European University Institute
Department of History and Civilization

# The Early Phase of Catalan Industrialisation, 1830-1861

Juan Ramón Rosés Vendoiro

Thesis submitted with a view to obtaining the degree of doctor of the European University Institute

Examining Jury:

Professor Albert Carreras i Odriozola, Universitat Pompeu Fabra
Professor Nicholas F.R. Crafts, London School of Economics
Professor Leandro Prados de la Escosura, Universidad Carlos III de Madrid
Professor Jaime Reis, European University Institute (supervisor)

Florence, October 1998

B/C-P

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To Eva and Claudia

# Abstract

There are few more crucial episodes in economic history than the industrialisation of some regions of Europe during the first half of the nineteenth century. This thesis attempts to make a contribution to the history of early industrialisation by rigorously analysing the transition process through which a proto-industrial region hopes to move from a condition of slow industry growth rates to one of self-sustained industry growth. I hope to accomplish this task by drawing liberally on the stock of existing economic theory and then proceeding to weave them into an explanation of industry growth in Catalonia from 1830 to 1861.

First, the familiar neo-classical equation for decomposing growth rates is used to estimate the contribution of factor accumulation and productivity improvement to modern industry growth rates. This leads to results that are significantly different from those advanced by the literature on Catalan industrialisation. The discussion underlines the importance of disembodied innovation, rather than the previous accumulation of capital, the transference of foreign technologies or the elastic supply of labour.

Second, I offer evidence that this increase in total factor productivity was the consequence of the development of new business institutions. In particular, the transition from the decentralised forms of production to more efficient factories. The thesis also supports the hypothesis that factor endowments and the level of human capital associated with scale economies explains the localization of factories in Catalonia.

Finally, two points of broad relevance should be noted. One is that the conventional wisdom that factor accumulation is crucial in early industrialisation needs to be reconsidered. The other point is that it seems necessary to recognize that factor endowments, local knowledge and market forces, specially those connected with the development of new institutions and new products, were far more important than standard texts of European economic history tended to allow.

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## Acknowledgments

This dissertation represents a learning process (inevitably still under way, although now arrested in its public form), which is deeply indebted to the teachers who guided it and to the many friends, colleagues, and experts who contributed advice and information. Above all I thank Jaime Reis, who has tirelessy read and responded to drafts of dissertation and articles with wonderfully thoughful and learned advice. His seemingly infinite patience, and his unwillingness to allow the passage of glib evasions, has conferred a valuable rigour upon this work. I am also particularly grafetul to other academics who generously supervised my work in several occasions: Àngels Solà, Pere Pascual, Carles Sudrià and René Leboutte.

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Chapter 6 first appeared in a shorther version in the *European Review of Economic History* **2** (1), pp. 25-48 (1998). In this ocassion I benefited from the helpful comments of two anonimous referees and the editors. A Spanish version of Chapter 8 was published at Santiago López and Jesus Mª Valdaliso (eds). *¿Qué inventen ellos? Technología, empresa y cambio económico en la España contemporánea*, Madrid: Alianza editorial (1997).

And finally, there is my greatest debt. I owe more than I can say to my wife, Eva. Her keen intelligence and gentle understanding have sustained me throughout.

# Weights and Measures

### Weights

1 vara castellana = 0.835 metres

1 cana catalana = 1.552 metres

1 libra castellana = 0.4605 Kg.

1 libra catalana = 0.4010 Kg.

1 Arroba castellana = 11.5125 Kg

1 Arroba catalana = 10.426 Kg

1 Quintal castellano = 46.05 Kg.

1 Quintal catalán = 40.10 Kg

### Currencies

1 Real de vellón (Rv) = 0.25 Pta.

1 Escudo = 2.5 Pta

1 Duro = 1 Peso fuerte = 5 Pta.

# Chapter 1

# Introduction and Overview

## 1.1. Some Words on the Purpose and Limits of this Dissertation.

This dissertation is not a general survey of the early industrialisation of Catalonia between the establishment of the Bonaplata factory in 1832 and the 'Cotton Famine' in the 1860s. It is not intended as such and should not be read as an introduction to the subject. There are several excellent textbooks covering the period and a dominant paradigm among Catalan historians.[1] It is obvious that disagreements among scholars persist and new revisionist positions recently appeared. Therefore, I believe that the writing of a new textbook should be postponed until these revisionist theories affect the actual paradigm.

My purpose in this work is to answer one question which is central to European economic history using Catalonia as example. How did industry grow in the early industrialising regions? I do not provide an overall picture of all aspects of the economy during early industrialisation in Catalonia. The dissertation puts more emphasis on the mutations in industry than on the transformations in agriculture, services or demography. Similarly, the rhetoric of the text is on the side of economics not on the side of sociology or politics. Neither political events, nor social changes, nor cultural transformations are explicitly discussed because the purpose of this investigation is not to produce a piece of ***Histoire Total***. Certainly, there are many other interesting research topics on the economic history of early industrialisation in Catalonia: the development of agriculture, the rise of the commercial

[1] See, for example, Maluquer (1998).

economy, the integration of Catalonia into the world economy, the role of banks, the rise of the industrial bourgeoisie, the demographic transition, and so on. However, in my view, what is most striking about this region is that in the Southern Europe periphery it was the first and the most important industrial region during a great part of the nineteenth century.[2] But why? An obvious explanation is difficult to find because Catalonia did not enjoy deposits of coal or other minerals, a central position in the maritime routes or a large and rich home market.

Answering questions concerning causation in economic history is always controversial. It is not possible to prove anything beyond reasonable doubt. One can begin by formulating a series of hypotheses which can be based on some economic theory or historical intuitions. These hypotheses can then be tested using mathematical (econometric) methods. In order to do so, we must accept some *a priori* assumptions which can yield a testable hypothesis. It is obvious that some assumptions are themselves absurd and can lead directly to an answer. Note that it is even harder to discriminate between plausible and non-plausible assumptions when one refers to economic history. Moreover, rigorous statistical tests are difficult to perform on historical data. In some cases the data is not consistent, in other cases the data that we need does not exist or it was collected in such way that it can not be employed for our purposes. None the less, deficient as this methodology is, it is the best available.

The dissertation covers the period from 1830 to 1861, with the main focus on the 1840s and 1850s. Perhaps, for those familiar with Catalan economic history, the justification of this chronology would be superfluous. But the author thinks that it would be convenient to say something. The period was chosen because an acceleration in Catalan industrial output took place in the 1830s. This acceleration was accompanied by some important changes in industrial organisation that were consolidated in the two subsequent decades. However, there was not a simple 'spurt' or 'take-off', but a long period of gradual preparation, that was translated into sustained growth in manufacturing output throughout the 1840s. Note that this acceleration was strongly influenced by the changes in the cotton industry since that industry had the lion's share of Catalan manufacturing output.

[2] Pollard (1981).

This chronology for early industrialisation has received general support by leading Catalan historians, such as Jaume Vicens Vives, Miquel Izard, Jordi Nadal, Jordi Maluquer de Motes and Albert Carreras. Who describe the 'revolutionary' character of the period from 1830 to 1861.[3] In that scheme, the period that began in the 1830s was an abrupt transition to modern industry. With a substantial increase in industrial output being achieved over a fairly short period of time, roughly thirty years.

Alternative chronologies are not unwarranted. Pierre Vilar emphasises that industrial change originated in the eighteenth century, when new 'modes of production' appeared, and not during the mechanisation period. He, together with others, asserts that the accumulation of capital, which from this point of view is the key for defining the historical relation between manufacture and industry, took place during the eighteenth century. Vilar points out that the period from 1830 to 1860 was more a 'recovery' than a 'revolution'. He argues that the movement towards mechanisation, which had begun in the early years of the nineteenth century, was interrupted by the political disturbances of the revolutionary and Napoleonic periods.[4]

The more recent view is that, despite the spectacular changes of the period 1830-1860, Catalan industrialisation began before 1830. Alex Sánchez and James K.J. Thomson are the two leading proponents of this view.[5] They acknowledge that the performance after 1830 was important, but also stress that the modern industry has its roots in the developments of the second half of the eighteenth century and the first thirty years of the nineteenth century. The origin of modern industry was the development of calico printing in Barcelona between the 1730s and the 1760s. In a following period, situated at the end of the eighteenth century, the Catalan cotton industry expanded the production to cotton yarn and cloth. According to Alex Sánchez, this process of expansion culminated with the mechanisation, without steam-engines,

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[3] Vicens Vives and Llorens (1984), Izard (1969), Nadal (1975), Maluquer (1985)(1998), and Carreras (1990a).

[4] Vilar (1962).

[5] Sánchez (1989) and Thomson (1992).

of cotton spinning from 1815 to 1839.[6]

Two points should be made before continuing. First, the extent of change in the second third of the nineteenth century must be kept within the perspective of the impressive metamorphosis of the twentieth century. Questions analysed in isolation invariably assume an exaggerated importance. Which is why it is necessary to set them in context and consider their general interrelationships. Second, the second third of the nineteenth century in Catalonia is of considerable interest *per se*. Indeed, it repays close study. It is the period of transition from the relative stability of the traditional economy to a new industrialising economy. The period when the essential characteristics and direction of transformations were worked out. The second third of the nineteenth century in Catalonia can be identified as the period of early industrialisation in Catalonia.

The choice of Catalonia as a focal point is justified by the fact that, during this period, the development of modern Spain's industry was largely confined to this region. As is well known, during the nineteenth century, Catalonia grew to dominate the Spanish production of textiles. Eclipsing the older textile centres of Galicia and western Castilia. Moreover, the spatial concentration of the textile industry within the Catalan borders took only thirty years, from approximately 1830 to 1860. Catalonia not only kept its place as the first textile region in Spain but grew to dominate the entire Spanish industrial sector during the nineteenth century. In 1856, it was the dominant Spanish region in textiles, paper and miscellaneous industries. In 1900, it was dominant in textiles, glass, leather, chemistry, metallurgy, paper, and wood. It was second in wine and alimentary and third in wheat, flour and olive oil refining.[7] It should be emphasised that in Spain there were no other regions at the Catalan level until the last decades of the nineteenth century. Various 'old' industries survived in other regions of Spain but none showed the modernisation features that characterised Catalan development. For this reason Spain's industrialisation during the nineteenth century is best examined region by region rather than from a national point of view. Furthermore, the

[6] Sánchez (1989).

[7] Nadal (1985).

national view fails to pick up on the regional dynamism that was unique to the period and revolutionary in its impact. In this sense, William N. Parker and Sydney Pollard have emphasised that industrialisation has a regional scope.[8] In considering the basic unit of analysis it is important, too, to consider the importance of European dynamics. One cannot comprehend the functioning of different regions without addressing the role of each one within Europe.

## 1.2. Catalonia in the European debate

Many readers probably agree with me that the two major influential and long lasting scholar visions of early industrialisation in the Western World are due to Walt W. Rostow and Alexander Gerschenkron.[9] However, recently it seems that a new paradigm is emerging based on a revisionist view of the amplitude and significance of the process of industrialisation in Great Britain. And the spread of industrialisation through Europe and the United States. This new paradigm is less unified and his based on the works of Rondo Cameron, Pat O'Brien, and Nicholas F.R. Crafts.[10]

Rostow developed his original formulation in the mid 1950s and must be interpreted within this historical context. The sub-title of his path-breaking work *-A non-Communist Manifesto-* can only be understood in the context of the 'Cold War'. Basically, Rostow sketched a description of the process of industrialisation assuming that his 'ideal' British model was necessarily followed by many countries in their industrialisation processes, ignoring the period when their industrialisation began and their geographical position. His vision was, one could argue for ideological reasons, optimistic about the diffusion of industrialisation.

[8] Pollard (1981) and Parker (1984).

[9] Rostow (1956)(1960) and Gerschenkron (1962).

[10] Cameron (1985), O'Brien (1986) and Crafts (1984)(1985a).

Rostow envisaged five periods, stages in his terminology, in the process of growth.[11] In this sense, his formulation was not very original since it did not differ from the ideas of the German historical school and from the Marx-Engels formulation of the process of historical development. In the words of William Parker "the stages have oddly memorable names".[12] They were called (in chronological order): traditional society, preconditions of take-off, take-off, drive to maturity, and the age of high mass-consumption. Each stage had a few general characteristics, and was necessary for the process of growth.

The stage called 'take-off' is undoubtably the most controversial and debated by economic historians. In the spirit of Rostow's thesis, the 'take-off' was a (short) phase of growth caused by a vast increase in industrial investment, a large movement of labour towards industry, and a substantial increase in productivity. Along with a rise in *real* income per capita. He also asserted that the growth rate of gross domestic product might be above four percent per year. It is certainly obvious why, rapidly, this term became synonymous with the other famous/infamous term 'Industrial Revolution'. Therefore, in the 1960s, hordes of quantitative historians began empirical tests, hunting for the 'take-off' in their respective nations.[13] Unfortunately for Rostow the historical evidence have provided very little support for his hypothesis. In other words, there was practically no evidence of a sudden and massive discontinuity in national economic performance for any European industrialised nations. Even in the British case, the evidence for a sudden 'take-off' was less than convincing.[14]

The thesis of Alexander Gerschenkron is also very influential and, in some respects, has stood up quite well (of course, better than Rostow's hypothesis) to criticisms and empirical tests.[15] Gerschenkron claims that the spurt of industrialisation was related to capital. Modern industry, for him, originated in the transformation of commercial-agricultural capital

[11] Rostow (1960).

[12] Parker (1984).

[13] A review of the research on Rostow's hypothesis is available in Kindleberger and Di Tella (eds)(1982).

[14] Crafts (1981)(1985a).

[15] See a review of Gerschenkron's thesis in Sylla and Toniolo (eds)(1991).

into industrial capital or, in other words, the conversion of working capital into physical (fixed) capital. Gerschenkron's view is that the state of relative backwardness, and absence of prerequisites, had fundamental implications for the course and nature of the development process itself but did not necessarily prevent economic growth. Relative backwardness is very important because the requirements of capital increase with the passing of time. The main reason is that the 'standard of technology' became more complicated and, consequently, more expensive during the nineteenth and twentieth centuries. At this point, he argues for the substitution of prerequisites as the main 'engine of growth' in the backward countries. Because when a country does not have enough factors of production it can replace them with institutions such as Banks or the State's intervention in industrial investment. This seems to be the most powerful part of Gerschenkron's thesis because it describes economic growth as a goal with alternative routes.

