0.47	0.40
N	10,375	10,376	10,375	5,657	5,718	5,657
F	20736.26			6099.25		
stage	first	second	second	first	second	second
period	1840s	1840s	1840s	1860s	1860s	1860s
urban		$ln(pop)$	$ln(pop)$		$ln(pop)$	$ln(pop)$
pop 1806	0.995***			1.041***		
	(0.003)			(0.007)		
pop		0.075***	0.158***		0.070***	0.133***
		(0.009)	(0.027)		(0.008)	(0.033)
R2		0.39	0.33		0.46	0.40
N	10,375	10,376	10,375	5,657	5,718	5,657
F	97,849.5			24,760.2		

robust standard errors in parentheses; unweighted

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Includes a full set of control variables (continuous and log-transformed) as well as industry and regional fixed effects.

B.2 Additional tables & figures

Table B.11: Source of power in Britain from 1760 to 1907

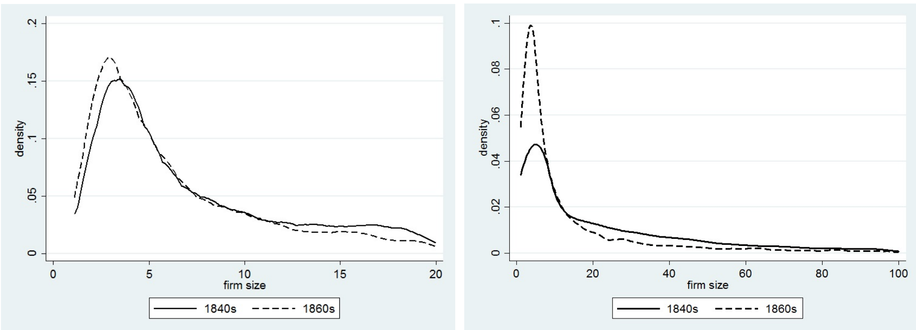
	Total	Steam		Water	
Year	HP	HP	%	HP	%
1760	85,000	5,000	6.7%	70,000	93.3%
1800	170,000	35,000	22.6%	120,000	77.4%
1830	350,000	165,000	50.0%	165,000	50.0%
1870	2,300,000	2,060,000	90.0%	230,000	10.0%
1907	9,842,000	9,659,000	98.2%	178,000	1.8%

Notes: Power use is stated in horsepower. Percentages of steam and water are calculated not with respect to total power (which covers wind power as well) but with respect to the total of water and steam. Hence, the percentages presented are comparable with those in table B.12 for the French economy.
Source: Kanefsky (1979, p.338) cited by Crafts (2004, p.342).

Table B.12: Source of power in France from 1860 to 1931

		Steam		Water	
Year	# DEP	HP	%	HP	%
1861-65	90	122,000	35.2	225,000	64.8
1901	87	1,320,000	77.1	393,000	22.9
1906	87	1,954,000	77.1	580,000	22.9
1926	87	5,613,000	74.2	1,955,000	25.8
1926	90	6,254,000	75.8	1,996,000	24.2
1931	90	7,889,000	76.0	2,491,000	24.0

Notes: This table shows the distribution of horsepower by steam and water power in the French economy between the 1860s and 1930s. Percentages are based on the sum of water and steam power rather than total power.
Source: France (1936, p.6) Statistique generale de la France, Statistique des forces motrices en 1931.



(a) firm size < 20 (b) firm size < 100

Figure B.1: Kernel densities: firm size

Table B.13: Summary statistics: 1839-47

	mean	sd	min	p25	p75	max
urban10	.556	.497	0	0	1	1
UR10	.143	.155	0	0	.260	.581
steam	2.781	10.602	0	0	0	402.5
steamD75	.1	.3	0	0	0	1
steam/L	.082	.508	0	0	0	32.2
water	14.897	132.116	0	0	5.6	4200
waterD75	.304	.46	0	0	1	1
water/L	.3	.693	0	0	.184	16.8
size	58.988	125.428	1.125	5	61	2301
factory	.546	.498	0	0	1	1
women/L	.177	.22	0	0	.31	.967
children/L	.103	.134	0	0	.188	.923
L	61.081	257.599	2	6	53.625	22638
EST	4.751	27.994	1	1	1	761

