A Quantitative Analysis of U.S. Economic Development, 1870-1913

Author:
Yeo Joon Yoon

Supervisor:
Prof. Nicholas Crafts
Prof. Anthony Venables

A thesis submitted for the degree of
Doctor of Philosophy

Department of Economics
University of Warwick
Coventry, United Kingdom

December 2013

Contents

List of Figures

List of Tables

Acknowledgements

I am extremely grateful to my supervisors Nicholas Crafts and Anthony Venables for their valuable comments and supports. I also would like to thank Stephen Broadberry, Natalie Chen, Bishnupriya Gupta, Kevin O'Rourke, Dennis Novy and the seminar and workshop participants at Warwick and LSE for their helpful comments and suggestions. I also thank Mark Thomas for providing me with the data. I am also grateful to my MA supervisor Byung Sam Yoo. Many thanks go to my friends and colleagues including Wanyu Chung, Chris Chiang, Byungkuk Kim, Jungju Kim, Soo Yeon Kim, Choong Hyun Nam and Ruben Pastor who were close to me during this process of joys and agonies. Finally I wish to say that this whole thing would not have been possible without never-ending encouragements and supports from my parents and sister.

Declaration

I declare that the thesis is my own work and has not been submitted for a degree at another university.

Yeo Joon Yoon

December 2013

Abstract

The transition of U.S. economy, from a large primary products exporter based on abundant endowments of natural resources to a leading industrial producer and a successful manufacturing exporter from the late 19th century to the early twentieth century, is a remarkable historical event. In this thesis I investigate the quantitative importance of various factors and policies behind the development of the U.S. and the North Atlantic economy from 1870 to 1913. The factors considered are exogenous changes in : sectoral productivities; endowments in labour and land; and trade costs. While these may not be all the factors that mattered, they were certainly important forces behind the development of the region.

I then ask some historically interesting counterfactual questions which are closely related to these forces. First, I explore the implications of the high tariffs imposed on U.S. manufacturing imports. More particularly, I ask "Could U.S. manufacturing and its economy grow as it did without the tariffs?" The second counterfactual exercise is related to the mass migration. There is no doubt that the mass immigration to the U.S. in the nineteenth century contributed considerably to its overall economic growth. But what is uncertain is its quantitative implications on the overall and the sectoral development. I also look at its implications on the Anglo-American real wage convergence.

The focus is on several dimensions of the development : the large increase in U.S. share of world manufacturing output and the decline in that of Britain; the growth of their primary and manufacturing output and real GDP; and its structural transformation. In order to disentangle the effects of each force, I build a model of the North Atlantic economy calibrated to be consistent with some key facts during this period.

Chapter 1

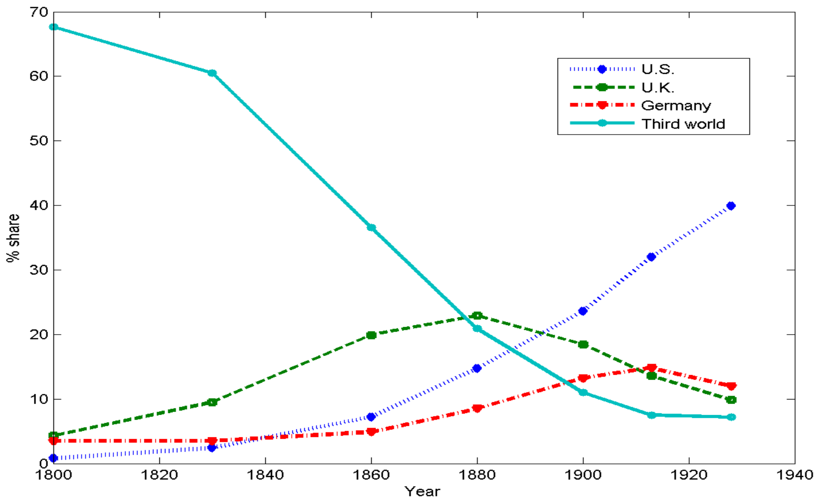
Introduction

1.1 Introduction

1.1.1 Addressing the Question

The transition of U.S. economy, from a large primary products exporter based on abundant endowments of natural resources to a leading industrial producer and a successful manufacturing exporter from the late 19th century to early 20th century, is a remarkable event. According to Bairoch (1982), U.S. share of the world manufacturing production in 1860 was only 7.2% but its share surged to 32.0% in 1913. In contrast, U.K share went down from 19.9% in 1860 to 13.6% in 1913. Figure 1 below depicts the relative development path of U.S. and U.K. manufacturing from 1800 to 1928. From this it can be observed that the growth of U.S. manufacturing accelerated from the mid-nineteenth century, overtaking the U.K. in late-nineteenth century. Also by 1913 the U.S. was the only non-European country in the Atlantic Economy to establish its position as a net manufacturing exporter and represented the third largest share (13.3%) in world manufacturing exports, having net exports of $368 million in 1913 prices (Yates, 1959)

In this thesis I investigate the quantitative importance of various forces and issues behind the development of the U.S. and the North Atlantic economy from 1870 to 1913. In doing this I view the phenomenon in an international context. In other words, I regard the rise of the U.S. and the relative decline of Britain, especially their manufacturing sectors, as a closely related event that happened through interactions of the forces that determined the comparative advantages of each region. For this purpose I build a model that accounts for several key characteristics of the North Atlantic economy - featuring Britain, the U.S. and the rest of world - during the period from 1870 to 1913.



(Source : Bairoch (1982))

Figure 1: Share of world industrial output

Like most of the development experiences of nations or regions, the rise of the U.S. (and the relative decline of Britain) was not an event that can be attributable to one simple cause. It must have been a result of many forces working together. Therefore to evaluate the effect of an individual force, it must be isolated from other forces. And the model briefly mentioned above is built to serve this purpose.

Basically, the forces considered are exogenous changes in : sectoral productivities; endowments in labour and land; and trade costs. While these may not be all the factors that mattered, they were certainly important forces behind the development of the region. First, the productivity of the U.S. grew substantially relative to the most of other regions including Britain.[1] Second, the land area and labour force of the U.S. exploded, mainly due to the westward movement and the mass immigration, respectively. Finally, the changes in trade costs are considered. It is well documented by O'Rourke and Williamson (1999), that the large reduction in transport costs was important in many respects for the North Atlantic economy during this period. But here I do not restrict trade costs to transport costs only. They are perceived as the implied trade costs that include observable as well as unobservable components.[2] These forces would have considerable implications under the closed economy framework. But under the open economy framework considered here, they would have additional implications as they shift the comparative advantages among the regions.

The focus is on several dimensions of the development : the large increase in U.S. share of world manufacturing output and the decline in that of Britain; the growth of their primary and manufacturing output and real GDP; and its structural transformation. In order to disentangle the effects of each force, I restrict the model to be consistent with some key facts in the benchmark year of 1870. I then establish that the model accounts for the important developmental facts, just mentioned above, in 1913 when the changes in productivities, endowments and trade costs are fed in. Then the effects of each force on the development of the U.S. are isolated and evaluated by feeding in the change in each force while keeping others unchanged.

The baseline model features increasing returns to scale (IRTS) in manufacturing, following the evidences that there existed IRTS in U.S. manufacturing in the late nineteenth century.[3] Given the significance of IRTS in U.S. manufacturing, the quantitative implications of this will be investigated. In order to isolate the effects of IRTS, a simple change is made to the baseline IRTS model so that the manufacturing sector now exhibits constant returns to scale (CRTS). It is established that the CRTS model yields identical cal-

[1] In the following chapter, the implied changes in sectoral productivities will be measured. Broadberry (1997) and Broadberry and Irwin (2006) clearly establish that the sectoral labour productivities of the U.S. were growing substantially both in absolute terms and relative to Britain during the period.

[2] For more discussion of this, see Anderson and van Wincoop (2004).

[3] This will be discussed more in detail in the following section.

ibrated parameter values and equilibrium values in the benchmark year. It is then shown that the CRTS model accounts for the key characteristics of the economy closely when the changes implied by CRTS are fed in. These properties make the two models highly comparable. Then the shocks implied by the IRTS model are fed into this otherwise CRTS model. Then by comparing the outcome with that of the baseline model, I disentangle and evaluate the effects of IRTS.

I also ask some historically interesting counterfactual questions which are closely related to these forces. First, I explore the implications of the high tariffs imposed on U.S. manufacturing imports. More particularly, the question I try to answer is "Could U.S. manufacturing and its economy grow as it did without the tariffs?" or put in a more historical context "What if the South had won the War?" The role of tariff in the development of the U.S. in the second half of nineteenth century is still a hotly debated issue among economic historians. I aim to contribute to these literatures by providing some quantitative insights.

The second counterfactual exercise is related to the mass migration. There is no doubt that the mass immigration to the U.S. in the nineteenth century contributed considerably to its overall economic growth. But what is uncertain is its quantitative implications on the overall and the sectoral development. Even though it is not the main focus of the thesis, I also look at its implications on the Anglo-American real wage convergence. This issue is already explored in O'Rourke, Williamson and Hatton (1994) and they find that the contribution of the mass migration on the convergence is quite large. In doing this, they use a standard neo-classical model with constant returns to scale. But the baseline model here assumes IRTS in manufacturing, I investigate whether this assumption changes the result quantitatively and qualitatively.

1.1.2 Assumption of the Model

In this section I discuss the main assumptions of my model. The details of the model will be described in the next chapter. While I try to keep the model as simple as possible, there are some assumptions that need more explanations. The first and foremost important feature of the model is that there exists IRTS in manufacturing. Many previous works studying the economy assume CRTS but at the same time there are arguments and empirical evidences that there was IRTS in U.S. manufacturing during this period.[4] Given these evidences, assuming IRTS seems reasonable.

The goal of this thesis is to analyse the factors that contributed to the development of the U.S. and one of the driving forces considered here is the change in productivity, also called the technological progress. But in fact, a large part of this is still a 'black-box'. In the standard growth accounting exercise, this is treated as a residual which is left unexplained by other observable components. But by assuming IRTS - a reasonable assumption given the evidences - I can reduce the size of the 'black-box' and attribute larger parts of the development to more tangible factors. As we will see later in Chapter 2, U.S. manufacturing TFP implied by IRTS is indeed smaller than that implied by CRTS.

One more feature of the model that is closely related to the assumption of IRTS is that the manufacturing sector uses manufacturing products as intermediate goods. This basically generates the forward and backward linkage effects, thus inducing the agglomeration of manufacturing when certain conditions are met.[5] So this feature helps the model account for the agglomeration of manufacturing in the U.S., without relying on an absurdly large TFP. Crafts and Venables (2001) also argue that IRTS and the linkage effects are needed to replicate the key features of the economy such as the large growth of U.S. manufacturing and constant U.S. to U.K. real wage gap during this period. In addition to this, without this assumption, the implied manufacturing TFP under IRTS becomes identical to that of CRTS. So in a way, this is crucial to distinguish the baseline IRTS model from the CRTS variation.

Next assumption that deserves some explanation is that I do not include capital in the model. According to the estimation of Kendrick (1961), capital increased by more than ten folds during the period for the U.S. And

[4]For example see Wright (1990) and O'Rourke and Williamson (1994) for the works assuming CRTS and Chandler (1977), James (1983) and Cain and Paterson (1986) for the works of IRTS.

[5]See Fujita, Krugman and Venables (1999) for more discussion.

there is no doubt that the capital accumulation is one of the important factors for U.S. economic growth from the growth accounting perspective. Capital accumulation is usually treated as an endogenous process. And it is true that a model with an endogenous capital accumulation can yield quantitatively different results from the outcomes implied by the current model without capital, as the changes in the exogenous forces also influence capital accumulation process as well. But the bottom line here is that the focus of this work is not really on capital accumulation itself. In other words, the model is not focusing on a question such as how the productivity growth or the large increase in land change the pattern of capital accumulation. Besides, including capital in the model complicates things hugely. Also the tractability of the model is not guaranteed as the model needs to become dynamic. Therefore the expense of including capital seems too high given the objectives of the model and I choose simplicity over more realistic reflection of the history. In several numerical exercises, I include capital in an exogenous manner.

Also even though the model does not include physical capital endogenously, it does include land for primary production and manufacturing intermediate input for manufacturing sector. Land accumulation and capital accumulation are very closely related, especially for U.S. primary sector. According to O'Rourke and Williamson (1994), about 40% of the capital stock in U.S. primary sector was used to improve land in 1870.[6] And they argue that this portion of capital is 'analytically closer to land than capital'. So in this sense including land implies including substantial parts of capital used in the primary sector, if not all. For manufacturing sector, the link between manufacturing intermediates and capital is not so definite as the link between land and capital for primary sector. But one can think of manufacturing intermediate input as a short-lived capital or capital that depreciates fully within a given period. The bottom line is that at least the model includes some form of inputs that are similar to capital in several senses.

[6] They calculate the value of capital stock was $6363 million of which $2538 million was the value of land improvement.

1.1.3 Outline of Thesis

The remainder of the paper is organized as follows. In section 2 of this chapter, I summarize the results of Chapter 3, 4 and 5. In section 3 of this chapter, I review the related works. In Chapter 2, I describe the model, the data and the procedure for calibrating parameters and measuring the changes in each force. I then simulate the model to generate the development of the economy from 1870 to 1913 and establish that the model accounts for the history closely. In the last part of Chapter 2, I introduce the CRTS variation of the baseline model. In Chapter 3, I perform a growth decomposition exercise of U.S. economy using the model introduced in Chapter 2. I quantitatively evaluate the impact of each force on the development of U.S. economy. Then in Chapter 4, I study the implications of the tariff imposed on U.S. manufacturing imports. Finally in Chapter 5, I investigate the impacts of the mass migration on the development of the U.S. and Anglo-American real wage convergence.

1.2 Results of Chapter 3, 4 and 5

In this section I briefly discuss the outcomes of each chapter. Chapter 2 is designed for the model and the data so there really is no interesting result to talk about. Therefore I begin from chapter 3.

1.2.1 Chapter 3 : Growth Decomposition Exercise

In the first part of Chapter 3, I evaluate the quantitative contribution of each force to the development of the U.S. It turns out that the large increase in the labour force stands out as the single most important factor. It alone accounts for about 45% of the real GDP growth from 1870 to 1913. The increase in the labour force has uneven impacts on sectors. The manufacturing sector seems to benefit more from this exogenous shock than the primary sector. The second implication arising from this exercise is that the changes in trade costs are unfavourable to the development of U.S. manufacturing. Without any changes in the trade costs, the manufacturing output would have grown almost two times larger than it actually grew. I then take different approaches of measuring trade cost and TFP shocks and perform similar decomposition exercises. I also include exogenous capital and analyse the contribution of the increase in capital stock.

In the second part of the chapter, I disentangle the effects of IRTS. A caveat regarding this exercise is that it does not evaluate whether the model with IRTS performs better than the CRTS one in accounting for the development of the economy. But it tries to measure the quantitative implications of IRTS *assuming* that there exists IRTS in manufacturing. The effects of IRTS is not small. This force alone accounts for about one third of the growth in U.S. manufacturing and 10% of the real GDP growth.

1.2.2 Chapter 4 : The Implications of the Tariff

The role of the high tariffs in the development of U.S. economy has generated much controversy. In this chapter I try to add some contributions to this ongoing debate. In order to do this, I perform a counterfactual exercise by eliminating the tariffs on U.S. manufacturing imports. By doing this I can disentangle the effects of the tariff and see its quantitative implications on the development of U.S. economy. The model can serve as a good tool for this purpose.

The overall results suggest that the manufacturing tariffs helped promote its manufacturing sector but its quantitative effects were not so large. Even when I allow for the dynamic and cumulative effects of the tariffs by assuming that there exists learning-by-doing process in U.S. manufacturing, the quantitative effects of the tariffs in promoting the economy are not so large. Under a plausible value of the learning rate, the tariff only accounts for about 3% of the growth in U.S. manufacturing output and less than 1% of the growth in the real GDP.

The model does not feature all the possible mechanism through which the tariffs can influence the economy. But the result - generated under carefully devised model and parameters - suggests that the heavy protection of U.S. manufacturing characterised by the high tariff rates on its manufacturing imports, did not play a quantitatively important role in promoting its economic development.

1.2.3 Chapter 5 : The Implications of the Mass Migration

Another event that characterises the economy during this period is the mass migration. The massive inflow of immigrants to the U.S. contributed hugely to the increase of its labour forces. The model allows to distinguish the effects of the mass immigration from other forces. In the first part of the chapter I look at the development implications of the immigration. It turns out that the mass migration has quantitatively large impacts on the development. The net immigration to the U.S. contributes about 12.5% and 26.5% to the growth of primary and manufacturing output, respectively. So the impact is uneven across sectors. When the effects of the net immigration is eliminated, U.S. primary loses 1.6 percentage point in the world share but its manufacturing loses 7.5 percentage point from the world share. Also it accounts for about 20% of the real GDP growth.

The second part of the chapter deviates a little from the main focus of the thesis. While it mainly explores the quantity side of the economy, this part looks at the price side. Namely, it investigates the implications of the mass migration on Anglo-American real wage convergence. The general consensus so far, based on the works of O'Rourke, Williamson and Hatton (1994, OWH), is that the mass migration contributed substantially to the convergence of the real wages between Britain and the U.S. The CRTS model yields somewhat similar results as OWH who also used the standard neo-classical model with CRTS. Without the mass migration, the ratio of U.S. real wage to Britain's real wage increases by 6%. But the result changes qualitatively when the baseline IRTS model is used. It turns out that the migration contributes to the divergence rather than convergence. In this case, without the migration, the ratio decreases by 1.6%. The main force behind this reversal is the IRTS, the force which increases labour productivity as labour force increases. I then assume that the land is endogenous to the migration and this force quantitatively strengthen the result that the mass migration contributes to the divergence.

1.3 Related Literatures

The emergence of the U.S. as an industrial power is a remarkable historical event that occurred within such a short span of time. Therefore many studies focused on American economic growth during this period. I begin with those literatures that focus on the role of technology. The modern debate on American ascendancy began with Rothbarth (1946) and Habakkuk (1962). They argued that the relative land abundance in the U.S. raised its real wage rate, thereby increasing the cost of labour for manufacturers. In turn, this induced American entrepreneurs to substitute capital for the dearer labour, leading to a pattern of growth more capital intensive and more rapid than that of Great Britain.[7] In their views, the technology developed in the U.S. was only 'appropriate' for the conditions in the U.S. thus not optimal to be used in other countries with different endowment conditions. In the same vein, Abramovitz and David (1996) argued that the U.S. developed based on the technology that was intensive in using cheap and abundant natural resources. And for these natural resources were not available to Britain and Europe as cheaply, the technology was not transferable to them.

In a related study, Wright (1990) applied Heckscher-Ohlin model to examine the factor content of trade in manufacturing goods between 1880 and 1940 and drew conclusion that the single most robust characteristic of American manufacturing was intensity in non-reproducible natural resources. This result implies that American supremacy in natural endowments was important in its industrial success. Hutchinson (2002) supplements Wright's findings using new data from the U.S. Census of Manufactures.

A strand of literature also emphasizes the role of institution on the development of the U.S. In exploring the comparative development trajectory of North and Latin America, Engerman and Sokoloff (1997) argued that initial institutions differed between the two regions because of the different endowments with regards to soils, climates and the size of the native population.

[7] Their argument sparked so called 'Habakkuk Controversy' because the interest rate in the U.S. was actually higher than that of Britain. And Temin (1966), by using a simple neoclassical model, concluded that U.S. manufacturing must have been capital scarce relative to Britain, contrasting Habakkuk.

More specifically, these conditions in Latin America favoured economic institutions dominated by large-scale estates and plantations which were granted to only small portion of elites. As a result the distribution of wealth and human capital were extremely unequal and opportunities were restricted to the broad mass. On the other hand, the conditions in North America were somewhat opposite to Latin America thus creating institutions that were conducive to lower inequality. And this difference caused the divergent path in the economic development of the two regions. Similarly North, Summerhill and Weingast (2000) put forward an argument that the institutions from Spanish colonial rule in Latin America persisted even after ending of the colonialism. And the Latin American institutions contrasted with the North American institutions which were the legacies of British colonialism in the way that the latter promoted a strong sense of property rights and the former didn't. David and Wright (1997) linked the nature of the American institutions that effectively utilized the resource-rich condition to its economic supremacy. For example, they mentioned the role of institutions that promoted and subsidized education and research in the relevant fields such as mining.

In terms of modelling, it is largely based on Krugman and Venables (1995) and Fujita, Krugman and Venables (1999). They introduced the model of New Economic Geography in which the economies of scale and the linkage effects generate the agglomeration of manufacturing in one region. Also closely related is the work of O'Rourke and Williamson (1994). They built a computable general equilibrium model of the North Atlantic economy, calibrated to fit the data. The model, which was based on the standard Heckscher-Ohlin neoclassical framework, was used to study the implications of the global commodity market integration and the reduction in global transportation costs on the factor price convergence. In addition to this, it is also closely in line with the work of Herrendorf, Schmitz and Teixeira (2012) in which they found the large reduction in transportation costs was a quantitatively important force behind the settlement of the Midwest, the regional specialization and the increase in real GDP per capita in the U.S. from 1840 to 1860.

Finally, I discuss the works that documented the existence and the significance of the scale economy in U.S. manufacturing. First, Chandler (1977) argued that the capital deepening technological change, that was apparent in the late nineteenth century U.S. manufacturing, generated the economies of scale and this made possible the dramatic rise of the industry in the world stage. James (1983) and Cain and Paterson (1986) tested this argument empirically by estimating the translog production function and documented that the economies of scale in U.S. manufacturing were substantial and pervasive in the late nineteenth century.

Cain and Paterson (1986) use the Generalized Leontief production function to derive real factor demand equations.[8] Using this, they simultaneously test the presence of economies of scale, biased technical change and factor substitutability in U.S. manufacturing at the two digit level in the years from 1850 to 1919. The result shows the evidence of the economies of scale in U.S. manufacturing during the period. Out of 19 manufacturing sectors, only two sectors, food and beverage (SIC 20) and leather goods (SIC 31), are found to exhibit constant returns to scale technology. The presence of economies of scale in the other 17 sectors was more attributable to capital than labour.

James (1984) tests the hypotheses of Chandler (1977) that the rise of U.S. manufacturing was mainly due to the labour-saving and capital-intensive technological change which, in turn, made possible the development of large firms and big business. Even though its main objective is to examine the relationship between capital-biased technological change and changes in returns to scale, it also establishes that there existed a significant degree of scale economy and the range of economies of scale increased substantially in 16 manufacturing sectors during the periods between 1850 and 1890. Finally, Atack (1977) estimates a Cobb-Douglas production function for 5 major manufacturing sectors - boots and shoes, clothing, cotton, flour milling and lumber milling - in the antebellum year of 1850 and 1860. He establishes that there existed substantial economies of scale in U.S. manufacturing and

[8]The equation looks like $A_i = \sum_j \beta_{ij}(P_j/P_i)^{1/2} + \beta_{iY}Y + \beta_{it}t + \epsilon_i$ where A_i is real factor demand for i per unit of gross real output, P_i is price of factor i, Y is real gross output, t is time and β_{ij}, β_{iY} and β_{it} are parameters to be estimated. The parameter of interest regarding the scale economy is β_{iY} where a significant and negative value indicates the presence of economies of scale with respect to factor i.

the range increased from 1850 to 1860.

There are ample empirical evidences that support the presence of scale economies in U.S. manufacturing in the late nineteenth century. However as to whether this was internal or external economies of scale or a combination of both, it is not so clear while this obviously affects my modelling choice. As it will be more clear when I introduce my model in Chapter 2, I assume that it is internal economies of scale. The implications of this assumption will be discussed more in detail in Section 2 of Chapter 3.[9]

[9] More literature review relevant to questions in each chapter is included in the introduction part of each chapter. For example, the literatures on the role of the tariffs are included in Chapter 4 and on the mass migration in Chapter 5. The literature review in Chapter 1 only includes more general reviews.

Chapter 2

The Model and the Data

2.1 The Baseline Model

A benchmark model is constructed to account for some important characteristics of the U.S. and the North Atlantic Economy in the late nineteenth century. I consider factors that potentially could have been important forces driving the outcome: differences in sectoral productivity or TFP, trade costs and endowments.[10]

The economy consists of 3 regions : Britain, the U.S. and the rest of the world. Each region has 3 sectors of production : primary, manufacturing and services. Primary and manufacturing goods are tradable while goods produced in the service sector are non-tradable. There are 3 factors of production : land, labour and manufacturing intermediates. The primary sector uses land and labour, the manufacturing sector uses labour and manufacturing intermediates and the service sector only uses labour.[11] The manufacturing sector exhibits increasing returns to scale at the firm level

[10]Obviously, the Heckscher-Ohlin model assumes a common technology across regions but differences in sectoral productivity in levels and in growth were significant between two regions (Broadberry, 1997).

[11]Land is included in primary to reflect the comparative advantage of the U.S. in land endowment. This was clearly an imporant competing force against the agglomeration.

while the other sectors have constant returns to scale.[12] Labour is perfectly mobile across sectors so that wages are equalized across sectors. Basically the model obeys the standard assumptions of the New Economic Geography literature.

2.1.1 Consumer Behaviour

There is a measure $D_i > 0$ of identical consumers. Every consumer shares the same Cobb-Douglas tastes over the three types of goods,

$$U = (c_{ai} - \underline{c}_i)^{\theta_a} c_{mi}^{\theta_m} c_{si}^{\theta_s}$$

where c_{ai} and c_{mi} represent composite indexes of the consumption of primary and manufactured goods, respectively, and $\underline{c}_i$ is the subsistence level of consumption in primary and i=$\{b, us, rw\}$. The index c_{ai} is a sub-utility function defined over differentiated agricultural products that each region produces. Likewise c_{mi} is defined over a continuum of varieties of manufactured goods:

$$c_{ai} = \left[\gamma_b a_{i,b}^{\rho_a} + \gamma_{us} a_{i,us}^{\rho_a} + \gamma_{rw} a_{i,rw}^{\rho_a}\right]^{1/\rho_a}, \quad c_{mi} = \left[\int_0^n m(j)^{\rho_m} dj\right]^{1/\rho_m}$$

where $a_{i,j}$ represents region i's demand for region j's primary products and $m(j)$ represents manufacturing consumption of each available variety. n is the total number of manufacturing varieties produced in all three regions. This specification yields the price indexes for c_{ai} and c_{mi} as

$$G_{ai} = \left[\gamma_b^{\sigma_a}(p_{a,b}T_{bi}^a)^{1-\sigma_a} + \gamma_{us}^{\sigma_a}(p_{a,us}T_{usi}^a)^{1-\sigma_a} + \gamma_{rw}^{\sigma_a}(p_{a,rw}T_{rwi}^a)^{1-\sigma_a}\right]^{1/(1-\sigma_a)} \quad (1)$$

$$G_{mi} = \left[\sum_j n_{mj}(p_{mj}T_{ji}^m)^{1-\sigma_m}\right]^{1/(1-\sigma_m)} \quad (2)$$

[12]Later in the paper the assumption of increasing returns will be relaxed and some features of constant returns in manufacturing sector will be discussed and compared with the benchmark model.

where p_{ai} is the price of a primary good produced in i and T^a_{ji} and T^m_{ji} are the iceberg transportation costs of agriculture and manufacturing from region j to i respectively; $\sigma_a = \frac{1}{1-\rho_a}$ and $\sigma_m = \frac{1}{1-\rho_m}$. γ_i is the share parameter and the meaning of this parameter will be discussed more in detail in later in this chapter where I go over the calibration procedure.

2.1.2 Production

The primary good is produced using a constant returns to scale technology under perfect competition. It uses land and labour as inputs and has a production function as

$$Y_{ai} = A_{ai}(L_{ai})^{\alpha_a}(N_{ai})^{1-\alpha_a}$$

where L_{ai} is labour, N_{ai} is land and A_{ai} is TFP. Cost-minimization implies the following condition,

$$p_{ai} = \Gamma_a \omega_i^{\alpha_a} d_i^{1-\alpha_a} \tag{3}$$

where p_{ai} is the price of the primary good, ω_i is the wage and d_i is land rent; $\Gamma_a = (A_{ai}\alpha_a^{\alpha_a}(1-\alpha_a)^{1-\alpha_a})^{-1}$.

I assume the manufacturing sector exhibits IRTS. As in Krugman and Venables (1995), these economies of scale arise at the level of a firm and technology is the same for all firms in all regions and involves a fixed input of F. I also assume that in addition to labour, it uses its own produced variety. Its production function can be defined as

$$Y_{mi} = A_{mi}(l_{mi})^{\alpha_m}\left[\sum_j n_{mj} m_{ji}^{\rho_m}\right]^{(1-\alpha_m)/\rho_m} - F$$

where A_{mi} is TFP, m_{ji} is input of each manufacturing variety produced in region j and used in region i and n_{mj} is number of manufacturing firms in region j. l_{mi} is labour employed by a single manufacturing firm in region i. It should be distinguished from an upper-case letter L_{mi} which denotes the aggregate amount of labour employed in region i's manufacturing sector that will appear shortly.

The underlying assumption is that the elasticity of substitution among differentiated products for manufacturing firms is the same as that for consumers as they share the same ρ_m. In other words, this implies that firms and consumers in each region face the same manufacturing price index. This assumption would not be central to my results because the results are not sensitive to the elasticity of substitution parameters but this makes analysis much more tractable and manageable. Cost minimization implies the following,

$$\omega_i l_{mi} + G_{mi} M_i = \Gamma_{mi} \omega_i^{\alpha_m} G_{mi}^{1-\alpha_m} (Y_{mi} + F) \tag{4}$$

where $\Gamma_{mi} = (A_{mi} \alpha_m^{\alpha_m} (1 - \alpha_m)^{(1-\alpha_m)})^{-1}$ and $M_i = \left[\sum_j n_{mj} m_{ji}^{\rho}\right]^{1/\rho}$.