Concretely, Gerschenkron envisaged a staggered sequence of national industrial revolutions in Europe. He distinguished three types of countries depending on the chronology of their industrialisation: (1) The first comers where the capital flows directly into industry (e.g., Britain), (2) the relatively backward countries where the capital flows from banks to industry (e.g., Germany), (3) the most backward countries where the State played a direct role in the spurt of industrialisation (e.g., Russia). To reiterate, according to this line of reasoning, the main cause for this change of 'engine of growth' was that capital equipments increased with the delay in industrialisation. Gerschenkron argues that in conditions of relative backwardness the role of banks is crucial. When there was a high degree of economic backwardness banking was too limited and feeble to play a role in meeting the capital requirements of the industrial firms.

On a less optimistic note, Gerschenkron's thesis has important problems. The main problem is that he considers nations as the basic unit of analysis. Industrialisation was a period of great disparity in regional rates of change and economic fortunes. Expanding industrialising regions were matched by regions with declining industry, and chronic underutilisation of capital.[16] Another major problem is his definition of 'standard technology'.

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[16] Pollard (1981), Parker (1984), Hudson (1989).

Gerschenkron relates each historical period to one 'standard technology' that has particular capital requirements. Moreover, he adds that this technology is the most modern during the period. According to Gerschenkron, the development of backward countries is always related to the adoption of the latest technology, which also implies increasing capital requirements. Technology has changed during the past century, becoming more and more complicated, and, sometimes, more expensive. However, it is really very difficult to consider for each period one 'standard technology'. Several examples can be given, in England during the first phases of the Industrial Revolution, the most advanced technologies were in the cotton and iron industries. However, the capital requirements of these industries were very different. Moreover, in the same England several 'old' technologies survived, which were perfectly efficient, with lower fixed capital requirements.[17] The same could be argued for Germany, the classical backward country according to Gerschenkron. In Germany during the spurt of industrialisation different industries with very different capital requirements survived and flourished.[18] Consequently, what was standard technology in every period? What was the associated capital requirement? It is very easy to argue that every industry has a standard technology, but it is very difficult to argue this for every country and historical period.

The works of Rostow and Gerschenkron and the idea of universalities is now discredited. Nowadays, very few economics historians agree with the argument that European industrialisation merely consisted of the reiteration and diffusion of the British model in other countries. Or that every country followed a path according to its relative backwardness. In the words of Nicholas Crafts 'nineteenth century European economic development is increasingly coming to be regarded as hard to describe in terms of generally recognizable patterns'.[19]

Today, the recent works of Rondo Cameron, Pat O'Brien and Nicholas F. Crafts appear to be, in many senses, more influential. In 1985, Rondo Cameron rejected the whole idea of an 'industrial revolution', the existence of an universal model of industrialisation based on

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[17] See, for example, Mokyr (1994) and VonTunzelmann (1994).

[18] Feldenkirchen (1991).

[19] Crafts (1984), p. 438.

coal, cotton and iron that was imitated by the rest of the industrialisers. Cameron sees the emergence of industrialisation in many parts of Europe as the result of two factors: the existence of coal deposits and the availability of human capital.[20] On the other hand, Crafts found the Rostovian models not particularly illuminating but found that some parts of the Gerschenkron story are redeemable. He pointed out that the story of the followers would be better explained if one considers that: (1) coal was a decisive factor; (2) it is possible to achieve high income levels on the basis of exploiting a different comparative advantage; (3) economic policies appears to have little influence on the development of latecomers; (4) these countries appear to be unable to establish a comparative advantage in manufacturing goods.[21]

More recently, the debate has moved towards the concepts of 'globalisation' and 'convergence'. Economic historians have rapidly introduced into the debate many of the new instruments of Growth Theory and some new issues have displaced the preoccupation with industry. In the new accounts, human capital, migration, and trade have substituted technological transference as the main factors in European history.[22] Although, it is hard to explain the first half of the nineteenth century in the context of these new arguments. Basically, because the high cost of transport, especially in the periphery, made the impact of these 'globalisation' forces much less evident. Moreover, there are some pre-conditions for convergence which have not been studied.

The historiography of Spanish economic development is obsessed with the concepts backwardness and failure. Note that, in the last decades, the Spanish economy, Spanish society, and the debate on economic history in Spain have all converged towards the centre. Although a gap still divides Spain for the most advanced countries. Only thirty years ago, the debate in Spain was shaped by the political debate on the failure of the bourgeois revolution in Spain. Then, the pioneering work of Nicolás Sánchez-Albornoz represented the first break in the orthodox Marxist interpretation of the economic development of Spain and the first

[20] Cameron (1985).

[21] Crafts (1984).

[22] See Williamson (1996), O'Rourke and Williamson (1997), Williamson and Hatton (1998).

attempt to introduce Spain into the debates on economic history. Sánchez-Albornoz sees the Spanish economy of the nineteenth century as a dual economy with many similarities with today's underdeveloped countries.[23] Later research has discredited this view although one cannot denied its innovative character when it was published.

A few years later two economic historians introduced Spain into the core of the European debate. Jordi Nadal in his classic book *El fracaso de la revolución industrial en España* introduced the work of W. Hoffmann, W.W. Rostow and D. Landes.[24] Gabriel Tortella spread the thesis of A. Gerschenkron, and the tests of R. Cameron on the arguments of the Austrian-Russian economist.[25] According to Nadal, the case of Spain was the experience of an unsuccessful attempt to consolidate a process of industrialisation based on the adoption of the British model. He found evidence of the take-off and argues that Spain failed to consolidate its industry during the nineteenth century. This failure was a consequence of the weakness of the home demand for manufacturing goods. Therefore, it was a weak agriculture sector that impeded the industrialisation of Spain. Foreign trade, government policy and the land reforms had also a negative impact on Spanish industrialisation record.[26] On the other hand, Gabriel Tortella has stated that the lack of entrepreneurship and the limited role of the Spanish State enabled the banks to play a leading role in industrialisation.[27] However, the consolidation of the modern sectors, the railways, the banking system and industry was not absolutely successful during the nineteenth century.

In the 1990s Nadal and Tortella have refined their arguments. More recent versions of Nadal's work give pride of place to the traditional industries instead to the 'leader' industries, cotton and iron. But he has not modified his original formulation: Spanish backwardness has its roots in the poor agriculture. On the other hand, Tortella spoke of a

[23] Sánchez-Albornoz (1968b).

[24] Nadal (1974), Rostow (1956)(1960), Hoffmann (1955), Landes (1969).

[25] Tortella (1972a)(1972b), Gerschenkron (1962), Cameron (1967), Cameron, ed. (1972).

[26] Nadal (1974).

[27] Tortella (1972a)(1972b), p. 129

'Latin pattern of economic modernisation', by which he mean that countries in the Mediterranean basin have some common characteristics. He argues that in the nineteenth century Latin economies were in a vicious circle where physical and institutional factors retarded economic growth and development.[28]

Recently, three cliometric historians have changed the view on Spanish industrialisation. Albert Carreras quantitatively extended the works of Jordi Nadal. He was the first to develop an index of industrial production for Spain and to compare the Spanish pattern with other European patterns of industrialisation. His pathbreaking research resulted in two major conclusions: Spanish industry began to grow in the nineteenth century, and was characterised by slow growth rates.[29] Pedro Fraile severely criticises the 'demand' and 'exogenous' argument. In two influential works, he demonstrated that supply (industry) explanations for the Spanish backwardness cannot be rejected *a priori*. With his argument that Spanish industry failed to compete in foreign markets and that industrialists had rent-seeking attitudes, he directly confronted Nadal's interpretation of recent Spanish economic history.[30] Finally, Leandro Prados introduced Spain to the debates on convergence. He demonstrated that neither the European norm, nor the Third World norm, nor the Italian norm have been followed by Spain in the process of convergence. In other words, Spain was different.[31]

What can an analysis of Catalan early industrialisation contribute to the European economic history and to the Spanish debate? In terms of the European debate, this thesis serves to situate the experience of Mediterranean industrialisation in a broader context. Until now, quantitative studies of early industrialisation outside the core countries were very scarce. Consequently, there is little quantitative knowledge of the process industrialisation in the Southern Europe industrialising regions. In terms of the Spanish debate, it is clear that this thesis returns to one of the main topics: Why and how did Catalonia become the major

[28] Tortella (1994a).

[29] Carreras (1990b)(1997).

[30] Fraile (1985)(1991).

[31] Molinas and Prados (1989), Prados (1988)(1997).

industrial region in Spain? Answering this question can also help us understand the forces that hampered the process of industrialisation in other Spanish regions. Note also that this thesis concentrates on a supply-based explanation for the process of industrialisation.

### 1.3. Plan of the Thesis and Overview

This dissertation can be inserted within the mainstream of cliometric history. It should be noted, however, that the point of view is more heterodox than orthodox since not only the neo-classical perspective but also some of new economic theories are employed in the historical analysis. Specifically, in the second part of the dissertation, readers will find that some events are interpreted in the light of new growth theory, evolutionary economics, and new institutional economics. In any case, this dissertation makes use of, implicitly and explicitly, quantification and economic theory. But the objective is not to test economic models without making any reference to economic history. Quite the contrary, economic models are used as instruments in the narrative.

The strategy followed in this dissertation is simple. In the first part, a list of possible explanations of Catalan industrialisation are given, based on neo-classical economic theory. Once that list is complete, an attempt will be made to examine each of these hypotheses critically. What is important is that the final list does not have to be reduced to one single cause. The methodology employed serves to discriminate and to establish priorities. In other words, which factor was more important and decisive, but this does not mean that any factor was unimportant by itself. Once that analysis is complete, the second part of the dissertation is devoted to profoundly analysing that main factor.

Part one of the thesis is concerned with the explanation Catalan manufacturing growth from 1830 to 1861. This part shows that the key factor for manufacturing growth was the rapid improvement in total factor productivity. Chapter two investigates if an acceleration in manufacturing growth rates took place in the period from 1830 to 1861. It also explores how important the contribution of the development of Catalan manufacturing was to overall (Catalan and Spanish) growth rates. Chapter three analyses the contribution of capital accumulation to industry growth. Chapter four seeks to explain the changes affecting the labour market in manufacturing and the contribution of labourforce to the growth of industry output. This part is concluded by chapter five which discusses the neo-classical production function. The objective of chapter five is to determine the importance of productivity improvement and the accumulation of factors of production for the growth of Catalan manufacturing.

Part two is mainly concerned with the cotton industry although references are made to other sectors, especially in chapter seven. This part provides a detailed evaluation of the causes of the productivity performance of that industry. Unquestionably the most important Catalan industry and, in several ways, the leading industry in Catalan industrialisation. It should also be highlighted that to be convincing, any explanation of productivity performance must be able to stand up to scrutiny at a finer level of disaggregation. Chapter six analyses the contribution of human capital to output growth in the cotton industry. In order to do so, the chapter investigates how large the accumulation was of human capital prior to the emergence of the factory system, and what the role of human capital was during this process. Therefore, the goal of the chapter is to investigate the level and growth rate effects of human capital. Chapter seven seeks to explain the influence of the emergence of the factory system on the record of productivity and the causes behind the enlargement of firm size in Catalonia. Chapter eight analyses the main improvements in the organization of firms in the cotton industry after the emergence of the factory system; the development and diffusion of vertically integrated enterprises. Finally, chapter nine puts the Catalan cotton industry into the international context by comparing the Catalan industry with the largest cotton industries in the world. Which at that time were located in Lancashire and New England. In the first part of the chapter I address the relations between quality-mix, factor endowments and the technical choices of the cotton industry. The second part is devoted to analysing the competitiveness of the Catalan cotton industry in international markets.

Rigorous tests require numbers and theoretically sound and consistent reasoning. Much of this thesis is devoted to discussions of economic theory and quantitative analysis. Because of the obvious limitations of cliometric history, however, semi-quantitative and qualitative evidence is indispensable to this study. Therefore, qualitative and quantitative evidence have been seen as complements, not as substitutes.

This study makes no claim to being an exhaustive survey of all sources of Catalan economic history in the second third of the nineteenth century. Four sources play a central role in this study: the Sayró census (Sayró (1842) and Madoz (1846)), the Junta de Fábricas census (Junta de Fábricas (1850)), the industrial guide of 1861 (Gimenez Guited (1862)), and the tariff commission inquiry (Comisión especial arancelaria (1867)). Other nineteenth-century reports and investigations complement these four monumental sets of industrial data. Writings of contemporaries on Catalonia provide unusually good coverage of the main issues of industrial history. Furthermore, when it was necessary, firm accounts and non Catalan sources have been used. It should be noted that vast amounts of material still await historians and will allow them to confirm or reject the conclusions put forward in this study. In any case, I have tried to restrict the use of manuscript sources to those directly relevant to the questions posed.

# Part I. Explaining Output Growth

# Chapter 2

# The Growth of Industry Output

This chapter is devoted to computing and analysing the growth rates of Catalan industries during the early phase of industrialisation. Therefore, it has three main objectives. First, to provide a stylised description of the industrial path of the period 1830-1861. Second, it reviews the evolution of the Catalan industry in the Spanish context and, thus, can serve to describe the relative importance of the Catalan industrial experience. Finally, this chapter will provide some of the essential instruments used to measure productivity in chapter 5. The results show that Catalonia experienced a true process of industrialisation during the period 1830 to 1861, but that its contribution in rapid increase in Spanish GDP was relatively small.

## 2.1. Introduction

The measurement of the industry growth rates has a major role in the debate on the nature and characteristics of the beginnings of industrialisation since the subject of industrial growth rates has caused a great deal of controversy. Pioneering work on industrial output indices was based on the well-known non-superlative indices, such as Laspeyres or Paasche. These indices tended to concede large shares to the new sectors, cotton and iron, within industrial output. In broad terms, all these exercises tend to stress the existence of an explosive beginning where overall industry growth rates were fast.[32] By contrast, more recent work using superlative indices such as Fisher or Divisia has challenged that explosive view, and put emphasis on gradualism and slowness.[33] Critics of the explosive beginnings have

[32] See, for example, Rostow (1960).

[33] For example, Crafts and Harley (1992).

pointed out that only new industries experienced fast growth rates whereas the rest of industries remained in premodern backwardness.[34] Their analyses were based on a revisionist assessment of the size of the modern industries, with the implication that estimates of aggregate industrial growth should be lowered appreciably for the period of early industrialisation.

A similar debate also took place in the Spanish literature. Albert Carreras has pointed out that during the early period, 1830-1861, industrial growth rates were above 4 percent and that the share of the textile and metal industries, the modern industries, in Spanish industrial value-added was about 45 percent.[35] Moreover, he argued that early industrialisation was characterised by an abrupt change in industrial output. By contrast, Leandro Prados, a critic of the explosive beginnings, has pointed out that the share of modern industries of value-added was lower than Carreras suggested (about 27 percent).[36] By reducing the share of modern industries and considering more industries, he developed a new index with slow growth rates (about 2 percent per year).[37]

Albert Carreras has also computed an industrial index for Catalonia with fast growth rates (above 6 percent per year).[38] However, the recent revision of that index by Jordi Maluquer has not changed the general view on Catalan industrialisation.[39] This economic historian reduced the share of cotton of value-added and considered more industries, but the resulting growth rates remained impressive for this early industrialisation period (about 6 percent per year).[40]

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[34] See the recent revision of the debate at Temin (1997).