Table B.14: Summary statistics: 1861-65

	mean	sd	min	p25	p75	max
urban10	.558	.497	0	0	1	1
UR10	.141	.165	0	0	.226	.677
steam	19.894	138.727	0	0	5	5000
steamD75	.185	.388	0	0	0	1
steam/L	.089	.246	0	0	.056	6.25
water	45.137	182.052	0	0	6	2712
waterD75	.198	.399	0	0	0	1
water/L	.288	.744	0	0	.12	13.333
size	36.795	133.205	1.1	3.667	25	4701
factory	.331	.47	0	0	1	1
women/L	.121	.194	0	0	.175	.990
children/L	.052	.096	0	0	.069	.882
L	181.282	726.414	2	10.143	120.646	31141.14
EST	13.942	43.832	1	1	8	1240

Table B.15: French Departments (DEP) and Arrondissements (ARR)

DEP	# ARR	DEP	# ARR
AIN	5	MAINE-ET-LOIRE	5
AISNE	5	MANCHE	6
ALLIER	4	MARNE	5
BASSES-ALPES	5	HAUTE-MARNE	3
HAUTES-ALPES	3	MAYENNE	3
ARDECHE	3	MEURTHE	5
ARDENNES	5	MEUSE	4
ARIEGE	3	MORBIHAN	4
AUBE	5	MOSELLE	4
AUDE	4	NIEVRE	4
AVEYRON	5	NORD	7
BOUCHES-DU-RHONE	3	OISE	4
CALVADOS	6	ORNE	4
CANTAL	4	PAS-DE-CALAIS	6
CHARENTE	5	PUY-DE-DOME	5
CHARENTE-INFERIEURE	6	BASSES-PYRENEES	5
CHER	3	HAUTES-PYRENEES	3
CORREZE	3	PYRENEES-ORIENTALES	3
COTE-D'OR	4	BAS-RHIN	4
COTES-DU-NORD	5	HAUT-RHIN	3
CREUSE	4	RHONE (excl. LYON)	2
DORDOGNE	5	HAUTE-SAONE	3
DOUBS	4	SAONE-ET-LOIRE	5
DROME	4	SARTHE	4
EURE	5	SAVOIE	1
EURE-ET-LOIR	4	SEINE (excl. PARIS)	3
FINISTERE	5	SEINE-INFERIEURE	5
GARD	4	SEINE-ET-MARNE	5
HAUTE-GARONNE	4	SEINE-ET-OISE	6
GERS	5	DEUX-SEVRES	4
GIRONDE	6	SOMME	5
HERAULT	4	TARN	4
ILLE-ET-VILAINE	6	TARN-ET-GARONNE	3
INDRE	4	VAR	4
INDRE-ET-LOIRE	3	VAUCLUSE	4
ISERE	4	VENDEE	3
JURA	4	VIENNE	5
LANDES	3	HAUTE-VIENNE	4
LOIR-ET-CHER	3	VOSGES	5
LOIRE	3	YONNE	5
HAUTE-LOIRE	3		
LOIRE-INFERIEURE	5		
LOIRET	4		
LOT	3		
LOT-ET-GARONNE	4		
LOZERE	3		

Notes: Shows the number of arrondissements (# ARR) by department (DEP).