The service sector, like the primary sector, uses a constant returns to scale technology under the perfect competition and uses labour as its only input. Its production technology can be described as,

$$Y_{si} = A_{si} L_{si}$$

and profit maximization implies,

$$p_{si} = \frac{\omega_i}{A_{si}} \tag{5}$$

2.1.3 Demand

The demand for manufacturing goods can be decomposed into two parts: final goods or consumption demand and intermediate demand. The aggregated world demand for a manufacturing good produced in region i is

$$(p_{mi})^{-\sigma_m}\left[\sum_j \theta_m(Y_j - \underline{C}_i\, G_{aj})\left(\frac{T_{ij}^m}{G_{mj}}\right)^{1-\sigma_m} + \sum_j (1-\alpha_m) n_{mj} p_{mj} q_{mj}\left(\frac{T_{ij}^m}{G_{mj}}\right)^{1-\sigma_m}\right] \quad (6)$$

where $\underline{C}_i = D_i\ \underline{c}_i$. The first term is the world consumption demand and the second term is the world intermediate demand. Y_j represents income of region j and q_{mj} is sales of a manufacturing firm in region j that is in line with the zero-profit condition. Using (6) and profit maximization, the price index for the composite manufacturing good, p_{mi}, can be derived and q_{mi} can be obtained by imposing the zero-profit condition.

$$p_{mi} = \frac{\sigma_m}{(\sigma_m - 1)}\Gamma_{mi}\ \omega_i^{\alpha_m} G_{mi}^{1-\alpha_m} \quad (7)$$

$$q_{mi} = F(\sigma_m - 1) \quad (8)$$

It is easier to obtain the demand for primary goods as it is only used in consumption. The world demand for a primary good produced in region i is

$$\sum_j \left[\theta_a(Y_j - \underline{C}_i\ G_{aj}) + \underline{C}_i\ G_{aj}\right](p_{ai})^{-\sigma_a}\left(\frac{T_{ij}^a}{G_{aj}}\right)^{1-\sigma_a} \quad (9)$$

Finally, the demand for a non-tradable service good in region i is

$$\frac{\theta_a(Y_i - \underline{C}_i\ G_{ai})}{p_{si}} \quad (10)$$

2.1.4 Reformulation

In this section, I reformulate the equations in order to define the equilibrium in a simpler way. Primary and service expenditure of region i only come from final consumption while manufacturing expenditure comes from final consumption and intermediate usage. Therefore, region i's expenditures are given by

$$
\begin{aligned}
E_{ai} &= \theta_a(Y_i - \underline{C}_i\, G_{ai}) + \underline{C}_i\, G_{ai} && (11)\\
E_{mi} &= \theta_m(Y_i - \underline{C}_i\, G_{ai}) + (1-\alpha_m)n_{mi}p_{mi}q_{mi} && (12)\\
E_{si} &= \theta_s(Y_i - \underline{C}_i\, G_{ai}) && (13)
\end{aligned}
$$

The second term on the right hand side of (12) is intermediate demand.

Wage income in the manufacturing sector, $\omega_i L_{mi}$ (L_{mi} is total labour force in the manufacturing sector) is equal to the total value of manufacturing output times the share of labour, $\alpha_m n_{mi} p_{mi} q_{mi}$. The number of manufacturing firms can be expressed as

$$n_{mi} = \frac{\omega_i L_{mi}}{\alpha_m p_{mi} F(\sigma_m - 1)} \qquad (14)$$

Using (7) and (14), the manufacturing price-index (2) can be expressed in terms of wage and allocation,

$$(G_{mi})^{1-\sigma_m} = \sum_j B_j L_{mj} (\omega_j)^{1-\alpha_m\sigma_m} (G_{mj})^{\sigma_m(\alpha_m-1)} (T^m_{ji})^{1-\sigma_m} \qquad (15)$$

where $B_j = (\alpha_m F \sigma_m^{\sigma_m} (\sigma_m - 1)^{(1-\sigma_m)} \Gamma_{mj}^{\sigma_m})^{-1}$. Substituting (3) into (1), the primary price-index can be re-written as

$$(G_{ai})^{1-\sigma_a} = \sum_j \gamma_j^{\sigma_a} \Gamma_{aj}^{1-\sigma_a} (\omega_j)^{\alpha_a(1-\sigma_a)} (d_j)^{(1-\alpha_a)(1-\sigma_a)} (T^a_{ji})^{1-\sigma_a} \qquad (16)$$

The service-price index is the same as in (5) :

$$p_{si} = G_{si} = \frac{\omega_i}{A_{si}} \tag{17}$$

I reformulate the goods market clearing conditions in terms of expenditures (E_i), price-indexes (G_i) and wage (ω_i). First, for the primary sector in each region to clear, Y_{ai} has to equal (9). Using (3) and (11), I have

$$\left[\frac{\Gamma_a(\omega_i)^{\alpha_a}(d_i)^{1-\alpha_a}}{\gamma_i}\right]^{\sigma_a} Y_{ai} = \sum_j E_{aj}\left(\frac{T_{ij}^a}{G_{aj}}\right)^{1-\sigma_a} \tag{18}$$

Likewise for the manufacturing sector, (8) has to be equal to (6). Using (7), (12) and (14), it can be expressed as,

$$C_i\ \omega_i^{\alpha_m\sigma_m}(G_{mi})^{(1-\alpha_m)\sigma_m} = \sum_j E_{mj}\left(\frac{T_{ij}^m}{G_{mj}}\right)^{1-\sigma_m} \tag{19}$$

where $C_i = F\sigma_m^{\sigma_m}(\sigma_m - 1)^{(1-\sigma_m)}\Gamma_{mi}^{\sigma_m}$. Finally, using (10), (13) and (17), the goods market clearing condition for the service sector can be given as,

$$\omega_i L_{si} = E_{si} \tag{20}$$

Total endowment of labour in each region is given as $\underline{L}_i$ and the labour market clearing condition is

$$\underline{L}_i = L_{ai} + L_{mi} + L_{si} \tag{21}$$

Total endowment of land in each region is $\underline{N}_i$ and the land market clearing condition is

$$\underline{N}_i = N_i \tag{22}$$

Finally, the income of each region i is

$$Y_i = \omega_i \underline{L}_i + d_i \underline{N}_i \tag{23}$$

Two additional equations are required to define the equilibrium. They are factor demands for land and labour in the primary sector.

$$N_i = \frac{1}{A_{ai}} \left(\frac{1-\alpha_a}{\alpha_a} \frac{\omega_i}{d_i} \right)^{\alpha_a} Y_{ai} \tag{24}$$

$$L_{ai} = \frac{1}{A_{ai}} \left(\frac{\alpha_a}{1-\alpha_a} \frac{d_i}{\omega_i} \right)^{1-\alpha_a} Y_{ai} \tag{25}$$

2.1.5 Equilibrium

The general equilibrium determines each region's wage and land rent: $\{w_i, d_i\}$, land and labour allocations: $\{N_i, L_{ai}, L_{mi}, L_{si}\}$, price-indices: $\{G_{ai}, G_{mi}, G_{si}\}$, expenditures: $\{E_{ai}, E_{mi}, E_{si}\}$, agricultural output $\{Y_{ai}\}$, and income: $\{Y_i\}$. The expenditure equations (11)-(13), price-index equations (15)-(17), goods market clearing equations (18)-(20), labour and land market clearing equation (21)-(22), income equation (23) and factor demand equations (24)-(25) constitute 14 equations to solve for 14 unknowns for each region. Obviously there are three regions so that makes 42 equations with 42 unknowns.[13]

I use Matlab to solve this system of equations. It does not guarantee a unique solution as the New Economic Geography model typically has multiple equilibria. However I tried many different initial values and they all converged to the same equilibrium. The parameters are calibrated to match

[13]In this system of equations, the outputs for other sectors, Y_{mi} and Y_{si}, do not appear because they are substituted out in terms of other variables in order to simplify the expression.

various features of the economy during this period. A detailed description of the calibration procedure is discussed in the following section and in the appendix of Chapter 2.

2.2 Restricting the Model Parameters

In this section I restrict the parameters of the model to make them consistent with some key characteristics of the economy circa 1870, along with detailed descriptions of data. Essentially, I need to calibrate the following parameters. The region specific preference parameters γ_i for i=$\{b, us, rw\}$, $\underline{c}$, θ_a, θ_m and θ_s; the TFP parameters A_{ai}, A_{mi} and A_{si} for each region; the endowments $\underline{N}_i$ and $\underline{L}_i$ for each region; the elasticity parameters σ_a and σ_m which are common across regions; the production share parameters α_a and α_m which are common across regions; the fixed cost in manufacturing production and the amount of production by a single firm F; and the trade costs T^a_{ij} and T^m_{ij}

2.2.1 Classification

Tradeables are classified according to the Standard International Trade Classification (SITC, revision 4). Products under section 0, 1, 2 and 4 are classified as primary good and under section 3, 5, 6, 7 and 8 are classified as manufacturing good.[14] So basically food products (processed or unprocessed), raw materials or materials in crude state and products from farm are included in primary sector.

For sectoral output, due to limited availability of disaggregated data, I do not classify them using raw data. But rather I take them from other

[14]Section 0-food and live animals; section 1-beverages and tobacco; section 2-crude materials, inedible, except fuels; section 3-mineral fuels, lubricants and related materials; section 4-animal and vegetable oils, fats and waxes; section 5-chemicals and related products; section 6-manufactured goods classified chiefly by material; section 7-machinery and transport equipment; section 8-miscellaneous manufactured articles

sources, mainly from Bairoch (1982), Broadberry and Irwin (2006) and Federico (2004). Their classifications are very similar to the conventional system based on International Standard Industry Classification (ISIC) or North American Industry Classification System (NAICS). Primary sector includes farming, fishing and forestry and manufacturing sector includes mining, manufacturing and construction.[15]

Discrepancies necessarily arise between the definition of tradeable goods and of sectoral output, given the way they are classified. Basically, tradeable items are classified based on the characteristics of products whereas industries are classified based on the characteristics of production activities. For example, in my model, the food processing industry is included in manufacturing but the processed food itself is classified as a primary tradeable. This is reasonable as processed food contains disproportionately more value accrued from the primary activities (farming, fishing and so on).[16]

2.2.2 Gross Output or Value-added?

In the model manufacturing output of region i, $Y_{m,i}$, corresponds to gross output rather than to value-added. More specifically, $Y_{m,i}$ is gross output only including manufacturing intermediate inputs. Broadberry and Irwin (2006), one of the sources which I use to construct these figures, define manufacturing output in terms of value-added. Bairoch (1982) does not clearly specify whether they are value-added or gross output. Given the limited data availability, each region's manufacturing output data reflecting gross output are not available.

The model however implies that the value-added is a fixed proportion of the gross output. Real value-added in manufacturing of region i can be

[15] Engineering and metal manufactures; textiles and clothing; food, drink and tobacco; paper and printing; chemicals; wood industries; miscellaneous manufactures

[16] According to the U.S. Census, in 1869 the gross output in the food processing industry was \$870.3 million, of which \$672.6 million was material. And these materials mostly came from primary sectors (O'Rourke and Williamson, 1994).

defined as

$$\text{Real value added} = \frac{p_{m,i}Y_{m,i} - G_{m,i}M_i}{p_{m,i}}$$

where M_i is manufacturing intermediate input. The equilibrium condition implies that $G_{m,i}M_i = (1–\alpha_m)p_{m,i}Y_{m,i}$. Plugging this into the above equation, the real value-added is $\alpha_m Y_{m,i}$. When it comes to the *relative* terms, the model implies there is no difference between gross output and value-added.[17]

2.2.3 Normalization

Several normalizations are in order. To begin with, $\theta_a + \theta_m + \theta_s = 1$ for each region and $\gamma_b + \gamma_{us} + \gamma_{rw} = 1$. Moreover, I normalize the TFPs, land and labor endowments in Britain: $A_{a,b} = A_{m,b} = A_{s,b} = \underline{N}_b = \underline{L}_b = 1$. I also normalize domestic trade costs to 1, so $T^a_{ii} = T^m_{ii} = 1$. The choice of F, the fixed cost in manufacturing sector, proportionally scales up or down the number of firms in these industries, but leaves the values of all other aggregate variables unchanged in a relative sense. Therefore I can normalize them to arbitrary numbers and I set $F = 0.1$. F affects the economy through the zero-profit production level of a single manufacturing firm in equation (8) and the number of manufacturing firms in region i in equation (14). Of course different values of F yield different absolute values of q_{mi} and n_{mi} but as long as F is equal across regions, the relative values are not affected by the choice of F including the manufacturing price-index. I am mainly interested in the relative performance of U.S. economy (in terms of its growth over the periods and its performance relative to Britain), the relative values only matter. Also in the sense that it does not affect the relative price levels, it does not affect the relative real wages which will be the focus of Chapter 5.[18]

[17]Of course this comes from the underlying assumption that α_m is constant across regions. As we will see shortly, I am mostly interested in relative terms such as U.S. manufacturing output relative to Britain's output, $Y_{m,us}/Y_{m,b}$ or the growth factor, $Y_{m,b,1913}/Y_{m,b,1870}$.

[18]The crucial assumption for the normalization is that F is the same across regions. Choosing different values of F for each region allows for the case that each region ex-

2.2.4 Parameters I Calibrate Individually

σ_a and σ_m : the elasticity of substitution

I start with σ_a and σ_m which are the elasticity of substitution in primary and manufacturing products, respectively. According to Anderson and van Wincoop (2004), it is likely to be in the range of 5 to 10. So initially I choose 7.5 for both. Later, in a sensitivity analysis, I vary these values within this range to see how sensitive the results are.

$\underline{L}_i$ and $\underline{N}_i$: endowments

I continue with the endowments of land and labour force in each region. Feinstein (1972) reports the total labour force for Britain in 1870 is 13,950 thousands and Kendrick (1961) reports it for the U.S. in 1869 as 11,910 thousands. Therefore the share of U.S. labour force relative to Britain's is about 0.85. Given the normalization $\underline{L}_b = 1$, I set $\underline{L}_{us} = 0.85$. Employment data for the rest of world circa 1870 is incomplete therefore I infer world population from Maddison (2001) to calibrate $\underline{L}_{rw}$. The rest of world population is about 40 times larger than Britain's, so I assign $\underline{L}_{rw}$=40. *Abstract of British Historical Statistics* and *the U.S. Census of Agriculture* reports land usage for Britain and the U.S., respectively. According to them, land usage in the U.S. in 1870 is about 4 times larger than that of Britain, so I set $\underline{N}_{us} = 4$ given $\underline{N}_b = 1$.[19] Again, land usage data for the rest of world is incomplete, so I assign $\underline{N}_{rw} = 40$.[20]

hibits different degree of IRTS. This, however, is not a possible option under the current methodology because then the model solving procedure can get immensely complicated. Certainly this would be an interesting possibility to consider in many aspects including the real wage convergence story to be covered in Chapter 5. In this case I would need more realistic choice of F to reflect the difference in the degree of IRTS across regions.

[19] According to the *Historical Statistics*, 46,018 thousands acres of land was used for crops and pasture in Britain in 1870. The *Census* reports that 188,921 thousands acres of 'improved land', the classification which corresponds to the land usage in Britain, was used for the U.S.

[20] Indeed, $\underline{L}_{rw}$ only influences the equilibrium value of d_{rw} and the calibrated value of A_{arw} and is not critical for the overall results.

α_a : the share of labour in the primary sector

Next, I continue with the share parameters in primary and manufacturing production. As these parameters are assumed to be common across regions, I take the arithmetic average of each region's share. I start with the share of labour in primary sector. For Britain, O'Rourke and Williamson (1994) calculate the share of wage income in the primary sector in 1871 as 0.53. Clark (2010) estimates the share of farm capital and land income in total farm income for 1860-1869 as 0.48. If I take the residual as farm wage income then the share is 0.52, so they yield almost identical share parameter values. For the U.S., O'Rourke and Williamson (1994) calculates the share of capital and land income as 0.41 and in turn, the wage income share is 0.59. I use Sweden as a proxy for the rest of world as it is almost impossible to get all the data needed. According to Edvinson (2005), the labour income share in 1870 is 0.69. And by taking the average of these numbers, I set $\alpha_a = 0.6$.

Admittedly, it may be too much of a generalization to say that Sweden is a perfect representation of the rest of world circa 1870. But without loss of generality, we can say that Sweden can be a sensible approximation because it was a relatively more labour intensive economy than Britain or the U.S. circa 1870. And given data availability, Sweden is a plausible proxy for the rest of world in calibrating the labour share parameter.

α_m : the share of labour in manufacturing sector

Next I move to the share parameter in manufacturing sector. Here I pin down the share of manufacturing intermediates, $1-\alpha_m$, and take the share of labour as a residual using input-output tables. Unfortunately I do not have input-output tables for 1870 and have to use the ones closest possible.

To do so, I classify each industrial sub-category into primary, manufacturing or services according to the classification rule described above. Then I re-calculate the manufacturing gross output following my model specification. Manufacturing sector in my model does not include primary and service intermediate goods, therefore gross output is defined as value-added plus manufacturing intermediates only. Then $1-\alpha_m$ is obtained using this new measure of the gross output.

For Britain, there are input-output table for 1851 and 1907 constructed by Thomas (in progress) and Thomas (1984), respectively. I take the average of the values implied by these two input-output tables. In 1851, the share of labour turns out to be around 0.6 and in 1907, 0.49. So for Britain it is about 0.55. For the U.S., the only available input-output table is for 1899, constructed by Whitney (1968). And it yields a labour share of 0.53. For the rest of world, which is again proxied by Sweden, I use an input-output table for 1885 by Bohlin (2007) which estimates the labour share as 0.66. By taking the average, I set $\alpha_m = 0.58$.

γ_i : the weight on consumption of primary products from region i

Next, I calibrate γ_b, γ_{us} and γ_{rw} which are assumed to be equal across regions. The conventional way to calibrate γ_i parameters is to fit these to the expenditure share of goods from each region (for example, the share of imported products from Britain in U.S. total primary expenditure). This, indeed, is what the utility function implies. This approach is typically used in the standard computational general equilibrium (CGE) model. This, however, means that γ_is are not equal across regions (For example I would need to calibrate $\gamma_{us,i}$ instead of γ_{us} that indicates the share of imported products from region i in U.S. total primary expenditure. I would then need 9 different parameters in total). This approach is problematic for the purpose of this paper as my model can't reflect other important features of the economy during this period (for example, U.S. primary output relative to Britain, the share of labour force in primary sector and so on). It also makes analysis much more unmanageable and complicated. I therefore assume that γ_is are equal across regions. I calibrate these parameters using the price index equation (1). To draw a meaningful interpretation of γ_is, I compare equation (1) to equation (2), the manufacturing price index. In this equation the counterpart of γ_i is n_{mi} which corresponds to the number of manufacturing firms in region i. This defines the distribution of manufacturing varieties (activities) across regions. We can think of γ_i in the same manner. In other words, the number of varieties produced in a region is proportional to the volume of primary goods produced in that region. In my case, the rest of world which is the biggest producer of primary goods also produces the largest number of varieties.[21] The only difference between the two is that γ_i is fixed or exogenous whereas n_{mi} is endogenously determined. Fujita, Krugman and Venables (1999) takes this approach when they assign values to these parameters. I use each region's share of world primary production as estimated by Federico (2004) to pin down these values.

$A_{s,i}$: TFP for region i's services sector

Next, the TFPs for services sectors are calibrated. Broadberry and Irwin (2006) estimate that U.S. labour productivity in the services sector is 0.77 given that of Britain is 1. So I set $A_{s,us} = 0.77$. For the rest of world, I set $A_{s,rw} = 0.5$ arbitrarily. The overall results are not sensitive to this value because the services sector is a residual sector that produces non-tradable goods. The rest of world is not the focus in this paper anyway and the non-tradable service sector of this region has small impacts on primary or manufacturing sector of the U.S. or Britain which are the main focuses.

[21] For comparison I report the values of γs that match the expenditure shares of Britain and the U.S. $\gamma_{i,j}$ denotes the share of imported products from j in i's total primary expenditure : $\gamma_{us,b} = 0.00$, $\gamma_{us,us} = 0.95$, $\gamma_{us,rw} = 0.05$, $\gamma_{b,b} = 0.67$, $\gamma_{b,us} = 0.09$ and $\gamma_{b,rw} = 0.24$

D_i **: measure of region i's consumer**

This parameter only controls $\underline{C}_i = D_i \ \underline{c}_i$ in the aggregate equilibrium. I use the population of each region to proxy this. I normalize $D_b = 1$ then according to Maddison (2001), $D_{us} = 1.37$ and $D_{rw} = 40$.

2.2.5 Parameters I Calibrate Jointly

At this point, I am left with 27 parameters. 12 trade costs: T^a_{ij} and T^m_{ij}, 9 preference parameters: θ_a, θ_m and $\underline{C}$ for each region and 6 TFPs: $A_{a,i}$ and $A_{m,i}$ for each region. I choose them such that the model replicates key characteristics of the benchmark year economy circa 1870. Specifically, I target: (1) the shares of each region's labour forces in each sector as reported; (2) each region's primary and manufacturing value-added relative to Britain; (3) each region's nominal GDP relative to Britain; (4) the income elasticity of demand for food estimated by various sources; (5) Britain and the U.S. exports to GDP ratio in current prices; (6) the ratio of Britain's and U.S. manufacturing imports to their total imports; (7) the ratio of Britain's and U.S. manufacturing exports to their total exports; (8) the ratio of Britain's primary and manufacturing exports to the U.S. to its total primary and manufacturing exports, respectively; (9) the ratio of U.S. primary and manufacturing exports to Britain to its total primary and manufacturing exports, respectively. Below I provide a detailed description of data and algorithm of the calibration procedure.

(1) The share of labour in each sector

Broadberry and Irwin (2006) report sectoral employment for Britain for 1871 and the U.S. for 1869 which is shown in Table 1 below.

Table 1: Sectoral Employment circa 1870 (in thousand)

	agriculture	industry	service	whole economy
Britain	3,120	5,930	5,000	14,050
U.S.	5,758	2,831	3,321	11,910

Source: see the text

(2) Sectoral output relative to Britain

For each region's value-added in the primary sector, I rely on Federico (2004). He includes 49 countries and 23 products that account for more than 70% of the world primary output. He measures relative prices for these products in terms of wheat with which he obtains PPP-adjusted value-added for these countries for 1913. In order to obtain the figures for 1870, I use the volume indices that he provides from 1800 to 1938. Table 2 below reports the primary value-added of each region in 1870 and 1913 with which I construct value-added relative to that of Britain.

Table 2: Primary value-added (in wheat units)

	in 1913	in 1870
Britain	17,152	18,387
U.S.	127,031	49,288
World	884,124	468,586

Source: see the text. Note: volume-index in 1870 was 107.2, 38.8 and 53.0 for Britain, U.S. and the world, respectively with 1913=100.

To construct the value-added figures in the manufacturing sector I use Bairoch (1982). Table 3 is taken from Bairoch's (1982). This provides comparable production figures for various years but not for 1870. I apply the annual growth rate from 1860 to 1880 implied by his numbers to obtain them.

Table 3: Manufacturing output by major regions

	Developed countries				
	U.K.	U.S.	Total	Third World	World
Absolute volumes (U.K. in 1900=100)					
1860	45	16	143	83	226
1880	73	47	253	67	320
1900	100	128	481	60	541
1913	127	298	863	70	933
Percentages of the world share					
1860	19.9	7.2	63.4	36.6	100
1880	22.9	14.7	79.1	20.9	100
1900	18.5	23.6	89.0	11.0	100
1913	13.6	32.0	92.5	7.5	100

Source : see the text

(3) Nominal GDP relative to Britain

Officer and Williamson (2010) provide nominal GDP for Britain and the U.S. in domestic currencies. I use the bilateral exchange rates, from the same source, to convert the GDPs in U.S. dollar. For the rest of world, as nominal GDP is not available, I rely on Maddison (2001) which reports the world's and each region's GDP in Geary-Khamis international dollars. I can then subtract the Britain and U.S. GDP from world GDP to obtain the rest of world GDP (relative to Britain).

(4) Income elasticity of demand for agricultural output

Crafts (1980) argues that this elasticity was likely to be between 0.5 and 0.7 during the British Industrial Revolution. According to Houthakker (1957) who estimates the elasticity for food with respect to total expenditure, covering 30 countries and the period from 1853 to 1953, this elasticity ranges between 0.5 and 0.75. Williamson and Swanson (1966) estimate the expenditure elasticity of demand for food for Massachusetts workers in 1875. It turns out to be about 0.607 for industrial workers, 0.570 for skilled workers and 0.730 for unskilled workers. Given these, the most plausible value seems to be around 0.6 and I rely on this value in my model.

(5)-(9) Trade data

Basically all the trade data are taken from *the Annual Statement of Trade of the United Kingdom* and *Annual Report of the Commerce and Navigation of the United States.* I classify each good traded into either primary or manufacturing according to the classification rule described above. Tables 4 and 5 below describe the trade statistics constructed for calibration. Finally, Table 6 summarizes the targets and their values. In the appendix I provide a detailed description of the joint calibration procedure. Table 7 summarizes the parameters common across regions, Table 8 summarizes the region specific parameter values and Table 9 reports the trade costs.

Table 4: Britain and U.S. trade in 1870 (in millions)

	prim. IM	manu. IM	prim. EX	manu. EX
Britain(£)	211.2	40.5	11.4	182.6
U.S.($)	259.7	280.6	372.4	80.6

Note : Imports(IM) defined here are net-imports which are as imports - re-exports.
U.S. imports and re-exports are in gold-terms, so I convert them into currency terms using an exchange rate of $1=0.742 gold$ as in O'Rourke and Williamson (1994).

Table 5: Bilateral exports between Britain and U.S. (in millions)

	primary exports	manufacture exports
Britain to U.S.(£)	0.5	25.9
U.S. to Britain($)	233.5	10.4

Table 6: Calibration targets

Targets for benchmark year 1870	Value
Share of Britain's LF in primary	0.22
Share of Britain's LF in manufacturing	0.42
Share of US LF in primary	0.48
Share of US LF in manufacturing	0.24
Share of rest of world LF in primary	0.60
Share of rest of world LF in manufacturing	0.20
US primary VA relative to Britain	2.68
RW primary VA relative to Britain	21.8
US manu. GO relative to Britain	0.48
RW manu. GO relative to Britain	3.21
US GDP relative to Britain	1.30
RW GDP relative to Britain	9.57
Income elasticity of food consumption	0.60
Ratio of Britain's exports to its GDP	0.19
Ratio of U.S. exports to its GDP	0.06
Ratio of Britain's manu. imports to its total imports	0.19
Ratio of U.S. manu. imports to its total imports	0.52
Ratio of Britain's manu. exports to its total exports	0.94
Ratio of U.S. manu. exports to its total exports	0.18
Ratio of U.S. manu. exports to Britain to its total manu. exports	0.13
Ratio of U.S. primary exports to Britain to its total primary exports	0.63
Ratio of Britain's manu. exports to U.S. to its total manu. exports	0.14
Ratio of Britain's primary exports to U.S. to its total primary exports	0.05

LF: labour force, GO: gross output

Table 7: Common parameter values

σ_a	σ_m	α_a	α_m	F	γ_b	γ_{us}	γ_{rw}
7.5	7.5	0.6	0.58	0.1	0.04	0.10	0.86

Table 8: Region specific parameter values

	Britain	U.S.	R.O.W
$\underline{N}$	1.00*	4.00	40.0
$\underline{L}$	1.00*	0.85	40.0
θ_a	0.28	0.35	0.42
θ_m	0.30	0.32	0.30
θ_s	0.42	0.33	0.28
$\underline{C}$	0.21	0.34	0.15
A_a	1.00*	1.06	0.30
A_m	1.00*	1.04	0.33
A_s	1.00*	0.77	0.50

* indicates normalization.

Table 9: Trade costs

$T^a_{b,us}$	$T^a_{b,rw}$	$T^a_{us,b}$	$T^a_{us,rw}$	$T^a_{rw,b}$	$T^a_{rw,us}$	$T^m_{b,us}$	$T^m_{b,rw}$	$T^m_{us,b}$	$T^m_{us,rw}$	$T^m_{rw,b}$	$T^m_{rw,us}$
2.38	1.64	1.74	1.85	1.91	2.05	2.30	1.48	1.56	1.45	1.53	2.56

Conventionally, most of the trade cost literature assumes symmetric trade costs between two regions.[22] But from Table 9, it can be seen that the calibrated trade costs yield quite large asymmetries between the U.S. and other regions with a larger asymmetry for manufacturing goods. One of the factors that can explain this discrepancy around 1870 is the trade policy. It is well-know that the U.S. erected high barriers on its imports in order to protect its industry during this period. On the other hand, Britain was essentially a free trade country. Therefore this difference must have

[22]See Anderson and Wincoop (2004). One of the few exceptions that assumes asymmetric trade cost is Waugh (2008).

contributed to a significant extent to the asymmetry observed in the table. More on this issue will be discussed in the following chapters.

One thing to note is that even though I do not target the model to match the real GDP of the U.S. relative to Britain, the implied values match the data quite closely. Real GDP can be defined as

$$\text{Real GDP} = \frac{Y}{G_a^{\theta_a} G_m^{\theta_m} G_s^{\theta_s}}$$

where the regional subscript i has been dropped. The term in the denominator can be interpreted as a price-index. The implied ratio of U.S. real GDP per capita to that of Britain is about 0.97. Maddison (2001) suggests that this ratio is about 1.03 when measured in 1990 Geary-Khamis international dollar.

Next I demonstrate that the benchmark year equilibrium generated by the calibration is internally consistent - expenditure plus net exports, gross output and factor costs of each region are equalized and trades are balanced. To do this I construct a Social Accounting Matrix (SAM) in the benchmark year of 1870 implied by the model. Table 10 below presents the SAM. Note that the value of U.S. primary gross output is normalized to 1 and all other values are in relative terms.

First, the model correctly predicts that the U.S. is a net exporter of primary product while being a net importer of manufacturing product (and vice versa for Britain). The table shows that the value of each region's gross output in each sector is equal to the value of net exports plus expenditure (GO = Expenditure + NX). It also shows that the trades are balanced in each region (NX across sectors in each region add up to zero).

I provide a more detailed picture of trade flows between each region in Table 11. The table can be read as follows. The numbers on rows indicate the value of imports. For example, the numbers 0.39, 0.05 and 0.14 on the first row of the table represent the value of Britain's primary imports from

Table 10: Social Accounting Matrix

Industry	GO	Input Cost			VA	NX	Expenditure
		L	*N*	*M*			
U.S.							
P	1.00	0.60	0.40		1.00	0.03	0.97
M	0.52	0.30		0.22	0.30	-0.03	0.55
S	0.35	0.35			0.35		0.35
Total	1.87	1.25	0.40	0.22	1.65	0.00	1.87
Britain							
P	0.41	0.24	0.16		0.41	-0.18	0.58
M	0.80	0.46		0.34	0.46	0.18	0.62
S	0.40	0.40			0.40		0.40
Total	1.61	1.11	0.16	0.34	1.27	0.00	1.61
Rest of World							
P	8.68	5.21	3.47		8.68	0.15	8.53
M	2.99	1.74		1.26	1.74	-0.15	3.14
S	1.74	1.74			1.74		1.74
Total	13.40	8.68	3.47	1.26	12.15	0.00	13.40

GO: gross output, VA: value-added, NX: net exports,

L: labour, N: land, P: primary, M: manufacturing and S: service

Britain, the U.S. and the rest of world, respectively. Because 0.39 is the value of domestic trades (i.e. consumption of British primary products by British consumers), 0.05 (imports from the U.S.) and 0.14 (imports from the rest) add up to the foreign imports of primary products for Britain.