[35] Carreras (1990b).

[36] Prados (1988), pp. 163. recently, Prados has revised part of his earlier estimates see, for example, Prados (1997). Unfortunately, for the purposes of this chapter, his series begin too late (by 1850).

[37] Prados (1988), pp. 166.

[38] Carreras (1990b).

[39] Maluquer (1994b).

[40] Maluquer (1994b), Table 6, pp. 61.

Unfortunately, the stimulating revisions of Carreras' indices have not dealt with two important methodological (index) problems.[41] Firstly, Prados and Maluquer did not compute changes in the quality of output. In contrast, they assumed the quality remained constant throughout the period, since their quantity indices are the result of multiplying the gross weight of the main raw materials by a fixed coefficient.[42] It should be noted that this kind of procedure is likely to understate growth rates of modern sectors, where quality change was very important. Secondly, Maluquer and Prados weighted their indices with the last year weights assuming, implicitly, that the relative prices and the composition of the output remained constant. It is well known that this assumption overstates the rate of growth since it gives larger weights to the faster growth sectors.[43] Therefore, in order to measure correctly the industry growth rates, a different kind of index number is necessary.

For that reason, the main objective of this chapter is to recalculate industry growth rates in Catalonia from 1830 to 1861, employing a different kind of index number. Using a superlative index number, specifically a Törqvist index, one is able to solve the two shorthcomings mentioned above.

It should be noted that there are important limits to the degree to which growth estimates for many Catalan industries can be developed, since data is not available for the whole manufacturing sector. Thus, only the following sectors can be studied, cotton spinning, cotton weaving, cotton finishing, linen, metal, mixed fabrics, paper, silk and wool. We use two benchmark years: 1840 and 1861. However, it should be noted that, empirically, the industrial growth rate is determined by three different findings: the rate of growth of the modern industries, their share in the industrial output, and the rate of growth of pre-modern industries. If the rate of growth and share of modern industries is large enough, overall growth rates are necessarily higher. Consequently, by estimating the share and growth rates of modern

[41] See the criticisms to Prados's methodology in Bustelo (1993).

[42] In both studies Prados and Maluquer recognized the existence of these biases and the possible influence in the resulting growth rates (Prados (1988), pp. 148 and Maluquer (1994b), pp. 51-53).

[43] It should be noted that Prados only employed Laspeyres indices for 1830-1860, since in the rest of periods he employs the *exact* Divisia indices. The reason is that there is not enough data to construct the two benchmark estimates necessary for Divisia weights (Prados (1988), pp. 145-147).

industries we can calculate a range of plausible growth rates.

The plan of this chapter is as follows. Section 2.2 discusses the construction of a new annual index for the Catalan cotton industry for 1830 to 1861. It should be noted that growth findings in cotton industry are very important since it was the main Catalan industry during the period and, therefore, its growth rates heavily influence the results. The next section describes the elaboration of new production measures for the other Catalan manufacturing industries for the period 1840 to 1861. In section 2.4, I present a brief analysis of the results and the contribution of Catalan industry to Spanish growth rates. The bulk of the chapter then takes up the technical and empirical issues related to the construction of the new measures for Catalan manufacturing.

Because all statistics are imperfect and, obviously, they are more imperfect the older they are, the author wants to make clear that the results displayed in the next chapters contain substantial error margins and they must be interpreted as 'best guesses' rather than facts. Nevertheless, the presence of these substantial error margins should not invalidate the quantitative methodology since the error margins necessary to change the direction of the results are large. Moreover, when there were alternative numbers the most conservative of the possible calculations and/or the most reliable data source was chosen.

### 2.2. A New Yearly Index of Cotton Industry Production (1830-1861)

Traditionally, the cotton industry has been regarded as the central industry in many regional processes of industrialisation in Europe.[44] Catalonia is not an exception to this general rule since, from 1830 to 1861, the most important industry in Catalonia was the cotton industry.[45] In the Spanish panorama of the middle of the Nineteenth Century, cotton was unusual because it was the most dynamic industry and the only industry that depended on imports of foreign raw materials, (here, in value order, raw cotton, coal and chemical

[44] See the evidence presented in Pollard (1981),or Landes (1969).

[45] Nadal (1974), chapter 7.

products).[46] Despite the cotton industry being widespread in several Spanish regions, it should be noted that Catalonia possessed a large portion of that industry during the whole period.[47]

Before going further it is necessary to define what industries formed the Catalan cotton industry, since there is some confusion on this point. In several contemporary censuses, and in many recent studies, cotton industries not only comprised cotton spinning, weaving and finishing but also mixed fabrics weaving. The first three industries employed exclusively cotton fibre, or process cotton, as textile inputs, while the last blended cotton fibres with other textile fibres such as wool, linen and silk. This section is only devoted to analysing the evolution of the cotton sectors that employed only raw cotton or its by-products as textile inputs; in other words, cotton spinning, weaving and finishing but not mixed fabrics weaving. The choice of an 'enlarged' cotton industry is capable of producing different results due to the different evolution of 'pure' cotton and the other textile industries.[48] For example, during the 'cotton famine' in the 1860s, mixed fabrics production partly substituted pure cotton cloth production, and therefore their market share grew whereas cotton cloth's decreased.[49]

The objective of this section is to develop new measures of the growth of the Catalan cotton industry from 1830 to 1861.[50] My analysis begins with a review of the measures of the cotton industry developed by other economic historians and their flaws. In the light of these observations, I develop Törqvist indices (also called Divisia or Translog) of sectoral (gross) output, physical intermediate inputs, and value-added for the cotton industry and its sub-components (spinning, weaving and finishing).[51]

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[46] At the beginning of the period, Motril, in Andalusia, produced raw cotton but during the 1840s its crops were reduced drastically and practically disappeared in the following years.

[47] For example, in 1861, Catalonia produced about 75 percent of cotton spinning output, about 70 percent of weaving output, and about 77 percent of calico printing output (Gimenez Guited (1862), pp. 209).

[48] See sections 3 and 4 in this chapter.

[49] Comisión especial arancelaria (1867), pp. 113-153.

[50] The measures developed in this dissertation are all based on the economic theory of production, rather than traditional national accounting methods.

[51] More exactly, throughout this dissertation I employ a concept closely allied to gross output: 'sectoral output'. According to the Bureau of Labor Statistics definition sectoral output is 'the name

This is not the first time that attempts have been made to compute the value of the production of the Catalan cotton textile industry. Albert Carreras, Carles Sudrià, Leandro Prados de la Escosura and Jordi Maluquer de Motes have proposed different figures for Catalan cotton industry production in the nineteenth Century.[52] All the previous studies have employed the same methodology to compute the consumption of cotton cloth, whereas several alternative methods have been employed to calculate quantity indices (i.e., to combine into a single measure the different components of the cotton industry).

To compute consumption of cotton cloth, all these economic historians have transformed the raw material figures by means of fixed coefficients into output figures. In particular, they have hypothesised that the quantity of raw cotton imported minus 10 percent of wastage was equal to the quantity of cotton cloth produced.[53] This method is likely to produce a downward estimate of the output indices, since it does not consider one of the main characteristics of modern growth and the growth of the Catalan cotton industry during this period: the increase in the quality of output.[54]

Consequently, the major source of the differences among the different authors is the methodology used to weight quantity figures (i.e., the kind of quantity index). Broadly, two great families of indices can be distinguished: the non-superlative indices, which were employed by Carreras and Maluquer, and superlative, which were used by Prados.

It should be noted that the superlative indices have several important advantages over the non-superlative indices. The most common used and best-known non-superlative indices are the Laspeyres, Paasche and Geometric. Empirically, Paasche indices tend to reduce the

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given to gross output less intra-industry transactions'. In other words, sectoral output for an industry represents deliveries to purchasers outside the industry (see, Dean at alt. (1996), pp. 192).

[52] Carreras (1990b), Sudrià (1983), Prados (1983)(1988) and Maluquer (1994b).

[53] However, it should be noted that Maluquer (1994) has employed two different wastage measures: until 1870 he assumed 10 percent wastage, whereas after this year he progressively reduced the wastage because new machinery was introduced. Machinery which was capable of reducing raw cotton losses.

[54] The same Prados discusses these biases (Prados (1988), pp. 148).

rates of growth whereas Laspeyres indices tend to increase the rates. Moreover, the Laspeyres and Paasche indices are similar to the Leontief production function, which is a first-order approximation of an arbitrary Neoclassical production function. In other words, they assume a constant elasticity of substitution among the factors of production. If the choice is a non-superlative index, the analysis of the interrelations among the factors of production is biased, because a correct measure of growth must consider that sometimes the innovation implies changes in the elasticities of substitution, and the output measure necessarily assumes that there were no changes in the quality of production. For this reason, modern growth accounting, and growth measurement, has abandoned these indices and introduced superlative indices.[55] These indices are a second-order approximation to an arbitrary Neoclassical economy because they assume multiple elasticities of substitution among the factors of production. The best-known superlative indices are the Fisher *ideal* and the Divisia (also called Törnqvist). The first assumes a quadratic production function and the second a Translog production function. Both production functions assume, obviously, multiple elasticities of substitution among the factors of production and quality changes during the period considered.[56]

Several steps must be carried out to solve the flaws present in the previous studies. Firstly, according to the most recent practices, the *exact* measure of quantities is not their unweighted sum but a bilateral quantity index that is a weighted average of quantity relatives.[57] Then, one of the primary objectives for output and value-added measures is to start with as much detail or disaggregation of the measured outputs as possible. It is also convenient that subaggregates are homogeneous.[58] The intent is to develop output indices that correctly reflect the differing trends in the output of the various products produced within the industry. Secondly, to combine quantities and prices in a single measure Törqvist indices must

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[55] See a review of recent practices at Hill (1993).

[56] On index theory see: Diewert (1976)(1987), Diewert and Nakamura (1993) and Hill (1993).

[57] To make this distinction clear some authors named this weighted index 'volume index' (Hill (1993), pp. 381).

[58] Subaggregates are homogeneous when the price dispersion of their components is not statistically significant.

be employed due to their conceptual advantages. Finally, according to the Törqvist index methodology, the weights of the industry must be computed as the average value in the period.

Briefly, this work differs from the previous works for six main reasons: (1) the solving of the index number problem by using Törqvist indices; (2) the disaggregation of output into several components; (3) the method used to estimate the value-added; (4) the technique of computing the yearly amount of raw cotton which was employed by the industry (i.e., the estimate of the quantity of cotton cloth produced each year); (5) the estimating of the wastage as result of the spinning and weaving process; (6) the relative prices of the different types of outputs and inputs.

To measure output, physical inputs and value-added I use Törnqvist quantity indices, which are the changing-weight indices that have been used most frequently in the literature on productivity measurement.[59] These indices make use of logarithms for comparing a variable at two points of time. When used to compare outputs for two time periods, they employ an average of value-share weights for the two periods being considered. The index number is computed after first determining the logarithmic change as follows:

[59] See Dean et alt. (1996), pp. 184.

(2.1) $$lnX_t - lnX_{t-1} = \sum_i [\overline{\Theta}_{X_i}(\ln xi_t - \ln xi_{t-1})]$$

Where xi designates outputs, where n outputs (1..i..n) are being considered, the two time periods are t and t-1, and the value share weights $\Theta_{xi}$ are computed as:

$$\overline{\Theta}_{X_i} = 1/2[\theta_{xi}(T) + \theta_{xi}(T-1)],$$
$$(i=1,..i,..n).$$

Where the $\Theta_{xi}$'s denote the share of each output in total payments to its aggregate outputs. The exponential of this logarithmic change yields an index number.

The starting point for the construction of Törnqvist indices of sectoral (gross) output is the measurement of the total product in current prices (i.e., the measurement of total payments).[60] Empirically, the total product in current prices is equal to the sum of the values of all components of output or, equivalently, to the result of multiplying quantities by the unit prices of each component. Here, the system chosen to calculate the total output has been to compute yearly quantities of output and multiply these by their current prices (unit values). Because it is not methodologically convenient to employ a unique value for cotton spinning, weaving and finishing, employing five unit values and output categories for each of these sub-sectors, I compute their values. Therefore, the total product of subsector x in the year i is equal to:

(2.2) $$P_i = \sum_i^n (Q_{i,x} P_{i,x}).$$

The sum of the prices (unit values) x quantities (yearly consumption) of the n different types of output. Consequently, to construct these estimates of total product it is necessary to establish quantities of inputs and to infer quantities of outputs. For spinning, the yearly production of the five qualities of yarn has been inferred from the consumption of raw

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[60] The methodology is based on Christensen, Cummings, and Jorgenson (1980) and Jorgenson (1990).

cotton.[61] For weaving, the production of the five qualities of grey cloth have been inferred from the estimated consumption of the five different qualities of yarn. Finally, for finishing, the quantity of the five qualities of finished cloth have been derived from the estimated consumption of the five qualities of grey cloth.

The previous calculations used two different systems to estimate the yearly consumption of raw cotton by the Catalan industry. Albert Carreras and Leandro Prados used the importation figures directly, whereas Carles Sudrià and Jordi Maluquer created new figures because they transformed the original figures by means of a three-year average centred on the middle year.[62] The latter argued that this mathematical transformation is necessary because the yearly fluctuations of the importations figures are excessive. Moreover, Jordi Maluquer added to the import figures the Spanish raw cotton which was produced in Motril and imported through the Port of Barcelona, which was the main entrance for the raw materials used by the Catalan cotton industry. The Carreras-Prados solution implies that all the imported raw cotton was transformed into final products during the year in which they arrived in Catalonia. Therefore, there were no stocks of raw cotton in the hands of the wholesalers or semi-finished products in the hands of the cotton industry. Obviously, this does not seem plausible. On the other hand, the Sudrià-Maluquer solution implies that the quantity of raw cotton consumed by the industry in one year must necessarily depend on the quantity of raw cotton that would be imported during the following year. This also does not seem plausible. Therefore, the solution adopted in this paper is quite different from these two proposals.

The departure point for the computation of the quantities of raw cotton is to add to the original importation figures Motril's raw cotton sold in the Port of Barcelona.[63] Although this national raw cotton was only important before 1840, because after this date its production was

[61] It should be noted that this procedure is possible due to the fact that each quality of yarn can only be produced by a particular combination of different types of raw cotton. For example, to produce the finest grades of yarn only Egyptian raw cotton was employed.

[62] Carreras (1990b), Sudrià (1983), Prados (1983)(1988) and Maluquer (1994b).