Table B.16: Classification of French industry

	INTBRAG	CODB3000	INTB3000		INTBRAG	CODB3000	INTB3000
1	Textiles	3068	Hosiery	7	Pottery	3260	Earthenware, porcelain, pottery
1	Textiles	3108	Wool	7	Pottery	3797	Glass and crystal
1	Textiles	3280	Hemp	8	Chemicals	3908	Chemicals
1	Textiles	3283	Cotton	9	Construction	3355	Binding materials
1	Textiles	3288	Linen	9	Construction	3777	Bricks and tiles
1	Textiles	3289	Silk	9	Construction	3909	Diverse building materials
1	Textiles	3407	Printing	10	Lighting	3163	Wax and candles
1	Textiles	3565	Small wares	10	Lighting	3365	Gas
1	Textiles	3726	Dry cleaning and laundry	11	Furniture	3558	Furniture
1	Textiles	3727	Mixed and undetermined fibres	12	Apparel	3146	Hats
1	Textiles	3901	Other textiles	12	Apparel	3154	Shoes
2	Mining	3266	Iron mines	12	Apparel	3362	Gloves
2	Mining	3392	Fuel	12	Apparel	3912	Other clothing
2	Mining	3503	Clay and stones	13	Food and beverages	3082	Breweries
2	Mining	3594	Non-ferrous metals	13	Food and beverages	3225	Distilleries
2	Mining	3683	Salt	13	Food and beverages	3400	Oil mills
3	Metallurgy	3382	Iron foundries	13	Food and beverages	3504	Flour mills
3	Metallurgy	3422	Non-ferrous metallurgy	13	Food and beverages	3703	Sugar refining
4	Metal products	3029	Weapons	13	Food and beverages	3913	Other food products
4	Metal products	3169	Nails	14	Transport equipment	3078	Saddlery and carriage building
4	Metal products	3192	Cutlery	14	Transport equipment	3183	Ship construction
4	Metal products	3440	Machines	15	Paper, printing, instruments	3408	Printing
4	Metal products	3691	Locksmith, hardware, tools	15	Paper, printing, instruments	3550	Paper
4	Metal products	3904	Other iron products	15	Paper, printing, instruments	3915	Watches and instruments
5	Leather	3510	Leather	16	Luxury	3542	Luxury items
6	Wood	3676	Sawmills				
6	Wood	3759	Woodwork				

Notes: This table gives an overview over the harmonised industry classification of the 1839-47 and 1861-65 French industrial censuses, showing 16 (INTBRAG) and 52 (INTB3000) industry aggregates.
Source: Chanut et al. (2000)

Appendix C

to chapter 5

C.1 Maps

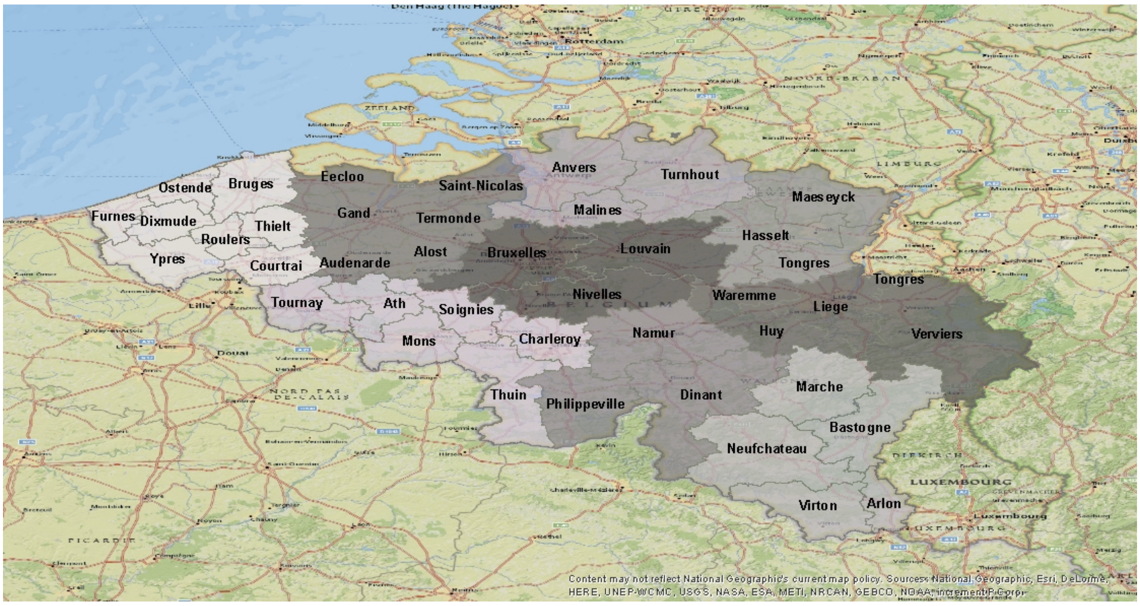
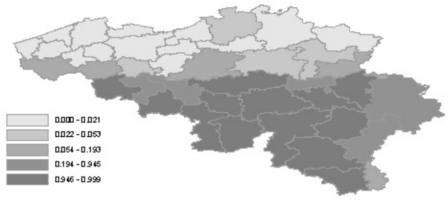
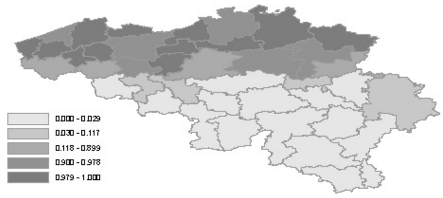