The numbers on columns are the values of exports. For example, the numbers 0.05, 0.92 and 0.03 on the second column of the table represent the values of U.S. primary exports to Britain, the U.S. and the rest, respectively. In this case, the foreign exports add up to 0.08. The expenditure (in the last column) can be derived by adding all the imports (for example U.S. manufacturing expenditure is $0.03 + 0.50 + 0.02 = 0.55$). As we can see, the values of expenditures from this table are consistent with the values in the previous table. The gross output, likewise, can be calculated by adding all the exports which are again consistent with the values in the SAM table.

Table 11: Trade flows in the benchmark year

Primary	Britain	U.S.	Rest	Imports	Expenditure
Britain	0.39	0.05	0.14	0.19	0.58
U.S.	0.001	0.92	0.05	0.05	0.97
Rest	0.01	0.03	8.49	0.04	8.53
Exports	0.01	0.08	0.19		
Net exports	-0.18	0.03	0.15		
Gross output	0.41	1.00	8.68		
Manufacture	Britain	U.S.	Rest	Imports	Expenditure
Britain	0.58	0.002	0.04	0.05	0.62
U.S.	0.03	0.50	0.02	0.05	0.55
Rest	0.19	0.02	2.93	0.21	3.14
Exports	0.22	0.02	0.06		
Net exports	0.18	-0.03	-0.15		
Gross output	0.80	0.52	2.99		

I end this section with some discussions on alternative ways of calibrating the parameters. First, the main purpose of my calibration is to match the output side of the data in 1870 given the objectives of the thesis. But depending on the objective, alternative strategies are possible. For example I also tried to match the price side of the data such as the real wages, but this distorts the output side of the economy hugely. Therefore in the end I chose the current strategy over other possible options. Matching the price side, however, can be a more relevant choice in analysing the convergence of Anglo-American real wages in Chapter 5. I leave this for a future project.

2.3 Generating the Development of the Economy

In this section, before studying the effects of each force in isolation, I establish that the model can generate several features of the development in the North Atlantic Economy. To this end I need to feed in the changes in TFPs, endowments and trade costs. I start by quantifying these changes. These changes are later fed into the equilibrium in the benchmark year and the performance of the model in accounting for the economy in 1913 will be evaluated.

One thing to note before I proceed is that, as we will see, some changes such as the change in primary and manufacturing TFP of the rest of world and the changes in trade costs are calibrated to fit the model to the data due to the lack of data availability. Therefore the model's close fit to some features of the data is not a new finding of this exercise but rather the result of the imposition made at the onset.

2.3.1 Measuring the Changes

Changes in Sectoral TFP

I start with changes in sectoral TFP for each region. Using the production function in the primary sector, the change in TFP in the primary sector of region i can be represented as

$$\frac{(A_{a,i})_{1913}}{(A_{a,i})_{1870}} = \frac{(Y_{a,i})_{1913}}{(Y_{a,i})_{1870}} \left[\frac{(L_{a,i})_{1870}}{(L_{a,i})_{1913}}\right]^{\alpha_a} \left[\frac{(N_i)_{1870}}{(N_i)_{1913}}\right]^{1-\alpha_a} \tag{26}$$

The first term on the right hand side of (26) is obtained from Federico's (2004) value-added index for Britain and the U.S.[23] The second term, the change in labour force employed in primary sector, can be obtained from Broadberry and Irwin (2006). It only provides 1871 and 1911 figures for Britain and 1869 and 1909 figures for the U.S. Therefore I have to use the growth rates from Broadberry and Irwin to obtain the 1870 and 1913 values.[24] Finally, the change in land endowment is taken from the *Abstract of British Historical Statistics* for Britain and the *Census* for the U.S.[25]

[23]The index for Britain in 1870 is 107.2 and for the U.S. it is 38.8 with the 1913 levels for both countries normalized to 100.

[24]For Britain's annual growth rate of labour force in primary sector from 1861 to 1871 is about -1.2% and from 1901 to 1911 is about -0.08%. And for U.S. it is about 0.74% from 1859 to 1869 and 0.63% from 1899 to 1909.

[25]This will be discussed more in detail when I talk about changes in endowments.

Next I move on to manufacturing TFP. It is clear from the model that an α_m share of revenue in manufacturing sector is distributed as labour income. This implies the following equation

$$Y_{m,i} = \frac{w_i L_{m,i}}{\alpha_m p_{m,i}} \tag{27}$$

I use equation (27) to derive an expression for TFP. To this aim I need the following equations derived from the model.

$$p_{m,i} = \frac{\sigma_m}{1-\sigma_m}(A_{m,i}\alpha_m^{\alpha_m}(1-\alpha_m)^{1-\alpha_m})^{-1} w_i^{\alpha_m} G_{m,i}^{1-\alpha_m} \tag{28}$$

$$G_{m,i} = \left[\sum_j n_j (p_{m,j} T_{j,i}^m)^{1-\sigma_m}\right]^{1/(1-\sigma_m)} \tag{29}$$

$$T_{j,i}^m = \left(\frac{n_{m,i}}{n_{m,j}}\right)^{\frac{1}{1-\sigma_m}} \left(\frac{p_{m,i}}{p_{m,j}}\right) \left(\frac{p_{m,j} m_{ij}}{p_{m,i} m_{ii}}\right)^{\frac{1}{1-\sigma_m}} \tag{30}$$

These equations are just restatements of equation (7), (2) and (A.1), respectively. Inserting (30) into (29), the price index can be expressed as

$$G_{m,i} = \left[n_{m,i}\, p_{m,i}^{1-\sigma_m}\, X_i^{-1}\right]^{\frac{1}{1-\sigma_m}} \tag{31}$$

where I define $X_i = \frac{p_{mi} m_{ii}}{\sum_j p_{mj} m_{ij}}$ as the home trade share (share of expenditure on domestic products in total expenditure). Also from the model we know that $n_{m,i} = \frac{w_i L_{mi}}{\alpha_m p_{mi} F(\sigma_m - 1)}$ which can be plugged in (31). Then this can be substituted in (28) which yields,

$$p_{m,i} = w_i \left[A_{m,i}^{-1}(L_{m,i} X_i^{-1})^{\frac{1-\alpha_m}{1-\sigma_m}}\right]^{\frac{1-\sigma_m}{1-\alpha_m \sigma_m}} \tag{32}$$

In deriving (32) I dropped all the common parameters that will eventually cancel out when I calculate the change in TFP. I plug (32) into (27) to obtain,

$$Y_{m,i} = \left[A_{m,i}^{1-\sigma_m} X_i^{1-\alpha_m} L_{m,i}^{\alpha_m(1-\sigma_m)}\right]^{\frac{1}{1-\alpha_m\sigma_m}} \tag{33}$$

With (33), I can obtain the growth rate of TFP from 1870 to 1913 as

$$\frac{A_{m,1913}}{A_{m,1870}} = \left(\frac{X_{1870}}{X_{1913}}\right)^{\frac{1-\alpha_m}{1-\sigma_m}} \left(\frac{L_{m,1870}}{L_{m,1913}}\right)^{\alpha_m} \left(\frac{Y_{m,1913}}{Y_{m,1870}}\right)^{\frac{1-\alpha_m\sigma_m}{1-\sigma_m}} \tag{34}$$

where I dropped the regional subscript i. This approach of measuring the manufacturing TFP shock has the advantage that data on manufacturing intermediate usage does not have to be used as we do not have any accurate data on it anyway.[26] Instead, the home trade share X can be calculated more accurately using trade and expenditure data.

To obtain X_{us}, I rely on *The Historical Statistics of the United States.* It reports the 'value of commodities destined for domestic consumption for 1869 to 1919' (table Cd378-410). This corresponds to $\sum_j p_{mj} m_{ij}$ or total expenditure and the value of imports is subtracted from this in order to obtain $p_{m,us} m_{usus}$ or the expenditure on domestic products. As a result $X_{us,1869} = 0.72$ and $X_{us,1913} = 0.86$.[27] So the share of U.S. expenditure on domestic manufacturing increased from 1869 to 1913.

I use Jefferys and Walters (1955) to calculate X_b. They provide values for 'consumption of home-manufactured consumer goods' which corresponds to $p_{m,b} m_{bb}$ in the model. But they only include the value of final consumption which means that expenditure on intermediate goods is not included. Their data are therefore rather limited for my purposes. The values for $X_{b,1870}$ and $X_{b,1913}$ are 0.865 and 0.714, respectively.

[26] From the specification of the production function $Y_m = A_m L_m^{\alpha_m} M^{1-\alpha_m} - F$, where M is intermediate manufacturing usage, it is easy to see that data on M is needed to implement the conventional growth accounting exercise.

[27] It reports only decennial data from 1869 to 1889.

The second term on the right hand side of (34), the change in labour force in the manufacturing sector, can be obtained from Broadberry and Irwin (2006) for Britain and the U.S. in the same manner as for the change in labour force in the primary sector.[28] The third term comes from Bairoch (1982) for Britain and the U.S.[29]

Finally, the change in service TFP implied by the model is

$$\frac{(A_{s,i})_{1913}}{(A_{s,i})_{1870}} = \frac{(L_{s,i})_{1870}}{(L_{s,i})_{1913}} \frac{(Y_{s,i})_{1913}}{(Y_{s,i})_{1870}} \tag{35}$$

which I directly take from Broadberry and Irwin's (2006) service sector labour productivity figures for Britain and the U.S. Table 12 below reports the changes in sectoral TFP.

I calibrate TFP changes for the rest of world to match its share of output in 1913 as closely as possible given the TFP changes for Britain and the U.S. The rest of world in this model is taken to be a residual and an imaginary region of all other countries merged together. Therefore there is no 'correct' way to measuring a TFP shock for the rest of world including the method I used for Britain or for the U.S.

Table 12: Changes in sectoral TFP

	Britain	U.S.
$\frac{A_{a,1913}}{A_{a,1870}}$	1.09	1.22
$\frac{A_{m,1913}}{A_{m,1870}}$	1.14	1.40
$\frac{A_{s,1913}}{A_{s,1870}}$	1.28	1.97

[28]For Britain annual growth rate of the labour force in the manufacturing sector from 1861 to 1871 is about 1.1% and from 1901 to 1911 is about 0.9%. For the U.S. it is about 2.9% from 1859 to 1869 and 3.6% from 1899 to 1909.

[29]See Table 3.

Alternative Measures of TFP Changes

In the approach above, I measure the TFP shocks as *implied* by the production functions. In other words, I assume that TFPs are residuals left unexplained by other factors like land, labour and intermediate input. As I do not include capital in my baseline model, the TFP measured according to this methodology is not really *total* factor productivity but rather *land* and *labour* factor productivity.[30] Therefore it would be meaningful to use TFP shocks taken from other literature that correspond more closely to the term *total*. Since most of the works that measure TFP assume CRTS production technologies, this approach can be problematic if there exists IRTS like in my model because productivity increases arising from the scale economies can not be identified from the pure technological progress. This issue will be discussed more in details in the next section.

U.S. primary TFP shock is taken from Atack, Bateman and Parker (2000, Table 6.1) according to which the average annual TFP growth rates are 0.45%, 0.54% and 0.58% during 1870-1880, 1880-1890 and 1890-1900 period, respectively. They do not have the growth rate for 1900-1913 period so I use the growth rate of 1890-1900 for this period. It implies that U.S. primary TFP grew by a factor of 1.256 from 1870 to 1913. I take U.S. manufacturing TFP shock from Kendrick (1961, Table 34). He measures TFP as the ratio of real product to real income deflated by factor prices. According to this, the annual growth rate before 1899 for U.S. manufacturing TFP is 1.4%, 0.7% for 1899-1909 and 0.3% for 1909-1913. This implies that it grew by a factor of 1.624 during the periods. For Britain there is no *a priori* information like the case of the U.S. as far as I know. Therefore I recover Britain's sectoral TFP shocks using the approach by Broadberry (1993, 1998).[31] He takes a simple growth accounting approach where he

[30] Later I also include capital in an alternative specification.

[31] He does not explicitly calculates the TFP growth rates, rather he is interested in Anglo-American comparative productivity levels in manufacturing sector.

assumes that the production function is CRTS Cobb-Douglas function with two factors of input, labour and capital. The share of wages is 0.77. The capital data are taken from Feinstein and Pollard (1988) as in Broadberry (1998). Britain's manufacturing TFP shock from 1870 to 1913 turns out to be 1.265. Broadberry does not include primary/agricultural sector in his analysis but I can take a similar approach as the manufacturing sector. I assume that there are three factors of input which are labour, land and capital. Again the data for capital employed in the primary sector are taken from Feinstein and Pollard (1988). The share of each input is taken from O'Rourke and Williamson (1994) as 0.529, 0.275 and 0.196 for labour, land and capital, respectively. Britain's primary sector's TFP grew by a factor of 1.065.

Changes in Endowments

I begin with changes in land endowments for Britain and the U.S. According to the *Abstract of British Historical Statistics*, 46,018 and 46,849 thousands acres of land were used in 1870 and 1913 for crops and pasture, respectively. *The U.S. Census of Agriculture* reports 188,921 and 478,452 thousands acres of 'improved land' in 1870 and 1910, respectively. For the rest of world, I assume it did not change. Again this assumption is not critical to the overall result.

As discussed in the previous section for labour force endowments, I have to interpolate the 1870 and 1913 levels from Broadberry and Irwin (2006). First, I obtain the labour force in 1870 and 1913 for Britain and the U.S. by adding up the sectoral labour force obtained from the previous section. Then I use these figures to calculate the changes in labour force. For the rest of world, I have to assume that it changed in accordance to population growth which I obtain from Maddison (2001). Table 13 reports the values.

Table 13: Changes in endowments

	Britain	U.S.	R.O.W
$\underline{N}_{1913}/\underline{N}_{1870}$	1.02	2.53	1.00
$\underline{L}_{1913}/\underline{L}_{1870}$	1.49	3.21	1.37

Changes in Trade Costs

Next, I measure changes in trade costs. One possible option is to use theoretical gravity equations derived from the model (using equations (A.1) and (A.2)). But the main drawback of this method is that I have to rely on incomplete data series, especially regarding the price data. Moreover the price for the rest of world is even more difficult to measure.[32]

Therefore I take an alternative approach. This approach measures the changes to match the target trade data in Table 6 for 1913. Exactly matching the data is possible but this yields trade costs in 1913 to be below 1. Hence I impose an additional restriction that $T_{i,j} > 1.1$ for any $i \neq j$.

Table 14: Changes in trade costs (growth factor)

$\Delta T^a_{b,us}$	$\Delta T^a_{us,b}$	$\Delta T^a_{b,rw}$	$\Delta T^a_{rw,b}$	$\Delta T^a_{us,rw}$	$\Delta T^a_{rw,us}$
0.850	1.084	0.675*	1.894	0.601*	1.686
$\Delta T^m_{b,us}$	$\Delta T^m_{us,b}$	$\Delta T^m_{b,rw}$	$\Delta T^m_{rw,b}$	$\Delta T^m_{us,rw}$	$\Delta T^m_{rw,us}$
0.808	1.251	1.447	0.723*	1.900	0.468*

* indicates the cases where the restriction is needed.

Some discussions on this are in order. First, these numbers are growth factors and for example, $\Delta T^a_{b,us} = 0.85$ means that the level of the primary trade cost from Britain to U.S. in 1913 is 85% of that in 1870. So it implies that $T^a_{b,us}$ has decreased from 2.38 in 1870 (Table 9) to 1.97 in 1913. In

[32]Indeed when the changes in trade costs measured this way are applied, the simulated result seriously flaws the key trade statistics in 1913. The details are not reported here but are available upon request.

this particular case of the primary trade cost from Britain to the U.S., the value looks plausible. O'Rourke and Williamson (1999) demonstrate that the large reduction in transportation costs during this period contributed to the reduction in trade costs. Jacks, Novy and Meissner (2010) also show that bilateral international trade costs for major countries decreased significantly relative to domestic trade costs.

The values involving the rest of world look much less plausible. For example, the primary trade cost from Britain to the rest of world ($T^a_{b,rw}$) decreases by 33% while that from the rest of world to Britain ($T^a_{rw,b}$) increases by 89%. Another example is the manufacturing trade cost between the U.S. and the rest of world. $T^m_{us,rw}$ increases by 90% while $T^m_{rw,us}$ decreases by 53%. Admittedly, even if I allow for asymmetry in bilateral trade costs, the calibrated trade costs that match the trade data seem to be far from being realistic. This problem mainly comes from the aggregation of the rest of the world. For example the rest of world in the model includes countries that barely exported manufacturing goods to the U.S. as well as countries in North-Western (NW) Europe that exported substantial amounts. In fact those countries in NW Europe account for most of manufacturing imports of the U.S. from the rest of the world. This implies that combining industrially developed NW Europe together with industrially lagging countries as the rest of world would generate a region that is relatively inefficient or has less comparative advantage in manufacturing compared to NW Europe while exporting the same amount of manufacturing goods as NW Europe did in 1913. This would require the model to need a very low trade cost from the rest of world to the U.S. to account for the manufacturing trade flow.

Alternative Measures of Trade Cost Changes

As mentioned earlier asymmetric changes in the bilateral trade costs can not be constructed using the gravity equations implied by the model due to lack of data. Some of the trade cost changes calibrated for this reason look quite implausible. But I can, at least, get a sense of what more realistic changes in trade costs were like during this period from the work of Jacks, Novy and Meissner (2010). They derive a gravity equation implied by a trade model that is similar to my model with which they recover bilateral trade costs from 1870 to 1913.[33] Since their model does not have multiple sectors, their trade costs do not exactly correspond to the trade costs of my model. Nevertheless, their measures provide some more insights regarding the changes in trade costs during this period.

Table 15 presents the changes in trade costs implied by Jacks, Novy and Meissner (2010). Note that I assume trade cost shocks in primary goods and in manufacturing goods are identical as their model has only one sector. I also assume that trade costs involving the rest of world are symmetric.[34] Comparing the calibrated changes in trade costs from my model to that of Jacks et al., the pictures are quite different. First, their model does not predict such dramatic changes as my model does. In particular, the trade costs involving the rest of world in Jacks et al. are not as extreme as the counterparts calibrated from my model. Given the fact that Jacks et al. use much more disaggregated data regarding the rest of world, one can judge that, trade costs per se, their numbers are more realistic than mine. I also use these shocks to simulate the model in later sections.

Accordingly the calibrated changes in trade costs (Table 14) can be decomposed into two parts, 'actual' changes and 'residual' changes, rather

[33] The model is single-sector general equilibrium and features multiple countries where monopolistically competitive firms produce differentiated products.

[34] Apart from Britain and the U.S. their analysis includes Australia, Belgium, Brazil, Canada, Denmark, Dutch East Indies, France, Germany, Italy, Japan, Netherlands, New Zealand, Portugal, Spain and Sweden. I treat them as the rest of world.

Table 15: Changes in trade costs (growth factor) by Jacks et al.

$\Delta T^a_{b,us}$	$\Delta T^a_{us,b}$	$\Delta T^a_{b,rw}$	$\Delta T^a_{rw,b}$	$\Delta T^a_{us,rw}$	$\Delta T^a_{rw,us}$
1.003	0.972	1.006	0.946	1.006	0.946
$\Delta T^m_{b,us}$	$\Delta T^m_{us,b}$	$\Delta T^m_{b,rw}$	$\Delta T^m_{rw,b}$	$\Delta T^m_{us,rw}$	$\Delta T^m_{rw,us}$
1.003	0.972	1.006	0.946	1.006	0.946

* indicates the cases where the restriction is needed.

than just treating them as 'mere' changes in trade costs. To do this, I use the values by Jacks et al., shown in Table 15, as 'actual' changes. Their measures are more ideal for my purpose than other alternatives. First, they are derived from the theoretical gravity equations and include observable as well as unobservable components of trade costs whereas other measures only focus on transportation costs. Second, their measures, like the measures implied by my model, are not absolute changes but changes relative to domestic trade costs. They also normalize domestic trade costs to 1, capturing changes in international trade costs over domestic trade costs. For example, $\Delta T^a_{b,us}$ having the value of 1.003 does not mean that the primary trade cost from Britain to the U.S. has increased in absolute terms over the periods. Instead it is saying that it has increased relative to domestic trade costs. Therefore it could still mean that the trade cost was decreasing in absolute terms if there was a substantial reduction in domestic trade costs. More issues regarding domestic trade costs will be discussed shortly.

'Residual' changes are the values needed apart from 'actual' changes to account for the trade data during the periods. Basically 'actual'×'residual' equal the changes in trade costs presented in Table 14. Table 16 below presents the values of 'residual' changes. A value close to 1, like that of $\Delta T^a_{us,b}$, means that the calibrated change is close to the 'actual' changes implied by Jacks et al. As discussed earlier, the trade costs involving the rest of world need a larger 'residual' to account for the data.

Table 16: Residual changes in trade costs (growth factor)

$\Delta T^a_{b,us}$	$\Delta T^a_{us,b}$	$\Delta T^a_{b,rw}$	$\Delta T^a_{rw,b}$	$\Delta T^a_{us,rw}$	$\Delta T^a_{rw,us}$
0.848	1.078	0.695	1.883	0.635	1.783
$\Delta T^m_{b,us}$	$\Delta T^m_{us,b}$	$\Delta T^m_{b,rw}$	$\Delta T^m_{rw,b}$	$\Delta T^m_{us,rw}$	$\Delta T^m_{rw,us}$
0.805	1.244	1.489	0.719	2.009	0.495

* indicates the cases where the restriction is needed.

It may be more appropriate *not* to interpret the 'residual' changes in the context of trade costs given the large discrepancy between the 'actual' and the calibrated changes involving the rest of world. Instead it would be more appropriate to interpret them as the part unexplained by the changes in endowments, TFP and 'actual' changes in trade costs that gives each region the 'needed' comparative advantage to account for the data.

I have briefly discussed about the implications of normalizing domestic trade costs earlier. However more discussions about the role of domestic trade costs are in order. One of the underlying assumptions regarding trade costs are that intra-regional trade costs throughout the periods are constant (normalized to 1). Of course this is far from true as it is well-known that expansions in rail roads and advances in telecommunications in the late nineteenth century reduced intra-national trade costs hugely as well, probably more so in the U.S. Given this, slight increases in some trade costs such as $\Delta T^a_{b,us}$ and $\Delta T^a_{us,rw}$ do not necessarily mean absolute increases, rather it is still likely to mean decreases in absolute terms.

Treating domestic trade costs to reflect the history complicates the model immensely. Of course it is hard to tell the exact consequences of treating domestic trade costs like this. Changes in trade costs in my model broadly have two implications which are not mutually exclusive. First, it shifts comparative advantages of each region. Second, it also generates forces for or against the agglomeration of manufacturing. Normalizing domestic trade costs may not distort the picture in terms of the first point but it may do so for the second point. As discussed briefly, if we bring the large reduction in domestic trade costs into picture during this period, we may observe larger reductions in the overall trade costs. With all the changes in the TFP and the size effect that were favourable to U.S. manufacturing during this period, it could have a larger impact on the agglomeration of manufacturing in the U.S. than the current methodology would suggest. But again it is impossible to tell the magnitude of this effect at this stage.

Changes in Population

Maddison (2001) provides the changes in population from 1870 to 1913 for each region. According to him, $\frac{D_{b,1913}}{D_{b,1870}} = 1.37$, $\frac{D_{us,1913}}{D_{us,1870}} = 2.44$ and $\frac{D_{rw,1913}}{D_{rw,1870}} = 1.37$.

2.3.2 Generating the Development

In this section, I apply these measured changes in endowments, trade costs and TFP to the benchmark equilibrium of 1870 and evaluate how well the model performs in accounting for the various features of the economy in 1913. This exercise is carried out in two parts. First I use the baseline changes in TFP and trade costs which are measured or calibrated. I then use the alternative shocks taken from the external sources.

Using the Measured/Calibrated Shocks

Table 17 compares the simulated equilibrium with the actual data in 1913. Overall the model matches the data fairly closely. In particular, the model is quite successful in generating the large increase in the world share of U.S. manufacturing and its growth. It slightly over-predicts the growth of U.S. sectoral and overall output (real GDP). Also the model generates a substantially bigger share of labour force in primary for the U.S. compared to the data (37% vs. 30%). This means, given that the model predicts the share in manufacturing closely, it does not generate enough shifts of labour force into the services sector (31% vs. 40%).

In terms of predicting Britain's economic development, the model over-predicts the growth of its primary sector while slightly under-predicting the growth of manufacturing. The model predicts Britain's economy in 1913 to be more agrarian than the data. In fact, the data says that over the period, the share of labour force in manufacturing in Britain barely increased (42% in 1870 to 44% in 1913). But most of the transformation occurred from primary to service sector. The share in primary decreased from 22% in 1870 to 12% in 1913 while the share in service increased from 36% to 45%. This suggests that the model needs some kind of mechanism that puts more labour into service sector to account for the data.[35] But this should not change the overall picture drastically because Britain's primary output still occupies a very small share in world output and the services sector is treated as non-tradable.

Next I evaluate the model's performance on predicting the trade statistics in 1913. As discussed previously, the changes in trade costs are calibrated to match these figures as closely as possible while maintaining plausible values for trade costs. It is reported in Table 18 below.

Again the model generates the large increase and decrease in U.S. manufacturing exports and imports, respectively, from 1870 to 1913 along with other features. One noted deviation is that the model over-predicts Britain's primary exports to the U.S. This result may be attributable to the model's over-prediction of the growth of Britain's primary sector that I just discussed above.

[35] One possible way to incorporate this is to add non-homotheticity in the consumption of service. Then the utility function would look something like $U = (c_{ai} - \underline{c}_i)^{\theta_a} c_{mi}^{\theta_m} (c_{si} + s)^{\theta_s}$ where parameter s adds this feature.

Table 17: Simulated results vs. data in 1913

	Britain		The U.S.	
	model	data	model	data
Share in world primary (%)	2.5	1.9	13.9	14.4
Share in world manufacture (%)	13.4	13.6	32.2	31.9
Share of LF in primary (%)	23	12	37	30
Share of LF in manufacture (%)	40	44	32	30
$Y_{a,1913}/Y_{a,1870}$	1.45	0.93	3.04	2.58
$Y_{m,1913}/Y_{m,1870}$	1.94	2.15	9.74	9.46
$\text{RGDP}_{1913}/\text{RGDP}_{1870}$	1.72	2.24	5.52	5.26

The data for real GDP come from Maddison (2001)

Table 18: Simulated trade output vs. data in 1913 (current prices)

	model	data
Britain's exports / GDP	0.18	0.21
U.S. exports / GDP	0.04	0.06
Britain's manu. imports / total imports	0.28	0.29
U.S. manu. imports / total imports	0.32	0.44
Britain's manu. exports / total exports	0.97	0.89
U.S. manu. exports / total exports	0.61	0.50
U.S. manu. exports to Britain / total manu. exports	0.15	0.14
U.S. primary exports to Britain / total primary exports	0.68	0.37
Britain's manu. exports to U.S. / total manu. exports	0.06	0.05
Britain's primary exports to U.S. / total primary exports	0.49	0.10

Using the External Shocks

In this section I use the alternative measures of trade cost and TFP shocks which are culled from the external sources. First I only apply the external trade cost shocks while keeping the baseline TFP shocks. Table 19 reports the results. The values in the parenthesis are the equilibrium from the baseline case, reiterated from Table 17 for comparison.

Table 19: Simulated results: using the alternative trade cost shocks

	Britain		The U.S.	
	model	data	model	data
Share in world primary (%)	2.4 (2.5)	1.9	13.9 (13.9)	14.4
Share in world manufacture (%)	12.2 (13.4)	13.6	**33.3 (32.2)**	31.9
Share of LF in primary (%)	18 (23)	12	29 (37)	30
Share of LF in manufacture (%)	46 (40)	44	40 (32)	30
$Y_{a,1913}/Y_{a,1870}$	1.24 (1.45)	0.93	2.62 (3.04)	2.58
$Y_{m,1913}/Y_{m,1870}$	2.24 (1.94)	2.15	**12.76 (9.74)**	9.46
$\text{RGDP}_{1913}/\text{RGDP}_{1870}$	1.87 (1.72)	2.24	6.05 (5.52)	5.26

The data for real GDP come from Maddison (2001)

From Table 19 we can find out that it also accounts for the data pretty closely.[36] One thing that stands out is that it substantially overpredicts the growth of U.S. manufacturing compared to the baseline calibration methodology. For example, this methodology predicts U.S. manufacturing to grow by a factor of 12.8 over the periods while the baseline methodology predicts it to be 9.7. On the other hand, it matches the data for Britain and the data for U.S. primary sector more closely.

Table 20 presents the simulated results for trade. The trade equilibrium generated under this methodology are more distorted than the baseline methodology. First, the predicted share of U.S. manufacturing imports in total imports is about 4% whereas it is 44% according to the data. On the other hand, the predicted share of U.S. manufacturing exports in total exports is about 93% versus 50% according to the data. In line with Table 19, the model predicts an excessive comparative advantage in U.S. manufacturing, virtually predicting that the most of the exports are manufacturing exports while the most of imports are primary. The U.S., however, was not

[36]Note that given the way I calibrate the primary and manufacturing TFP for the rest of world, $A_{a,rw}$ and $A_{m,rw}$, they take different values from the original calibrated values. To reiterate the original values are $A_{a,rw} = 2.232$ and $A_{m,rw} = 1.096$ whereas the newly calibrated values are $A_{a,rw} = 1.766$ and $A_{m,rw} = 1.387$

a country that completely specialized in manufacturing by 1913. Instead it still maintained its position as a large primary-product-producing country, exporting substantial amount of these products. Even though the model does not predict the changes in U.S. trade pattern closely, it still predicts the output side of the data pretty closely. Besides the U.S. never was a trade-oriented country during this period, therefore this overprediction would not affect the overall result much.