[63] Comisión del Gobierno (1841).

drastically reduced.[64] Where there are no figures for the Motril raw cotton trade it is hypothesised that the Motril raw cotton figures maintained a straight-line relation with the trade of American raw cotton. Second, from 1850 to 1861, figures on the raw cotton imports of the *Almanaque del Diario de Barcelona*[65] replace Nadal's figures, but these new figures do not differ strongly from Jordi Nadal's.[66] Third, mobile averages that differ strongly from Sudrià-Maluquer's have been computed in order to transform the original import figures to production figures. Thus:

(2.3) $$\text{Quantity }(\text{Year}_t) = 0.8 * \text{Imports }(\text{Year}_t) + 0.2 * \text{Imports }(\text{Year}_{t-1}).$$

The choice of this mobile average has been based on different historical evidence: the quantity of raw cotton and intermediate products that different cotton firms declared as having in their factories,[67] literary evidence on the stocks of raw cotton, and the recommendations of different historical technical books on the problems of storing raw cotton for long periods.[68] Thus, different averages have been computed for nine unusual years (i.e. about 30 percent of years), although these maintain the raw cotton stock for no more than two years.[69]

All the previous studies assume that wastage of the raw cotton during the spinning and weaving process was equal to ten percent of its weight, in this study wastage is not constant because we assume it varies with the quality of raw cotton. Huberman, in his study on the Lancashire cotton industry, has divided raw cotton into five qualities (G1, G2, GF, F1 and F2), from the coarsest to the finest, matching to each quality a different wastage during the spinning process. Beginning with a wastage of nine percent for quality G1, wastage grew successively by one percent for each quality because the best qualities that were employed

[64] Nadal (1974) and Maluquer (1994b).

[65] Diario de Barcelona (1866).

[66] Nadal (1974).

[67] Comisión especial arancelaria (1867).

[68] Calvet (1857), Arau (1855), Ferrer Vidal (1875), and Ronquillo (1851-1857).

[69] In particular: 1844 ($0.6\text{Year}_t + 0.2\text{Year}_{t-1}$); 1845 ($0.8\text{Year}_t + 0.4\text{Year}_{t-1}$); 1850 ($0.7\text{Year}_t + 0.3\text{Year}_{t-1}$); 1851 ($0.8\text{Year}_t + 0.3\text{Year}_{t-1}$); 1856 ($0.6\text{Year}_t + 0.2\text{Year}_{t-1}$); 1857 ($0.8\text{Year}_t + 0.4\text{Year}_{t-1}$); 1858 ($\text{Year}_t + 0.2\text{Year}_{t-1}$); 1859 ($0.9\text{Year}_t$); 1860 ($0.8\text{Year}_t + 0.1\text{Year}_{t-1}$).

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[69] In particular: 1844 (0.6Year$_t$ + 0.2Year$_{t-1}$); 1845 (0.8Year$_t$ + 0.4Year$_{t-1}$); 1850 (0.7Year$_t$ + 0.3Year$_{t-1}$); 1851 (0.8Year$_t$ + 0.3Year$_{t-1}$); 1856 (0.6Year$_t$ + 0.2Year$_{t-1}$); 1857 (0.8Year$_t$ + 0.4Year$_{t-1}$); 1858 (Year$_t$ + 0.2Year$_{t-1}$); 1859 (0.9Year$_t$); 1860 (0.8Year$_t$ + 0.1Year$_{t-1}$).

to produce the finest yarn suffered most friction during the spinning process. Huberman derived the five figures by observing the places of production of the raw cotton, since quality depended on the place where the raw cotton was produced.[70]

In this study the quality figures have been drawn from the Diario de Barcelona, in which was listed the producing places of the raw cotton bales and their weights, from 1851 to 1861.[71] However, this source only specified the producing countries and not the different locations within each country. Concerning the United States, this incompleteness in the sources is important because Huberman has computed the quality of British yarn by referring to three different producing locations in the United States (Sea Island, Upland and Alabama).[72] For this reason, the raw data for 1850,[73] which distinguished the producing locations of raw cotton for different regions within the United States, has been extrapolated to the following years. Moreover, the Huberman equations have been modified to adapt to the Catalan procedures, which are described in different technical handbooks.[74] The results are in the equations below:[75]

(2.4) C1 = 0.30 (US) + (India and China) + (Levant)

C2 = 0.50 (US)

CF = 0.19 (US) + 0.50 (Brazil) + (Motril and Puerto Rico)

F1 = 0.50 (Brazil)

F2 = 0.01 (US) + (Egypt)

For the period before 1850 the wastage had to be calculated in a different way. Different estimates on the counts (quality) of the yarn produced by the Catalan industry were

[70] Huberman (1991a)(1996).

[71] Diario de Barcelona (1866).

[72] Huberman (1991a)(1996).

[73] Ronquillo (1851-1857).

[74] Calvet (1857) and Arau (1855).

[75] The quality C1 corresponds to yarn below 20 count; the C2 from 21 to 30 count; the CF from 31 to 40 count; the F1 from 41 to 60 count; and the F2 from 61 count (all measures are Catalan measures).

available for 1840, 1846 and 1849.[76] Thus, if one treats as equivalent the counts of yarn and the five qualities specified in equation (2.4), it is possible to derive the same figures for those years. A straight-line evolution between the proportion of the qualities has been assumed to hold throughout the years. However, for the period before 1840 there was no data on the quality of yarn, so it has been assumed that the production of coarse yarn depended on the proportion of functioning hand spindles. This idea is based on technical handbooks and historical data stating that Catalan hand spinners could not produce the finest yarns.[77] Therefore, quality figures from 1831 to 1840 have been constructed by deflating the proportion of coarse yarn to the proportion of production produced by the hand spindles.[78]

The former calculations did not consider the process of doubling. This process consisted of doubling the yarn in order the increase its resistance but maintain the count. Note that doubling did not increase the quantity of yarn. Moreover, the doubling process was mainly carried out with fine yarn since doubled yarn was mainly employed in the production of fine cloth and mixed fabrics. Consequently, the relative importance of doubling increased with the increase in the quality of Catalan yarn. For example, in 1841, the doubling process only affected 4 per cent of Catalan yarn, while by 1850 this proportion had increased to 14 percent.[79]

Moving to cotton weaving, the output has been derived from the difference between the total production of yarn and the quantity of yarn employed in mixed fabrics.[80] The calculation of wastage in weaving is much simpler than in spinning, because the proportion

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[76] Madoz (1846) and Figuerola (1968).

[77] Calvet (1857), Arau (1855) and Figuerola (1968).

[78] See the next chapter for a description of the sources for functioning hand spindles.

[79] Madoz (1846) for 1841 and Ronquillo (1851-1857) for 1850.

[80] The information about mixed-fabrics production and the origin of yarn derives from Comisión del Gobierno (1841) and Comisión Especial Arancelaria (1867). In Catalonia, high quality mixed-fabrics were woven with English fine cotton yarn, while Catalan yarn was used in the production of low-middle quality mixed fabrics. Information due to Madoz (1846) and Figuerola (1968) has been employed to establish yearly figures for the imported English yarn. Finally, the total demand of national yarn by the production of mixed fabrics has been established by assuming that the proportion of high quality mixed fabrics, which were produced with English yarn, and low-middle quality fabrics, which were produced with Catalan yarn, was the same as the figures for 1841 and 1861.

of wastage was the same for all qualities and types of machines. The wastage while weaving was equal to 5 per cent of the yarn employed.[81] Moreover, the quality of the cotton cloth relied exclusively on the quality of yarn because coarse yarn could be employed only to produce coarse cloth and, on the contrary, fine yarn could be only employed to produce fine cloth.[82] In other words, the improvements in the quality of cotton cloth were due to the improvements in the quality of yarn produced by the spinning industry. Consequently, each of the five qualities of grey cloth (GC1, GC2, GCF, GF1, GF2) was produced with the equivalent of the five qualities of yarn (C1, C2, CF, F1, F2).

In cotton finishing the total quantity of output was equal to the quantity of output in weaving, since in finishing the wastage was negligible. However, estimating the different categories (qualities) of finishing production generates new problems since quality of finished cloth is partly independent of grey cloth quality. Specifically, the main problem is generated by the fact that not only the finest cloth was printed, but that some coarse cloth was also printed. The solution chosen is to consider five categories of finished cloth: two types of bleached cloth (B1, B2) and three different types of printed cloth (CA1, CA2, CA3). Since the cost of bleaching was the same in B1 and B2, these two kinds of cloth only differed by the grey cloth employed (coarser in B1 than in B2). In printed cloth, the quality CA1 was produced with coarse cloth since it was employed in upholstery and curtains.[83] The quality CA2 corresponds to the calicoes produced with medium grey cloth and a reduced range of colours. The most expensive calicoes (CA3) were produced with the finest quality of grey cloth and printed with several fine colours, and they were employed to produce good quality materials.[84] Finally, note that the quality of the final production also grew since the proportion

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[81] Comisión Especial Arancelaria (1867).

[82] Comisión Especial Arancelaria (1867).

[83] Some confusion can be caused by the fact that the quality CA1 by metre was more expensive than the finer qualities CA2 and CA3, but when the price is calculated by kg. quality CA1 was cheapest.

[84] Obviously, these three qualities of printed cloth are a necessary simplification of the large range of products produced by the Catalan mills. A complete description of all qualities of Catalan cloth is furnished by Ronquillo (1851-1857) and Orellana (1860).

of cloth printed grew. [85]

Considering all the issues mentioned above and the data of the historical sources I estimated the next equation to convert grey cloth output into finishing output:[86]

(2.5) B1 = 0.75 (GC1)

B2 = 0.50 (GC2)

CA1 = 0.25 (GC1) + 0.50 (GC2)

CA2 = (GCF)

CA3 = (GF1) + (GF2).

The last step in the computation of the total value is to establish the prices for each quality of yarn and cotton cloth. However, yearly price data for all qualities of yarn, grey cloth and finished cloth is not readily available. In particular, there are yearly price figures for the Spanish 30 count of yarn, middle quality grey cloth and cheap calicoes. It should be noted that these figures seem very accurate according to the different sources contrasted.[87] The main problem with these figures is that they refer to the typical products from the 1850s onwards, but before the 1850s typical Catalan cotton products were coarse. Moreover, it should be taken into account that prices of the different qualities did not evolve in the same way. Therefore, to employ one of these series as a unique deflator could provoke severe distortions in the results.[88] The correct way to solve this data constraint is to construct some kind of superlative price index using a set of prices for all qualities of cotton products available. A Fisher price index was computed for five types of yarn using the 30 count figures

[85] For these proportions see Sayró (1842), Madoz (1846), Ronquillo (1851-1857) Gimenez Guited (1862), and Comisión Especial Arancelaria (1867).

[86] This formula is mainly based on the data of Sayró (1842) and Comisión especial arancelaria (1867).

[87] The equivalence with the measures of other countries is: the Spanish 30 count is equal to the English 31-32 count and the French 26 count. In other words,the equivalence is 1 Spanish = 1.042 English = 0.883 French. The data is from Ferrer Vidal (1875), pp. 70-71.

[88] For the different evolution of the technical innovation in fine and coarse textiles see Von Tunzelmann (1978) and Hubermann (1991a)(1996).

as a yearly deflactor and two complete price weights, one by 1840 and one by 1861.[89] The main advantage of the Fisher price deflator is that the prices reflect technological innovations.[90] The method used to estimate the prices of grey cloth is similar to the method used with yarn. Two complete price weights for different kinds of cloth and the annual series of grey cloth prices have been employed to construct five different price indices.[91]

The method used to estimate the prices of finished cloth is slightly different to the method used with grey cloth. As with yarn and grey cloth, yearly figures on the prices of cheap calicoes have been used to compute the prices of the three qualities of printed cloth (CA1, CA2 and CA3), with two weights.[92] However, it is not convenient to employ the prices of printed cloth for estimating the prices of bleached cloth. Since the difference between the two prices is larger, as sometimes calicoes sold for two or three times price of bleached cloth. Moreover, the technological innovation in bleaching had different chronology to that in finishing and, hence, the evolution of their prices would diverge. Consequently, the prices of the two qualities of bleached cloth (B1 and B2) have been computed by adding the price of the bleaching process to the prices of grey cloth (GC1 and GC2). As described in several sources.[93] In the next page, table 2.1 presents the prices of the main inputs and outputs in weight units (Qm).

Once total payments for every year and kind of output has been computed it is simple to compute the final index. The quantities have been estimated previously and the shares of these quantities are the average of the relative values in the *n* years considered. The

[89] The weights for 1840 come from Madoz (1846) and Sayró (1842) whereas the weights for 1861 come from Comisión Especial Arancelaria (1867).

[90] Moreover, it is practically equivalent to the Törqvist price index. See Diewert (1987) and Hill (1993).

[91] The weights of 1840 are drawn from Madoz (1846) and Sayró (1842) whereas the weights for 1861 are drawn from Comisión Especial Arancelaria (1867).

[92] The weights for 1840 come from Madoz (1846) and Sayró (1842) whereas the weights for 1861 come from Comisión Especial Arancelaria (1867).

[93] It should be noted that bleaching was sometimes sub-contracted by weaving firms to specialised bleaching firms. Then, after the process of bleaching, weaving firms sold the bleached cloth directly to cloth wholesalers.

exponential of the resulting logarithmic change yields an index number. These indices of sectoral (gross) output for cotton spinning, weaving and finishing are presented in table 2.2.