Figure C.1: Political map of Belgium by arrondissement

province	arr	province	arr	province	arr
Antwerp	Anvers	Hainaut	Ath	Luxembourg	Arlon
	Malines		Charleroy		Bastogne
	Turnhout		Mons		Marche
South Brabant	Bruxelles		Soignies		Neufchateau
	Louvain		Thuin		Virton
	Nivelles		Tournay	Namur	Dinant
West Flanders	Bruges	Liege	Huy		Namur
	Dixmude		Liege		Philippeville
	Ypres		Verviers	East Flanders	Alost
	Courtrai		Waremme		Termonde
	Ostende	Limbourg	Hasselt		Eecloo
	Roulers		Maeseyck		Gand
	Thielt		Tongres		Audenarde
	Furnes				Saint-Nicolas



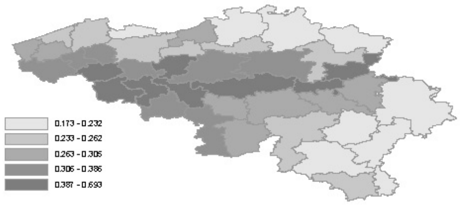
(a) French



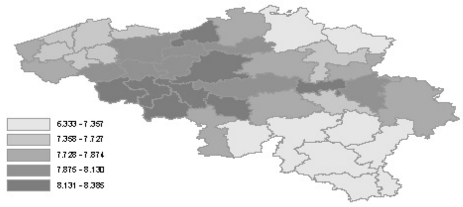
(b) Dutch

Figure C.2: Shares of French and Dutch speakers in 1846

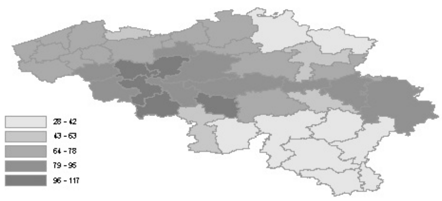
Notes: The maps show the share of the French (figure C.2a) and Dutch (figure C.2b) speaking population for Belgian arrondissements as reported in the 1846 population census.



(a) soil quality



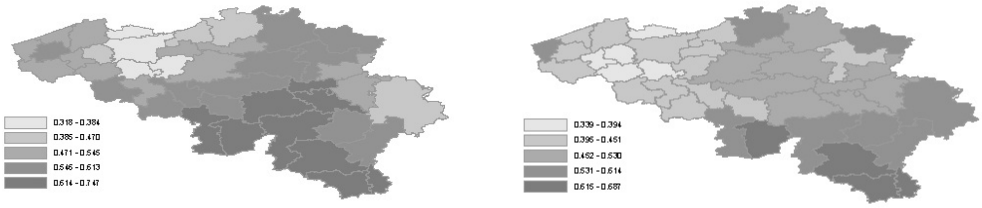
(b) land value



(c) lease rate

Figure C.3: Agricultural suitability by Belgian region

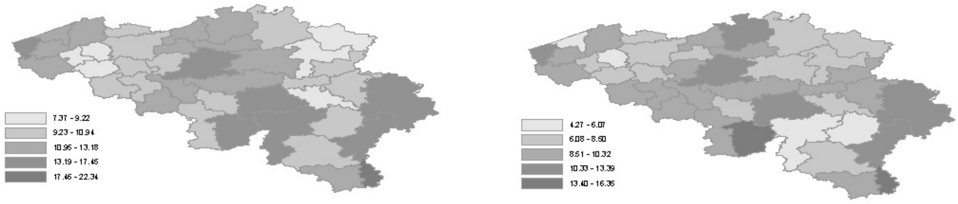
Notes: Figure C.3a maps the inverse of the spatially joined crop suitability index from the *Global Agro-ecological Zones Data Portal version 3.0 (GAEZ v3.0)* with the following specifications: Crop (Wheat), Water Supply (Rain-fed), Input Level (Intermediate), Year (Baseline period 1961-1990), no CO2 fertilization. Figure C.3b maps the average land value and figure C.3c the average lease rate by arrondissement as stated in the 1846 agricultural census.