Table 20: Simulated trade output: using the alternative trade cost shocks

	model	data
Britain's exports / GDP	0.25 (0.18)	0.21
U.S. exports / GDP	0.10 (0.04)	0.06
Britain's manu. imports / total imports	0.27 (0.28)	0.29
U.S. manu. imports / total imports	**0.04 (0.32)**	0.44
Britain's manu. exports / total exports	0.96 (0.97)	0.89
U.S. manu. exports / total exports	**0.93 (0.61)**	0.50
U.S. manu. exports to Britain / total manu. exports	0.07 (0.15)	0.14
U.S. primary exports to Britain / total primary exports	0.61 (0.68)	0.37
Britain's manu. exports to U.S. / total manu. exports	0.03 (0.06)	0.05
Britain's primary exports to U.S. / total primary exports	0.21 (0.49)	0.10

Next I use the external TFP shocks instead of the measured ones to simulate the model. I also use the external trade cost shocks instead of the calibrated trade cost shocks. Numbers in the parenthesis are the results from Table 19. The results are presented in Table 21. It overpredicts the growth of U.S. and Britain's manufacturing sector substantially, as expected. This is because of the higher values that $A_{m,b}$ and $A_{m,us}$ take than the baseline case. In other words, given the IRTS technology in manufacturing, applying the TFP implied by the CRTS technology yields a substantial over-prediction of the growth of manufacturing sector. The growth of U.S. manufacturing sector suffers more from over-prediction because the discrepancy between the external value and the measured value is larger. Over-prediction problem of the relative position of manufacturing (share in world manufacturing) is less severe. More about this issue will be discussed in the following section.

Table 21: Simulated results under external TFP shocks

	Britain		The U.S.	
	model	data	model	data
Share in world primary (%)	2.4 (2.4)	1.9	13.9 (13.9)	14.4
Share in world manufacture (%)	11.4 (12.2)	13.6	**34.2 (33.3)**	31.9
Share of LF in primary (%)	19 (18)	12	28 (29)	30
Share of LF in manufacture (%)	45 (46)	44	41 (40)	30
$Y_{a,1913}/Y_{a,1870}$	1.23 (1.24)	0.93	2.67 (2.62)	2.58
$Y_{m,1913}/Y_{m,1870}$	2.72 (2.24)	2.15	**16.99 (12.76)**	9.46
$\text{RGDP}_{1913}/\text{RGDP}_{1870}$	1.99 (1.87)	2.24	6.76 (6.05)	5.26

The data for real GDP come from Maddison (2001)

2.4 Constant Returns to Scale in Manufacturing

One of the arguments about the rise of U.S. manufacturing during this period is the existence of increasing returns to scale. Many studies such as Cain and Paterson (1986) and James (1983) strongly suggest that there were IRTS in U.S. manufacturing. Following this, my baseline model assumes that there exists IRTS in manufacturing and I just demonstrated that this model works quite well in accounting for the economy in 1913.

On the other hand, still more studies such as Wright (1990) and O'Rourke and Williamson (1994) assume CRTS when analysing the economy during this period. And it would be worthwhile to consider a model built and calibrated under the assumption of CRTS. With a CRTS model that performs well I can draw some meaningful comparisons between the two assumptions that are often employed in the literatures. In this section I consider a deviation from the baseline model of IRTS.

2.4.1 The Model and Calibration

For this purpose I need to maintain the main features of the baseline model as much as possible. The simplest way to do this is to eliminate the fixed cost component, F, from the manufacturing production function. The composite index of manufacturing consumption now looks similar to that of primary consumption

$$C_{mi} = [\gamma_{mb} m_{i,b}^{\rho_m} + \gamma_{mus} m_{i,us}^{\rho_m} + \gamma_{mrw} m_{i,rw}^{\rho_m}]^{1/\rho_m}$$

As a result the manufacturing price index becomes

$$G_{mi} = \left[\gamma_{mb}^{\sigma_m}(p_{mb}T_{bi}^{m})^{1-\sigma_m} + \gamma_{mus}^{\sigma_m}(p_{mus}T_{usi}^{m})^{1-\sigma_m} + \gamma_{mrw}^{\sigma_m}(p_{mrw}T_{rwi}^{m})^{1-\sigma_m}\right]^{1/(1-\sigma_m)}$$

Basically dropping F eliminates the increasing returns component and the number of manufacturing firms is no longer endogenously determined so that the consumers consume a fixed proportion of manufacturing goods from each region. Therefore the number of variety (or firms) is fixed or one can think of a representative firm in each region producing everything. In this sense the number of firms is indeterminate under CRTS but it does not matter because it is fixed over time. Essentially the model is very similar to the standard CGE model with an Armington assumption.

The procedure of restricting the parameters is almost identical to the case of IRTS except that $\gamma_{m,i}$ is pinned down in the same way as $\gamma_{a,i}$. More detailed calibration procedure is described in the appendix at the end of the chapter. The resulting benchmark equilibrium and parameter values are exactly identical to the IRTS case. This is convenient as I can ignore the possibility that the difference (between IRTS and CRTS) comes from the differences in parameter and initial equilibrium values.

However the CRTS specification has different implications for the changes in manufacturing TFP and trade costs. To see this more closely, I derive the change in manufacturing TFP under the CRTS specification, the counterpart of equation (34).

$$\frac{A_{m,1913}}{A_{m,1870}} = \left(\frac{X_{1870}}{X_{1913}}\right)^{\frac{1-\alpha_m}{1-\sigma_m}} \left(\frac{L_{m,1870}}{L_{m,1913}}\right)^{\alpha_m} \left(\frac{Y_{m,1913}}{Y_{m,1870}}\right)^{\alpha_m} \tag{36}$$

Using (34) and (36), I can derive a relation between a change in TFP under IRTS and that implied by CRTS as follows:

$$\left(\frac{A_{m,1913}}{A_{m,1870}}\right)_{\text{CRTS}} = \left(\frac{A_{m,1913}}{A_{m,1870}}\right)_{\text{IRTS}} \underbrace{\left(\frac{Y_{m,1913}}{Y_{m,1870}}\right)^{\frac{1-\alpha_m}{\sigma_m-1}}}_{A} \tag{37}$$

First thing to note from (37) is that given $\alpha_m < 1$, $\sigma_m > 1$ and $\frac{Y_{m,1913}}{Y_{m,1870}} > 1$, $\left(\frac{A_{m,1913}}{A_{m,1870}}\right)_{\text{CRTS}}$ is bigger than $\left(\frac{A_{m,1913}}{A_{m,1870}}\right)_{\text{IRTS}}$. It says that what is perceived as a purely exogenous technological change in the CRTS model actually contains an endogenous component (underbrace A on the right hand side of equation) if there are IRTS. But if $\alpha_m = 1$ then the underbrace A becomes one and the change in TFP under CRTS is identical to that of IRTS. This means that the manufacturing sector using itself as intermediate goods is the crucial feature that makes the difference between CRTS and IRTS. $\left(\frac{A_{m,1913}}{A_{m,1870}}\right)_{CRTS}$ for Britain and the U.S is 1.20 and 1.63, respectively. As expected the CRTS model yields larger TFP changes than the baseline model. If I compare these values with the external sources, they are not so different from each other. For comparison, I reiterate the TFP shocks measured under the different approaches again in Table 22.

Under the 'IRTS' and 'CRTS' are the measured TFP shocks under the assumption that there exist IRTS and CRTS in manufacturing sectors, respectively. The values under 'External' are the ones taken or recovered from the external sources, including capital. Overall the measured values and the values culled from the external sources are quite similar. One noted differ-

Table 22: TFP shocks

	IRTS	CRTS	External
$A_{a,b}$	1.09	1.09	1.07
$A_{m,b}$	1.14	1.20	1.27
$A_{a,us}$	1.22	1.22	1.26
$A_{m,us}$	1.40	1.63	1.62

ence is U.S. manufacturing TFP shock between 'IRTS' and 'External'. As discussed earlier, Kendrick (1961) implicitly assumes CRTS technology and the TFP is inevitably over-estimated if there exists IRTS. Instead the shock measured under the assumption of CRTS is almost identical to the value taken from Kendrick (1961). In this sense, my measures of TFP shocks also represent the real *total* factor productivity well.

I discuss more about the implications of using the external TFP shocks. TFP is conventionally measured as a residual from the production function after accounting for factor inputs. This means one usually needs to make an assumption about the form of production function to measure TFP. The external TFP shocks in Table 22 are derived by assuming that the production function exhibits CRTS, as far as I understand. I also demonstrated that those values for Britain and the U.S. are very similar to the TFP shocks inferred from my CRTS model earlier. If there really exists IRTS in an economy, the TFP shocks inferred from a CRTS assumption actually include the components contributed by the IRTS effects. Therefore if I use the external TFP shocks inferred from CRTS models to simulate an IRTS model, the effects of the scale economy are 'double-counted' and there is an inevitable over-prediction of simulated results. In this sense it can be problematic to use TFP shocks inferred from CRTS on IRTS model. What I do in section 2.4.1 is to identify this effects coming from the assumption of IRTS. To reiterate, the TFP change under CRTS, $\left(\frac{A_{m,1913}}{A_{m,1870}}\right)_{\text{CRTS}} = 1.63$

and the change under IRTS, $\left(\frac{A_{m,1913}}{A_{m,1870}}\right)_{\text{IRTS}} = 1.40$ for the U.S. and the difference between these numbers can be identified as the effects of IRTS. For the CRTS case, applying the external TFP shocks generates very similar results as the baseline case (using the measured shocks), so I do not report the results here.

Next I calibrate the changes in trade costs under CRTS specification. The way that the changes in trade costs are calibrated, implies that those under CRTS would take on different values from IRTS specification. Table 23 reports the values below. One pronounced difference is in the change in manufacturing trade costs between Britain and the U.S. Under the IRTS specification, $T^m_{b,us}$ decreases while $T^m_{us,b}$ increases but under the CRTS we get the opposite result. This is probably because the IRTS gives relatively more comparative advantage to U.S. manufacturing than the CRTS case (even though $A_{m,us}$ is higher under CRTS). And because of this, a lower trade cost from Britain to the U.S. is needed under IRTS to match the given amount of Britain's manufacturing exports to the U.S. Also for the same reason, the trade cost from the U.S. to Britain should be higher under the IRTS to account for U.S. manufacturing exports to Britain.

Table 23: Changes in trade costs under CRTS (growth factor)

$\Delta T^a_{b,us}$	$\Delta T^a_{us,b}$	$\Delta T^a_{b,rw}$	$\Delta T^a_{rw,b}$	$\Delta T^a_{us,rw}$	$\Delta T^a_{rw,us}$
0.850	1.084	0.669*	1.906	0.595*	1.696
$\Delta T^m_{b,us}$	$\Delta T^m_{us,b}$	$\Delta T^m_{b,rw}$	$\Delta T^m_{rw,b}$	$\Delta T^m_{us,rw}$	$\Delta T^m_{rw,us}$
1.044	0.968	1.508	0.717*	1.532	0.489

* indicates the case that the restriction is needed.

2.4.2 Simulation Results and Discussion

I feed in these newly measured changes under CRTS to the benchmark year equilibrium to generate the development of the economy. Table 24 reports the result. The results are not much different compared to the IRTS model.

Table 24: Simulated results vs. data in 1913 under CRTS

	Britain		The U.S.	
	model	data	model	data
Share in world primary (%)	2.4	1.9	13.9	14.4
Share in world manufacture (%)	13.8	13.6	31.8	31.9
Share of LF in primary (%)	23	12	37	30
Share of LF in manufacture (%)	41	44	31	30
$Y_{a,1913}/Y_{a,1870}$	1.43	0.93	3.06	2.58
$Y_{m,1913}/Y_{m,1870}$	1.99	2.15	9.58	9.46
$\text{RGDP}_{1913}/\text{RGDP}_{1870}$	1.79	2.24	5.32	5.26

The data for real GDP come from Maddison (2001)

The CRTS model specified and calibrated in this way performs equally well in accounting for the North Atlantic economy in 1913. Basically higher implied TFP in manufacturing and the difference in trade cost make up the difference coming from the absence of IRTS. Even though I don't report it here, the result for the trade statistics are also very similar to the baseline case.

Then what can I learn from this exercise? Within this framework I cannot make any comparisons between the IRTS and the CRTS models because each model yields different implied values for some shocks and as a result they yield almost identical results. In other words, I cannot answer "Which model does a better job in accounting for the economy?" with these two models. Instead I can ask answer "If we assume that there *really* existed IRTS in the manufacturing sector, what are their quantitative contribution to the development of the economy?"

I can do this by feeding in the shocks measured under IRTS assumption to otherwise CRTS model as specified above. Given that both model yield very similar results. And also the parameters calibrated under each specification and the benchmark year equilibrium values are identical, I can effectively isolate the effect of IRTS. I perform a detailed analysis of this in the following chapter.

Appendix : Description of Calibration Procedure

This section describes the algorithm for the joint calibration procedure. There are 27 parameters to calibrate jointly. 12 trade costs: T_{ij}^a and T_{ij}^m, 9 preference parameters: θ_a, θ_m and $\underline{C}$ for each region and 6 TFPs: A_{ai} and A_{mi} for each region. In this procedure, these parameter values and the benchmark year equilibrium are determined simultaneously such that the equilibrium matches some key characteristics of the economy described above.

The Baseline IRTS Model

To begin with, N_i for each region is determined by (22) given $\underline{N}_i$ from the individual calibration. Then L_{ai} is determined given the target of $L_{ai}/\underline{L}_i$ (the share of labor force in primary sector from Table 1). Then given the normalization $A_{a,b} = 1$ and the production function in primary sector, Britain's primary output, $Y_{a,b}$, is determined. And by taking the ratio of each region's primary production function to that of Britain, $A_{a,us}$ and $A_{a,rw}$ are pinned down given the target $Y_{a,i}/Y_{a,b}$ (the ratio of each region to Britain's primary value added, Table 2)

$$A_{a,i} = A_{a,b} \left(\frac{L_{a,b}}{L_{a,i}} \right)^{\alpha_a} \left(\frac{N_b}{N_i} \right)^{(1-\alpha_a)} \left(\frac{Y_{a,i}}{Y_{a,b}} \right)$$

This, in turn, determines $Y_{a,us}$ and $Y_{a,rw}$ from the production function in primary sector.

Next, by dividing (24) by (25), w_i/d_i for each region is determined.

$$\frac{w_i}{d_i} = \frac{\alpha_a}{1-\alpha_a} \frac{N_i}{L_{a,i}}$$

By assuming $w_b = 1$, d_b is determined. Then given the target Y_i/Y_b (each region's GDP relative to Britain) and using (24), w_b, w_{rw}, d_{us} and d_{rw} are determined. Again by (24), Y_b, Y_{us} and Y_{rw} are determined.

I continue with $p_{a,i}$ (price of primary product in region i). It is determined by (3), then $p_{a,i}Y_{a,i}$ for each region is determined. Also, given Cobb-Douglas functional form,

$$w_i L_{m,i} = \alpha_m p_{m,i} Y_{m,i}$$

which states that labour income in manufacturing sector should equal to the sales value times the share of labour. And this determines the value of gross output, $p_{m,i}Y_{m,i}$, for each region. Given the targets of Britain and U.S. imports to GDP ratios (in current prices), values of imports for Britain and the U.S. are determined (At this point, I already obtained Y_i which is GDP within the model framework). Then the ratio of Britain and the U.S manufacturing imports to their total imports determine the values of their manufacturing imports. Also the ratio of their manufacturing exports to total exports determine the values of their manufacturing exports. Consequently, the values of their net exports in manufacturing ($NX_{m,i}$) are determined (by adding up imports and exports). And given the balanced trade assumption, the values of their net exports in primary products ($NX_{a,i}$) are determined as well. NX_m and NX_a for the rest of world are determined as to insure the world trade is balanced. Then, expenditure in primary good ($E_{a,i}$) is determined as,

$$E_{a,i} = p_{a,i} Y_{a,i} - NX_{a,i}$$

Similarly, expenditure in manufacturing good (E_{mi}) is determined as,

$$E_{m,i} = p_{m,i} Y_{m,i} - NX_{m,i}$$

And $E_{s,i}$ is determined by (14).

Next I calibrate trade costs for primary goods. (9) expresses the world demand for a primary good produced by a single firm in region i. Then the world demand for region i's primary products can be expressed as

$$\left(\frac{\gamma_i}{p_{a,i}}\right)^{\sigma_a} \sum_j E_{a,j} \left(\frac{T^a_{i,j}}{G_{a,j}}\right)^{(1-\sigma_a)}$$

This equation can be decomposed to show demand of each region. For example the amount that the U.S. demands from Britain is

$$\left(\frac{\gamma_b}{p_{a,b}}\right)^{\sigma_a} E_{a,us} \left(\frac{T^a_{b,us}}{G_{a,us}}\right)^{1-\sigma_a}$$

Indeed, given there are 3 regions, I can construct 9 of them including demands for domestic products. And with these, I can express trade cost from i to j as

$$T^a_{i,j} = \left(\frac{\gamma_j}{\gamma_i}\right)^{\frac{\sigma_a}{1-\sigma_a}} \left(\frac{p_{a,j}}{p_{a,i}}\right) \left(\frac{p_{a,i}a_{ji}}{p_{a,j}a_{jj}}\right)^{\frac{1}{1-\sigma_a}} \tag{A.1}$$

where a_{ji} is j's demand for i's products. Therefore $p_{a,i}a_{ji}$ can be interpreted as value of j's imports from i. The share of Britain's primary imports from U.S. in its total imports and the share of its primary exports to U.S. in its total exports determine $p_{a,i}a_{ji}$ for all i and j. Because as the value of Britain's total imports in primary goods is already determined, the share of imports from U.S. determines the value of imports from the U.S. and the rest of world ($p_{a,us}a_{b,us}$ and $p_{a,rw}a_{b,rw}$). And the value of Britain's domestic imports ($p_{a,b}a_{b,b}$) is determined by subtracting $p_{a,us}a_{b,us}$ and $p_{a,rw}a_{b,rw}$ from its primary expenditure ($E_{a,b}$). Also the value of its total exports in primary goods and the share of its exports to U.S. determine the value of exports to the U.S. and the rest of world which should be equal to the value of U.S. and the rest of world's primary imports from Britain ($p_{a,b}a_{us,b}$ and $p_{a,b}a_{rw,b}$). Then in turn, the value of U.S. total primary imports determine its imports from the rest of world ($p_{a,rw}a_{us,rw}$). And the value of its domestic imports ($p_{a,us}a_{us,us}$) is determined by subtracting $p_{a,b}a_{us,b}$ and $p_{a,rw}a_{us,rw}$ from its primary expenditure ($E_{a,us}$). Moreover, the value of the rest of world's primary imports from U.S. ($p_{a,us}a_{rw,us}$), or the value of U.S. primary exports to the rest of world, can be calculated by subtracting $p_{a,us}a_{b,us}$ and $p_{a,us}a_{rw,us}$ from the value of U.S. output in primary sector ($p_{a,us}Y_{a,us}$). Finally, the rest of world's domestic imports ($p_{a,rw}a_{rw,rw}$) can be determined by subtracting $p_{a,b}a_{rw,b}$ and $p_{a,us}a_{rw,us}$ from its primary expenditure ($E_{a,rw}$). And T^a_{ij} can be pinned down by (26), consequently. With calibrated trade costs, $G_{a,i}$ (price level in primary sector) can be determined by (1).

I continue with manufacturing TFPs and trade costs. Like a primary trade cost, a manufacturing trade cost from i to j can be expressed as

$$T^m_{ij} = \left(\frac{n_{m,j}}{n_{m,i}}\right)^{\frac{1}{1-\sigma_m}} \left(\frac{p_{m,j}}{p_{m,i}}\right) \left(\frac{p_{m,i}m_{ji}}{p_{m,j}m_{jj}}\right)^{\frac{1}{1-\sigma_m}} \tag{A.2}$$

where m_{ji} is j's demand for i's manufacturing products. $p_{m,i}m_{ji}$ for all i and j are determined similarly as in the primary sector case to match the manufacturing bilateral trade targets. Next, plugging (2), (14) and (27) into (7),

$$p_{m,i} = \left[\frac{\sigma_m}{\sigma_m - 1}(A_{m,i}\alpha_m^{\alpha_m}(1-\alpha_m)^{1-\alpha_m})^{-1}w_i^{\alpha_m}\left(\frac{w_iL_{m,i}}{\alpha_mF(\sigma_m-1)}\frac{E_{m,i}}{p_{m,i}m_{ii}}\right)^{\frac{1-\alpha_m}{1-\sigma_m}}\right]^{\frac{1-\sigma_m}{1-\alpha_m\sigma_m}}$$

Then I can use this equation to determine $A_{m,us}$ and $A_{m,rw}$ as

$$\frac{A_{m,j}}{A_{m,i}} = \left(\frac{p_{m,i}Y_{m,i}}{p_{m,j}Y_{m,j}}\frac{Y_{m,j}}{Y_{m,i}}\right)^{\frac{1-\alpha_m\sigma_m}{1-\sigma_m}} \left(\frac{w_j}{w_i}\right)^{\alpha_m} \left(\frac{B_j}{B_i}\frac{E_{m,j}}{E_{m,i}}\frac{p_{m,i}m_{ii}}{p_{m,j}m_{jj}}\right)^{\frac{1-\alpha_m}{1-\sigma_m}} \tag{A.3}$$

where $B_i = \frac{w_i L_{mi}}{\alpha_m F(\sigma_m - 1)}$. Then given $A_{m,b} = 1$, $A_{m,us}$ and $A_{m,rw}$ are pinned down. And (27) and (14) determine $p_{m,i}$ and $n_{m,i}$, respectively. Then T_{ij}^m is determined by (27) which in turn determines $G_{m,i}$ with (2).

Finally, I calibrate $\underline{c}$, θ_a, θ_m and θ_s. Here the target is income elasticity of demand for food which is set to be 0.6.

$$\frac{\partial C_a}{\partial Y}\frac{Y}{C_a} = \frac{\theta_a Y}{\theta_a Y + G_a \underline{C}(1-\theta_a)} = 0.6$$

where I utilized the optimal consumption for primary product, $C_a = \theta_a Y / G_a + \underline{C}(1-\theta_a)$. Remember that these are all in aggregate terms and $\underline{C} = P\underline{c}$. And because $E_a = G_a C_a$, I can simplify the equation as

$$\theta_a = \frac{(0.6)E_a}{Y}$$

So this pins down θ_a. And given θ_a, $\underline{C}$ and $\underline{c}$ can be obtained as

$$\underline{C} = \frac{E_a - \theta_a Y}{G_a(1-\theta_a)} \quad , \quad \underline{c} = \frac{\underline{C}}{P}$$

Given the value for $\underline{C}$ and using equation (12) and (13), θ_m and θ_s are obtained. Table 7 summarizes the parameters common across regions, Table 8 summarizes the region specific parameter values and Table 9 reports the trade costs.

The CRTS Model

The calibration procedure for CRTS model is almost identical to that of the baseline IRTS case. The key difference is to eliminate the fixed cost F and introduce the weight parameter, $\gamma_{m,i}$ in manufacturing sectors. These changes generate slightly different procedures for the calibration process. First, the implied equation to pin down the manufacturing TFP in 1870,

$A_{m,j}$ becomes

$$\frac{A_{m,j}}{A_{m,i}} = \left(\frac{p_{m,i}Y_{m,i}}{p_{m,j}Y_{m,j}}\frac{Y_{m,j}}{Y_{m,i}}\right)^{\alpha_m}\left(\frac{w_j}{w_i}\right)^{\alpha_m}\left[\left(\frac{\gamma_{m,i}}{\gamma_{m,j}}\right)^{\frac{\sigma_m}{1-\sigma_m}}\left(\frac{E_{m,i}}{E_{m,j}}\frac{p_{m,i}m_{ii}}{p_{m,j}m_{jj}}\right)^{\frac{1}{1-\sigma_m}}\right]^{1-\alpha_m}$$

This equation replaces (A.3) in the appendix. Likewise the equations that calibrate the manufacturing trade costs, T_{ij}^m and the price of domestic manufacturing product, $p_{m,i}$ are replaced with

$$T_{ij}^m = \left(\frac{\gamma_{m,j}}{\gamma_{m,i}}\right)^{\frac{\sigma_m}{1-\sigma_m}}\left(\frac{p_{m,j}}{p_{m,i}}\right)\left(\frac{p_{m,i}m_{ji}}{p_{m,j}m_{jj}}\right)^{\frac{1}{1-\sigma_m}}$$

$$p_{m,i} = \left[(A_{m,i}\alpha_m^{\alpha_m}(1-\alpha_m)^{1-\alpha_m})^{-1}w_i^{\alpha_m}\left(\gamma_i^{\frac{\sigma_m}{1-\sigma_m}}\left(\frac{E_{m,i}}{p_{m,i}m_{ii}}\right)^{\frac{1}{1-\sigma_m}}\right)^{1-\alpha_m}\right]^{\frac{1}{\alpha_m}}$$

The calibrated $A_{m,i}$ and T_{ij}^m yield identical values as the baseline case and the price of manufacturing relative to that of Britain is also identical to that of the baseline case. Other than these differences I use exactly the same equations (reported in the appendix) and the data moment (reported in Table 6) as the baseline case.

Chapter 3

Decomposition of U.S. Economic Growth

With a model that accounts for the key characteristics of the economy from Chapter 2, I am ready to undertake various numerical experiments. In this chapter I evaluate the quantitative contributions of each shock to the development of U.S. economy. That is, I disentangle the effects of the changes in the sectoral TFP, in the labour force and land endowments and in the trade costs to assess their individual as well as cumulative contribution. Then in the second part of this chapter, I perform an analysis that isolates the effects of IRTS, as mentioned earlier.

3.1 Quantitative Assessment of Each Force

In this section I evaluate the quantitative implications of each force in accounting for the rise of the U.S. The rise of the U.S. as an industrial power in such a short span of time is a remarkable historical event. U.S. economy as well as the international environment surrounding it, went through a large transformation during this period. Domestically, its population and labour force shot up, partially due to the mass immigration. Also the land area began to increase rapidly after the Homestead Acts. It was not only the period of increasing resources but also the period of technological progress. The revolutionary production and managerial system, such as the mass production, for its manufacturing sector began to settle during this period, too. There is no doubt that all these changes contributed positively to the development of the U.S. in one way or the other. But the focus here is on the quantitative side so that the relative contribution of each factor can be assessed.

3.1.1 Procedure and Results

I use the baseline model to perform this task. Later in the chapter, the CRTS model will be used, the results of which will be compared with the results from the baseline case. Before we turn to the results, I briefly describe the procedure. To disentangle the effects of each force, I initially turn off the measured changes in endowments, TFP and trade costs for the U.S. while maintaining them for other regions. The endowments, TFP and trade costs for the U.S are at year 1870 level while those for Britain and the rest of world are at 1913 level. Then, to this initial state, I feed in the change in each force individually.[37] By doing this I measure the percentage variance that each force contributes to various features of the development of U.S economy. Then I feed in the changes cumulatively to see how the combination of forces affect the economy. The variables of interests are real GDP (RGDP), manufacturing output ($Y_{m,us}$), primary output ($Y_{a,us}$), and changes in the world share of U.S. primary and manufacturing ($\frac{Y_{a,us}}{Y_{a,w}}$ and $\frac{Y_{m,us}}{Y_{m,w}}$). Table 25 below reports the results.

The table is read as follows. The primary TFP shock ($A_{a,us}$), land endowment shock ($\underline{N}_{us}$) and manufacturing TFP shock ($A_{m,us}$) together account

[37] The change in population, D_{us}, is fed in accordingly with the change in $\underline{L}_{us}$.

Table 25: Decomposing contribution of each shock (%)

		$A_{a,us}$	$\underline{N}_{us}$	$A_{m,us}$	$\underline{L}_{us}$	$A_{s,us}$	T	$A_{m,us}+\underline{L}_{us}$
RGDP	cumul.	1.6	4.6	11.6	85.2	111.9	**100.0**	-
	indiv.	1.6	2.9	8.2	46.9	5.6	-*	78.3
$Y_{m,us}$	cumul.	2.4	-2.5	27.1	198.1	198.1	**100.0**	-
	indiv.	2.4	0.3	47.0	99.3	5.7	-*	243.6
$Y_{a,us}$	cumul.	5.6	36.4	14.0	34.8	34.8	**100.0**	-
	indiv.	5.6	17.9	-24.5	5.0	-6.5	-*	-20.9
$\frac{Y_{m,us}}{Y_{m,w}}$	cumul.	5.4	3.5	14.2	56.8	56.8	**32.2**	-
	indiv.	5.4	4.6	21.3	36.7	6.7	-*	67.9
$\frac{Y_{a,us}}{Y_{a,w}}$	cumul.	5.5	8.5	6.2	7.4	7.4	**13.9**	-
	indiv.	5.5	6.7	2.5	5.1	4.3	-*	2.5

-* indicates no equilibrium

for about 11.6% of the predicted growth of RGDP and 27.1% of the predicted growth of $Y_{m,us}$ from 1870 to 1913. $A_{m,us}$ alone can only account for about 8.2% and 47.0% of the growth in RGDP and $Y_{m,us}$, respectively. The last two rows present world share of U.S. manufacturing and primary products. For example when the changes in $A_{a,us}$, $\underline{N}_{us}$ and $A_{m,us}$ are fed in together while other changes are held fixed, the share of U.S. manufacturing is 14.2%, about 18 percentage point short of the baseline value. Obviously when all the shocks are applied simultaneously, we reach the baseline equilibrium in 1913 and the shocks account for 100% of the growth predicted by the model (in bold letters). Several interesting points arise here. First, the increase in labour force ($\underline{L}_{us}$) stands out as the single most important contributor. It accounts for close to half of real GDP growth and almost 100% of manufacturing growth. But this has uneven impacts across sectors. While it has massive impacts on the manufacturing sector, its impact on the primary sector is relatively small. This means that most of the increase was absorbed by the manufacturing sector. There are two forces working behind this result. The first and obvious force is the IRTS in manufacturing. And the second force is the non-homothetic preference such that the income elasticity for primary goods is less than one. This generates the structural transformation from primary to manufacturing as the increase in labour force raises GDP.

In the last column I consider an interesting combination of shocks where I feed in the changes in $A_{m,us}$ and $\underline{L}_{us}$ simultaneously. Together they account for more than three quarters of the increase in real GDP. Also they generate the manufacturing output that is about 2.5 times larger than the equilibrium level. Of course, as other shocks that give the comparative advantage to primary sector, such as increase in land and primary TFP, are also considered, the massive effects of the two shocks on manufacturing sector thins out.