**Table 2.1** Prices of the Main Input and Outputs: Cotton Industry 1830-1861

| | Raw Cotton US Middling Pta/Qm | Yarn 30 count Pta/Qm | Grey Cloth for printing Pta/Qm | Calicoe cheap colours Pta/Qm |
|---|---|---|---|---|
| 1830 | 188.00 | 656.25 | 1537.74 | 2529.03 |
| 1831 | 192.00 | 625.00 | 1309.68 | 3129.68 |
| 1832 | 182.00 | 593.75 | 1309.68 | 2287.42 |
| 1833 | 199.00 | 593.75 | 1309.68 | 2287.42 |
| 1834 | 239.00 | 593.75 | 1203.55 | 2167.74 |
| 1835 | 273.00 | 562.50 | 1115.48 | 2167.74 |
| 1836 | 257.00 | 562.50 | 1083.87 | 2045.81 |
| 1837 | 227.00 | 531.25 | 1022.90 | 2045.81 |
| 1838 | 184.00 | 531.25 | 992.42 | 1926.13 |
| 1839 | 212.00 | 531.25 | 948.39 | 1926.13 |
| 1840 | 175.00 | 531.25 | 977.74 | 1926.13 |
| 1841 | 155.00 | 500.00 | 951.77 | 1806.45 |
| 1842 | 134.00 | 437.50 | 784.68 | 1506.13 |
| 1843 | 133.00 | 406.25 | 706.77 | 1806.45 |
| 1844 | 166.00 | 406.25 | 690.97 | 1521.94 |
| 1845 | 121.00 | 406.25 | 690.97 | 1506.13 |
| 1846 | 136.00 | 375.00 | 690.97 | 1323.23 |
| 1847 | 168.00 | 343.75 | 570.16 | 1264.52 |
| 1848 | 125.00 | 329.38 | 540.81 | 1235.16 |
| 1849 | 146.00 | 312.50 | 585.97 | 1203.55 |
| 1850 | 188.00 | 375.00 | 660.48 | 1144.84 |
| 1851 | 188.00 | 375.00 | 585.97 | 1144.84 |
| 1852 | 156.00 | 343.75 | 570.16 | 1115.48 |
| 1853 | 163.00 | 329.38 | 601.77 | 1083.87 |
| 1854 | 158.00 | 375.00 | 616.45 | 1144.84 |
| 1855 | 165.00 | 343.75 | 585.97 | 1054.52 |
| 1856 | 164.00 | 343.75 | 555.48 | 1054.52 |
| 1857 | 188.00 | 343.75 | 540.81 | 1022.90 |
| 1858 | 200.00 | 343.75 | 555.48 | 1002.58 |
| 1859 | 189.00 | 343.75 | 555.48 | 961.94 |
| 1860 | 178.00 | 350.00 | 503.55 | 912.26 |
| 1861 | 197.00 | 386.25 | 555.48 | 1004.84 |

**Notes and sources:** Original raw cotton prices are drawn from Izard (1969). Similar prices are available in Diario de Barcelona (1866)(1870). Original yarn prices in *Libras Catalanas* converted to Qm by multiplying by 250. Grey cloth and Calicoes: Original prices in *Canas Catalanas* converted to Qm by multiplying by 903.2258. Weights are drawn from Comisión especial Arancelaria (1867) and Ferrer Vidal (1875). The prices of yarn, grey cloth and calicoes are drawn from the figures of Diario de Barcelona (1866).

**Table 2.2** Sectoral Output Indices: Cotton Industry, 1830-1861

| | Spinning | Weaving | Finishing |
|---|---|---|---|
| 1830 | 100.00 | 100.00 | 100.00 |
| 1831 | 102.20 | 103.75 | 103.49 |
| 1832 | 101.21 | 103.95 | 103.69 |
| 1833 | 98.98 | 102.68 | 102.43 |
| 1834 | 96.69 | 102.07 | 101.83 |
| 1835 | 88.75 | 94.65 | 94.85 |
| 1836 | 101.05 | 108.58 | 108.00 |
| 1837 | 117.73 | 127.84 | 126.31 |
| 1838 | 141.62 | 155.52 | 152.63 |
| 1839 | 121.31 | 137.61 | 136.02 |
| 1840 | 201.74 | 235.65 | 229.16 |
| 1841 | 232.61 | 277.96 | 267.35 |
| 1842 | 156.67 | 189.95 | 184.23 |
| 1843 | 86.85 | 106.47 | 105.99 |
| 1844 | 172.26 | 214.41 | 204.82 |
| 1845 | 306.12 | 392.50 | 371.54 |
| 1846 | 343.52 | 452.27 | 425.34 |
| 1847 | 218.26 | 293.35 | 281.27 |
| 1848 | 300.77 | 402.71 | 385.77 |
| 1849 | 358.73 | 478.59 | 458.55 |
| 1850 | 433.56 | 620.69 | 653.25 |
| 1851 | 532.47 | 751.19 | 777.54 |
| 1852 | 499.74 | 695.38 | 696.74 |
| 1853 | 480.16 | 668.25 | 663.50 |
| 1854 | 470.54 | 657.27 | 665.26 |
| 1855 | 536.18 | 750.27 | 771.35 |
| 1856 | 601.30 | 837.23 | 840.97 |
| 1857 | 685.91 | 953.13 | 947.75 |
| 1858 | 678.26 | 941.97 | 927.35 |
| 1859 | 605.73 | 836.22 | 802.52 |
| 1860 | 592.34 | 818.58 | 787.41 |
| 1861 | 622.60 | 857.14 | 825.20 |

**Notes and sources:** see text.

In the next pages I will develop Törqvist indices of physical intermediate inputs for cotton spinning, weaving and finishing. Then, I employ these indices and sectoral output indices to compute value-added indices.

To measure intermediate inputs I employ the same method than it was used to measure output. Therefore, one of the primary objectives is to start with as much disaggregation of the measured inputs as possible. Then, I divide intermediate inputs into homogeneous categories which must then be weighted by their share in the total value of intermediate inputs. For that reason, I consider up to six categories of inputs in cotton spinning, weaving and finishing. In spinning the six categories of inputs are: five types of raw cotton and rest of materials (mainly coal); in weaving, the five types of yarn and rest of materials (mainly, again, coal); and in finishing, the five types of grey cloth, coal, and chemical materials for bleaching or printing.

In spinning, the quantity of raw cotton is drawn from the figures described above, while the price figures for each type of raw cotton are drawn from Izard.[94] In the years without prices for one kind of cotton its price has been estimated as a proportion of the price of the two kinds of raw cotton most widely consumed (U.S. and Brazil). Moreover, the price of the raw cotton from Motril and Puerto Rico is assumed to be equal to the price of the raw cotton that is most similar in terms of quality, i.e. Brazilian raw cotton. The rest of the intermediate inputs in spinning have also been estimated. For example, coal, vegetal coal, food for horses, gas for lights, starch, oil for machinery, and so on. In 1840 the proportional cost of these intermediate inputs was lower than in 1861.[95] An index according to the procedure described in the equation 2.1 was estimated.

In weaving, the main input was, obviously, the yarn, for which the complete figures have already been used for the spinning calculations. Next, the amount of Catalan yarn employed to produce mixed fabrics instead of pure cotton cloth was computed and the figure obtained has been subtracted from the total yarn figures. Finally, as in spinning, the costs and

[94] Izard (1969).

[95] For 1840, Comisión del Gobierno (1841) and for 1861 Comisión Especial Arancelaria (1867).

weights of the intermediate inputs were calculated and, again as in spinning, it is seen that these costs increased during the period. This is because the new machinery required increasing quantities of coal and other intermediate inputs.[96] As before an index according to the procedure described in the equation 2.1 was estimated.

Moving to finishing, the main input was grey cloth, for which the complete figures were already given for weaving. Then, the consumption of energy, chemical and colouring products during the process of finishing cloth was computed. It should be underlined that to produce each kind of finished cloth different quantities and types of inputs were employed. Thus, the evolution in the consumption of different inputs is related to the changes in the composition of finished cloth production. For example, to produce finest calicoes with several colours, printers had to employ more energy and colour than to produce coarse calicoes. An index according to the procedure described in equation 2.1 was estimated. Table 2.3 shows all the indices for physical intermediate inputs.

[96] For 1840 Sayró (1842) and for 1861 Comisión especial arancelaria (1867).

**Table 2.3** Intermediate Inputs Indices: Cotton Industry, 1830-1861

| | Spinning | Weaving | Finishing |
|---|---|---|---|
| 1830 | 100.00 | 100.00 | 100.00 |
| 1831 | 102.12 | 103.27 | 103.72 |
| 1832 | 99.79 | 102.64 | 103.98 |
| 1833 | 97.24 | 100.80 | 102.79 |
| 1834 | 94.68 | 99.84 | 102.22 |
| 1835 | 85.32 | 91.96 | 94.98 |
| 1836 | 101.72 | 104.52 | 108.97 |
| 1837 | 117.16 | 121.40 | 128.45 |
| 1838 | 141.24 | 145.44 | 156.47 |
| 1839 | 110.82 | 126.62 | 139.06 |
| 1840 | 207.94 | 208.88 | 238.34 |
| 1841 | 214.16 | 241.82 | 279.92 |
| 1842 | 128.37 | 166.95 | 191.40 |
| 1843 | 69.84 | 95.41 | 107.62 |
| 1844 | 177.00 | 190.41 | 215.59 |
| 1845 | 375.87 | 341.13 | 393.07 |
| 1846 | 202.52 | 381.27 | 454.87 |
| 1847 | 198.37 | 244.86 | 297.39 |
| 1848 | 285.36 | 332.72 | 408.25 |
| 1849 | 329.44 | 393.85 | 485.21 |
| 1850 | 416.59 | 467.51 | 644.68 |
| 1851 | 394.76 | 556.94 | 778.73 |
| 1852 | 415.48 | 527.80 | 716.77 |
| 1853 | 390.32 | 511.90 | 687.77 |
| 1854 | 384.22 | 502.21 | 679.14 |
| 1855 | 447.76 | 567.05 | 777.46 |
| 1856 | 651.14 | 637.49 | 862.99 |
| 1857 | 395.31 | 725.80 | 980.21 |
| 1858 | 499.47 | 723.04 | 966.92 |
| 1859 | 559.75 | 657.68 | 853.33 |
| 1860 | 545.59 | 646.23 | 835.76 |
| 1861 | 565.84 | 676.77 | 874.95 |

**Notes and sources:** see text.

Once the sectoral output and intermediate sectoral inputs indices were constructed, it was possible to develop value-added indices for each sector. Value-added is defined as the sum of the value of capital input and the value of labour input or, equivalently, sectoral (gross) output minus (sectoral) physical (intermediate) inputs. Specifically, the rate of growth of sectoral value-added is equal to the rate of growth of sectoral output minus the rate of growth of sectoral intermediate inputs multiplied by their share in total payments. Thus:

$$\text{(2.6)} \qquad lnVA_t - lnVA_{t-1} = \sum_i [\bar{\Theta}_{x_i}(\ln xi_t - \ln xi_{t-1})] - \sum_i [\bar{\Theta}_{y_i}(\ln yi_t - \ln yi_{t-1})]$$

where VA designates value-added, x sectoral (gross) outputs and y sectoral intermediate inputs, where n outputs and inputs (1..i..n) are being considered. Two time periods are t and t-1, and the value share weights $\Theta_{xi}$ are computed as:

$$\bar{\Theta}_{x_i} = 1/2[\theta_{xi}(T) + \theta_{xi}(T-1)], \qquad (i=1,..i,..n).$$

Where the $\Theta_{xi}$'s denote the share of each output (total payments) in its sectoral output. Similarly, the $\Theta_{yi}$'s denote the share of each input (total payments) in sectoral output. Table 2.4. shows the indices of value-added.

**Table 2.4** Value-added Indices: Cotton Industry, 1830-1861

| | Spinning | Weaving | Finishing |
|---|---|---|---|
| 1830 | 100.00 | 100.00 | 100.00 |
| 1831 | 101.16 | 101.95 | 100.99 |
| 1832 | 101.33 | 102.50 | 101.02 |
| 1833 | 100.43 | 102.25 | 100.61 |
| 1834 | 99.63 | 102.19 | 100.41 |
| 1835 | 98.06 | 99.48 | 98.38 |
| 1836 | 98.43 | 105.65 | 102.00 |
| 1837 | 104.02 | 113.60 | 106.63 |
| 1838 | 111.64 | 123.77 | 112.60 |
| 1839 | 109.67 | 119.44 | 108.76 |
| 1840 | 128.06 | 150.01 | 126.71 |
| 1841 | 145.46 | 162.33 | 131.97 |
| 1842 | 122.64 | 138.07 | 119.05 |
| 1843 | 87.71 | 109.42 | 98.99 |
| 1844 | 105.13 | 141.70 | 124.65 |
| 1845 | 116.57 | 178.26 | 152.20 |
| 1846 | 174.45 | 191.91 | 157.52 |
| 1847 | 111.99 | 163.04 | 139.29 |
| 1848 | 123.61 | 183.90 | 155.85 |
| 1849 | 135.24 | 197.26 | 165.31 |
| 1850 | 138.82 | 231.61 | 192.94 |
| 1851 | 176.70 | 251.33 | 201.39 |
| 1852 | 160.89 | 240.81 | 190.91 |
| 1853 | 160.66 | 235.71 | 187.21 |
| 1854 | 158.91 | 234.53 | 189.42 |
| 1855 | 165.77 | 248.11 | 199.50 |
| 1856 | 142.76 | 257.02 | 202.03 |
| 1857 | 223.75 | 268.44 | 208.16 |
| 1858 | 194.14 | 265.97 | 205.70 |
| 1859 | 159.99 | 251.45 | 195.64 |
| 1860 | 159.46 | 249.21 | 195.02 |
| 1861 | 163.30 | 252.21 | 197.51 |

**Notes and sources:** see text.

Finally, I construct new indices of sectoral (gross) output and value-added for the Catalan cotton industry. Sectoral output is computed according to the Törqvist quantity equation:

$$lnX_t - lnX_{t-1} = \sum_i [\bar{\theta}_{X_i}(\ln xi_t - \ln xi_{t-1})] \qquad (2.7)$$

where X designates sectoral cotton industry output, x individual outputs, and where n outputs (1..i..n) are being considered. Two time periods are t and t-1, and the value share weights $\Theta_{xi}$ are computed as:

$$\bar{\theta}_{X_i} = 1/2[\theta_{xi}(T) + \theta_{xi}(T-1)], \quad (i=1,..i,..n).$$

The $\Theta_{xi}$'s denote the share of each output (total payments) in its aggregate sectoral output.

According to the definition of sectoral output, the nominal value of sectoral output in the cotton industry is equal to the value of finished cloth production plus the part of spinning production 'exported' to the mixed-fabrics industry. Similarly, the value of grey cloth and yarn employed in the production of 'pure' cotton cloth are not considered, since they are deliveries to purchasers inside the industry. Empirically, the aggregate index is computed as a weighted sum of spinning and finishing sectoral indices, where the weights of spinning and finishing are computed using the value of deliveries to buyers outside the cotton industry.

The aggregate value-added not only requires the assumption of separability of value-added from intermediate inputs, but also that all sectoral value-added functions must be identical to the aggregate production function. In other words, the value-added function and the capital and labour input functions must be replicas of the aggregate functions.[97]

In this case, the current value of aggregate value-added (VA) of the cotton industry is the sum of the values of the value-added in all sub-sectors (spinning, weaving and finishing). In other words, the value of sectoral cotton industry output minus intermediate

[97] Gullickson (1995).

physical inputs bought outside the sector. Thus, it is computed as follows:

$$\ln VA_t - \ln VA_{t-1} = \overline{\Theta}_{X_i}(\ln Xi_t - \ln Xi_{t-1}) - \overline{\Theta}_{\alpha_i}(\ln \alpha i_t - \ln \alpha i_{t-1}) \tag{2.8}$$
$$- \overline{\Theta}_{\beta_i}(\ln \beta i_t - \ln \beta i_{t-1}) - \overline{\Theta}_{\gamma_i}(\ln \gamma i_t - \ln \gamma i_{t-1}) - \overline{\Theta}_{\delta_i}(\ln \delta i_t - \ln \delta i_{t-1}).$$

Where X designates sectoral output of cotton industry and $\alpha$ is raw cotton inputs, $\beta$ is energy in cotton spinning, $\gamma$ is energy in cotton weaving and $\delta$ is energy in cotton finishing and other secondary inputs purchased outside the cotton industry. The two time periods are t and t-1, and the value share weights $\Theta_{xn}$ and $\Theta_{yn}$ are computed as in equation 2.6. The exponential of this logarithmic change yields an index number.