(a) School enrolment rates 1846 (b) Literacy rate

Figure C.4: Human capital by Belgian region

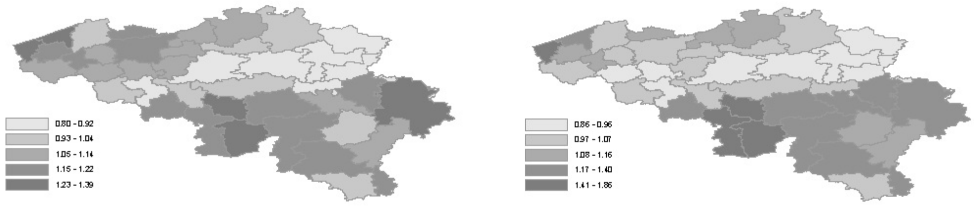
Notes: Figure C.4a maps the share of pupils in primary and secondary school among the age group of 5 to 15 years based on the 1846 population census. The age distribution at the arrondissement level was approximated based on the urban and rural age distribution of Belgian provinces. Figure C.4b maps the share of the literate population in 1866.



(a) Eligible voters (b) Actual voters

Figure C.5: Political participation in 1841/1843 by Belgian region

Notes: Figure C.5 displays eligible voters per 1000 inhabitants (figure C.5a) and actual voters per 1000 inhabitants (figure C.5b) in the partial legislative elections for the Belgian Chamber of Representatives in 1841 and 1843.
Source: Belgique (1852, part 3).



(a) 1830 (b) 1846

Figure C.6: Agricultural wage in 1830 and 1846 by Belgian region

Notes: male agricultural wage without payment in kind in 1830 and 1846 as reported in the 1846 agricultural census (page CCX).

C.2 Regression tables

Table C.1: Validity of instruments: carboniferous rock strata and urban markets in 1700

	(1)	(2)	(3)
	ln(coal)	ln(domestic MP)	ln(foreign MP)
	OLS	*OLS*	*OLS*
ln(dist carbon)	0.64	0.02	0.03
	(0.16)***	(0.02)	(0.01)**
ln(domestic MP 1700)	0.51	0.9	-0.02
	(0.33)	(0.04)***	(0.01)
ln(foreign MP 1700)	-0.32	-0.02	0.59
	(0.38)	(0.11)	(0.05)***
F-statistic	27.8	6785.3	23773.1
N	82	82	82
R2	0.67	0.96	0.99

Standard errors in parentheses clustered at the province level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Includes a full set of controls

Table C.2: IV Poisson model of regional industrial employment: adding controls by sub-industry

	(1)	(2)	(3)	(4)	(5)	(6)
	IND	TEX	FOOD	MET	Group 1	Group 2
ln(coal)	0.39	0.50	-0.22	0.73	0.03	1.21
	(0.09)***	(0.21)**	(0.14)	(0.17)***	(0.06)	(0.62)*
ln(domestic MP)	1.64	2.61	1.43	1.96	1.45	1.25
	(0.17)***	(0.49)***	(0.16)***	(0.29)***	(0.14)***	(0.62)**
ln(foreign MP)	0.39	3.77	0.50	-2.54	0.32	1.09
	(0.71)	(1.48)**	(0.48)	(1.11)**	(0.39)	(5.18)
Controls						
culture	yes	yes	yes	yes	yes	yes
agriculture	yes	yes	yes	yes	yes	yes
human capital	yes	yes	yes	yes	yes	yes
institutions	yes	yes	yes	yes	yes	yes
proto IND	yes	yes	yes	yes	yes	yes
labour cost	yes	yes	yes	yes	yes	yes
constant	yes	yes	yes	yes	yes	yes
time dummy	yes	yes	yes	yes	yes	yes
N	82	82	82	82	82	82

Heteroskedasticity robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: the same controls are used as in specification (9) of table 5.3.