One more interesting result is that the changes in trade costs were not favourable to U.S. economy in general. The cumulative effects of all shocks excluding the changes in trade costs yields a real GDP that is 11.9% higher than the equilibrium level. This effect is much greater on manufacturing with output 98.1% higher than in equilibrium. On the other hand, the changes in trade costs were favourable to the primary sector. They account for massive 65.2% of the growth in primary output. The equilibrium is not economically interpretable when the trade cost shocks are applied individually because the equilibrium value of $Y_{m,us}$ becomes negative. One way to interpret this is that the manufacturing sector collapses due to the trade cost changes alone.

The result regarding the trade costs are perhaps exaggerated given the problems arising from the aggregation of the rest of world.[38] This yields a very large reduction in $T^{a}_{us,rw}$ and $T^{m}_{rw,us}$ while $T^{a}_{rw,us}$ and $T^{m}_{us,rw}$ increase hugely.[39] The large reduction in $T^{a}_{us,rw}$ and the large increase in $T^{a}_{rw,us}$ give a comparative advantage to U.S. primary and induces more production.

[38]Please see Section 3.1.3 of Chapter 2 for a detailed discussion.

[39]Please see Table 14 in Chapter 2.

At the same time the large reduction and increase in $T^{m}_{rw,us}$ and $T^{m}_{us,rw}$, respectively, give a comparative disadvantage to U.S. manufacturing, further inducing the U.S. to relocate its resources to producing primary products.

If the rest of world can be disaggregated into finer regions and the changes in trade costs between the U.S. and each region (within the rest of world) are calibrated as in Chapter 2, then they may not appear as extreme as the ones reported in Table 14. But on average it would still be the case that the manufacturing trade costs from the U.S. to the rest increase while those from the rest to the U.S. decrease over the period. In other words, even if I include more regions, the direction or qualitative changes in trade costs would not be altered even though the magnitudes would be smaller. One of the main reason is that the share of U.S. manufacturing imports in total imports was still very high in 1913 (52% in 1870 and 44% in 1913) despite the sector's rapid development and the huge comparative advantage gained during this period. And in order for the model to account for this figure, the manufacturing trade costs into the U.S. would need to decrease.

The implication of the trade costs here suggests something for a direction of future researches. Most of the literatures assume symmetric trade costs. Jacks, Novy and Meissner (2010) also imposes symmetry in dealing with the changes in trade costs from 1870 to 1913. But the implications of this paper suggests that there was a substantial degree of asymmetry at the sectoral level and this may have mattered for some facets of the development.

3.1.2 Decomposing Trade Cost

In the previous section I looked at the effects of the overall change in trade costs on the U.S. as part of the analysis. In this section I perform a more detailed analysis on the changes in trade costs. In order to do this I begin with a model in which I feed in all the shocks except the shocks in trade costs (so the real GDP in the initial equilibrium is 111.9% that of the baseline equilibrium). Then I apply the calibrated changes in trade costs individually or in combination to this initial equilibrium. Table 26 reports the results. It decomposes the trade costs and looks at the individual contributions of trade costs.

First some explanations about the notations are in order. $T^m_{us,i}$ is the manufacturing trade cost from the U.S. to i where i includes Britain and the rest of world ($\therefore T^m_{us,b}$ and $T^m_{us,rw}$) and $T^a_{i,us}$ is the primary trade cost from i to the U.S. ($\therefore T^a_{b,us}$ and $T^a_{rw,us}$). T^m_{us} is the manufacturing trade cost that involves the U.S. so $T^m_{us,i}$ and $T^m_{i,us}$. The changes in $T^a_{i,us}$ and $T^m_{us,i}$ have main

Table 26: Decomposing trade cost shocks (%)

	$T^a_{i,us}$	$T^a_{us,i}$	$T^m_{i,us}$	$T^m_{us,i}$	T^a_{us}	T^m_{us}
RGDP	-6.5	0.0	0.0	-6.2	-6.5	-6.2
$Y_{m,us}$	-25.5	-0.3	-0.4	-24.1	-25.6	-24.3
$Y_{a,us}$	45.9	0.6	2.2	43.5	46.0	43.9

impacts. The change in $T^a_{i,us}$ alone depresses RGDP by 6.5% and $Y_{m,us}$ by -25.5%. On the other hand it promotes $Y_{a,us}$ by massive 45.9%. The change in $T^m_{us,i}$ has almost identical impacts as $T^a_{i,us}$, quantitatively. It decreases RGDP and $Y_{m,us}$ by -6.2% and -24.1%, respectively while increases $Y_{a,us}$ by 43.5%. Impacts of $T^a_{us,i}$ and $T^m_{i,us}$ turn out to be minimal.

These results are quite intuitive when we consider the calibrated changes in trade costs in Table 14 in Chapter 2. First as it becomes much more costly for the rest of world to export primary goods to the U.S. ($\Delta T^a_{rw,us}$=1.686), the comparative advantage in primary shifts to the U.S. inducing $Y_{a,us}$ to increase and $Y_{m,us}$ to decrease. At the same time it becomes more costly for the U.S. to export manufacturing products ($\Delta T^a_{us,b}$=1.251 and $\Delta T^a_{us,rw}$=1.900). This further shifts the comparative advantage in manufacturing away from the U.S. In the aggregate the effects are quantitatively large and reduce the manufacturing output substantially but also real GDP is reduced as resources are relocated away from the faster growing productive manufacturing sector to the slower growing productive primary sector.

3.1.3 Using the Alternative Shocks

In this section I perform a similar decomposition exercise using the alternative trade cost shocks taken from Jacks et al (Table 15). For the points discussed in Section 2.3.1 and 2.4.1 on the implications of using the external TFP shocks in the IRTS model, I do not use the external TFP shocks. Table 27 presents the results.

Table 27: Decomposition Using Alternative Trade Cost Shocks (%)

		$A_{a,us}$	$A_{m,us}$	$\underline{N}_{us}$	$\underline{L}_{us}$	$A_{s,us}$	actual T	$A_{m,us}+\underline{L}_{us}$
RGDP	cumul.	1.6	7.4	11.0	75.2	99.2	**100.0**	-
	indiv.	1.6	5.8	-*	41.4	5.1	0.2	63.1
$Y_{m,us}$	cumul.	-8.1	12.9	8.3	93.1	93.1	**100.0**	-
	indiv.	-8.1	16.5	-*	36.1	-5.0	-5.6	148.1
$Y_{a,us}$	cumul.	29.4	5.5	39.1	107.0	107.0	**100.0**	-
	indiv.	29.4	-8.4	-*	53.5	9.3	10.3	9.0
$\frac{Y_{m,us}}{Y_{m,w}}$	cumul.	0.1	8.1	6.3	31.2	31.2	**33.3**	-
	indiv.	0.1	9.5	-*	16.1	1.4	1.1	47.6
$\frac{Y_{a,us}}{Y_{a,w}}$	cumul.	8.7	6.5	9.5	14.5	31.2	**13.9**	-
	indiv.	8.7	5.2	-*	10.5	6.9	7.0	6.2

-* indicates no equilibrium

An increase in $A_{a,us}$ has differential impacts on U.S. manufacturing sector under the two different approaches. According to the calibration (of trade cost shocks) approach, a rise in $A_{a,us}$ has a positive impact as opposed to that it has a negative impact under the second approach. Basically, $A_{a,us}$ contributes to the growth of $Y_{m,us}$ by 2.4% and -8.1% under the first and the second scenario, respectively. There are largely two opposing forces that dictate the effects of $A_{a,us}$ on $Y_{m,us}$. First, an increase in $A_{a,us}$ shifts the comparative advantage toward U.S. primary products, inducing more production of primary goods and less of manufacturing products. On the other hand, the non-homothetic preference implies that a rise in the productivity would generate the structural transformation, shifting labour forces out of the primary sector into the manufacturing sector. As less labour forces are employed in the primary sector and more in the manufacturing sector, it tends to reduce $Y_{a,us}$ and increase $Y_{m,us}$. Therefore whether $Y_{m,us}$ increases or decreases is a question of which of the two forces dominate. Based on this explanation under the baseline approach, the second force dominates the first force, generating the net effect of increasing $Y_{m,us}$ while under the second approach it is vice-versa. This difference mainly comes from the different calibrated values of the primary and the manufacturing TFP shocks for the rest of world, $A_{a,rw}$ and $A_{m,rw}$. Under the first scenario $A_{a,rw} = 2.232$ and $A_{m,rw} = 1.096$ whereas under the second scenario $A_{a,rw} = 1.766$ and $A_{m,rw} = 1.387$. It clearly tells something about the comparative advantage of the rest of world under the two cases. It suggests that the rest of world has more comparative advantage in primary sector under the first case than under the second case because the calibrated $A_{a,rw}$ shock is higher and $A_{m,rw}$ shock is lower under the first than the second case.[40] Given that the rest of world already has a huge comparative advantage in primary products under the first scenario, the rise in U.S. primary TFP does not give much comparative advantage in primary products to the U.S. In other words the effect of the first force would not be so large under the first approach. As this is the case, it speeds up the structural transformation process, shifting labour forces out of the primary sector and into the manufacturing sector which, in turn, increase $Y_{m,us}$. In the end the second force dominates the

[40]Remember that I am only holding the shocks of the U.S. fixed. The shocks for Britain and the rest of world are still being fed in.

first and the net effect is an increase in $Y_{m,us}$. Under the second scenario, however, the net effect is reversed because the calibrated shocks for the rest of world imply that the rise in $A_{a,us}$ gives substantially more comparative advantage to U.S. primary products, inducing diversion of resources from the manufacturing sector into the primary sector.

Overall the role of trade costs is substantially downplayed under the second scenario. While the trade cost shocks reduces $Y_{m,us}$ by half (from 198% to 100%) and increases $Y_{a,us}$ almost by a factor of three (100/34.8) under the first scenario, the effects of the shocks under the second scenario are relatively minimal. These are straightforward given such extreme changes under the first approach and much more moderate changes under the second approach. As seen in the table, the trade cost shocks have slightly favourable effects on $Y_{m,us}$ while having negative impacts on $Y_{a,us}$.

3.1.4 Including Capital

The baseline model does not include capital as a factor of input. U.S. capital stock increased more than ten folds during the periods (Kendrick, 1961) and it is hard to deny that capital was one of the crucial factors for U.S. economic growth. As discussed earlier, incorporating capital into the model properly is a very complicated matter as it needs to be endogenized. However if one is willing to be more *ad-hoc*, including capital as an exogenous factor can still provide more insights. By doing this, I can analyse the contribution of capital in U.S. economic growth. More importantly, this has an important implication on the effects of immigration on the Anglo-American real wage convergence to be covered in Chapter 5.

I need to introduce additional parameters in the model to include capital. I assume that all three sectors employ capital as an input. I then need the capital share parameters in the production functions which I take from O'Rourke and Williamson (1994). Changes in capital stock are taken from

Kendrick (1961) and Feinstein and Pollard (1988) for the U.S. and Britain, respectively. Calibration procedure is almost identical as the baseline model. I perform a growth decomposition exercise similar to the previous one without capital. For comparison I use the measured TFP shocks employed in the baseline case and the trade cost shocks taken from Jacks et al. even though this scenario substantially over-predicts the growth of U.S. manufacturing sector.[41] The results are reported in Table 28.

Table 28: Decomposing contribution of each shock with capital(%)

			$A_{a,us}$	$A_{m,us}$	$\underline{N}_{us}$	$\underline{K}_{us}$	$\underline{L}_{us}$	$A_{s,us}$	actual T	$\underline{L}_{us}$+$\underline{K}_{us}$
RGDP	w/ K	cumul.	-*	4.9	6.2	34.1	87.2	99.1	100.0	-
		indiv.	-*	3.9	-*	18.6	14.3	-*	-*	54.0
	w/o K	cumul.	1.6	7.4	11.0	-	75.2	99.2	100.0	-
		indiv.	1.6	5.8	-*	-	41.4	5.1	0.2	-
$Y_{m,us}$	w/ K	cumul.	-*	4.8	2.9	38.6	94.3	94.3	100.0	-
		indiv.	-*	6.3	-*	15.0	1.9	-*	-*	41.3
	w/o K	cumul.	-8.1	12.9	8.3	-	93.1	93.1	100.0	-
		indiv.	-8.1	16.5	-*	-	36.1	-5.0	-5.6	-
$Y_{a,us}$	w/ K	cumul.	-*	10.4	30.7	37.7	109.6	109.6	100.0	-
		indiv.	-*	-3.2	-*	17.7	62.6	-*	-*	70.2
	w/o K	cumul.	29.4	5.5	39.1	-	107.0	107.0	100.0	-
		indiv.	29.4	-8.4	-*	-	53.5	9.3	10.3	-

-* indicates no equilibrium

To make comparison easier I also report the results from the case without capital (Table 27). One noted difference between the two cases is that the role of the labour force shock is substantially downplayed when I include the capital shock. Without capital, $\underline{L}_{us}$ contributes 41.4% and 36.1% to the

[41] If I measure the TFP as a residual like I did in the baseline case, capital needs to be accounted for. Manufacturing TFP shocks for the U.S. and Britain are $\Delta A_{m,us} = 1.10$ and $\Delta A_{m,b} = 1.01$, respectively. Note that the shocks are smaller than the shocks in the baseline case.

growth of real GDP and $Y_{m,us}$, respectively. But it decreases to 14.3% and 1.9% when I included capital. This is rather expected because as one more factor of input is included, the roles of other inputs inevitably subdue. In this sense, it would be more ideal to interpret $\underline{L}_{us}$ in the baseline case as factors of inputs rather than labour force itself. In that vein, the contribution of $\underline{L}_{us}$ in the case without capital and $\underline{L}_{us}+\underline{K}_{us}$ in the case with capital should be compared to evaluate the role of factor inputs. $\underline{L}_{us}$ alone in the former case contributes 41.4%, 36.1% and 53.5% to the growth of real GDP, $Y_{m,us}$ and $Y_{a,us}$, respectively. In the latter case, $\underline{L}_{us}$ and $\underline{K}_{us}$ together contribute 54.0%, 41.3% and 70.2% to the growth of these variables. Comparing these numbers, the model with capital puts slightly more weights on the role of factor inputs, overall magnitudes of contributions of each force are similar in both scenarios. Including capital in the model also predicts that the role of input was substantially more important for the growth of U.S. economy under the presence of the scale economies.

3.1.5 Implications Under Constant Returns

In this section, I perform the same exercise using the CRTS model. The results from this exercise will be compared with the baseline results (Table 25). Here let me restate and emphasize that two things are different in the CRTS model, the implied change in the manufacturing TFP and the trade costs. The implied change in $A_{m,us}$ under the CRTS is higher than that under the IRTS and the magnitudes of change in trade costs involving the U.S. in the CRTS are a bit smaller than those in the IRTS. The results are presented in Table 29.

The overall result does not change much from the baseline result, including that the increase in $\underline{L}_{us}$ still is the factor that contributes the most to the overall development of the U.S. One noticeable difference, however is that the CRTS model reduces the quantitative implications of $\underline{L}_{us}$. Par-

Table 29: Decomposing contribution of each shock under CRTS (%)

		$A_{a,us}$	$\underline{N}_{us}$	$A_{m,us}$	$\underline{L}_{us}$	$A_{s,us}$	T	$A_{m,us}+\underline{L}_{us}$
RGDP	cumul.	1.3	5.1	12.8	75.6	100.5	**100.0**	-
	indiv.	1.3	3.0	7.3	38.8	5.4	-*	62.1
$Y_{m,us}$	cumul.	3.2	0.2	33.8	157.5	157.5	**100.0**	-
	indiv.	3.2	1.8	50.6	58.0	5.5	-*	206.7
$Y_{a,us}$	cumul.	4.0	30.7	12.3	59.9	59.9	**100.0**	-
	indiv.	4.0	14.9	-22.9	25.3	-7.0	-*	-4.7
$\frac{Y_{m,us}}{Y_{m,w}}$	cumul.	5.8	4.5	16.1	44.7	44.7	**31.8**	-
	indiv.	5.8	5.2	21.7	23.7	6.6	-*	54.4
$\frac{Y_{a,us}}{Y_{a,w}}$	cumul.	5.3	7.9	6.1	9.9	9.9	**13.9**	-
	indiv.	5.3	6.4	2.6	7.1	4.3	-*	4.1

-* indicates no equilibrium

ticularly, its contribution to the real GDP growth decreases from 46.9% in the baseline case to 38.8% in the CRTS case. The reduction of its impact is more pronounced in the manufacturing sector. It alone accounts for 58% of the increase in $Y_{m,us}$ compared to 99% in IRTS. On the other hand, its role is relatively more important in the primary sector, contributing 25.3% of the growth, compared to mere 5.0% in IRTS. The intuition behind this result is very clear. The existence of economies of scale highlights the role of $\underline{L}_{us}$ in the baseline model.

Also note the implications of the trade costs. The trade cost shocks do not have much impact on the real GDP unlike the baseline case. Feeding in the trade cost shocks on top of everything else only depresses the real GDP by 0.5% whereas in the baseline it is reduced by 11.9%. So the changes in trade costs are not so unfavourable to the overall economy. But at the sectoral level, it generates similar results as the baseline model. The changes depress the manufacturing sector while promoting the primary sector. But

Table 30: Decomposing trade cost shocks under CRTS (%)

	$T^a_{i,us}$	$T^a_{us,i}$	$T^m_{i,us}$	$T^m_{us,i}$	T^a_{us}	T^m_{us}
RGDP	-1.1	0.1	0.6	-0.9	-1.1	-0.7
$Y_{m,us}$	-21.7	-1.0	-0.7	-12.5	-21.9	-13.1
$Y_{a,us}$	24.5	1.1	2.0	14.5	24.6	15.4

the magnitude of impact is smaller under the CRTS assumption with $Y_{m,us}$ decreasing by 57.5% (vs. 98.1%) and $Y_{a,us}$ increasing by 40.1% (vs. 65.2%) due to the trade cost shocks. As discussed earlier, these quantitative differences mainly come from the different implied changes in trade costs. In Table 30 below, I perform an exercise that decomposes the contribution of trade costs, similar to the ones in Table 26.

The results in Table 30 are very similar to the results in Table 26 qualitatively, if not identical. Basically the changes in $T^a_{i,us}$ and $T^m_{us,i}$ are the ones that matter most as the changes in $T^a_{us,i}$ and $T^m_{i,us}$ have much less impact on these variables. The quantitative implications are smaller because the magnitudes of the implied changes are smaller than the baseline case as discussed above.

3.2 Assessing the Effects of IRTS

3.2.1 Introduction

In this section, I disentangle the effects of increasing returns to scale in manufacturing. As discussed in Chapter 1, while the existence of IRTS in U.S. manufacturing during this period is still a debated issue, some studies point out that this was a crucial feature that promoted the development of U.S. economy during this period.[42] But, to my knowledge, its quantitative

[42]See Chapter 1 for more discussion about this.

effects have never been evaluated and in this section I try to pursue this goal. Before I turn to the procedure and result, I discuss more about the IRTS assumption imposed in the model.

There are several ways to consider the economies of scale. For example, Johnston (1990), in investigating the possible impact of Civil War debt repayment, assumes that there existed learning effects from investments in U.S. production technology. More specifically, he postulates that investments also generate industrial knowledges about how to manage and produce more efficiently. This knowledges cannot be kept private but 'spill over' to other producers, thus creating positive externalities. In other words, he applies the famous mechanism emphasized by the endogenous growth literature. According to this line of thought, the production function would look like the following,

$$Y = AL^{\alpha}K^{1-\alpha+\mu} \quad \text{where} \quad 0 < \alpha < 1 \ \text{ and } \ \mu > 0$$

where Y is output, L is labour supply and K is capital. Obviously, $\mu > 0$ creates the economies of scale as well as positive externalities. This kind of externality is called 'non-pecuniary externality' or 'technological externality'. According to Ottaviano and Thisse (2000), this kind of IRTS and the externalities generated seem to be more reasonable to explain 'geographical cluster of somewhat limited spatial dimension such as cities and highly specialized industrial districts'.

On the contrary, the externality generated by the kind of IRTS considered in the model is called 'pecuniary externality'. The origin of externality is clearer in this case as it emphasizes the role of market interactions among consumers and firms whereas 'non-pecuniary' externality is perceived as a 'black-box'. More specifically, the pecuniary externality is generated by the agglomeration force due to the backward and forward linkages which are responses to changing prices and market conditions.[43] Also Ottaviano and Thisse (2000) puts forward an argument that the pecuniary externality is more ideal to explain 'inter-regional agglomeration such as the Manufacturing Belt in the U.S. and the Hot Banana in Europe'.

Finally, under the current assumption about the IRTS, it seems much easier to pin down the parameters that control the degree of IRTS and externality. For example, the value of the fixed cost, F, can be anything as it does not influence the aggregate variables. And α_m, the parameter that determines the share of manufacturing intermediate usage and the agglomeration effect, can be calibrated using input-output tables. On the other hand, at least, the process of determining μ does not look as simple as that as one needs to correctly identify the pure technology (or residual) shock from the spill-over effects.

3.2.2 Procedure and Results

The CRTS model from the previous chapter yields identical calibrated parameters and benchmark equilibrium as the baseline IRTS model. In addition the results generated from the CRTS model account for the data in 1913 quite closely and yield almost identical results as the baseline IRTS model.[44] This gives an ideal condition to isolate the effects of IRTS. A simple way to do this is to feed in the shocks implied by the *IRTS* framework to the *CRTS* model. Note that the changes in endowments are measured using *a priori* informations so that they are identical under both frameworks. The measured changes in TFP for primary and services sector for Britain and the U.S. are identical as well, as they are assumed to have same functional forms. But the implied changes in the manufacturing TFP for all regions and the primary TFP for the rest of world and the trade costs take different values. The effects of IRTS can be isolated as the difference between the

[43] see Fujita, Krugman and Venables (1999) for the details.

[44] See Chapter 2 for details.

results generated by this exercise and that by the IRTS model. Table 31 below presents the result for U.S. economy.

The first two columns are restatements of the data and of the baseline equilibrium for the sake of comparison. The last column presents the simulation results. We can see that without IRTS, U.S. share of world manufacturing is reduced to 25.1% from 32.2%. Therefore IRTS contribute about 7 percentage point increase in the share. And without the IRTS the model only accounts for around 67% of increase in manufacturing output (6.52/9.74). So the remaining 33% can be attributed to the presence of IRTS. On the other hand, the primary sector grows about 7% without the IRTS in manufacturing ($\frac{3.24-3.04}{3.04}$). This is natural because the U.S. loses its comparative advantage in manufacturing coming from the scale economy and consequently the comparative advantage shifts to the primary. This can be readily seen in the results for the trade in Table 32 below. Finally IRTS accounts for about 10% of the increase in real GDP.

Table 31: The effects of IRTS on U.S. economy

	Data	BL IRTS	IRTS removed
Share in world primary (%)	14.4	13.9	14.8
Share in world manufacture (%)	31.9	32.2	25.1
Share of LF in primary (%)	30	37	41
Share of LF in manufacture (%)	30	32	27
$Y_{a,1913}/Y_{a,1870}$	2.58	3.04	3.24
$Y_{m,1913}/Y_{m,1870}$	9.46	9.74	6.52
CF RGDP / BL RGDP	-	-	0.90

BL: baseline, RGDP: real GDP

The effects of IRTS in manufacturing are not small and they are more pronounced in manufacturing, as expected. But again I emphasise that these results are more meaningful *if* the assumption of IRTS is valid.

Table 32: Implications of IRTS on U.S. trade

	Data	BL IRTS	IRTS removed
Exports/GDP	0.06	0.04	0.05
manu. exports / total exports	0.50	0.61	0.19
manu. imports / total imports	0.44	0.32	0.74

BL: baseline simulation

3.3 Conclusion

In the first part of this chapter, I disentangled the effects of changes in land, labour force and sectoral TFP on U.S. economy. Two main points emerge from this exercise. First, it depends on how I treat the trade cost shocks but the massive increase in labour force and capital was the single outstanding force that contributed to the development of the U.S. over the period. In terms of sector, it was unproportionately more beneficial to manufacturing than primary.

The second point is that the changes in trade costs were not beneficial to the U.S. at all, especially to its manufacturing sector, when the trade cost shocks are calibrated. The trade statistics suggest that by 1913 the U.S. was still importing too much manufacturing despite its huge comparative advantage in this sector and for the model to account for this historical fact, the *implied* changes in manufacturing trade costs from other regions to the U.S. have to be very low as depicted in Table 14 and 23 in Chapter 2. On the other hand this may be partially attributable to the aggregation of the rest of world, as discussed earlier. In order to remedy this, the changes in trade costs need to be measured/calibrated more accurately. For this purpose, the rest of world should be disaggregated into more regions and the trade costs between the U.S. and those particular regions need to be calibrated.

When I include more realistic values for the trade costs, the role of the shocks changed dramatically both qualitatively and quantitatively from the baseline case. Their quantitative significance reduced substantially and the shocks were beneficial to the manufacturing sector as opposed to it benefited the primary sector in the baseline case.

Chapter 4

Tariffs and the Development of the U.S.

4.1 Introduction

Throughout the nineteenth and early twentieth century, the U.S. maintained high tariff rates on manufacturing imports, averaging about 33%. This period of high protectionism is associated with the rapid economic growth, especially the development of its industrial or manufacturing sector. According to Bairoch (1982), U.S. share of world manufacturing production in 1860 was only 7.2% but its share surged to 32.0% in 1913. This correlation between growth and high tariffs has often been used as a historical justification for protective trade policies by politicians, scholars and other prominent figures.[45] However others argue that the tariffs mattered far less for U.S. economic development.

The controversy generated many works that shed light on this issue.

[45]See Batra (1993), Buchanan (1998) and Chang (2002). Irwin (2001) also provides a summary of this when the debate was heated in 1990's.

O'Rourke (2000), Clemens and Williamson (2004) and O'Rourke and Lehman (2008) clearly document that tariffs are positively correlated with growth by analysing a cross-section of countries including the U.S. during this period. Irwin (2001 and 2002), in a partial equilibrium analysis, finds the high tariffs on U.S. iron imports did not play a quantitatively large role in promoting the domestic iron industry in 1869. James (1978), using a computable general equilibrium model, analyses the antebellum U.S. economy and concludes that the quantitative impact of the tariffs on the development of its manufacturing was small in 1859.[46] This paper attempts to contribute to these existing works by exploring the quantitative implications of the manufacturing tariffs on the development of U.S. economy from 1870 to 1913. To do this I ask a historically counterfactual question: Could the U.S. have developed as it did *if* tariffs on its manufacturing imports had been eliminated?

My work differs from those studies in several aspects. First, I use a general equilibrium model that focuses on the postbellum U.S. economy. This period deserves a similar quantitative analysis as in James (1978) and Harley (1992) because U.S. manufacturing during this period experienced an unprecedented growth while the tariff rates on manufacturing imports were maintained at even higher levels than the antebellum period. Secondly, I introduce a simple dynamic by assuming that there exists learning-by-doing in U.S. manufacturing sector.[47] The static nature of the previous studies allow one to see only one-time effects of eliminating the tariffs. So these studies do not investigate a question like: what the U.S. would have been like in 1859

[46]The U.S. was a net exporter of primary products such as raw cotton and a net importer of manufacturing products during the antebellum period. In his model the protection of U.S. manufacturing had terms of trade improving effects because of the market power it had in raw cotton. This force acted against the expansion of the manufacturing sector. Harley (1992) argues that this effect generated in James' model is largely due to his unintended assumption that the U.S. also had market power in food. He demonstrates that if this is corrected, the tariff protection does not generate such a large terms of trade improving effects and the quantitative impacts of the tariffs on U.S. manufacturing are much larger than what James suggests.

[47]David (1970) argues that there existed strong learning effects in U.S. textile industry during the nineteenth century.

if it had not imposed any tariff on the manufacturing imports since 1812. In contrast my model allows one to explore this kind of question. Finally my model has a novel feature that there exists increasing returns to scale (IRTS) in the manufacturing production. More specifically this assumption is teamed up with another assumption that the manufacturing sectors use manufacturing intermediate inputs. These features can generate the agglomeration of manufacturing, as emphasized in the New Economic Geography literature. Indeed these are important features that have not been considered in this kind of quantitative analysis on U.S. economy. James (1983) and Cain and Paterson (1986) clearly document that economies of scale in U.S. manufacturing were substantial and pervasive during this period. Also Crafts and Venables (2001) argue that the agglomeration effect was an important force behind the industrialization of the U.S. These additional features allow me to explore the role of tariffs in generating the agglomeration of manufacturing in the U.S.

I focus on several dimensions of the development: the large increase in U.S. share of the world manufacturing output; the growth of its primary and manufacturing output; and its structural transformation. When doing this analysis, it is important to account for forces other than the tariffs that could have mattered for the rise of U.S. manufacturing during this period. To do this I use the model introduced in Chapter 2 to isolate the effects of the tariffs from other forces. It allows for exogenous changes in sectoral productivities; endowments in labour and land; and trade costs.[48] The tariffs make up a part of the trade costs - expressed in tariff-equivalent terms - calibrated in Chapter 2.

The calibrated model from Chapter 2 is used to analyse the quantitative implications of the tariffs. I proceed in two steps. First, I look at the static implications of the tariffs. I do this by feeding in the counterfactual changes

[48]See Chapter 1 for more discussion of these forces.

in trade costs when U.S. manufacturing tariffs are removed in 1913, while keeping other changes unaltered. The results from this exercise suggest that even though tariffs help promote the manufacturing sector, its quantitative impacts are small, contributing only 3% to the growth of manufacturing output. Intuitively, this is because a large part of comparative advantage shifted to the manufacturing by 1913 due to the exogenous increase in its productivity and economies of scale. Also the role of tariffs in generating the agglomeration effect is somewhat limited.[49]

Then I look at the dynamic implications of the tariffs by assuming that learning-by-doing effects exist in U.S. manufacturing sector. In particular I assume that cumulative experiences, proxied by cumulative output, have positive spill-over effects on productivity. For this I decompose U.S. manufacturing TFP and identify the part contributed by learning effects. With learning effects, eliminating the tariffs during the period generates further amplifying effects than in the first exercise. Because now manufacturing TFP is endogenous to the cumulative output and a no-tariff-economy would generate less cumulative output by 1913 than in the static case. And the counterfactual level of the manufacturing TFP in 1913 would be lower than the static case. Even with learning-by-doing effects, the results don't change much. Under an extreme case where the entire TFP increase comes from learning, tariffs only contribute about 7% to manufacturing growth and its world share of manufacturing output drops only by 2 percentage points. The overall results of this exercise quantitatively support the recent arguments made by Irwin (2001 and 2002).