These sectoral output and value-added indices are presented in table 2.5. Moreover, other index (which is called a pure quantity index) has been computed. This index is close to the indices developed by other authors. This index is the exponential of the difference of successive logarithms of the actual imports of raw cotton into Catalonia (Motril or foreign), minus a constant wastage of 10 percent. Therefore, it assumes that quality and relative prices remained constant throughout the period.

**Table 2.5** Aggregate Indices: Cotton Industry, 1830-1861

| | Pure Quantity | Sectoral Output | Sectoral Value-added |
|---|---|---|---|
| 1830 | 100.00 | 100.00 | 100.00 |
| 1831 | 102.03 | 103.40 | 102.82 |
| 1832 | 99.36 | 103.53 | 103.23 |
| 1833 | 96.69 | 102.21 | 102.40 |
| 1834 | 94.02 | 101.50 | 102.24 |
| 1835 | 84.43 | 94.46 | 97.84 |
| 1836 | 101.10 | 107.56 | 105.64 |
| 1837 | 116.03 | 125.76 | 117.87 |
| 1838 | 139.63 | 151.93 | 134.72 |
| 1839 | 107.62 | 135.10 | 126.57 |
| 1840 | 204.99 | 227.46 | 180.02 |
| 1841 | 206.50 | 265.21 | 206.04 |
| 1842 | 120.57 | 182.57 | 157.90 |
| 1843 | 65.31 | 104.88 | 103.10 |
| 1844 | 172.99 | 202.85 | 159.50 |
| 1845 | 376.86 | 367.74 | 233.14 |
| 1846 | 168.59 | 420.78 | 290.65 |
| 1847 | 181.50 | 278.01 | 199.16 |
| 1848 | 262.81 | 381.34 | 245.78 |
| 1849 | 301.87 | 453.32 | 279.00 |
| 1850 | 379.35 | 644.10 | 360.02 |
| 1851 | 359.78 | 766.96 | 425.19 |
| 1852 | 388.77 | 687.89 | 380.59 |
| 1853 | 364.66 | 655.19 | 368.67 |
| 1854 | 356.81 | 656.60 | 369.84 |
| 1855 | 417.33 | 761.03 | 407.91 |
| 1856 | 628.73 | 830.23 | 401.08 |
| 1857 | 346.34 | 935.91 | 499.93 |
| 1858 | 455.97 | 915.99 | 466.32 |
| 1859 | 530.43 | 793.32 | 398.01 |
| 1860 | 516.56 | 778.32 | 393.84 |
| 1861 | 488.53 | 815.74 | 404.94 |

**Notes and sources:** See text.

## 2.3. Catalan Manufacturing Output (1840-1861)

The goal of this section is to generate new measures of the growth of Catalan manufacturing from 1840 to 1861. In this chapter I develop measures of real sectoral (gross) output, physical intermediate inputs and value-added for nine Catalan industries. I also construct an aggregate measure for manufacturing.

Output data on current values for two benchmark years (1840 and 1861) is available for nine industries. In the paper, metal, and mixed fabrics industries output values are taken from the sources.[98] The values of cotton industry (spinning, weaving and finishing) output are those computed in the previous section. Finally, the values of the wool, linen and silk industries have been estimated from several sources.[99]

For the wool industry in 1840 the quantity and current value of production was computed using raw wool figures. The quantity of raw wool employed by the wool industry is equal to the quantity of raw wool imported into Catalonia (300,000 arrobas) minus the quantity of raw wool employed by mixed fabrics (21,570 arrobas).[100] Since, at that time, six arrobas of raw wool were necessary to produce one wool fabric,[101] which had on average 40 varas castellanas, and the average price was 10 Rv per vara,[102] the current value of the production was 18,562,000 Rv (i.e., 4,640,500 Pta).[103] For silk and linen, the methodology

[98] For the metal and mixed fabrics industries, for 1840 Sayró (1842) and Madoz (1846). For the paper industry, for 1840 Delgado (1991), pp. 214 and Gutierrez (1837). For all industries, the 1861 data comes from Gimenez Guited (1862).

[99] It should be noted that the wool and silk industries comprised spinning, weaving and dyeing whereas linen only dyeing and weaving.

[100] The quantity of raw wool is from Benaül (1991), pp.119 (this figure is based on a survey of the *Junta de Comercio*) and the mixed fabrics data comes from Sayró (1842).

[101] Benaül (1991), pp. 119.

[102] Figuerola (1968), pp. 225.

[103] A test of the quality of the result can be obtained by computing the implicit density (kg./m.) of the average fabric and comparing this result with the data that appeared in the contemporary technical handbooks. Density can be calculated by multiply raw wool by 0.4 (eliminating the wastage in the process of cleaning), then by 0.95 (eliminating the wastage in the process of spinning), and then dividing by the number of fabrics multiplied by 33.4 (the measure in metres of 40 varas). The implicit

differs slightly from that employed for wool. As for wool, the quantity of fibre (silk in hanks and linen yarn respectively) consumed by the silk and linen industries is equal to the quantity imported into Catalonia, minus the quantities consumed by mixed fabrics production and lost in wastage.[104] Since the prices of cloth are only available in varas, it has been necessary to compute the quantity of varas produced.[105] The quantity of varas is computed in two steps: (1) the weight of cloth is obtained, deleting the wastage through weaving from the quantity of yarn, (2) the resulting figure is multiplied by the average density of the cloth.[106] Then, the value of output is the quantity of varas multiplied by its average price. Finally, for 1861, the value of output in silk, linen and wool is taking directly from the source, but before using the figure one must first subtract the quantities sold to the mixed fabrics industry.[107]

A further problem is that Gimenez Guited's guide included a lot mixed fabrics production within the production of the silk, wool and linen industries. Furthermore, many weavers, especially those that wove with jacquard looms, changed textile fibre (even two or three times during the year) according to the changes in fashion and season. For example, in the summer they produced winter textiles with wool, or blended wool with cotton or silk.

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density was 0.7858 kg./m. whereas the technical handbooks show that the densities of wool fabrics produced in Catalonia were in the range of 0.55 to 0.95 kg./m. (see Ronquillo 1851-1857, pp. 373-385). The wastage of raw wool is based on the coefficient of Prados (1983), pp. 469.

[104] The imports of silk amounted 67,000 kg. 7,000 kg. were used in the production of mixed fabrics. The data on imports comes from Figuerola (1968), pp. 226 and consumption by mixed fabrics from Sayró (1842). In the case of linen, the imports of linen yarn amounted to 142,540 kg. and 41,675 kg. were consumed by mixed fabrics. The first data comes from Madoz (1846), pp. 555 and the second from Sayró (1842).

[105] In particular, the average price of silk cloth per vara was 25 Rv, whereas the price of linen cloth was 6 Rv (the first number from Figuerola (1968), pp. 224-225 and the second from Madoz (1846), pp. 555). The wastage of silk and linen is based on the coefficients of Prados (1983), pp. 470-471.

[106] The average densities were 0.14205 kg./vara for silk and 0.1492 kg./vara for linen (these densities are an average of the data of Ronquillo (1851-57), pp.385-389 and 394-409).

[107] Gimenez Guited (1862), pp. 210-212. Note that the value that appeared in the source was the sum of the values of yarn and cloth. Therefore, to convert these values into sectoral output it was necessary to remove yarn from the total value. This is possible since the source gives the quantities of yarn and cloth produced.

While in the winter they produced summer textiles with linen, silk or/and cotton.[108] In other words, it does not seem justifiable to separate the different non-cotton textile sectors and, therefore, I put these industries together in a single measure. The next table presents these current values and shows the extraordinary differences in the composition of the sector between the two years. These results justify the option taken in this chapter.

**Table 2.6** Value of Sectoral Output: Other Textiles, 1840-1861
(Current prices, thousand Pta)

| | 1840 | | 1861 | |
|---|---|---|---|---|
| | Value | Share | Value | Share |
| Mixed Fabrics Textiles | 35,445 | 81.19 | 18,580 | 20.18 |
| Wool Textiles | 4,641 | 10.63 | 45,881 | 49.85 |
| Silk Textiles | 2,640 | 6.05 | 17,420 | 18.93 |
| Linen Textiles | 931 | 2.13 | 10,159 | 11.04 |
| Total | 43,657 | 100.00 | 92,040 | 100.00 |

**Notes and sources:** see text. Numbers subject to rounding errors.

The values of intermediate inputs were also estimated.[109] Sources only provided the value of all inputs in the metal, mixed fabrics, linen and paper industries for 1840.[110] Therefore, all the values for 1861 and the rest of the values for 1840 have been estimated from the available cost functions and/or the quantities consumed of the main inputs. Specifically, the quantities of raw fibre consumed were used to estimate values of inputs for wool and silk in 1840.[111] In the metal, linen, mixed fabrics, silk, and wool industries, detailed cost functions are available and they have been used to compute the values of inputs for 1861.[112] Table 2.7. reports the evidence on the values of industrial output and inputs at current

[108] This flexible production is described in Comisión Especial Arancelaria (1867) and in Cerdá (1968).

[109] See the previous section for the estimation of intermediate inputs in the cotton industry.

[110] The sources are: Metal: Madoz (1846) and Figuerola (1968); Mixed fabrics: Sayró (1842); Paper: Gutiérrez (1837).

[111] It should be noted that in 1840 in both industries all machinery was hand-powered and that the other costs of production, except transport that is included in the price of raw materials, were relatively small.

[112] The sources of these cost functions are Ronquillo (1851-1857), Comisión especial arancelaria (1867), and Escribano (1986).

prices.

**Table 2.7** Sectoral Output and Intermediate Inputs: Modern Industries, 1840-61 (current prices, thousand Pta)

| **Sectoral Output** | **1840** | **1861** |
|---|---|---|
| Cotton Spinning | 31,592 | 67,422 |
| Cotton Weaving | 46,419 | 93,758 |
| Cotton Finishing | 76,597 | 143,296 |
| Cotton Industry | 80,484 | 147,519 |
| Metal Industry | 2,402 | 8,703 |
| Other textiles | 43,656 | 92,040 |
| Paper Industry | 5,250 | 6,366 |
| **Intermediate inputs** | **1840** | **1861** |
| Cotton Spinning | 17,356 | 48,094 |
| Cotton Weaving | 28,005 | 68,560 |
| Cotton Finishing | 53,309 | 106,480 |
| Cotton Industry | 22,192 | 62,393 |
| Metal Industry | 1,941 | 4,666 |
| Other textiles | 29,794 | 60,031 |
| Paper Industry | 2,007 | 2,844 |

**Notes and sources:** See text. Cotton industry sectoral output is here the agreggation of finishing sectoral output value and the cotton yarn sold to mixed fabrics industry.

Given the measures of outputs and intermediate inputs in current prices, the next task is to separate this data into price and quantity components, the *real* sectoral output. The traditional method is to separate components using deflators. Here, the deflators are Divisia (Törqvist) price indices[113], which have been computed according to the next equation:

[113] However, when the information is sparse the deflators of the main product of the industry have been used. It should be noted that these deflators are equivalent to Divisia deflators if the product considered is the average product of the industry. See Hill (1993).

(2.9) $$lnP_t - lnP_{t-1} = \sum_i [\overline{\Theta}_{P_i}(\ln pi_t - \ln pi_{t-1})]$$

where pi designates prices, and n prices (1..i..n) are being considered. The two time periods are t and t-1, and the value share weights $\Theta_{xi}$ are computed as:

$$\overline{\Theta}_{P_i} = 1/2[\theta_{pi}(T) + \theta_{pi}(T-1)], \quad (i=1,..i,..n).$$

The $\Theta_{pi}$'s denote the share of each output (price x quantity) in total payments. The exponential of this logarithmic change generates an index number.

Törqvist price indices have two important advantages: (1) they avoid the problems related to the fact that some Catalan industries changed substantially the quality of products during this period and/or in the composition of the physical inputs;[114] (2) the measures computed by deflating current values with these indices are equivalent to the measures computed with Törqvist quantity indices. Hence, they are adequate for productivity calculations. However, the Törqvist, like other superlative indices, has some practical and conceptual disadvantages: (1) prices and quantities for both periods under consideration are required, whereas non-superlative indices require both price vectors but only base period quantities; (2) the indices are not additively consistent.[115]

Here, Törqvist deflators were constructed for outputs and inputs for each industry, except the paper industry's inputs, where the deflator is the index of wholesale prices computed by Sardà.[116] In the cotton industry, the prices are the same as section 2.1. Therefore, the inputs price indices are composed of up to six categories. In the metal industry the prices of inputs correspond to the prices of iron ingot and coal. Output prices are for metal plate and

[114] It should be noted that in this kind of situation alternative Laspeyres, Paasche or unit-value deflators tend to bias the results. For example, the cotton spinning industry modified the composition of its output towards more quality yarn, thus increasing the proportion of input costs that were due to energy use. Therefore a unit-value deflator tends to artificially increase the price of outputs and decrease the price of inputs.

[115] Hill (1993), pp. 384.

[116] Sardá (1948).

steam engines. For the input deflator the weights are: 90 percent iron ingot, 10 percent for coal. For the output deflator metal plate and steam engines have equal weighting.[117] In the paper industry the price of output corresponds to the price of common paper, while the price of inputs is computed with the Sardà wholesale index.[118]

The most formidable problems arise in the construction of price indices for the remaining textiles, especially for outputs. Specifically, in outputs the main problem was to convert many different measures into an equivalent unit of weight. Then after this one must construct coherent output categories. To convert the unit that appeared in the 1840 sources, *varas castellanas* (a length unit equivalent to 0.835 metres), to the weight unit of 1861 (kg.), I must obtain the density of each kind of cloth and then multiply by the 1840 data. It should be noted that another problem is caused by the fact that different types of cloth had different widths, and hence densities per vara not only change due to weight but also due to width. Ronquillo collected data on all kinds of cloth produced in Catalonia and their standard weight and densities.[119] Moreover, cautiously, I do not employ prices of the kinds of cloth that have altered their composition or quality (for example, during the period some kinds of mixed fabrics reduced the quantity of cotton yarn increasing, in turn, the quantity of the other textiles fibres). The table below presents the prices in current values of inputs and outputs for that industry.