Table C.3: IV Poisson model of regional industrial employment: total MP by sub-industry

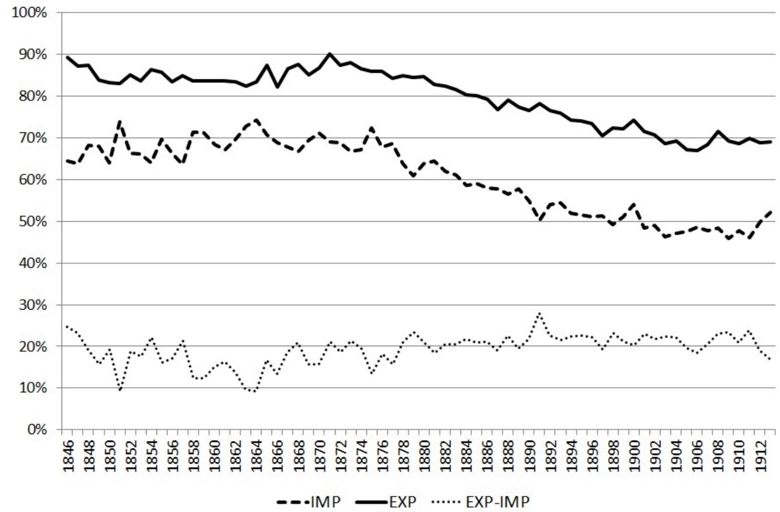
	(1) IND	(2) TEX	(3) FOOD	(4) MET	(5) Group 1	(6) Group 2
ln(coal)	0.40	0.49	-0.21	0.73	0.02	1.09
	(0.09)***	(0.20)**	(0.14)	(0.20)***	(0.07)	(0.43)**
ln(MP)	1.48	2.65	1.26	1.44	1.31	1.24
	(0.15)***	(0.54)***	(0.15)***	(0.33)***	(0.13)***	(0.52)**
ln(coal)	0.31	0.27	-0.24	0.62	-0.02	1.02
	(0.07)***	(0.20)	(0.14)*	(0.19)***	(0.06)	(0.44)**
ln(MP cost)	0.90	1.57	0.80	0.85	0.84	0.72
	(0.08)***	(0.35)***	(0.10)***	(0.17)***	(0.06)***	(0.30)**
ln(coal)	0.4	0.44	-0.40	0.84	-0.03	-
	(0.13)***	(0.33)	(0.45)	(0.25)***	(0.08)	
ln(urban pop)	0.39	0.52	0.20	0.45	0.40	-
	(0.11)***	(0.35	(0.10)*	(0.25)*	(0.06)***	
ln(MP cost excl)	0.72	1.76	0.91	-0.08	0.59	-
	(0.19)***	(0.67)***	(0.33)***	(0.38)	(0.14)***	
Controls						
culture	yes	yes	yes	yes	yes	yes
agriculture	yes	yes	yes	yes	yes	yes
human capital	yes	yes	yes	yes	yes	yes
institutions	yes	yes	yes	yes	yes	yes
proto IND	yes	yes	yes	yes	yes	yes
labour cost	no	no	no	no	no	no
constant	yes	yes	yes	yes	yes	yes
time dummy	yes	yes	yes	yes	yes	yes
N	82	82	82	82	82	82