In addition to the works introduced earlier, more works investigate the role of the tariffs in promoting U.S. iron industry. Head (1994) introduces

[49]In this framework, the agglomeration of manufacturing is generated by the positive feedback between the backward and the forward linkage, as emphasized in the New Economic Geography literature. The forward linkage in a region arises as it becomes less costly to produce in that region and the backward linkage arises as firms in that region face increased demands for their products. The positive feedback between the two linkage effects induce more firms to locate in that region, thus generating the agglomeration.

learning-by-doing to examine the impacts of tariff on U.S. steel rail industry and finds that the overall welfare effects of the tariff were positive. Naknoi (2008) demonstrates that without tariff protection the industry would have been wiped out by 1881 when learning-by-doing effects are considered. These studies focus on particular industries and use partial equilibrium analysis. In contrast mine focuses on the overall economy and uses a general equilibrium model.

4.2 Effects of Tariffs on U.S. Manufacturing

Before moving to numerical exercises I explore the channels through which the tariffs can influence the manufacturing production in a more analytical fashion. To simplify I consider the case when the manufacturing tariffs imposed on imports from Britain are decreased which, in turn, reduces $T^m_{b,us}$.

Substitution Effect: U.S. demand for Briatin's manufacturing products, $m_{us,b}$ can be easily derived from equation (6) as

$$m_{us,b} = n_b p_b^{-\sigma_m} E_{m,us} G_{m,us}^{\sigma_m - 1} (T^m_{b,us})^{1-\sigma_m}$$

A direct effect of reducing $T^m_{b,us}$ is that $m_{us,b}$ increases as $\frac{\partial\, m_{m,us}}{\partial\, T_{b,us}} < 0$. This is because Britain's manufacturing products for U.S. consumers get relatively cheaper and they demand more of them. And they replace domestic products with imports from Britain. As a result demands for Britain's manufacturing relative to their own also rise.

$$\frac{\partial}{\partial T_{b,us}} \left(\frac{m_{us,b}}{m_{us,us}} \right) = (1 - \sigma_m) \left[\frac{n_b}{n_{us}} \right] \left[\frac{p_b}{p_{us}} \right]^{-\sigma_m} T_{b,us}^{-\sigma_m} < 0$$

As they substitute domestic products with Britain's, the domestic manufacturing sector shrinks and $n_{m,us}$ or $Y_{m,us}$ decreases.

Demand Effect: As $m_{us,b}$ increases this instantaneously raises $n_{m,b}$ or $Y_{m,b}$.

Then Britain's demands for U.S. intermediate manufacturing, denoted as $im_{b,us}$, will increase.

$$im_{b,us} = (1 - \alpha_m) n_{m,b} p_{m,b} F(\sigma_m - 1) \left(\frac{T_{us,b}}{G_{m,b}} \right)^{1-\sigma_m}$$

It is easy to see $\frac{\partial\, im_{b,us}}{\partial\, n_{m,b}} > 0$. This effect alone will increase exports of U.S. manufacturing to Britain, therefore $n_{m,us}$.

According to the substitution effect, eliminating the tariffs would shrink the size of U.S. manufacturing while the exports effect says it would promote the sector. But this is not the end of the story. There is one more important force to consider that is closely related to the model's assumption that the manufacturing sector exhibits IRTS and it uses itself as intermediate inputs.

Price Index Effect: From equation (2), it can be seen that a decrease in $T^m_{b,us}$ directly reduces $G_{m,us}$ because for U.S. consumers, Britain's manufacturing goods become relatively cheaper. This effect alone generates the forward and backward linkage effect, emphasized in the New economic geography literature. As manufacturing inputs become cheaper, more firms will be located in the U.S. leading to an increase in $n_{m,us}$ and $Y_{m,us}$ (forward linkage). As more firms are located in the U.S., the demand for manufacturing intermediate will increase, inducing further increase in $n_{m,us}$ (backward linkage). This effect can also simply be summarized as a multilateral resistance effect from Anderson and Wincoop (2003). Of course this is the direct effect of decreasing $T^m_{b,us}$ while holding other variables constant. In the general equilibrium framework, we can not hold other variables constant. For example, $n_{m,us}$ and $n_{m,b}$ that affect $G_{m,us}$ vary as well. Thus the linkage effect can arise from the substitution and export effect too. To see whether eliminating the tariffs generate a positive or a negative linkage effect, I have to resort to simulation exercises.

Considering learning-by-doing has additional effects on $Y_{m,us}$ through its influence on $A_{m,us}$. For now I will assume that a reduction in $T^m_{b,us}$ decreases $A_{m,us}$. Then this instantaneously raises the domestic price of U.S. manufacturing, $p_{m,us}$. This affects $Y_{m,us}$ negatively through two channels.

(Additional) Demand Effect : region i's demand for U.S. manufacturing can be written as

$$\begin{aligned} m_{i,us} &= (p_{m,us})^{-\sigma m} E_{m,i} \left(\frac{T_{us,i}}{G_{m,i}}\right)^{1-\sigma m} \\ &= \left(\frac{\omega_{us}^{\alpha m} G_{m,us}^{1-\alpha m}}{A_{m,us}}\right)^{-\sigma m} E_{m,i} \left(\frac{T_{us,i}}{G_{m,i}}\right)^{1-\sigma m} \end{aligned}$$

It is easy to see that $\frac{\partial\, m_{i,us}}{\partial\, A_{m,us}} > 0$. Obviously as the price of U.S. manufacturing increases the demand for U.S. products goes down. And this will in turn decrease U.S. manufacturing output.

(Additional) Price Index Effect : From equation (1) we can see that $\frac{\partial\, G_{m,us}}{\partial\, p_{m,us}} > 0$. An increase in $p_{m,us}$ will increase $G_{m,us}$ and generate the linkage effects that will decrease $Y_{m,us}$ further.

In this comparative static exercise I demonstrated main channels through which the tariffs can have impacts on U.S. manufacturing output. Simulation exercises later will evaluate which effects come to dominate.

4.3 The Average Tariff Rates

In this section I calculate the average tariff rates for U.S. imports. The average tariff rate is defined as the amount of duties collected divided by the amount of total imports. All the relevant sources are obtained from *The Statistical Abstract of the United States* and *The Annual Reports of the Commerce and Navigation of the United States*. Figure 1 illustrates the average tariff rates of the U.S. from 1870 to 1913.

The average tariff rate decreased substantially from 1870 to 1913. But through out the period the level of manufacturing tariff rate was higher than the overall rate with the gap being reduced as it gets toward the end. Even though not illustrated here, the tariff rates on *dutiable* imports did not change much during this period, thus the reduction of the average tariff rates was mainly due to reduction in the contents of dutiable imports.

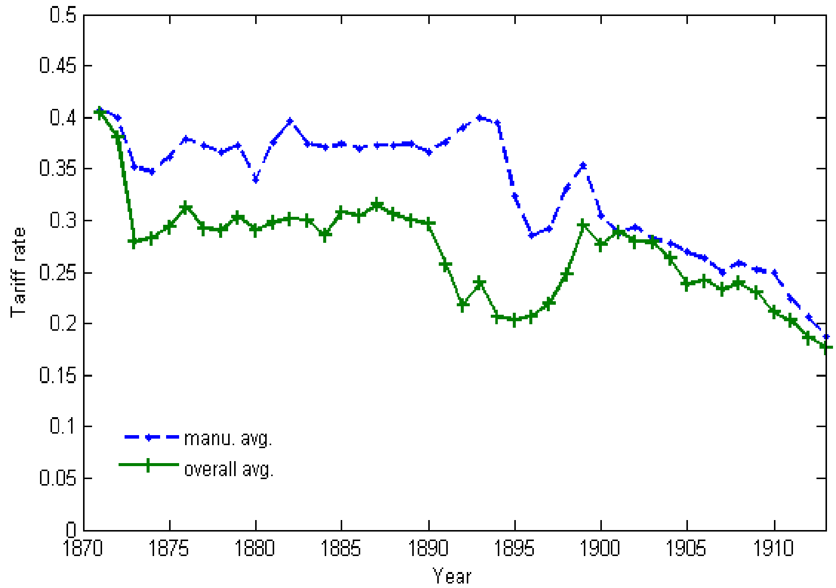


Figure 2: U.S. tariff rates from 1870 to 1913

4.4 Static Implications of the Tariff

To explore the role of tariff, the baseline model presented in Chapter 2 is used except that I use the counterfactual changes in trade costs implied by the case of no manufacturing tariff for the U.S. The relevant number here is the tariff rate on manufacturing imports in 1913 which is 0.188. I subtract this number from the relevant trade costs, $T^m_{b,us}$ and $T^m_{rw,us}$ in 1913. Then I can calculate counterfactual changes in trade costs from 1870 to 1913. I feed in these changes to see the implications of U.S. manufacturing tariffs. One thing to note is that under the assumption, removing the tariffs during the whole periods and only in 1913 have identical impacts on the economy in 1913. This is because the changes in tariffs do not influence other exogenous forces. But it would be interesting to know the implications of eliminating the tariffs in other years, especially in the earlier years of the period. So I look at the effects of the tariffs in 1870 when the rate is 0.408. As we can also observe from Figure 1 the average rate actually decreased substantially from 1870 to 1913. But as noted the tariff rate on dutiable imports did not change much during the period. This could imply that the effective rate of protection did not change much from that in 1870. So I add one more counterfactual exercise where I assume that in 1913 the level of protection is similar to that of 1870.

4.4.1 Main Results

Now I am ready to study the effects of the manufacturing tariff on the development of U.S. economy. Table 33 presents the outcomes of these exercises.

Eliminating U.S. manufacturing tariffs in 1913 transforms U.S. economy into a relatively more agrarian economy with its primary share rising from 13.9% to 14.1% and its manufacturing share decreasing from 32.2% to 31.3%. Also the share of the labour force in the primary sector increases from 37% to 38% while the share in the manufacturing sector decreases from 32% to 31%. The manufacturing tariff contributes about 3% to the growth of manufacturing output in 1913 ($\frac{9.74-9.47}{9.74}$). In 1870 removing the tariffs has larger impacts on the manufacturing output, contributing about 14%. Finally assuming that the rate in 1913 is the same as that of 1870 at 40.8% and eliminating this amount decreases the manufacturing output by 8%. In all cases, the tariffs contribute positively to U.S. manufacturing output. As the tariff is eliminated foreign manufacturing goods become relatively cheaper and the U.S. imports more of them. As the foreign manufacturing imports replace the domestic manufactured goods (in terms of final, as well as intermediate consumption), resources are diverted away from the manufacturing to the other sectors. So the manufacturing activity shrinks while the primary one expands (*the substitution effect*).

To see this more clearly I perform an exercise that decomposes the contribution of the tariffs to the growth of $Y_{m,us}$ the results of which are presented in Table 34. When the tariffs are removed in 1913, due to *the demand effect* the total exports of the U.S. rises and its contribution to U.S. manufacturing growth is about 1.6%. But as U.S. consumers substitute their own products with cheaper imports, the domestic production of manufacturing decreases. In other words, *the substitution effect* drives $Y_{m,us}$ down by 4.3%. The net effect is that the manufacturing output is reduced by about 3% by elimination of the tariffs as we saw in Table 34.

The decrease in $n_{m,us}$ (or $Y_{m,us}$) due to removing the tariffs creates a force *against* the backward linkage in U.S. manufacturing sector. This is because as less firms are located in the U.S., there is relatively less demand for the manufacturing intermediate inputs by U.S. firms. This reduces incentives for firms to locate in the U.S. What about the forward linkage? As we can see from Table 34, the manufacturing price index for the U.S. relative to other regions ($\Delta\frac{G_{m,us}}{G_{m,b}}$ and $\Delta\frac{G_{m,us}}{G_{m,rw}}$) decreases due to the tariff elimination. This is largely due to the decreases in $T^{m}_{b,us}$ and $T^{m}_{rw,us}$ that directly reduce $G_{m,us}$ relative to others. This implies the tariff elimination creates the forward linkage because lower $G_{m,us}$ means it is cheaper for firms to locate and buy the intermediate inputs in the U.S. Summing up, the tariff protection promoted U.S. manufacturing by creating the backward linkage but at the same time it also created a force against the forward linkage by increasing the manufacturing price index. So it did not really generate any feedback between the forward and the backward linkage. This means that the role of the tariffs teamed up with IRTS in generating the linkage effects and the agglomeration of manufacturing in the U.S. was somewhat limited. This can be one reason why its quantitative impacts are small.

The reason that the tariffs have larger impacts in 1870 than in 1913 is partially because the average tariff rate is lower in 1913 than in 1870. But as can be observed in Table 33, eliminating the 1870-tariff-rate in 1913 still yields the qualitatively same results. Intuitively, this is because the major part of U.S. comparative advantage was already in the manufacturing sector by 1913, due to the growth in the manufacturing productivity and economies of scale arising from the large increase in labour force. So the role of tariff protection became less important in 1913 compared to in 1870.[50] The impacts of the tariffs can vary according to the economy's comparative advantage. In other words, if one has a strong comparative advantage in the primary sector, then by imposing high tariffs on manufacturing imports, it can better prevent the movement of labour out from the manufacturing sector. This is indeed a point made by Irwin (2002) who analyses 27 countries from 1870 to 1913. But by 1913, the U.S. already had a strong comparative advantage in the manufacturing and the effects of tariffs were not so large.

This is the conclusion that can be drawn *if* the TFP is exogenous to the levels of tariffs. But this does not always have to be the case. If I assume that there exists learning-by-doing effects in U.S. manufacturing then the tariffs affect the level of productivity. Because learning-by-doing assumes cumulative experiences generate spill-over effects and positively affect productivities. So I analyse the implications of the tariffs when learning-by-doing is present. But before moving on to this exercise, I perform a sensitivity

[50]To see this point more clearly, I performed an exercise (not reported here) to look at the implication of the tariffs when the U.S. has a smaller degree of comparative advantage in manufacturing by controlling for its productivity growth. More specifically I assume a counterfactual world where U.S. manufacturing TFP grows at the same rate as that of Britain from 1870 to 1913 while keeping the changes in other forces identical as in the baseline case. In this case the tariffs contribute to about 14% (not mere 3%) of the growth of manufacturing output.

analysis first.

Table 33: Static implications of tariffs

	1913 (18.8%)			1870 (40.8%)			1913* (40.8%)		
	BL	CF	CONT	BL	CF	CONT	BL	CF	CONT
Share in world primary(%)	13.9	14.1	-0.2 p.p	9.7	10.9	-1.2 p.p	13.9	14.4	-0.5 p.p
Share in world manufacture	32.2	31.3	0.9 p.p	10.2	8.8	1.4 p.p	32.2	29.7	2.5 p.p
Share of LF in primary	37	38	-1.0 p.p	48	51	-3.0 p.p	37	39	-2.0 p.p
Share of LF in manufacture	32	31	1.0 p.p	24	21	3.0 p.p	32	29	3.0 p.p
$Y_{a,1913}/Y_{a,1870}$	3.04	3.08	-1.3%	-	-	-3.8%	3.04	3.16	-4.0%
$Y_{m,1913}/Y_{m,1870}$	9.74	9.47	2.8%	-	-	14.3%	9.74	8.96	8.1%
CF RGDP/BL RGDP	-	1.00	-0.2%	-	1.00	-0.4%	-	1.00	-0.8%

BL: baseline simulation, CF: counterfactual, CONT: contribution, LF: labour force, p.p: percentage point

1913*: If the tariff rate were the same as that of 1870 at 40.8%.

Table 34: Effects of removing the tariffs on trade and price variables

	Contribution of exports to growth of $Y_{m,us}$ (%)					Change in manu. price index (%)	
	$us \to b$	$us \to rw$	foreign total	$us \to us$	$\Delta Y_{m,us}$	$\Delta\left(\frac{G_{m,us}}{G_{m,b}}\right)$	$\Delta\left(\frac{G_{m,us}}{G_{m,rw}}\right)$
1913 (18.8%)	0.2	1.4	1.6	-4.3	-2.8	-3.6	-3.6
1870 (40.8%)	0.2	1.3	1.5	-15.8	-14.3	-6.9	-6.0
1913* (40.8%)	0.9	5.7	6.6	-14.7	-8.1	-10.9	-11.4

$us \to b$: U.S. exports to Britain, $us \to rw$: U.S. exports to the rest, $us \to us$: U.S. domestic exports,

1913*: If the tariff rate were the same as that of 1870 at 40.8%.

4.4.2 Sensitivity Analysis

The levels of calibrated trade costs are very sensitive to the elasticity of substitution parameters, σ_a and σ_m. And these parameters are pinned down using prior information. For example, under the value used for the benchmark calibration ($\sigma_m = 7.5$), the level of manufacturing trade cost to the U.S., $T^m_{b,us}$ and $T^m_{rw,us}$, are 1.88 and 1.23 in 1913, respectively. But if I assume $\sigma_m = 6$, $T^m_{b,us}$ and $T^m_{rw,us}$ become 2.27 and 1.32, respectively. Thus under different values of the parameter, the proportion of the manufacturing tariff in trade cost varies.[51] And this difference can have quantitatively different implications. Table 35 below presents a sensitivity analysis by varying the value of σ_a and σ_m. In addition to the benchmark value of 7.5, I consider the case where $\sigma_m = \sigma_a = 6$ and 9.

First of all the baseline result is not sensitive to the different values of the elasticity of substitution parameters within the plausible range suggested by Anderson and Van Wincoop (2004). Also the effects of the manufacturing tariff turn out to be almost identical under the different values of σ_m.[52]

This sensitivity analysis also has some implications on the home bias in international trade. The home bias in international trade is well documented and pervasive. This may be no exception to the late nineteenth century North Atlantic economy. Introduction of more home bias in manufacturing would mean that the agglomeration of manufacturing is less likely. This is because even if the strong comparative advantage in manufacturing exists in the U.S., other regions would still prefer to consume unproportionately more home manufacturing goods and the relocation of manufacturing from other regions to the U.S. based on the linkage effects is less likely.

[51] For example when $\sigma_m = 7.5$, the share of the tariff in the trade cost from Britain to the U.S. is about 24% (0.21/0.88) but when $\sigma_m = 6$, it decreases to 17% (0.21/1.27).

[52] The elasticity applies to the whole manufacturing sector. Within this sector there is a large degree of variation with elasticities quite different across products at more disaggregated levels (Broda and Weinstein, 2006). Therefore it is possible that the robustness at this level might mask heterogeneity a more disaggregated level.

Table 35: Sensitivity analysis

	$\sigma_m = 6$		$\sigma_m = 7.5$		$\sigma_m = 9$	
	BL	CF	BL	CF	BL	CF
Share in world primary(%)	13.9	14.0	13.9	14.1	13.8	14.0
Share in world manufacture	32.6	31.8	32.2	31.3	32.7	32.1
Share of LF in primary	37	38	37	38	37	37
Share of LF in manufacture	32	31	32	31	33	31
$Y_{a,1913}/Y_{a,1870}$	3.06	3.09	3.04	3.08	3.02	3.07
$Y_{m,1913}/Y_{m,1870}$	9.74	9.50	9.74	9.47	9.81	9.60
CF RGDP/BL RGDP	-	1.00	-	1.00	-	1.00

BL: baseline simulation, CF: counterfactual simulation

The elasticity of substitution parameter dictates the degree of home bias. A higher value of σ_m means home goods and foreign goods are more substitutable and would mean relatively less home bias. On the other hand a lower value of σ_m means they are less substitutable and more prone to the home bias. The sensitivity analysis also tells that the results are not so sensitive to the degree of home bias.[53]

4.5 Learning-by-doing Effect

So far I have assumed that the productivity is exogenous to the level of tariff. But if there existed a learning-by-doing in U.S. manufacturing during this period, the outcome could have been different from the above. Ac-

[53]If we look at Table 10 which illustrates the trade flows among the three regions in the benchmark year of 1870, the equilibrium reflects the home bias clearly. For example, the U.S. even though it did not have a strong comparative advantage in manufacturing around 1870, the share of domestic manufacturing consumption is 90%. Out of the total expenditure of manufacturing products, 0.5, the U.S. consumes 0.45 from the domestic market and imports 0.03 from Britain and 0.02 from the rest of world. Similar patterns can be observed for Britain and the rest of world. If I narrow the focus on the consumption of manufacturing intermediates, 95% of U.S. intermediate expenditure comes from the domestic market so this market is even more home biased. This is partly the results of my calibration strategy that I match the exports to GDP ratio of each region.

cording to the learning-by-doing mechanism, the growing experiences have positive spill-over effects on the productivity. And within this framework the domestic industry could have accumulated more experiences due to the tariff protection and with learning-by-doing effects this had additional effects on the economy through enhanced productivity growth.[54] In this section I quantitatively evaluate the role of the tariff when the learning-by-doing effect is present. But before proceeding any further I discuss more about the learning-by-doing in the historical context.

Arrow (1962) was the first to lay down the theoretical groundwork of the learning-by-doing. But empirically the famous case study of the Liberty ship by Searle (1945) and Rapping (1965) demonstrated how experiences could have important implications on productivities. The Liberty ship case drew attentions of many economists because of the dramatic increase in labour productivity observed within such a short span of time. It grew, on average, by 40% annually over three years and until recently most scholars attributed this to the learning-by-doing. But in a recent study, Thompson (2001), using new and improved data set for capital, documented that the increase was more attributable to capital-deepening than to accumulated experiences.

There are a number of literatures that explore the role of learning-by-doing in the nineteenth century U.S. development. David (1970) finds that the learning effect contributed substantially to the development of the antebellum U.S. cotton textile industry. Naknoi (2008) also concludes that the learning effect was important for U.S. pig iron industry from 1870 to 1940 and without the tariff protection the industry would have been wiped out by 1881.[55]

[54] Please see the discussion of *Additional Demand Effect* and *Additional Price Index Effect* in Section 4.2 for more detailed analysis of the interaction between tariffs and learning-by-doing.

[55] Both works use the cumulative output as a proxy for the cumulative experience.

4.5.1 Strategy

Essentially the goal is to obtain a counterfactual level of U.S. manufacturing TFP in 1913, $A_{m,us}$ in case of no tariff protection. Obviously it would be smaller than the measured level in the previous section because eliminating the tariff would shrink the cumulative experience in the sector and this would negatively affect the TFP when there is a learning effect. Then I feed this counterfactual TFP to the model along with other shocks to disentangle the effect of learning-by-doing coming from the tariff protection.

In order to proceed I need to introduce a few additional assumptions to the baseline model regarding the manufacturing TFP. I do this in a simplest way possible following the literatures on the learning-by-doing.[56] As discussed earlier I now assume that the level of the manufacturing TFP depends on the cumulative experience and it can be expressed as

$$\left(A_{m,us}\right)_t = a_t E_{t-1}^{\alpha_e}$$

where a is the productivity coming from sources other than the learning effect, E is the amount of cumulative experiences and the coefficient α_e determines the learning rate. t is time subscript so the level of productivity at period t depends on the cumulative output until $t-1$. The learning rate is formally defined as $1-2^{\alpha_e}$ and interpreted as the rate at which costs fall with each doubling of cumulative experience. I use the *cumulative* manufacturing output as a proxy for the cumulative experience following the literatures. Then the equation looks like

$$\left(A_{m,us}\right)_t = a_t \left(CY_{m,us}\right)_{t-1}^{\alpha_e} \tag{38}$$

where $\left(CY_{m,us}\right)_{t-1}$ is the cumulative output of U.S. manufacturing until period $t-1$.

[56]See Arrow (1962), David (1970), Irwin and Klenow (1994) among others.

Given the specification in (38), it is important to effectively identify a_t and the no-tariff-counterfactual $CY_{m,us}$. Then I can recover the counterfactual $(A_{m,us})_t$. I describe the process below. For the ease of description I separate equation (38) into two cases.

$$\begin{aligned}\left(A^{\mathrm{BL}}_{m,us}\right)_t &= a_t\left(CY^{\mathrm{BL}}_{m,us}\right)^{\alpha_e}_{t-1} && \text{Baseline}\\ \left(A^{\mathrm{CF}}_{m,us}\right)_t &= a_t\left(CY^{\mathrm{CF}}_{m,us}\right)^{\alpha_e}_{t-1} && \text{Counterfactual}\end{aligned}$$

The first equation decomposes U.S. manufacturing TFP under the baseline specification. And the second equation describes the no-tariff-case. So for example $\left(Y^{\mathrm{CF}}_{m,us}\right)_{t-1}$ indicates the manufacturing output at period $t-1$ in case the tariff is eliminated. Also note that a_t is identical across the cases because this is the contribution to the TFP outside the learning effect.

1. I generate the sequence of $\left(Y^{\mathrm{BL}}_{m,us}\right)_t$ for $t = \{1871, ..., 1913\}$. In order to do this I introduce dynamics in a very simple manner. I assume uniform growths for the endowments, the TFPs and the trade costs from 1870 to 1913.[57] In this process I also obtain $\left(A^{\mathrm{BL}}_{m,us}\right)_t$ for all t. And I feed in the yearly changes to the baseline model to obtain the sequence of $\left(Y^{\mathrm{BL}}_{m,us}\right)_t$.

2. I obtain the sequence of $\left(CY^{\mathrm{BL}}_{m,us}\right)_t$ for $t = \{1870, ..., 1913\}$. The initial year's cumulative output, $\left(CY^{\mathrm{BL}}_{m,us}\right)_{1870}$, is calculated from Bairoch (1982). According to this, the cumulative output of U.S. industrial output from 1800 to 1870 is about 19 times larger than the output produced in the single year of 1870.[58] And with the series of $\left(Y^{\mathrm{BL}}_{m,us}\right)_t$ obtained previously, I can easily calculate $\left(CY^{\mathrm{BL}}_{m,us}\right)_t$ for $t = 1871, ..., 1913$.

3. I calculate the sequence of a_t for $t = \{1871, ..., 1913\}$. With $\left(A^{\mathrm{BL}}_{m,us}\right)_t$,

[57] I already calibrated these values for 1870 and 1913 in the previous chapter and I calculate the annual growth rates implied by these numbers.

[58] The reason that I chose the initial year as 1800 is because Bairoch's data only begins from that year. But given the output of the single year 1800, the cumulative output until 1800 should be minimal compared to the cumulative output until 1870.

$\left(CY^{\mathrm{BL}}_{m,us}\right)_{t-1}$ and α_e given, a_t can be calculated. Choosing the value for α_e will be discussed more in detail in the following section.

4. $\left(A^{\mathrm{CF}}_{m,us}\right)_{1871}$ is calculated. Using $\left(CY^{\mathrm{BL}}_{m,us}\right)_{1870}$ and a_{1871} from 2. and 3. respectively, it can be obtained.[59]

5. I simulate $\left(Y^{\mathrm{CF}}_{m,us}\right)_{1871}$ by feeding in the counterfactual trade costs without the tariff (see figure 1 for the tariff rate) along with other shocks. And using $\left(Y^{\mathrm{CF}}_{m,us}\right)_{1871}$, I calculate $\left(CY^{\mathrm{CF}}_{m,us}\right)_{1871}$.

6. $\left(A^{\mathrm{CF}}_{m,us}\right)_{1872}$ is calculated using $\left(CY^{\mathrm{CF}}_{m,us}\right)_{1871}$ and a_{1872} followed by simulation of $\left(Y^{\mathrm{CF}}_{m,us}\right)_{1872}$. This process is repeated until $\left(Y^{\mathrm{CF}}_{m,us}\right)_{1913}$ is obtained. Then I can isolate the effects of the manufacturing tariffs in an economy where the learning-by-doing effect is present.

4.5.2 Choosing α_e

The parameter α_e that represents the learning rate is very important in this exercise because it determines the overall magnitude of the learning-by-doing effect. There are many papers that estimate this parameter for particular industries for post World War II era. But there are not many works that focus on the late nineteenth century American industry. A few exceptions are David (1970) and Naknoi (2008) as discussed earlier, but they focus on particular industries like cotton textile and pig iron. Estimation is one option but the data usually required for the estimation procedure are lacking for this time period.[60]

Therefore I take an alternative approach. I set α_e such that the learning-by-doing contributes to all of the increase in the manufacturing TFP from 1870 to 1913. In other words, a_t in equation (38) is set to be more or less constant for all t. Of course this is unreasonable as there must have been

[59] I remove the tariff from 1871, thus $\left(CY^{\mathrm{BL}}_{m,us}\right)_{1870} = \left(CY^{\mathrm{CF}}_{m,us}\right)_{1870}$

[60] Usually one needs price or cost data for the industry of interest, but, to my knowledge, appropriate price or cost data for U.S. manufacturing sector as a whole are not available.

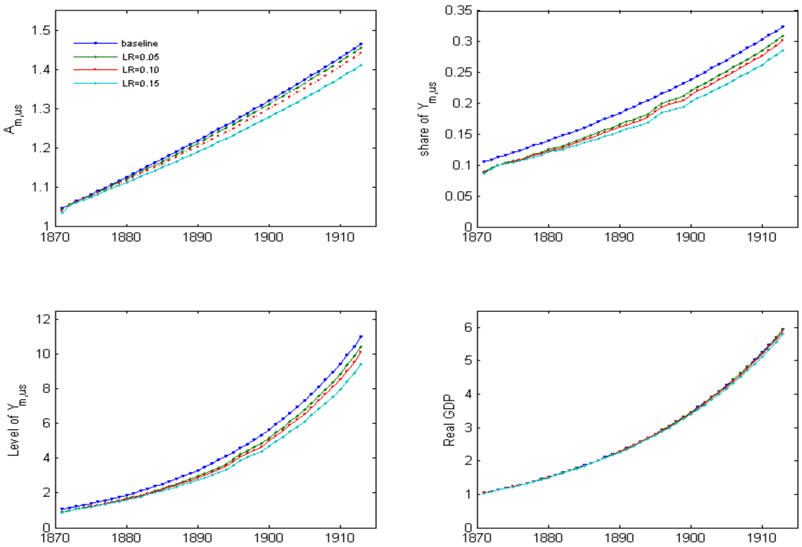
many other factors that contributed to the productivity growth. But at least this can serve as an upper-bound. So here, the goal is not to pin down an exact value for α_e but rather to define a range with an upper-bound. And the value of α_e that satisfies this condition turns out to be around 0.15, implying the learning rate of around 10%.

4.5.3 Implications of the Tariff with Learning Effect

Now I am ready to study the effects of removing the tariffs when the learning effect is present. First I plot the evolution of $\left(A^{\text{CF}}_{m,us}\right)_t$, U.S. manufacturing share, its manufacturing output and real GDP under various learning rates against the baseline cases. In doing this, I try several different learning rates which are 5%, 10% and 15%. As I have argued, the learning rate of 10% is the upper-bound implied by the model. But I also include the learning rate of 15% as this is close to the rate estimated by Naknoi (2008) for U.S. pig iron industry from 1870 to 1940. The result is shown in Figure 3 below.