[117] In particular, the prices are: coal 5.5945 Pta/Qm (1840) and 5.875 Pta/Qm (1861), iron ingot 21.13 Pta/Qm (1840) and 23.64 Pta/Qm (1861), for iron plates 88.76 Pta/Qm (1840) and 80.5 Pta/Qm (1861), steam engines of low pressure (below 25 h.p.) are 1500 Pta/h.p. (1840) and 1240 Pta/h.p. in 1861. The prices for 1840 come from Sayró (1842), except the price of steam engines which comes from Figuerola (1968) whereas the prices for 1861 came from Comisión Especial Arancelaria (1867).

[118] The prices are 175 Pta/kg. in 1840 and 137,36 Pta/kg. in 1861. The sources are Gutiérrez (1837) for 1840 and Gimenez Guited (1862) for 1861.

[119] Ronquillo (1851-1857), pp. 344-414. In the case of several weights and densities I decided to take an average of the available data.

**Table 2.8** Prices of Inputs and Outputs: Other Textiles 1840-1861

| | 1840 | 1861 | Growth rate (percent per year) |
|---|---|---|---|
| **Inputs** | | | |
| Low-quality washed Raw Wool (Spanish) | 1.79 | 2.24 | 1.07 |
| High-quality washed Raw Wool (Spanish) | 6.51 | 7.66 | 0.77 |
| Imported wool yarn (French, count no. 80) | 9.77 | 13.20 | 1.43 |
| Linen white yarn (Imported) | 3.75 | 5.48 | 1.81 |
| Silk yarn in hanks (Spanish) | 48.86 | 45.48 | -0.34 |
| Cotton yarn (Catalan, count no. 59) | 11.80 | 8.58 | -1.52 |
| Imported cotton yarn (English, count no. 80) | 20.63 | 16.13 | -1.17 |
| Imported Coal (British) | 5.43 | 5.87 | 0.37 |
| **Outputs** | | | |
| Damasco de lana (pure wool cloth) | 19.43 | 16.45 | -0.79 |
| Raso de seda (fine silk cloth) | 95.55 | 83.56 | -0.64 |
| Cutíes (pure linen cloth) | 14.24 | 10.82 | -1.31 |
| Dril (linen and cotton cloth) | 13.24 | 14.85 | 0.55 |
| Telas para vestidos (cheap wool and cotton cloth) | 23.19 | 19.37 | -0.86 |
| Pañoleria de Invierno (fine wool and cotton cloth) | 36.80 | 30.53 | -0.89 |
| Damasco de mezcla (fine wool and cotton cloth) | 25,62 | 19,23 | -1.34 |

**Notes and sources:** All prices are in Pta /kg. except coal that is in Pta/Qm. and are prices in Barcelona's market. Prices included taxes (tariffs and indirect taxes) and transport costs from producing sites to Barcelona. The prices of 1840 from Sayró (1842) except linen white yarn from Madoz (1846) and the prices of 1861 from Comision especial arancelaria (1867). The price of high-quality raw wool is an average of the price of *Extremeña superior* and *Aragonesa superior.*

Table 2.9. reports price indices for sectoral output and intermediate inputs, 1840 is taken as base year. These price indices has been constructed using equation 2.8. Perhaps the most striking pattern that emerges from a comparision between the output and input price indices is that the prices of outputs declined significantly relative to those of inputs. In all industries the price of outputs grew less than the price of inputs. From these results and the fact that real wages rose during the period, it can be inferred by duality that total factor productivity must have rosen.[120]

[120] See chapter 5.

**Table 2.9** Price Indices of Sectoral Output and Intermediate Inputs: Modern Industries, 1840-61 (1840=100)

| **Sectoral Output** | **1840** | **1861** |
|---|---|---|
| Cotton Spinning | 100 | 69.82 |
| Cotton Weaving | 100 | 56.81 |
| Cotton Finishing | 100 | 53.58 |
| Cotton Industry | 100 | 54.21 |
| Metal Industry | 100 | 86.59 |
| Other textiles | 100 | 85.77 |
| Paper Industry | 100 | 78.49 |
| **Intermediate inputs** | **1840** | **1861** |
| Cotton Spinning | 100 | 112.49 |
| Cotton Weaving | 100 | 72.46 |
| Cotton Finishing | 100 | 63.73 |
| Cotton Industry | 100 | 105.80 |
| Metal Industry | 100 | 111.37 |
| Other textiles | 100 | 107.91 |
| Paper Industry | 100 | 116.98 |

**Notes and sources:** See text.

The next table presents estimates of growth rates of sectoral output, intermediate inputs, its share in total payments, and value-added. According to the methodology proposed by Jorgenson, value-added growth rates are equal to the growth rate of output minus the growth rate of intermediate inputs, weighted by their share in sectoral output payments.[121]

**Table 2.10** Growth Rates (yearly percent) of Sectoral Output and Value-added: Modern Industries, 1840-1861

| | **Sectoral Output** | **Intermediate Inputs** | **Share Intermediate** | **Value Added** |
|---|---|---|---|---|
| Cotton Spinning | 5.32 | 4.29 | 0.63 | 2.61 |
| Cotton Weaving | 6.04 | 5.80 | 0.67 | 2.17 |
| Cotton Finishing | 5.95 | 5.44 | 0.72 | 2.04 |
| Cotton Industry | 5.80 | 4.65 | 0.35 | 4.18 |
| Metal Industry | 6.82 | 3.66 | 0.67 | 4.35 |
| Other textiles | 4.28 | 2.97 | 0.67 | 2.30 |
| Paper Industry | 2.07 | 0.91 | 0.41 | 1.69 |

**Notes and sources:** See text for methodology and sources.

[121] Jorgenson (1990).

To aggregate single measures into sectoral gross output and value-added figures, I employ the methodology developed by Jorgenson.[122] Two kinds of aggregation have been developed. The first is a weighted average of the individual industries' sectoral output, intermediate inputs and value-added, with weights given by the current values. The second has been developed under the assumption of separability of value-added and the existence of an aggregate function for the whole industry. Therefore, current values of sectoral output, intermediate inputs and the corresponding (Törqvist) price indices were computed. The results are presented in the table below:

**Table 2.11** Growth rates of Aggregate Sectoral Output, Intermediate Inputs and Value-added: Modern Industries, 1840-61 (percent per year)

| | Sectoral Output | Intermediate inputs | value added |
|---|---|---|---|
| **Weighted sum** | 5.29 | 3.68 | 3.81 |
| **Aggregate model** | 5.13 | 3.72 | 3.44 |

**Notes and sources:** see text.

It should be noted that the difference between the first model and the second model is, according to Jorgenson, the result of market failures and, consequently, to the misallocation of resources. Traditionally, economic historians have preferred the first version.[123]

### 2.4. The Role of the Catalan industry in the Growth of the Economy

In the two previous sections I developed new measures of output and value-added for several Catalan industries. The next table aids the comparison of previous estimates with the new figures:

[122] Jorgenson (1990).

[123] See, for example, Crafts (1985a), pp. 27-28 or Prados (1988), pp. 163.

**Table 2.12** Alternative Industrial Indices: Catalonia, Spain and Andalusia, 1830-1861)

| | Growth rate per year |
|---|---|
| **Catalonia** | |
| - Maluquer (1830-1861) | 5.91 percent |
| (1840-1861) | 5.28 percent |
| - Carreras (1844-1861) | 6.20 percent |
| - New Estimates | |
| (1) Sectoral Output | |
| Modem Industries (1840-1861) | 5.13-5.29 percent |
| Cotton Industry (1830-1861) | 6.77 percent |
| (2)Value-added | |
| Modem Industries (1840-1861) | 3.37-3.81 percent |
| Cotton Industry (1830-1861) | 4.51 percent |
| **Spain** | |
| - Bairoch (1830-1860) | 1.31 percent |
| - Carreras (1830-1860) | 4.60 percent |
| - Prados (1830-1860) | 2.32-2.64 percent |
| **Andalusia** | |
| - Parejo | 2.35 percent |

**Notes and sources:** Catalonia: Maluquer (1994b), pp. 70, Carreras (1990b), pp.56; New estimates: previous tables 2.4, and 2.11. Spain: Bairoch (1982), pp. 292, Carreras (1990b), Prados (1988), pp. 166; and Andalusia: Parejo (1995), pp. 40.

It is immediately apparent from table 2.12 that the difference between the new and the previous industrial output estimates for Catalonia is relatively small. With the early Carreras's index about one point, with the more recent Maluquer's index the difference is negligible. In spite of these small differences in growth rates, in each study the contribution of their sub-components is different. Thus, in Carreras's index the cotton industry explained about 77 percent of Catalan growth in 1860. For 1844 to 1859 Carreras used imports of raw cotton as an index for Catalan production.[124] In Maluquer's the proportions vary from a minimum of about 40 percent to a maximum of about 49 percent.[125] This study puts the proportion at around 67 percent. It is clear that some discussion of the causes is required. I suspect that the differences between the other two indices and the new figures are mainly caused by the

[124] Carreras (1990b), pp. 60.

[125] Maluquer (1994b), pp. 59.

different choice of index numbers.[126]

The growth rates of the new quantity indices of the cotton industry, which were computed with the Törqvist formula, are higher than those estimated by Maluquer and Carreras. The reason is simple since the Törqvist indices consider quality shifts in the composition of sectoral output. This is shown table 2.5, where the 'pure quantity index' has a yearly growth rate of 5.12 percent (1830 to 1861). This contrasts with the new sectoral output index, which has a yearly growth rate of 6.77 percent. Since this study's estimate of the rate of growth of the cotton industry is higher than the estimates of Maluquer and Carreras we should infer that the other industries had lower growth rates. However, these lower growth rates cannot be attributable to my treatment of index numbers. Since there were large output quality increases in the metal, linen, silk, and mixed fabric industries. I can only suspect that the difference is related to the treatment of the mixed fabrics industry as Carreras and Maluquer assume that all cotton yarn is used for the production of pure cotton cloth.

Nevertheless, the growth rates of value-added are lower than the growth rates of output. I want, though, to stress that industry value-added grew much more slowly than was once thought. Even though value-added growth was more modest than was previously believed, it did create a genuine process of industrialisation, that is reflected in a shift in industrial growth rates. Interestingly, this result confirms the opinions of several Catalan historians such as Graell, Vicens Vives, Izard, Nadal, Maluquer de Motes or Carreras, who all stressed the importance of this period.[127] It is important to appreciate that the industries present in the index grew at respectable rates, except the paper industry, which was the only sector with growth rates below the average Spanish industry growth rates. This result is also consistent with the comments of many nineteenth century observers. Who not only emphasised the extraordinary development of Catalan cotton mills, but also the importance

[126] It should be noted, however, that it is impossible to compare my weights with the weights of the other authors since they do not provide enough information on this aspect.

[127] Graell (1910), Vicens Vives and Llorens (1961), Nadal (1974)(1985), Izard (1969), Maluquer (1976)(1985)(1994a)(1998), and Carreras (1990a)(1990b).

of the metal, paper, linen, silk, mixed fabrics and wool factories and workshops.[128]

The comparison of the evolution of the Catalan index with the Spanish indices and the recent industrial index for Andalusia is very revealing. The sectoral output indices are comparable with the indices of Maluquer, Carreras, Bairoch and Parejo, whereas the value-added indices are comparable with Prados' one. Any indicator shows that Catalan industrial growth rates were almost 30 percent higher than Spanish rates.

On a less optimistic note, however, one can argue that the sample used for the new index is biased in favour of the modern and capital intensive industries, and is biased against the traditional sectors. Note that a characteristic of the Catalan secondary sector was its capacity to produce many different industrial goods. For example, in 1861, Gimenez Guited collected data on 13 major industries located in Catalonia (cotton, olive oil refining, flour, wool, silk, soap manufacturing, spirits & liquors distilling, linen, metal manufacturing, paper, mixed fabrics, curtains and cork).[129] The industries in the index had about 85 percent of workers and 92 percent of the capital.[130] Furthermore, other minor industries such as bakery, beer brewing, card-making, chemical products, gloves, jewellery, pottery, shoemaking, woodwork & furniture, glass, hosiery, boatyards, quarries, publishing, clothing, pin-making, wax, wine, hat manufacturing, canning, and coaches were also located in Catalonia.[131] Therefore, it seems necessary to compute the coverage of the sample in order to determine the bias introduced by measuring only the modern sectors and paper.

I do this with two alternative measures: one based on the active population figures and another on value-added. Ideally I would like to examine the Catalan population census and the Gimenez Guited data on labour to establish the part of the industrial working population

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[128] See Gutiérrez (1837), Sayró (1842), Madoz (1846), Ronquillo (1851-1857) and Gimenez Guited (1862).

[129] Gimenez Guited (1862), pp. 207-214

[130] Gimenez Guited (1862) appendices to the provinces of Barcelona, Gerona, Lérida and Tarragona.

[131] See the references to these industries in Madoz (1846) and Cerdà (1968).

covered by this sample. Two major problems with the male workforce figures make it impossible to directly compare the data of Gimenez Guited and the population censuses: (1) the figures for males in the Spanish censuses included an important part of industrial workers in a heterogenous category *jornaleros* (labourers), that also comprised agrarian and services workers, (2) Gimenez Guited did not give information on the number of industrial entrepreneurs but on the number of industrial establishments, which could have more than one entrepreneur. Furthermore, I cannot use the number of female workers in the whole sample for the modern industries, since it is likely that the percentage of women in the modern industries was higher.[132] Consequently, the coverage of my sample must be estimated with an indirect method, employing the detailed census of Cerdá on the Barcelona workers of 1856. According to the data of Cerdá, the industries described by Gimenez Guited employed about 58.8 percent of the manufacturing workforce (excluding construction workers).[133] A simple comparison among Cerdá's censuses, Gimenez Guited's data of females in industry, and the population census of 1860 prove that the structure of Barcelona industrial workforce represents the whole of Catalonia.[134] I can therefore extrapolate the relative figures for Barcelona. Briefly, my sample covers about 50 percent of the labour force in the Catalan industry (i.e., 85 percent x 58.8 percent).

Moving to value-added figures, the first step is to compare the value-added figures for Catalonia and Spain. According to Nadal, in 1856 Catalonia paid 25.04 of Spanish manufacturing tax.[135] Considering that the Basque Provinces and Navarre did not pay direct

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[132] See the discussion of this issue in chapter 4.

[133] According to Cerdá (1968) pp. 587-616, the salaried workforce in Barcelona and its surroundings was around 55875, of which 39078 worked in industry: 22990 (41.14 percent) of workers were in the major industries (those industries where Gimenez Guited collected data), 12886 workers were in minor industries, and 3202 workers were in construction. I use the average of the minimum and maximum workers by each occupation.