Heteroskedasticity robust standard errors in parentheses

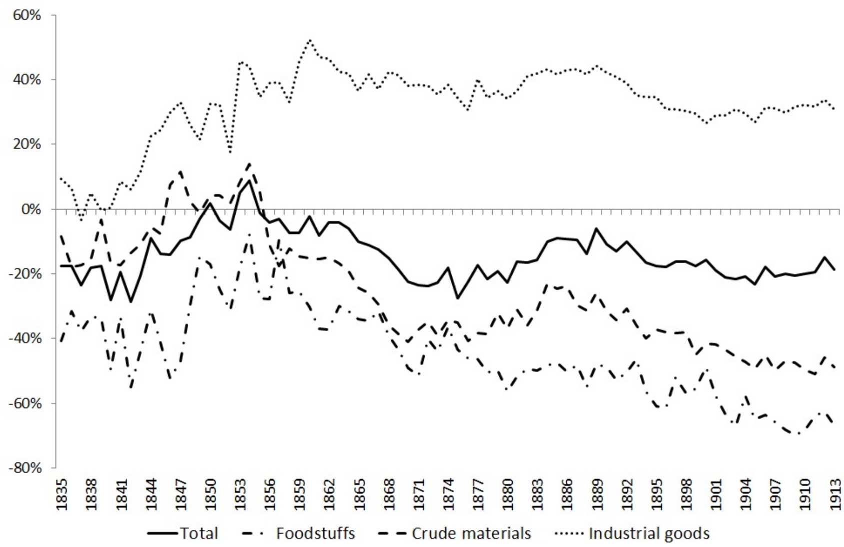
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: the same controls are used as in specification (9) of table 5.3.

C.3 Additional tables & figures



(a) EXP & IMP shares of neighbours



(b) Trade balance by product category

Figure C.7: Belgian foreign trade by destination and product category

Sources: Trade balances by product category have been estimated based on Horlings and Smits (1997). Trade shares by destinations are based on official Belgian trade statistics (Belgique, 1842, 1912).

Table C.4: Industrial employment in 1846 and 1896 at the national level

	1846	1896
Coal and Coke	46,257	126,150
Textiles	96,509	90,370
Linen	60,016	27,881
Wool	18,132	24,231
Cotton	14,593	16,632
Other	3,768	21,626
Food	29,769	91,025
Metal	42,287	134,776
Group 1	39,469	160,337
Wood	20,944	92,474
Leather	13,150	44,041
Paper and Printing	5,375	23,822
Group 2	10,163	47,594
Chemicals	6,211	24,563
Glass	3,952	23,031
sample	264,454	650,252
sample (excl. coal)	218,197	524,102
census (excl transp. & constr.)	314,478	851,020

Notes: The table contains consistent industry employment aggregates from the 1846 and 1896 Belgian industrial censuses, excluding cottage industries. All employment figures are based on original census figures which have been accessed through Belgique (1851) in the case of the 1846 industrial census and *LOKSTAT, the Historical Database of Local Statistics in Belgium. http://www.lokstat.ugent.be* in the case of the 1896 industrial census.

Table C.5: Industrial employment by region and industry in 1846

PROV	ARR	TEX	FOOD	MET	Group1	Group2	sum
Antwerp	Anvers	3,065	1,813	1,171	2,617	399	9,065
	Malines	1,875	767	515	1,401	170	4,728
	Turnhout	1,173	426	267	948	46	2,860
South Brabant	Bruxelles	5,037	2,405	2,398	5,552	1,303	16,695
	Louvain	1,773	1,783	845	1,383	207	5,991
	Nivelles	2,096	736	549	1,263	112	4,756
Flandre Occidentale	Bruges	1,685	652	400	905	177	3,819
	Dixmude	2,012	438	79	252	49	2,830
	Ypres	1,267	731	316	880	245	3,439
	Courtrai	4,990	863	399	1,168	347	7,767
	Ostende	381	290	132	413	55	1,271
	Roulers	2,812	656	162	673	197	4,500
	Thielt	13,226	493	153	617	156	14,645
	Furnes	378	252	82	273	18	1,003
Flandre Orientale	Alost	4,862	678	327	1,126	231	7,224
	Termonde	3,154	652	210	710	391	5,117
	Eecloo	2,620	406	139	648	64	3,877
	Gand	13,699	1,894	1,704	2,338	615	20,250
	Audenarde	1,902	579	251	882	96	3,710
	Saint-Nicolas	5,216	911	490	1,907	179	8,703
Hainaut	Ath	1,312	672	464	491	44	2,983
	Charleroy	447	980	6,162	970	2,163	10,722
	Mons	421	1,580	744	989	167	3,901
	Soignies	1,813	1,309	354	647	468	4,591
	Thuin	569	555	978	1,045	294	3,441
	Tournay	2,042	1,540	472	1,006	164	5,224
Liege	Huy	21	335	2,015	985	40	3,396
	Liege	2,128	1,002	12,020	1,443	1,175	17,768
	Verviers	12,850	392	1,420	893	80	15,635
	Waremme	4	440	100	180	14	738
Limbourg	Hasselt	445	1,306	242	690	93	2,776
	Maeseyck	89	127	84	223	30	553
	Tongres	176	338	172	641	23	1,350
Luxembourg	Arlon	125	79	144	336	16	700
	Bastogne	10	53	55	175	2	295
	Marche	11	107	49	140	6	313
	Neufchateau	28	134	143	292	16	613
	Virton	95	207	287	427	16	1,032
Namur	Dinant	24	309	385	369	19	1,106
	Namur	466	563	1,755	1,130	268	4,182
	Philippeville	210	316	3,653	441	8	4,628
Belgium		96,509	29,769	42,287	39,469	10,163	218,197