First, as I increase the learning rate, the counterfactual levels of all the variables decrease for every year. Because a higher learning rate means a given amount of cumulative experience or output generate more spill-over effects. Therefore when the tariffs are removed, a higher learning rate implies a larger foregone spill-over effects. And this implies a lower counterfactual $A_{m,us}$ (the first panel) which, in turn, decreases the counterfactual level and share of $Y_{m,us}$ more (the second and third panel). Also a lower $A_{m,us}$ has negative impacts on the real GDP even though the effect is not as pronounced as other variables (the forth panel).

Overall, the pictures illustrate that the effects of tariff are not quantitatively large even after taking the learning effects into account. Even under an implausible learning rate of 15%, the quantitative effects do not seem to be large. Especially, removing the tariffs has barely any impact on real GDP. To see this more clearly, I report the results for 1913 in Table 36 below. Under the learning rate of 10%, the counterfactual level of $A_{m,us}$ in 1913 is about 98% of the baseline case (1.387/1.408). From this result alone, one can tell that the tariffs did not generate much learning effect at all. The share of its manufacturing only drops by 2 percentage points and the manufacturing tariff only accounts for about 7% of the increase in $Y_{m,us}$ ((9.74-9.02)/9.74). Finally its impact on real GDP is minimal.



(LR=learning rate, $Y_{m,us}$ and real GDP in 1870 are normalized to 1)

Figure 3: Implications of the manufacturing tariff

The picture does not seem to change drastically when I use an even higher learning rate of 0.15. In this case, the counterfactual $A_{m,us}$ is still 96% of the baseline level (1.360/1.408) and the tariffs account for about 13% of the increase in $Y_{m,us}$ ((9.74-8.47)/9.74). Also the world share of $Y_{m,us}$ and real GDP decline by 3.5 percentage points and by 2.4%, respectively, when the tariff is eliminated ((5.929-5.788)/5.929).

Finally, under more plausible rate of 5%, the effects seem to be almost infinitesimal. The counterfactual $A_{m,us}$ is more than 99% of the baseline

Table 36: No manufacturing tariffs with learning effects in 1913

	Baseline	Learning rate		
		0.05	0.10	0.15
$A_{m,us,1913}/A_{m,us,1870}$	1.408	1.401	1.387	1.360
share in world manu. (%)	32.2	30.9	30.2	28.7
$Y_{m,us,1913}/Y_{m,us,1870}$	9.74	9.32	9.02	8.47
$\text{RGDP}_{1913}/\text{RGDP}_{1870}$	5.929	5.914	5.871	5.788

level and the tariff only contributes about 4% to the growth of $Y_{m,us}$.

A similar decomposition exercise as in the static case is conducted for a learning rate of 10% (the upper-bound) the results of which are shown in Table 37. First, when I eliminate the tariffs, U.S. exports contribute less to the growth of $Y_{m,us}$ than the case without learning-by-doing effects (1.6% vs. 0.9%). This is because as I remove the tariffs, $A_{m,us}$ decreases as well and this directly increases the domestic price of U.S. manufacturing goods, $p_{m,us}$ which in turn makes U.S. manufacturing relatively more expensive. So *the demand effect* increases the demand for U.S. manufacturing products by Britain and the rest of the world, but this is off-setted by *the additional demand effect* arising from the decrease in productivity. That is why U.S. exports increase less than the case without the learning effects.

On the other hand the domestic exports reduce $Y_{m,us}$ even more than the static case (-4.3% vs. -8.3%). This is because *the substitution effect* is larger due to the decrease in $p_{m,us}$. Finally we can see that U.S. manufacturing price index relative to others decreases less than the static case (-3.6% vs. -2.3%). This is because even though reducing $T^{m}_{b,us}$ and $T^{m}_{rw,us}$ instantaneously decreases $G_{m,us}$, an additional force comes in. Now decreasing the trade costs is associated with a lower $A_{m,us}$ and this alone leads to a higher $p_{m,us}$ and higher $G_{m,us}$ through *the additional price index effect.*

Summing up, the manufacturing tariffs when the learning effects are

Table 37: Effects of removing the tariffs in 1913 on trade and price variables

Contribution of exports to growth of $Y_{m,us}$ (%)					Change in manu. price index (%)	
$us \rightarrow b$	$us \rightarrow rw$	foreign total	$us \rightarrow us$	$\Delta Y_{m,us}$	$\Delta\left(\frac{G_{m,us}}{G_{m,b}}\right)$	$\Delta\left(\frac{G_{m,us}}{G_{m,rw}}\right)$
0.1	0.7	0.9	-8.3	-7.4	-2.3	-2.3

present, contribute more to the growth of U.S. manufacturing sector. In terms of the linkage effect, it creates a stronger forward linkage (larger $n_{m,us}$) but still generates a force against the backward linkage (as it increases $G_{m,us}$ relative to others) but to a weaker degree.

4.6 Tariffs and Capital Accumulation

As noted earlier, capital is not included in the model and I discuss the possible implications of the tariffs on U.S. capital accumulation and its economic growth during this period. There are several channels through which a high tariff could have promoted capital accumulation. Irwin (2001) proposes a possible mechanism showing how the tariff on manufacturing imports could have helped the domestic manufacturing to expand and thus accumulate more capital as demand increased. But then he goes on to argue against this scenario based on the evidence that the relative price of capital goods and real interest rates declined sharply. He concludes that capital accumulation during this period was saving-driven rather than demand-driven.

A version of learning-by-doing mechanism emphasizes that investment produces not only capital but also knowledges and experiences which generate a positive externality and has a productivity enhancing effect. In other words, in this framework the cumulative experience is proxied by the amount of capital, instead of output. Thus capital deepening induced by the tariff could have had a further amplifying effects through productivity growth. But regarding this, De Long (1998) argues that the tariff had a depressing effect on capital accumulation. According to him, the tariff rates on capital goods were as high as on other consumer manufacturing products at about 40% throughout the period. And this not only raised the price of foreign capital goods but also the price of domestic capital goods. And this certainly would have had damaging effects on the rate of capital accumulation. According to his simple back-of-the-envelope calculation, this effect alone would reduce the real investment share of national product by 2 to 4% and the capital-output ratio by 10 to 20% in the long run. He goes further on to argue that if there is a linkage between capital accumulation and productivity, as emphasized by the learning-by-doing literature, then the high tariff could have imposed even higher costs on productivity, because depressed capital accumulation due to the tariff on capital goods must have had damaging effects on the productivity as well.

In line with this, Estevadeordal and Taylor (2008) analyses the tariff incidences before and after Uruguay Round and find that those countries that "liberalized" the tariff barriers on capital goods imports had faster GDP growth by a margin of 1 percentage point per annum. This amount seems marginal in a short run but over 20 years it implies the difference of 15-20% in the level of output. They confirm their empirical findings by demonstrating that a calibrated Solow growth model generates a similar magnitude of difference. Related to this, Taylor (1998) attributes the growth slow down of Argentina after the World War Two to the inward-looking trade policy that had implications on capital accumulation. He argues that the protection distorted the domestic cost of capital goods that machinery and equipments were 2 to 3 times more costly in Buenos Aires than in U.S. cities during the periods.

I did not explicitly explore the quantitative implications of the tariffs on investment and capital accumulation. But the U.S. was imposing high tariffs on capital goods during this period. As discussed above, some theoretical and empirical evidences suggest that this would raise the user cost of capital, thereby deteriorating capital accumulation and economic growth. Given this, the results of my analysis that the tariffs did not have quantitatively large implications, would not be biased by omitting capital accumulation in the model.[61]

4.7 Concluding remarks

Using a quantitative general equilibrium model, I disentangle the effects of U.S. manufacturing tariffs from other important forces to explore its development. The results suggest that, contrary to some of the popular beliefs, their quantitative effects are not so large. Not only their impact on real GDP is marginal but also the manufacturing sector is marginally affected. Even under unreasonably high learning rates, the effects are not so large. In addition, the role of tariffs in generating the agglomeration effect is somewhat limited. The tariff protection initially increases the number of manufacturing firms in the U.S. as consumers substitute more expensive imports for cheaper domestic products. This creates the backward linkage effect but it is not fed back into the forward linkage because the tariffs raise U.S. manufacturing price index, making the U.S. more unattractive place for firms. These results suggest that the role of tariff protection in the development of U.S. manufacturing and economy as a whole was not so crucial, at least on more aggregate levels. Then I ask what the important forces are. And it turns out that the large increase in labour force is the single most important factor behind the development of the U.S., accounting for a huge portion of

[61] Williamson (1974) proposes that the large fiscal surpluses generated by the tariffs could have 'crowded in' private investment and raised capital accumulation. But according to De Long (1998), whether this effect was quantitatively significant is not clear. He argues that given that the average tariff revenue during this period was about 1.8% of national product, about half of this was used to boost the national saving and investment and this would, in the long run, increase the level of national product by 1 to 2%. This includes the revenue from imposing tariffs on primary imports, so the amount of revenue due to the manufacturing tariffs would be even smaller.

the growth in manufacturing output and real GDP.

The results of this numerical exercise add contributions on the existing works that view the effects of tariff as marginal. These works include Taussig (1915), Temin (1964) and Irwin (2000) which analyse the iron industry and Irwin (2001) that analyses the economy as a whole.

The general equilibrium nature of this model allows for other interesting couterfactual exercises. For example, given the importance of the large increase in labour force in U.S. economic growth, I can turn my focus to this and explore the quantitative implications of mass migration. Also it is argued by Crafts and Venables (2001) that economies of scale in manufacturing and the large reductions in transport costs during this period could have helped to industrialize some countries while de-industrialize others. By including more regions and isolating transport costs, the model can test this argument.

Admittedly, as discussed earlier, I do not consider the channel that the tariff can influence U.S. economic development through capital accumulation. But the effect of this is not clear. Evidences regarding this issue provide mixed results. Some suggest that the effects of the tariff on capital accumulation could not have been large. It may even be the case that the tariff retarded capital accumulation and productivity if the negative effect of tariff on capital good imports was the dominating factor, as argued by De Long (1998). And if this was the case then the overall effect of the manufacturing tariff would be smaller than the results generated above or even be negative.

Chapter 5

The Mass Migration and the Development of the U.S.

5.1 Introduction

The nineteenth century was an age of mass migration and the U.S. was a major receiving country during this period. According to Vandenbroucke (2008), 'without international migration, U.S. population in 1900 would have been 52% below its actual value'. This implies that the mass migration to the U.S. also contributed substantially to the increase of its labour force. This will be discussed more in the following sections.

Given the significance of the mass migration on U.S. labour force, the objectives of this section are twofold. First, I explore the implications of the mass migration on the quantity side of the economy. For example I ask a counterfactual question "how would the world share of U.S. manufacturing change if there was no mass migration from 1870 to 1913?" Qualitatively some of the predictions are easier to make. For example, it certainly would have contributed positively to the economy's overall output or real GDP as it meant increased resources for the economy. But what are harder to predict are the direction of the structural transformation and the magnitude of changes in sectoral output variables. This exercise is aimed to provide some quantitative insights on the effects of mass migration.

Secondly, I focus on the price side of the economy. More specifically, I explore how much the mass migration contributed to the convergence in Anglo-American real wage gap during this period. The works of Hatton, O'Rourke, Taylor and Williamson explores this topic. But the main difference between their works and mine is that they use constant returns to scale, competitive model whereas mine assumes increasing returns in manufacturing.

I perform this counterfactual exercise in a simple way, using the baseline model introduced in Chapter 2. I already calibrated the changes in labour force endowments from 1870 to 1913 in Chapter 2. But here I calculate the changes in labour force implied by the no-migration-couterfactual and feed in these values instead of the actual ones. And by comparing the simulated outcome with that of the baseline outcome, I can disentangle the effects of mass migration.

A strand of papers explores the impacts of mass migration on U.S. economy. This includes O'Rourke, Williamson and Hatton (1994), O'Rourke, Taylor and Williamson (1996) and Hatton and Williamson (1998) among others. And their conclusion is that a substantial part of Anglo-American factor price convergence can be attributed to the mass migration. But these works are mainly concerned with the impacts of mass migration on the labour market conditions such as the convergence of the real wages and unemployment. Vandenbroucke (2008) analyses the effects of mass migration on the westward movement of population and changes in fertility. But he concludes that the migration played a minor role in the westward movement from 1800 to 1900.

The analysis of O'Rourke, Williamson and Hatton (1994) considers the role of capital by endogenizing it in a very simple manner. They assume perfect mobility of capital and it 'chases after' migrants. But in this exercise I do not include capital in any manner.[62]

5.2 Counterfactual Changes in Labour Forces

In this section I discuss how I measure the no-migration-counterfactual changes in labour forces. First the actual changes from 1870 to 1913 are reiterated from Chapter 2 below.

$$\text{Actual}: \quad \frac{\underline{L}_{b,1913}}{\underline{L}_{b,1870}} = 1.49, \quad \frac{\underline{L}_{us,1913}}{\underline{L}_{us,1870}} = 3.21 \quad \text{and} \quad \frac{\underline{L}_{rw,1913}}{\underline{L}_{rw,1870}} = 1.37$$

Theses numbers imply average annual growth rates of about 0.93%, 2.75% and 0.73% for Britain, the U.S. and the rest of world, respectively. According to Taylor and Williamson (1997), annual net migration rates of labour force from 1870 to 1910 are -0.30% for Britain and 0.53% for the U.S. These numbers imply that Britain was a net sender whereas the U.S. was a net receiver during the period. These numbers can be directly subtracted to the actual growth rates to obtain the counterfactual rates.

Therefore without the net migration effect, the labour force would have grown at about 2.22% instead of 2.75% for the U.S. and 1.23% instead of 0.93% for Britain. For arithmetic consistency I treat the rest of world as residual and its labour force changes to account for the difference between Britain and the U.S. Then the counterfactual changes in labour force from 1870 to 1913 turn out to be

$$\text{Counterfactual}: \quad \frac{\underline{L}_{b,1913}}{\underline{L}_{b,1870}} = 1.69, \quad \frac{\underline{L}_{us,1913}}{\underline{L}_{us,1870}} = 2.57 \quad \text{and} \quad \frac{\underline{L}_{rw,1913}}{\underline{L}_{rw,1870}} = 1.38$$

[62]See Chapter 1 for the discussion of capital in modelling of the North Atlantic economy.

I feed in these counterfactual changes to the baseline model along with other changes to isolate the effect of mass migration.

These are the changes only considering the immigrant labour forces themselves. O'Rourke, Williamson and Hatton (1994) uses the changes in labour force considering the influence of migrant children born after the move. This alternative measure can serve as an upper-bound and in the appendix I report the implications of the mass migration using this measure instead of the one reported above.

Before I proceed one comment is in order. I assumed that the changes in endowments in labour force and land are exogenous to the model. This implies that the reduction in labour force due to eliminating the mass migration has no impact on land endowments. But one might argue that the change in land endowment should be positively correlated to the change in labour force endowment. In other words, it should either be the case that an increase in land area induces labour force (and population) to increase or vice-versa. In fact, the consensus among economic historians is that the increase in land induced more immigration. Homestead Act in 1862, ignited the westward movement of population and the land area increased massively. The westward movement kept U.S. urban wages relatively high and this gave prospective immigrants incentives to come to the U.S. So according to this argument, a positive causality runs from increased land to increased immigration. But here I am more interested in the reverse causality. Namely, whether changes in labour force due to immigration induced changes in land endowments. Vandenbroucke (2008) studies a model of U.S. westward movement which endogenizes the land improvement activity. When he feeds in the no-international-immigration counterfactual shock, the model predicts a very small decrease in the stock of improved land by 1900. This outcome can be one justification for the assumption that the immigration does not affect the accumulation of land.

5.3 Implications of the Mass Migration

Now I am ready to study the effects of mass migration on U.S. economy as well as on Britain's economy. I report the simulation results on the main variables of interests for the U.S. and Britain below in Table 38. Erasing the impact of migration is quite large for the overall U.S. economy. But the effects are much larger for the manufacturing than the primary sector. Its primary sector loses only about 1.6 percentage point in world share whereas the manufacturing sector loses 7.5 percentage point. The net immigration contributes about 12.5% to the growth of primary output ($\frac{3.04-2.66}{2.66}$) but in the case of manufacturing output, it is massive 26.4% ($\frac{9.74-7.17}{9.76}$). In line with this, we can observe that the migration contributes to the movement of labour force away from the primary sector into the manufacturing sector. Due to this, the labour force share in the manufacturing sector gains about 2 percentage point. The impacts on the overall economy are also large. About 19% of real GDP is accounted for by the net immigration.

Table 38: Implications of mass migration

	Britain			U.S.		
	Data	BL	CF	Data	BL	CF
Share in world primary(%)	1.9	2.5	2.6	14.4	13.9	12.3
Share in world manufacture	13.6	13.4	17.4	31.9	32.2	24.7
Share of LF in primary	12	23	21	30	37	37
Share of LF in manufacture	44	40	44	30	32	30
$Y_{a,1913}/Y_{a,1870}$	0.93	1.45	1.48	2.58	3.04	2.66
$Y_{m,1913}/Y_{m,1870}$	2.15	1.94	2.45	9.46	9.74	7.17
CF RGDP/BL RGDP	-	-	1.14	-	-	0.81

BL: baseline simulation, CF: counterfactual simulation

On the other hand Britain experiences industrialization as it gains an additional share of 4.0 percentage point in world manufacturing. In line with this more labour force is relocated toward the manufacturing sector. Britain could have grown, respectively, by about 14% and 26% in terms of real GDP and manufacturing output, if it had not sent out its workers. Overall impact of the mass migration on Britain's economy is quite substantial too. Next I report the implications of the mass migration on both countries' trade patterns in Table 39.

The results in Table 39 show that Britain's trade pattern is not much affected by the migration. The share of manufacturing exports goes up only slightly while the share of manufacturing imports decreases slightly as well. But for the U.S. the implication is much more substantial. Its share of manufacturing exports decreases from 61% to 30% and the share of manufacturing imports increases from 32% to 61%. So the U.S. loses much of its position as a manufacturing producer and exporter.

Table 39: Implications of mass migration on trade

		Data	BL	CF
Britain	Exports/GDP	0.21	0.18	0.20
	manu. exports / total exports	0.89	0.97	0.99
	manu. imports / total imports	0.29	0.28	0.18
U.S.	Exports/GDP	0.06	0.04	0.05
	manu. exports / total exports	0.50	0.61	0.30
	manu. imports / total imports	0.44	0.32	0.61

BL: baseline simulation, CF: counterfactual simulation

Why does the mass migration have uneven impacts across sectors? In other words, why is U.S. (or Britain's) manufacturing more affected than the primary sector by the mass migration? It is quite straightforward. The mass migration adds more labour force to the existing U.S. labour force. And mainly due to the unrivalled productivity growth in manufacturing, by 1913 the U.S. already had its comparative advantage in manufacturing.

And in order to exploit this comparative advantage, proportionally more of additional labour force is allocated in the manufacturing sector.

On top of this, increasing returns to scale (IRTS) generates amplified effects. The immigration directly increases the number of U.S. manufacturing firm, $n_{m,us}$ and this generates the linkage effects. As more manufacturing firms are located in the U.S. the demand for manufacturing intermediate will increase, inducing further increase in $n_{m,us}$ (the backward linkage). A larger $n_{m,us}$ lowers U.S. manufacturing price index, $G_{m,us}$, relative to others. This means firms located in the U.S. are facing relatively cheaper manufacturing intermediate inputs, leading to a further increase in $n_{m,us}$ (the forward linkage).[63] A positive feedback between the two linkage effects generate the agglomeration of manufacturing in the U.S.

5.4 Convergence in Real Wages

In this section, I look at the implications of the mass migration on the Anglo-American real wage convergence. According to standard economic theories, with everything else fixed a large increase in labour force for the U.S. and a large decrease in labour force for Britain due to the mass migration would contribute to the convergence of the real wage. In fact this is the conclusion drawn by O'Rourke, Williamson and Hatton (1994). They use a CGE model to evaluate the quantitative implications of the mass migration on the Anglo-American real wage convergence. They conclude that the contribution of the migration was quantitatively large. In building the model, they assume each sector exhibits CRTS and is competitive. They also allow for the perfect international capital mobility and fix the effects of land and technologies. They find that U.S. real wage would have been 9.2% higher

[63]The mass migration decreases $\frac{G_{m,us}}{G_{m,b}}$ and $\frac{G_{m,us}}{G_{m,rw}}$ by 13% and by 11%, respectively. So the manufacturing price index of the U.S. relative to others decreases due to the mass migration.

and that of Britain would have been 6.6% lower without the migration when they allow for perfectly elastic international capital flow (i.e. capital chasing after labour).

In their model, the force that inhibits the convergence is the response of capital flows. Because if capital 'chases after labour', this force alone would increase the labour productivity for a net receiving country (the U.S.) and decrease it for a net sending country (Britain) and mute the effect of migration. On the other hand, in my baseline model, exogenous changes in land endowments and TFP act as off-setting forces. First, the land area for the U.S. increased massively during the period relative to Britain and this would have certainly acted as a buffer for the convergence. In addition to this, the U.S. experienced higher overall TFP growth than Britain. This raised U.S. labour productivity relative to Britain, making a positive contribution to the growth of U.S. real wage.

One very important distinction between their model and my baseline model is the assumption of scale economy. As mentioned above, they assume no economies of scale but the baseline model here assumes that there exists IRTS in manufacturing sector. As the existence of IRTS in U.S. manufacturing is supported by many evidences, it would be meaningful to explore the implications of the mass migration on the real wage convergence when the IRTS is considered.[64]

5.4.1 Generating the Real Wages

This section looks at the model's prediction on the real wage. The real wage is defined as

$$\omega_i = \frac{w_i}{P_i} \qquad \text{where} \quad P_i = G_{ai}^{\theta_{ai}} G_{mi}^{\theta_{mi}} G_{si}^{\theta_{si}} \tag{39}$$

Reiterating the notation, w is the nominal wage, P is the living cost where G_a, G_m and G_s are the price-index for primary, manufacturing and services

[64] See Chapter 1 for the discussion of IRTS in U.S. manufacturing during the period.

goods, respectively. θ_j is the share of consumption for good j. And the subscript i indicates the region.

I need the data on real wages to compare them with the model's predictions. Williamson (1995) constructs the PPP-adjusted real wage data for unskilled urban workers from 1830 to 1913 for 15 countries including Britain and the U.S. According to him, the real wage in the U.S. in 1870 was 66.7% higher than that of Britain and in 1913, it was still 54% higher. Generating the real wages in 1913 from my model is identical to generating other variables as discussed in Chapter 2. I report the predictions of the model in Table 40 below.

Table 40: Anglo-American real wages

	1870			1913		
	Data	IRTS	CRTS	Data	IRTS	CRTS
$\frac{\omega_{us}}{\omega_b}$	1.67	0.99	0.99	1.54	1.58	1.46

Values under 'IRTS' and 'CRTS' column are the results generated from the baseline IRTS model and the CRTS model, respectively. One noted feature is that as the model is not calibrated to match the real wage data in the benchmark year of 1870, $\frac{\omega_{us}}{\omega_b}$ predicted by the model is not close to the data in 1870. But in 1913, the predictions of the model matches the data quite closely. So looking at the picture from dynamic perspective, the exogenous changes in labour force, land, TFP and trade costs that are fed into the model generate a divergence of the Anglo-American real wage from 1870 to 1913 while the data imply that there was a convergence of small magnitude.

The reason that $\frac{\omega_{us}}{\omega_b}$ in the benchmark year of 1870 does not match the data is because the model is not calibrated to fit this data. The primary focus of this whole work is on the quantity side of the economy, not the price side. So the model is calibrated to match the quantities rather than the prices in the first place. Regarding the model's predictability on the real wages, it can mean several things. But one way to interpret this is that the model is missing a factor that creates the gap in the benchmark year (1.67 vs. 0.99). Secondly, the model also needs additional strong convergent forces to account for the small convergence from 1870 to 1913 (1.67→1.54 vs. 0.99→1.58). It is not clear what these factors are. And it is not clear how these factors would affect the results either.

One force that drives the divergent in the model is the change in the services TFP for the U.S. ($A_{s,us}$) which I take directly from Broadberry and Irwin (2006). To reiterate, $\frac{A_{s,1913}}{A_{s,1870}}$ for the U.S. is 1.97 and 1.28 for Britain. The difference is quite large and this difference would reduce the services price for the U.S., $G_{s,us}$ relatively more than that of Britain, $G_{s,b}$. But the service sector in the model does not influence the overall results much as it is non-tradable and treated as residual. For example, when I assume $\frac{A_{s,1913}}{A_{s,1870}}$ for the U.S. to be equal to that of Britain at 1.28 then the model generates much less divergence without changing the result much. Under the IRTS, $\frac{\omega_{us}}{\omega_b}$ becomes 1.37 rather than 1.58 and it becomes 1.26 rather than 1.46 in the case of CRTS. Again I emphasize the important results do not change. So this implies that the difference in $\frac{A_{s,1913}}{A_{s,1870}}$ between the U.S. and Britain, a force that does not affect the important results, accounts for 37% and 44% of the divergence in IRTS and CRTS case, respectively. The bottom line is without this force, the model still generates a divergence but it is not as big as it looks in Table 39. After all it would still be meaningful to see the implications of the mass migration on the Anglo-American real wage convergence albeit some dimensions that the model fails to account for.

5.4.2 Implications of the Mass Migration on the Convergence of Real Wage

In this section, I look at the implications of the mass migration on the convergence of Anglo-American real wages. For better comparability with O'Rourke, Williamson and Hatton (1994), I use the changes in labour force that they used (see Appendix). I proceed in the exactly same manner as in Section 3 where I explored the implications of the mass migration on the quantity variables. But of course here I am interested in the real wages instead of the quantities. Table 41 reports the effects of the mass migration on the real wages.

Under the CRTS specification, the model predicts that the mass migration contributes about 6.0% to the convergence of the real wage between Britain and the U.S. This result, even though the size of contribution is smaller, is qualitatively in line with the results of O'Rourke, Williamson and Hatton (1994).[65] More interesting results arise under the IRTS specification. In this case, the mass migration implies a divergence rather than convergence! The magnitude is not large at 1.6%

Table 41: Implications of the mass migration on real wages

	CRTS			IRTS		
	BL	CF	CONT(%)	BL	CF	CONT(%)
$\frac{\omega_{us}}{\omega_b}$	1.46	1.54	6.0	1.58	1.56	-1.6

BL: baseline, CF: counterfactual, CONT: the percentage contribution of the mass migration to the convergence, $\frac{\text{CF-BL}}{\text{BL}}$

The ratio of U.S. real wage to that of Britain can be defined as [66]

[65] Their model and mine are not directly comparable due to the difference in modelling and calibration strategy and factors considered. But in any case their model predicts that the mass migration contributed to the convergence by 15.8%.

[66] Of course, θ_a, θ_m, θ_s for each region are different but the equation is expressed as it is for the notational simplicity.

$$\frac{\omega_{us}}{\omega_b} = \frac{w_{us}}{w_b}\left(\frac{G_{a,b}}{G_{a,us}}\right)^{\theta_a}\left(\frac{G_{m,b}}{G_{m,us}}\right)^{\theta_m}\left(\frac{G_{s,b}}{G_{s,us}}\right)^{\theta_s} \tag{40}$$

In order to find out what generates this difference, I look at the changes in the each component that make up the equation (40). It is presented in Table 42. If the values under '% change' are positive it means the changes due to the migration is contributing positively to the convergence. For example, the nominal wages, w_b and w_{us}, are converging due to the migration under both scenarios (1.83 → 1.64 under CRTS and 1.72 → 1.70 under IRTS), thus contributing to the real wage convergence. On the other hand, the composite manufacturing price for the U.S., $G_{m,us}$, becomes relatively cheaper due to the migration under both cases ($\frac{G_{m,b}}{G_{m,us}} = 0.82 \rightarrow 0.90$ and $0.93 \rightarrow 1.12$). And this acts as a divergent force.

Table 42: Decomposition of the changes in real wages

	CRTS			IRTS		
	BL	CF	% change	BL	CF	% change
$\frac{w_{us}}{w_b}$	1.64	1.83	11.8	1.70	1.72	1.5
$\frac{G_{a,b}}{G_{a,us}}$	1.30	1.37	4.8	1.28	1.40	9.0
$\frac{G_{m,b}}{G_{m,us}}$	0.90	0.82	-8.9	1.12	0.93	-16.7
$\frac{G_{s,b}}{G_{s,us}}$	0.72	0.65	-10.5	0.70	0.69	-1.5

BL: baseline, CF: counterfactual,

% change: $\frac{\text{CF-BL}}{\text{BL}}$, contribution of the migration

Now I analyse the difference between the CRTS and the IRTS case. First, it can be observed that the nominal wages converge more under the CRTS than under the IRTS (11.8% vs. 1.5%). One of the main forces that drives the convergence in both cases is the relative changes in labour productivities. In the CRTS model, the labour productivity in U.S. primary and manufacturing sector decreases as it intakes more labour force while those of Britain increase as it sends out labour force. This decrease (increase) in the labour productivity leads to decrease (increase) in the nominal wage for the U.S. (Britain) with other effects fixed. But the IRTS in manufacturing puts a pressure on this convergent force. In this case U.S. (Britain) primary sector still experiences decreasing (increasing) labour productivity but the manufacturing does not. The scale economy in this sector implies a rising productivity for the U.S. as the immigrant workers are added. So under the IRTS specification, this counteracting force mute the convergence of the nominal wages.

The relative price of the composite primary goods becomes higher for the U.S. due to the immigration ($\frac{G_{a,b}}{G_{a,us}} = 1.37 \rightarrow 1.30$ and $1.40 \rightarrow 1.28$). As can be seen from Table 37, Britain becomes a relatively more agrarian economy while the U.S. becomes a more industrial economy because of the mass migration. It is intuitively clear that as the U.S. (Britain) produces relatively less (more) primary goods, the price of its domestic primary goods, $p_{a,us}$ ($p_{a,b}$), becomes relatively higher (lower). And these changes lead to the change in $\frac{G_{a,b}}{G_{a,us}}$ as shown in Table 41.[67]

The reason that the composite manufacturing good becomes relatively cheaper for the U.S. is very similar to the primary case. But in the IRTS case, the change is much larger than the CRTS case. In other words, due to the migration, U.S. composite manufacturing good becomes much cheaper relative to Britain's under the IRTS than under the CRTS. The main reasons are the scale economy and the agglomeration effect. The migration increases the size of U.S. manufacturing and this generates the linkage effects that cause the agglomeration of U.S. manufacturing. As the number

[67]It is not so intuitive how higher $p_{a,us}$ or lower $p_{a,b}$ or both lead to lower $\frac{G_{a,b}}{G_{a,us}}$ because the decrease in $p_{a,b}$ not only lowers $G_{a,b}$ but also $G_{a,us}$ (see equation (1) in Chapter 2). Here a rough intuition is that because of the presence of the trade costs in the price indices, changes in $p_{a,b}$ or $p_{a,us}$ have differential impacts on $G_{m,b}$ and $G_{m,us}$

of manufacturing firms (products) increases, U.S. consumers consume more of their domestic products which are not subject to the trade costs. On the other hand, British consumers consume more of U.S. products which are subject to trade costs. Therefore the price for the composite manufacturing for the U.S. becomes relatively cheaper than Britain.

There are many interacting forces that influence the real wages. One main force that acts toward the convergence is the decreasing (increasing) labour productivity for the U.S. (Britain). But also changes in prices matter as they affect the living cost. For this purpose it is important to look at how the mass migration changes the structure of the economy. For example, the U.S. becomes a more industrial economy due to the mass migration and as it specializes and produces relatively more of these goods, they get relatively cheaper. And this change alone raises the real wage of the U.S. But at the same time, the primary good for the U.S. becomes relatively more expensive as now it produces relatively less of these goods. And this, *ceteris paribus*, reduces the real wage. When IRTS is introduced, there exists an additional force that diverges the wages between Britain and the U.S. Hence several counteracting forces exist in one picture and the question comes down to analysing which forces are stronger, quantitatively. It seems that under the CRTS assumption, the convergent forces are stronger while under the IRTS, the divergent forces are.

5.4.3 Endogenous Land Supply

I could argue that land expansion is endogenous to the immigration of labour. Findlay (1993) and Harley (2010) analyse the implications of the endogenous land frontier. Findlay constructs a Heckscher-Ohlin type model of Europe and America where American frontier can be expanded at the cost of capital investment. The analytical result from his model suggests that immigration to America will induce an extension of the frontier but real wages in both regions will fall and land rent will rise. The Stolper-Samuelson effect plays an important role in generating the rise of land rent and the fall of wages even at the presence of the endogenous frontier.

Harley (2010) comes up with a different implications of the endogenous frontier in the case of Canada from 1870 to 1930. He argues that the price convergence due to the global commodity market had terms of trade improving effects for agriculture exporting Canada during this period. This, in turn, induced the expansion of the frontier and the land rent remained at a very low level because of the excess land still available to them. All the gains from trade were accrued to wages. In other words, the increase of the relative price of land-intensive agricultural goods did not lead to the relative increase of land rent (i.e. the Stolper-Samuelson effect does not hold in the case of Canada). This implies the divergence of wages due to the globalization, not the convergence as O'Rourke and Williamson argue.

If I assume that the immigration induced an expansion of land in the U.S. the implications of this would be very similar to that of Harley (2010). In my model, wages are equalized across sectors and as mentioned earlier more land means higher labour productivity in the primary sector. This means the immigration would generate a force that increases the productivity in the primary sector, putting an upward pressure on the overall wage rate in the U.S. I perform a simple numerical exercise assuming that the immigration induces an expansion of the land size.

As far as I know there is no estimate of quantitative contributions of the immigration to the increase of the land size in the U.S. during this period. So I proceed in a very simple manner. I perform counterfactual exercises assuming the immigration contributed 10%, 33% and 50% to the expansion of U.S. land and see the implications on the real wage convergence. The results are reported in Table 43.

If I assume that land is endogenous to the immigration, then it can be observed that the immigration contributes to the divergence more than the baseline case. As the immigration contributes more to the land increase, the implication of the immigration on the divergence gets larger (the last three columns of Table 43). Again this is because more land due to more immigration increases the productivity in U.S. primary sector and raises the wage.

Table 43: Real wages with endogenous frontier

	CRTS			IRTS (BL)			IRTS (endo. frontier) (%)		
	BL	CF	CONT(%)	BL	CF	CONT(%)	Case 1	Case 2	Case 3
$\frac{\omega_{us}}{\omega_b}$	1.46	1.54	6.0	1.58	1.56	-1.6	-2.2	-3.9	-5.4

BL: baseline, CF: counterfactual, CONT: the percentage contribution of the mass migration to the convergence, $\frac{\text{CF-BL}}{\text{BL}}$
Case 1,2 and 3 correspond to cases that the contribution of the immigration to the increase of the land by 10%, 33% and 50%, respectively

5.4.4 Including Capital

As briefly mentioned earlier, capital has important implications on the effects of immigration on the Anglo-American real wage convergence. A rise in capital stock is a force that increases labour productivity and contributes toward the divergence of the Anglo-American real wage (given that there was a larger increase in U.S. capital stock than Britain which was the case during this period). Given this significance, it would be interesting to analyse the impacts of mass migration on the real wage convergence story when capital is included.

Even though capital is treated as an exogenous force which is independent of the changes in labour forces, it is hardly the case in reality. Like the endogenous frontier argument regarding land, capital accumulation and the immigration to the U.S. in the nineteenth century are argued to be closely related matters (Neal and Uselding, 1972 and O'Rourke, Williamson and Hatton, 1994). I consider this scenario that the immigration (or more broadly the increase in labour force) is independent of capital accumulation together with the assumption that capital moves with labour. Again for comparability I apply the external TFP shocks.[68] The results are reported in Table 44.

Some explanations on notations are in order. CRTS w/o K and IRTS w/o K refer to the baseline cases without capital under constant returns and increasing returns to scale in manufacturing production. The results under these columns are just repetitions of Table 41. IRTS1 w/ K refers to the scenario that changes in labour force and in capital are independent to each other and that capital is a immobile factor. In other words, the mass migration did not have any impact on the process of capital accumulation. IRTS2 w/ K refers to the case where I assume that capital chased after labour. As briefly discussed, it is not certain how much capital actually chased after labour during this period. One fact that is certain, however, is that Britain was a large capital exporter, mainly to the New World and the U.S. was an importer. It is also true that capital outflow from Britain dominated labour outflow (O'Rourke, Williamson and Hatton, 1994). International capital market also was well-integrated in the late nineteenth century. Given these facts I can crudely determine how much capital followed after labour forces from Britain into the U.S. I assume that in the counterfactual case of no-migration, capital moved accordingly so that the returns to capital in Britain and the U.S. are restored to the baseline equilibrium in 1913. The underlying idea behind this assumption is that a rise in labour forces due to the mass immigration to the U.S. would decrease capital to labour ratio initially, increasing the returns to capital. In Britain

[68] When I use the TFP shocks implied by the production function with capital rather than the external shocks, the results are almost identical. So which TFP shocks to use is not critical.

an exactly opposite would happen that the outflow of labour forces would increase capital to labour ratio, depressing the returns to capital. If, however, capital is mobile internationally this gap in the returns to capital between the U.S. and Britain, initially created by the migration, would be reduced with subsequent movements of capital from Britain to the U.S. until the point where the old baseline equilibrium is restored.[69] Finally, IRTS3 w/ K considers the scenario of the endogenous frontier (that the immigration contributed 10% to the increase of land in the U.S.) together with IRTS2 w/ K case.

Table 44: Real wages with capital

	CRTS w/o K	IRTS w/o K	IRTS1 w/ K	IRTS2 w/ K	IRTS3 w/ K
CONT(%)	6.0	-1.6	17.5	-7.1	-10.9

CONT: the percentage contribution of the mass migration to the convergence,
$((\omega_{us}/\omega_b)_{\mathrm{CF}} - (\omega_{us}/\omega_b)_{\mathrm{BL}}))/(\omega_{us}/\omega_b)_{\mathrm{BL}}$
where CF: counterfactual and BL: baseline

First, when I assume capital is immobile (IRTS1 w/ K), it predicts that the mass migration contributes about 18% to the convergence of the Anglo-American real wages. This is a sharp contrast to the previous result (IRTS w/o K) that under IRTS, the net immigration contributes to the divergence rather than the convergence. As discussed earlier, a large increase in U.S. capital stock would have served as an additional force that promoted the labour productivity in the absence of the net immigration. The result demonstrates that this strong force actually dominated the opposite force arising from the scale economies. This is also in line with the result of

[69]Of course if we assume a perfect capital mobility, the returns to capital between Britain and the U.S. should be equalized which is not the case in the model. Treating the baseline equilibrium in 1913 as the equilibrium state regarding the movements of capital reflects the view that the mobility is less than perfect.

O'Rourke, Williamson and Hatton (1994) that the immigration contributed substantially to the convergence. This assumption, however, is a bit too extreme so let's turn to the case where capital and labour moved together (IRTS2 w/ K).

When I assume that capital moved accordingly with immigrants to ensure the returns to capital in Britain and the U.S. are equalized to the baseline levels, a qualitatively different result from IRTS1 w/ K scenario arises. This time the mass migration contributes about 7% to the divergence of the real wages. This effect increases if I assume the possibility of the endogenous frontier in which case it contributes about 11% to the divergence. The implications under these scenarios are qualitatively in line with the baseline scenario (IRTS w/o K).

Summing up, the scale economies alone certainly acted as a divergent force in this Anglo-American real wage story. But when other forces are considered together, the net effect of the mass migration under IRTS is either quantitatively or qualitatively uncertain. To understand it more clearly, we need to have a better understanding of the relevant histories. First, it is important to understand how much of other factors of input such as land and capital changed with the movement of labour forces. Secondly, the difference in the degree of the scale economies between the U.S. and Britain can be a crucial component. The fixed cost in the production function, F, in my model represents this component and I assume that they are equal across regions for simplicity. But while evidences show that U.S. manufacturing sector exhibited substantial degree of the scale economies, there is no such evidence for British counterpart. Considering this may be important for the outcome and I leave this for future endeavours.

5.5 Conclusion

In this chapter, I explored the quantitative implications of the mass migration on the quantity side of the economy as well as the price side. First, I found that it had big impacts on the quantity side of U.S. economy. In particular, the contribution of the immigration to the development of U.S. manufacturing was remarkable. The net immigration coupled with the IRTS had proportionately more impacts on U.S. manufacturing than the primary sector. But at the same time, Britain experienced de-industrialization of some degree due to the net emigration.

Then I looked at the implication of the mass migration on the Anglo-American real wage convergence. Under the CRTS assumption, the mass migration implied the convergence. This result is in line with that of O'Rourke, Williamson and Hatton (1994) even though the degree of convergence was somewhat smaller. But under the assumption of IRTS, the mass migration generated a divergence rather than convergence. This result mainly came from the strong divergent forces generated by the economies of scale and agglomeration effect. I then considered the effects of endogenizing land and including capital. Considering the endogenous frontier story generated further divergence but inclusion of capital acted as a strong convergent force.

Appendix : Alternative Measure of the Changes in Labour Forces

According to O'Rourke, Williamson and Hatton (1994), after taking the influence of migrant children born after the move, the British labour force would have been 16% larger and U.S. labour force would have been 27% smaller in 1911 without the migrations from 1870 to 1911. So I use the measures implied by these rather the ones reported in Section 2. As this measure considers fertility decisions of the migrants counterfactually, it can serve as a kind of an upper-bound. Table A-1 reports the result.

Table A-1 : Implications of mass migration using alternative measure

	Britain			U.S.		
	Data	BL	CF	Data	BL	CF
Share in world primary(%)	1.9	2.5	2.5	14.4	13.9	12.0
Share in world manufacture	13.6	13.4	18.4	31.9	32.2	21.5
Share of LF in primary	12	23	21	30	37	39
Share of LF in manufacture	44	40	44	30	32	28
$Y_{a,1913}/Y_{a,1870}$	0.93	1.45	1.47	2.58	3.04	2.59
$Y_{m,1913}/Y_{m,1870}$	2.15	1.94	2.51	9.46	9.74	6.11
CF RGDP/BL RGDP	-	-	1.16	-	-	0.73

BL: baseline simulation, CF: counterfactual simulation

As expected the quantitative implication of the mass migration is much larger in this case. U.S. manufacturing loses more and Britain's manufacturing gains more compared to the case in Section 3.

Chapter 6

Concluding Remarks

In this thesis, I explored the quantitative of U.S. economic development from 1870 to 1913. Even though the U.S. experienced the most remarkable economic growth both in relative and absolute terms during this period, surprisingly little amount of studies have quantitatively explored the economy In many senses, it is important to perform quantitative analysis of this kind. For example the debates about the role of the high protectionism on U.S. economic development would become more clear if we know 'how much' the tariff protection actually contributed. We also know that the mass immigration to the U.S. was important for its economic development but we do not know how much it contributed to the overall economy and to each sectors. I aimed to provide some quantitative answers to these questions.

I explored these historical events in a global framework. Because the world or at least the North Atlantic economy was well integrated during this period and it is generally perceived that the rise of the U.S. and the relative decline of Britain as a closely related phenomena. Namely, the rapid growth of U.S. manufacturing encroached Britain's share in the global market, overtaking Britain and consolidating its position as an industrial leader. For this reason the model is built to account for both the rise of the U.S. and the decline of Britain in the late nineteenth century.

One distinct feature of my model was the assumption of IRTS in manufacturing production which was reasonable given the empirical evidences that there existed IRTS in U.S. manufacturing during this period. Even though this is almost a conventional belief among economic historians this feature was rarely employed in the previous quantitative studies. It would then have qualitatively and quantitatively different implications from the standard CRTS model.

First I performed a growth decomposition exercise to evaluate the relative contributions of important factors. The factors considered were the productivity growth in each sector, increases in land and labour force endowments and changes in trade costs. It turned out that the single most important force in U.S. economic growth was the large increase in factor inputs. Especially its impacts on the manufacturing sector was massive. This was obviously largely due to the IRTS in manufacturing. Changes in sectoral TFPs did not play quantitatively large roles. Next I investigated the quantitative implications of the IRTS in manufacturing. The IRTS seemed to contribute substantially to the growth of real GDP and manufacturing output. It accounted for about one third of the growth in U.S. manufacturing output from 1870 to 1913.

In the second chapter I investigated the quantitative implications of U.S. manufacturing tariffs on the development of the U.S. particularly focusing on the development of its manufacturing sector. To do this I performed a counterfactual exercise by removing the tariffs from U.S. manufacturing imports. It turned out that even though the tariffs helped promote its manufacturing sector, it was small quantitatively. Even under the assumption of learning-by-doing, the contribution of the tariffs was small. This finding provides some quantitative evidence to the arguments of Irwin (2001) that the tariffs did not play a large role in U.S. economic development during this period. It also seemed that the assumption of IRTS did not amplify the effects of the tariffs as the tariffs made the manufacturing price index of the U.S. relatively higher, creating a force against the forward linkage. This finding is somewhat contrary to the arguments made by some papers such as Crafts and Venables (2001) and Nunn and Trefler (2010) that under the scale economy, the impacts of tariff in promoting the protected sectors would be substantial.

Next I look at the implications of the mass migration. First the net immigration contributes substantially to the growth of U.S. real GDP. Without the mass migration, the level of U.S. GDP would be about 80% of the actual level. The mass migration contributes more to the development of the manufacturing sector than the primary sector, accounting for about 13% and 26% of the growth of the primary and the manufacturing output, respectively. Also without the mass migration the U.S. would have still maintained its position as a leader in world manufacturing output but the gap between the U.S. and Britain would have been reduced substantially. Two forces are behind this. First, due to the comparative advantage in U.S. manufacturing unproportionately more immigrants are absorbed in the manufacturing sector. Secondly, the IRTS in manufacturing also created uneven impacts of the mass migration across sectors.

Finally I explored the implications of the mass migration on the Anglo-American real wage converegence in Chapter 5. O'Rourke, Williamson and Hatton (1994) study this topic using a standard Heckscher-Ohlin model with constant returns to scale technology. They conclude that the mass migration contributed substantially to the convergence of the real wages between the U.S. and Britain. This finding contributes to their broader conclusion from many other related works that the integration of world economy during the nineteenth century contributed to the factor price convergence among many countries as emphasized by Heckscher-Ohlin theory. But in my model the existence of IRTS predicts a qualitatively different result about the implications of the Anglo-American real wage convergence. The mass migration could have actually contributed to divergence rather than convergence. It depends on how much increase in land came from the mass migration and how much capital chased after the labour. This result changes the conventional belief that the mass migration contributed to the convergence of

.

Bibliography

[1] Abramovitz, Moses and Paul David (1996), "Convergence and Delayed Catch-Up: Productivity Leadership and the Waning of American Exceptionalism", in Ralph Landau, Timothy Taylor and Gavin Wright(eds.), *The Mosaic of Economic Growth.* Stanford: Stanford University Press.

[2] Anderson, James and Eric van Wincoop (2003), "Gravity with Gravitas: A Solution to the Border Puzzle", *American Economic Review*, 93, 170-192.

[3] Anderson, James and Eric van Wincoop (2004), "Trade Costs", *Journal of Economic Leterature*, 42, 691-751.

[4] Arrow, Kenneth (1962), "The Economic Implications of Learning by Doing", *Review of Economic Studies*, 29, 155-173.

[5] Atack, Jeremy (1977), "Returns to Scale in Antebellum United States Manufacturing," *Explorations in Economic History",* 14, 337-359.

[6] Atack, Jeremy, Fred Bateman and William Parker (2000), "The Farm, the Farmer, and the Market", in Engerman and Gallman (eds.) *Cambridge Economic History of the United States,* Vol.2, 245-284.

[7] Bairoch, Paul (1982), "International Industrialization Levels from 1750 to 1980", *Journal of European Economic History,* 11, 269-331.

[8] Batra, Ravi (1993), *The Myth of Free Trade*, New York: Scribner's.

[9] Bohlin, Jan (2007), "Structural Change in the Swedish Economy in the Late Nineteenth And Early Twentieth Century - The Role of Import Substitution And Export Demand", Goteborg University Working Paper.

[10] Broadberry, Stephen N. (1993), "Manufacturing and the Convergence Hypothesis: What the Long Run Data Show", *Journal of Economic History*, 53, 772-795.

[11] Broadberry, Stephen N. (1997), "Forging Ahead, Falling Behind and Catching Up : A Sectoral Analysis of Anglo-American Productivity Differences, 1870 - 1990", *Research in Economic History*, 17, 1-37.

[12] Broadberry, Stephen N. (1998), "How did the United States and Germany Overtake Britain? A Sectoral Analysis of Comparative Productivity Levels, 1870-1990", *Journal of Economic History*, 58, 375-407.

[13] Broadberry, Stephen N. and Douglas Irwin (2006), "Labor Productivity in the United States and the United Kingdom During the Nineteenth Century", *Explorations in Economic History*, 43, 257-279.

[14] Broda, Christian and David Weinstein (2006), "Globalization and the Gains From Variety", *Quarterly Journal of Economics*, 121, 541-585.

[15] Buchanan, Patrick (1998), *The Great Betrayal: How American Sovereignty and Social Justice Are Being Sacrificed to the Gods of the Global Economy*, Boston: Little, Brown.

[16] Cain, Louis and Donald Paterson (1986), "Biased Technical Change, Scale, and Factor Substitution in American Industry, 1850 - 1919", *Journal of Economic History*, 46, 153-164.

[17] Chandler, Alfred (1977), *The Visible Hand*, Cambridge, Mass. and London, England: Harvard University Press.

[18] Chang, Ha-Joon (2002), *Kicking Away the Ladder: Development Strategy in Historical Perspective*, London: Anthem Press.

[19] Clark, Gregory (2010), "The Macroeconomic Aggregates For England, 1209-2008", *Research in Economic History*, 27, 51-140.

[20] Collins, William and Jeffrey Williamson (2001), "Capital-Goods Prices and Investment, 1870-1950", *Journal of Economic History*, 61, 59-94.

[21] Crafts, N.F.R (1980), "National Income Estimates and the British Standard of Living Debate: A Re-appraisal of 1801-31", 17, 176-188.

[22] Crafts, N.F.R and Anthony J. Venables (2001), "Globalization and Geography in Historical Perspective", paper presented to the NBER Conference on Globalization in Historical Perspective, Santa Barbara, CA.

[23] David, Paul (1970), "Learning By Doing and Tariff Protection: A Reconsideration of the Case of the Ante-Bellum United States Cotton Textile Industry", *Journal of Economic History*, 30, 521-601.

[24] David, Paul and Gavin Wright (1997), "Increasing Returns and the Genesis of American Resource Abundance", *Industrial and Corporate Change*, 6, 203-245.

[25] DeLong, J. Bradford (1998), "Trade Policy and America's Standard of Living: An Historical Perspective", in Susan Collins(ed.), *Imports, Exports and the American Worker.* Washington DC: Brookings Institute.

[26] Edvinson, R. (2005), *Growth, Accumulation, Crisis : with New Macroeconomic Data for Sweden, 1880-2000*, Stockholm : Stockholm Studies in Economic History 41.

[27] Engerman, Stanley L. and Kenneth L. Sokoloff (1997), "Factor Endowments, Institutions and Differential Paths of Growth among New World Economies", in Stephen Haber(ed.), *How Latin America Fell Behind.* Stanford: Stanford University Press.

[28] Estevadeordal, Antoni and Alan Taylor (2008), "Is the Washington Consensus Dead? Growth, Openness, and the Great Liberalization, 1970S-2000S", NBER Working Papers 14264.

[29] Federico, Giovanni (2004), "The Growth of World Agricultural Production, 1800-1938", *Research in Economic History*, 22, 125-181.

[30] Feinstein, Charles (1972), *National Income, Expenditure and Output of the United Kingdom, 1855-1965*, Cambridge, UK: Cambridge University Press.

[31] Feinstein, Charles and S. Pollard, *Studies in Capital Formation in the United Kingdom, 1750-1920*, Oxford, UK: Oxford University Press.

[32] Findlay, Ronald (1993), "International Trade And Factor Mobility With An Endogenous Land Frontier: Some General Equilibrium Implications Of Christopher Columbus", in Ethier, Helpman and Neary (eds.) *Theory, Policy and Dynamics in International Trade*, 38-54.

[33] Fujita, Masahisa, Paul R. Krugman and Anthony J. Venables (1999), *The Spatial Economy: Cities, Regions and International Trade.* Cambridge, Mass.: MIT Press.

[34] Habakkuk, H. John (1962), *American and British Technology in the Nineteenth Century,* Cambridge: Cambridge University Press.

[35] Harley, Knick (2010), "Globalization and the Frontier, 1870-1930: the Canadian Prairies", University of Oxford, Department of Economics Working Paper.

[36] Hatton, Timothy and Jeffrey Williamson (1998), *Migration and the International Labor Market 1850-1939,* London and New York: Routledge.

[37] Head, Keith (1994), "Infant Industry Protection in the Steel Rail Industry", *Journal of International Economics,* 37, 141-165.

[38] Herrendorf, Berthold, James Schmitz Jr. and Arilton Teixeira (2012), "The Role of Transportation in U.S. Economic Development: 1840-1860," *International Economic Review,* 53, 693-715.

[39] Houthakker, Hendrik (1957), "An International Comparison of Household Expenditure Patterns, Commemorating the Centenary of Engel's Law", *Econometrica*, 25.

[40] Hutchinson, William K. (2002), "Explaining United States International Trade, 1870 - 1910", Vanderbilt University Department of Economics Working Paper.

[41] Irwin, Douglas (2000), "Did Late Nineteenth Century U.S. Tariffs Promote Infant Industries? Evidence from the Tinplate Industry", *Journal of Economic History*, 60, 335-360.

[42] Irwin, Douglas (2001), "Tariffs and Growth in Late Nineteenth Century America", *The World Economy*, 24, 15-30.

[43] Irwin, Douglas (2002), "Interpreting the Tariff-Growth Correlation of the Late Nineteenth Century", *American Economic Review Papers and Proceedings*, 91, 165-169.

[44] Irwin, Douglas and Peter Klenow (1994), "Learning-by-Doing Spillovers in the Semiconductor Industry", *Journal of Political Economy*, 102, 1200-1227.

[45] Jacks, David, Dennis Novy and Christopher Meissner (2010), "Trade Costs in the First Wave of Globalization", *Explorations in Economic History*, 47, 127-141.

[46] James, John (1983), "Structural Change in American Manufacturing, 1850-1890", *Journal of Economic History*, 43, 433-460.

[47] Jefferys, James and Dorothy Walters (1955), "National Income and Expenditure of the United Kingdom, 1870-1952", *Review of Income and Wealth*, 1-40.

[48] Johnston, Louis (1990), "Endogenous Growth and the American Economy, 1840-1900", (Ph.D. dissertation, University of California, Berkeley).

[49] Kendrick, J.W. (1961), *Productivity Trends in the United States,* Princeton, NJ: Princeton University Press.

[50] Krugman, Paul R. and Anthony J. Venables (1995), "Globalization and the Inequality of Nations", *Quarterly Journal of Economics,* 110, 857-880.

[51] Maddison, Angus (2001), *Monitoring The World Economy, 1820-1992*, Paris : OECD.

[52] Mitchell, B.R. and Phyllis Deane (1962), *Abstract of British Historical Statistics,* Cambridge: Cambridge University Press.

[53] Naknoi, Kanda (2008), "Tariffs and the Expansion of the American Pig Iron Industry: 1870-1940", Purdue University Department of Economics Working Paper.

[54] Neal, Larry and P.J. Uselding (1972), "Immigration, A Neglected Source of American Economic Growth: 1790 to 1912", *Oxford Economic Papers*, 24, 68-88.

[55] North, Douglas, William Summerhill and Barry Weingast (2000), "Oreder, Disorder and Economic Change: Latin America vs. North America", in Bruce Bueno de Mesquita and Hilton L. Root (eds.), *Governing for Prosperity.* New Haven, CT: Yale University Press.

[56] Nunn, Nathan and Daniel Trefler (2010), "The Structure of Tariffs and Long-term Growth", *American Economic Journal: Macroeconomics*, 2(4), 158-194.

[57] Officer, L.H. and S.H. Williamson (2010), *Measuring Worth*, www.measuringworth.com.

[58] O'Rourke, Kevin and Jeffrey G. Williamson (1994), "Late Nineteenth Century Anglo-American Factor-Price Convergence: Were Heckscher-Ohlin Right?", *Journal of Economic History,* 54, 892-916.

[59] O'Rourke, Kevin and Jeffrey G. Williamson (1999), *Globalization and History* Cambridge, Mass: MIT Press.

[60] O'Rourke, Kevin and Sibylle Lehmann (2011), "The structure of protection and growth in the late 19th century", *Review of Economics and Statistics*, 93, 606-616.

[61] O'Rourke, Kevin, Alan Taylor and Jeffrey Williamson (1996), "Factor price convergence in the late nineteenth century", *International Economic Review*, 37, 499-530.

[62] O'Rourke, Kevin, Jeffrey Williamson and Timothy Hatton (1994), "Mass migration, commodity market integration, and real wage convergence: the late nineteenth century Atlantic economy", in Timothy J. Hatton and Jeffrey G. Williamson(eds.), *International Migration and World Development.* London and New York: Routledge.

[63] Ottanviano Gianmarco and Jacques-Francois Thisse, "On economic geography in economic theory: increasing returns and pecuniary externalities", *Journal of Economic Geography*, 6, 5-37.

[64] Rapping, Leonard (1965), "Learning and World War II Production Function", *Review of Economics and Statistics*, 47, 81-86.

[65] Rothbarth, E. (1946), "Causes of the Superior Efficiency of U.S.A. Industry as Compared with British Industry", *Economic Journal,* 56, 383-390.

[66] Searle, Allan (1945), "Productivity Changes in Selected Wartime Shipbuilding Programs", *Monthly Labor Review*, 61, 1132-1147.

[67] Taylor, Alan (1998), "Argentina and the World Capital Market: Saving, Investment, and International Capital Mobility in the Twentieth Century", *Journal of Development Economics*, 57, 147-184.

[68] Taylor, Alan and Jeffery Williamson (1997), "Convergence in the Age of Mass Migration", *European Review of Economic History* 1, 27-63.

[69] Taussig, F.W. (1915), *The Tariff History of the United States*, New York: G.P. Putnam's sons.

[70] Temin, Peter (1964), "A New Look at Hunter's Hypothesis About the Antebellum Iron Industry", *American Economic Review*, supplement, 3415-351.

[71] Temin, Peter (1966), "Labor Scarcity and the Problem of American Industrial Efficiency in the 1850's", *Journal of Economic History*, 26, 277-298.

[72] Thomas, Mark (1984), "An Input-Output Approach to the British Economy, 1870-1914", (Ph.D. dissertation, Oxford University).

[73] Thomas, Mark (in progress), "The Mid-Victorian Economy: Making, Earning and Spending in Britain in 1851".

[74] Thompson, Peter (2001), "How Much Did the Liberty Shipbuilders Learn? New Evidence for and Old Case Study", *Journal of Political Economy*, 109, 103-137.

[75] Vandenbroucke, Guillaume (2008), "The American Frontier: Technology versus Immigration", *Review of Economic Dynamics*, 11, 283-301.

[76] Waugh, Michael (2008), "Bilateral Trade, Relative Prices, and Trade Costs", Working Paper.

[77] Whitney, W.G. (1968), "The Structure of the American Economy in the Late Nineteenth Century", (Ph.D. dissertation, Harvard University).

[78] Williamson, Jeffrey (1974), "Watersheds and Turning Points: Conjectures on the Long-Term Impact of Civil War Financing", *Journal of Economic History*, 34, 636-661.

[79] Williamson, Jeffrey (1995), "The Evolution of Global Labor Markets Since 1830: Background Evidence and Hypotheses", *Explorations in Economic History*, 32, 141-196.

[80] Williamson, Jeffrey and Joseph Swanson (1966), "The Growth of Cities in the American Northeast 1820-1870" in *Explorations in entrepreneurial history*, University of Wisconsin Press.

[81] Wright, Gavin (1990), "The Origins of American Industrial Success", *American Economic Review,* 80, 651-668.

[82] U.K. Board of Trade (various years), *The Annual Statement of Trade of the United Kingdom*, London.

[83] U.K. Bureau of Census (various years), *Statistical Abstract of the United States*, Washington DC : USGPO.

[84] U.S. Department of Commerce (various years), *Annual Report of the Commerce and Navigation of the United States,* Washinton D.C. : USGPO.

[85] U.S. Department of Commerce (various years), *The Census of the United States,* Washinton D.C. : USGPO.

[86] U.S. Department of Commerce (various years), *Historical Statistics of the United States,* Washinton D.C. : USGPO.

[87] Yates, P. Lamartine (1959), *Forty Years of Foreign Trade,* London: Allen and Unwin.