Notes: see notes in table C.4.

Table C.6: Industrial employment by region and industry in 1896

PROV	ARR	TEX	FOOD	MET	Group1	Group2	sum
Antwerp	Anvers	1,393	7,946	4,802	9,854	2,619	26,614
	Malines	1,425	2,321	2,345	6,994	324	13,409
	Turnhout	824	1,052	1,258	3,995	427	7,556
South Brabant	Bruxelles	6,482	10,169	12,553	29,640	5,832	64,676
	Louvain	325	5,191	3,791	4,151	1,217	14,675
	Nivelles	2,533	3,032	4,567	5,400	300	15,832
Flandre Occidentale	Bruges	330	1,732	1,472	3,903	240	7,677
	Dixmude	21	694	342	1,068	46	2,171
	Ypres	299	1,559	552	2,239	177	4,826
	Courtrai	3,582	2,098	1,012	3,026	637	10,355
	Ostende	67	967	346	1,288	74	2,742
	Roulers	2,982	1,307	672	2,376	262	7,599
	Thielt	433	794	297	1,160	82	2,766
	Furnes	31	589	251	732	4	1,607
Flandre Orientale	Alost	5,051	1,494	733	4,010	1,727	13,015
	Termonde	5,789	1,341	512	2,237	838	10,717
	Eecloo	589	1,577	327	1,794	253	4,540
	Gand	23,244	4,998	4,489	9,465	1,937	44,133
	Audenarde	2,990	927	763	2,146	303	7,129
	Saint-Nicolas	5,192	2,294	834	6,168	530	15,018
Hainaut	Ath	797	2,565	560	2,768	94	6,784
	Charleroy	163	3,389	21,063	5,012	13,872	43,499
	Mons	738	4,582	3,504	3,949	1,905	14,678
	Soignies	598	2,272	4,965	2,893	479	11,207
	Thuin	224	2,573	4,557	3,608	865	11,827
	Tournay	3,034	3,337	1,424	4,699	158	12,652
Liege	Huy	18	2,060	5,287	2,868	402	10,635
	Liege	1,495	3,931	38,412	8,230	6,663	58,731
	Verviers	17,446	1,940	3,354	5,172	193	28,105
	Waremme	2	3,519	460	1,052	53	5,086
Limbourg	Hasselt	55	1,598	773	1,611	250	4,287
	Maeseyck	97	399	600	856	241	2,193
	Tongres	41	951	382	1,927	23	3,324
Luxembourg	Arlon	26	194	634	761	16	1,631
	Bastogne	35	215	330	816	1	1,397
	Marche	6	252	216	1,124	17	1,615
	Neufchateau	70	416	571	1,524	105	2,686
	Virton	67	396	481	1,051	122	2,117
Namur	Dinant	1,106	838	851	2,102	37	4,934
	Namur	699	2,914	3,443	4,743	4,157	15,956
	Philippeville	71	602	991	1,925	112	3,701
Belgium		90,370	91,025	134,776	160,337	47,594	524,102

Notes: see notes in table C.4.