[134] For example, Gimenez Guited (1862) reported a figure of about 30,000 women in industry whereas the census (Nicolau (1990)) shows about 40,000, which is the same proportion that Cerdá reported in Barcelona (75 percent of female workers in Gimenez Guited's industries and 25 percent in the rest).

[135] Taxes for manufacturing and mining were paid separately and it is likely that mining taxes were higher than manufacturing ones. For example, in 1856, manufacturing taxes amounted about 2.4 million Pta whereas mining taxes amounted about 1.2 million Pta (Nadal (1992a), pp.156). If the taxes were set according to value-added then one could infer that mining produced about one third of

taxes and that they must represent about 10.25 percent of the Spanish manufacturing,[136] Catalonia might possess about 22.5 percent of Spanish manufacturing. Prados, correcting Mulhall's previous figures, estimated the current value of the value-added of the Spanish manufacturing production as 975 million of Pta in 1860.[137] Therefore, the total value-added of Catalan manufacturing was about 219.4 million Pta, whereas the value-added of the sample is 124.7 million Pta (i.e., about the 56.8 percent of the value-added of Catalan manufacturing). The similarity between this and the previous estimate of the share of working population supports the view that these two figures and the total figures are reasonable estimates.

The next step consists of computing a range of possible estimates of Catalan industry growth rates for the industries where there was no data. Empirically, the overall growth rate is equal to the growth rate of the modern industries multiplied by their share in value-added (which was about 56.8 percent) plus the growth rate of the non-represented industries (traditional sectors) multiplied by their share in value-added (which was 100 - 56.8 = 43.2). It seems plausible that the growth rates of the traditional sectors were positive but did not exceed the growth rates of the modern sectors. Therefore, their growth rates were between 0 and 5.29 percent per year. Then, resulting overall industry growth rates might be (in the case of zero growth in traditional sectors) between 3 percent and 5.29 percent per year (in the case of the same rates in modern and traditional industries). Therefore, I can argue that early industrialisation significantly increased overall industry growth rates, even if traditional sectors

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Spanish industrial value-added. However, Mulhall (Prados (1982), p 110) assigned to mining a value 125 million of Pta, around 11.4 percent of total Spanish industry value-added. Furthermore, Prados in his index gives mining share of industrial value-added of only 5.1 percent, whereas Carreras gives it share of 14.6 percent (Prados (1988) and Carreras (1990b), pp. 91). To sum up, to establish the share of mining in industrial value-added, taxes must not be used.

[136] In 1861 the Basque and Navarre Provinces had the following shares in several industries: 7.5 percent in flour, 5.1 percent in olive oil refining, 20.5 percent in cotton spinning, 16.9 in cotton weaving, 21.4 percent in calico printing, 2.0 percent in wool spinning, 7.8 percent in wool weaving, 12.5 percent in silk spinning, 13.3 percent in paper, 13.8 percent in leather, 13.9 in linen, 12.5 percent in soap and 10.3 percent in spirits. (Source: Gimenez Guited (1862), pp. 207-214). From this data we can infer several industry shares: 7.5 percent in food, 14 percent in textiles, 20 percent in metal, 12 percent in chemicals, 14 percent in leather and 13 percent in paper. Then, with the value-added shares of Prados (1988), pp. 163 it can be established their share in Spanish manufacturing was 10.25 percent.

[137] Prados (1982), pp. 110.

remained stagnant.

Using this range of estimates of Catalan industry, I can also estimate the contribution of Catalan industry to the growth of Catalan GDP and Spanish GDP. Specifically, the contribution of Catalan industry is the result of multiplying each estimate by the share of Catalan industry and then dividing the result by the overall growth rates. Since I employ value-added weights that corresponded to the last year the results are equivalent to a Laspeyres index and, hence, overstate the Catalan contribution to Spanish growth rates. Moreover, the results may be biased because it is likely that this revision of Catalan industry output altered Spanish figures by a significant amount. Therefore, in order to correctly establish the contribution of Catalan industry to Catalan and Spanish growth rates, I must review industrial output and GDP estimates for Spain.

The share of the value-added of Catalan industry in Catalan and Spanish GDP can be estimated by means of Mulhall's figures.[138] Carreras and Yáñez give the share of Catalonia in Spanish GDP as 13.4 percent in 1862.[139] Then, since the current value Spanish GDP was of 5,594 million Pta in 1860, and assuming the same proportion for 1862 and 1860, the Catalan GDP was 749.6 million Pta.[140] In other words, the share of value-added of Catalan industry was equal to 29.3 percent of Catalan GDP and 3.9 percent of the Spanish GDP.[141]

The data on Catalan GDP are very imperfect and so any estimates are controlled conjectures. Thus, I decide to estimate two alternative figures for Catalan GDP. The first (GDP A) is based on the assumption that the share of Catalonia in Spanish GDP in 1832 was

[138] Prados (1982), pp. 110.

[139] Carreras and Yañez (1992), pp. 156.

[140] It should be noted that the discrepancy between this estimate and that provided by Carreras and Yañez is because they computed Spanish GDP as 7,071 million Pta and Catalan GDP as 948 million Pta (Carreras and Yañez (1992), pp. 156). However, I preferred not to modify Prados' figures since he separates Spanish GDP into its different components.

[141] Similarly, since the value-added of Spanish industry (i.e., manufacturing plus mining) was 1,100 million Pta in 1860 (Prados (1982), pp.110), the share of Catalonia was about 19.9 percent.

the same as in 1802 (8.3 percent).[142] The second (GDP B) has been computed under the assumption that the portion of Catalonia in the Spanish GDP in 1832 was the geometric average of the quotas of 1802 and 1860 (the share in 1860 was 13.3 percent).[143] The rate of growth resulting with GDP A (2.57 percent per year) is the upper bound, and the rate of growth of GDP B is the lower bound (1.62 percent per year). The choice of GDP has strong implications for the interpretation of the period considered here and the previous phase (from 1802 to 1830). Specifically, with GDP A Catalonia grew during the period 1800-1830 at the same rate as Spain (a mere 0.31 percent per year) whereas with GDP B it grew at four times the Spanish rate (1.23 percent per year). By contrast, during the following period (1830-60), with GDP A Catalan growth was double the Spanish growth rate, whereas with GDP B grew at only a quarter faster than the rest of Spain. Demographic figures revealed that from 1800 to 1830 the Catalan experience was very similar to the rest of Spain, whereas in the 1830-1860 the growth rates of the Catalan population were double the Spanish average.[144] According to Pérez Moreda, Catalonia suffered during this period 'a precocious and striking decline in mortality as well as immigration from other regions.'[145] Admittedly, the estimates of the Catalan experience derived from GDP B is unlikely, but it would be desirable to expand our knowledge of the first third of the nineteenth century to discriminate definitively between both figures.

Finally, I must revise previous estimates of Spanish industrial production, considering the new growth rates.[146] It is of interest to note that the industries considered in my sample were the Catalan industries with larger shares in Spanish industry. My estimate based on the Gimenez Guited data suggests that Catalonia had 69.1 percent of the textile industry, 17.4

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[142] Sources: Spanish GDP, Prados (1982), pp. 110 and Catalan shares Carreras and Yañez (1992), pp. 157.

[143] The same sources as in previous footnote.

[144] In particular, the average annual demographic growth rates per thousand habitants in the period 1797-1833 was 4.3 in Spain and 5.4 in Catalonia, whereas in the next period (1834-1857) 9.6 in Spain and 19.4 in Catalonia (Pérez Moreda (1987), Table 2.3, pp. 18).

[145] Pérez Moreda (1987), pp. 19.

[146] I cannot recalculate Carreras' index since in his book (Carreras, (1990b) the industrial index is not disaggregated by sub-sectors.

percent of the metal industry and 30.8 percent of the paper industry.[147] By contrast, the share of the rest of the Catalan industries in Spanish value-added was reduced, except in cork manufacturing (a very small industry).[148] Consequently, I can conjecture that their growth rates did not affect total growth rates. Furthermore, since Prados does not consider the paper industry in his estimates, I only need to change the growth rates of the metal and textile industries.

I also introduce a further refinement to Prados' index by reweighting the textile industries. Similar to the debate on the British Industrial Revolution, the debate on the early phase of Spanish industrialisation was centred on the appropriate weights that must be given to the different industries. Two main issues have been raised by Carreras and Prados, the quotas of the two main sectors, food and drink and textiles, and the share of the cotton industry within textiles.[149] Indeed, the results are very sensitive to the weighting for cotton. The great advantage of this sector is the availability of good historical data (I believe that the second and third sections of this chapter support this assertion). Furthermore, Gimenez Guited calculated precisely the output of all the textile industries (cotton, wool, linen, silk and mixed fabrics), except the clothing industry, for all Spain, including the Basque and Navarre provinces. Therefore, employing this data and the production functions available, it is simple to compute the current value-added of the textile industries. These current values can then be weighted with the total current values given by Mulhall.[150]

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[147] Based on industrial tax (1856), Nadal reports similar figures: 66.3 percent in textiles, 21 percent in metal and 31.8 percent in paper (Nadal (1992a), pp. 153).

[148] According to Nadal (1992a), pp. 153, 10.1 percent in food and drink, 15.7 percent in construction goods, 13.3 percent in leather, 17.4 percent in chemicals, 24.5 percent in wood and furniture, and the exceptional 42.8 percent in miscellaneous industries (mainly cork manufacturing).

[149] Carreras employed a backward extrapolation of the ratio between the value-added at factor costs and the value of total product in 1958. Which was the first year in which highly reliable Spanish National Accounts data was available. Carreras also used a unique price vector for the whole cotton industry to determine the value-added share to total industrial production. In contrast, Prados used the shares of each industry in the industrial tax records (*Contribución industrial y de comercio*) for 1856 and 1900, under the assumption that these corresponded well to the value-added. See the criticism of the methodologies in: Prados (1988) chapter 4 and Carreras (1990b), addenda to chapter 3.

[150] Note that the shares computed with this method are not directly comparable with the shares computed by other authors since their indices were based on a sample of industrial activity rather than data for the whole sector.

**Table 2.13** Share of the Textile Industries: Spanish Industry Value-added, 1860

| | Share (percent) in total value-added | | | Share (percent) in textile industries | | |
|---|---|---|---|---|---|---|
| | Carreras | Prados | New | Carreras | Prados | New |
| Cotton | 27.0 | 8.0 | 11.6 | 78.7 | 34.8 | 56.9 |
| Wool | 2.7 | 12.4 | 4.5 | 7.9 | 53.9 | 22.1 |
| Linen | 4.0 | 1.9 | 2.5 | 11.7 | 8.3 | 12.2 |
| Silk | 0.6 | 0.7 | 1.1 | 1.7 | 3.0 | 5.4 |
| Mixed fabrics | | | 0.7 | | | 3.4 |
| Total | 34.3 | 23.0 | 20.4 | 100.0 | 100.0 | 100.0 |

**Notes and sources:** Carreras and Prados figures came from Carreras (1990b), pp. 91. The new estimates are derived from Gimenez Guited data ((1862),pp. 209-212) and are computed according to the method of the section 2.3. The share in the total values added is the result of to divide the value-added of each industry by Mulhall estimate on industrial value-added (Prados (1982), pp. 110).

*Prima facie*, the new estimates are relatively closer to Prados' than Carreras' figures. In this study the share of output of the textile industries is smaller than the share assigned by Prados and Carreras. However, it should be noted that the total share of the textile industry in the new estimates is probably the lower bound of the sector, since clothing has been not considered. Due to this, I do not modify the quota of the textile industry (23 percent) given by Prados.[151] But the composition of this new estimate for textiles differs greatly from those of Carreras and Prados. Thus, from this new point of view, Carreras overestimated cotton and underestimated wool whereas Prados does exactly the opposite.

With the new estimates of the textile and metal industries and the new (internal) share of textiles, I decide to estimate two alternative industry indices. Both of which are modifications of the original Prados industrial index.[152] In the first (Spain Industry A) index of industrial output, I assume that the textile and metal industries in Spain had the same growth rates as equivalent Catalan industries. In the second one (Spain Industry B) I consider that the non-Catalan industries maintained the growth rates computed by Prados. As in Catalan GDP, Industry A can be considered the upper bound whereas industry B the lower

[151] Unfortunately, the coverage of Gimenez Guited for the other major industrial sectors is patchy. Thus, food is underrepresented since only flour, oil refining and spirits were considered, whereas mining is not.

[152] Prados (1988), pp. 143-168.

bound. These alternative annual rates of growth lie, again, between the estimates of Carreras and Prados.

**Table 2.14** Contribution to Overall Growth Rates: Catalan Industry, 1830-1860

| | | Overall Growth Rate (percent) (a) | Share Catalan industry in value-added (percent) (b) | Contribution growth rates (percent) (c) |
|---|---|---|---|---|
| **Catalonia** | (1) GDP A | 2.57 | 29.3 | 34.3 - 60.4 |
| | (2) GDP B | 1.62 | 29.3 | 54.2 - 95.4 |
| **Spain** | (2) Industry A | 3.32 | 19.9 | 18.0 - 31.7 |
| | (3) Industry B | 2.99 | 19.9 | 20.0 - 35.2 |
| | (4) GDP A | 1.29 | 3.9 | 9.1 - 16.1 |
| | (5) GDP B | 1.21 | 3.9 | 9.7 - 17.0 |
| | (6) GDP C | 0.88 | 3.9 | 13.3 - 23.4 |

**Notes and sources:** The growth rates have been computed under the assumption that the growth rates of Catalan industry during the period 1830-60 were identical to those in the period 1840-61. Catalan GDP A and B: see text. Spain Industry A and B. see text. GDP A: Prados index of Spanish GDP (Prados (1988), pp. 38-47) computed with the Industry A. GDP B: the same than GDP B but calculated with Industry B. Spain GDP C: Mulhall's estimates of current Spanish GDP (Prados (1982), pp. 110) deflated with Sardá wholesale prices index. The contribution in the column c is the result of to multiply the range of Catalan industry growth rates (see text) by the share of the column b and to divide by the growth rate of the column a.

The range of estimates based on different assumptions suggest similar conclusions. The contribution of the Catalan industry to Catalan GDP was larger. In Catalan GDP A, industry is the main factor in Catalan growth whereas in GDP B practically the unique factor. Another relevant result concerns the contribution of modern industries to Catalan growth, the contribution is between 34 and 54 percent.[153] The image of early industrialisation as one in which modern industries produced strong changes at regional level is fully proved.

By contrast, the contribution of Catalan industry to Spanish figures was less important.

[153] It must be remembered that the lower contribution of industry to overall growth rates corresponds to the case when the rate of growth of the traditional industries is equal to zero. Consequently, it can be interpreted as the direct contribution of the modern industries to overall growth rates.

Particularly, the contribution of Catalan to Spanish industry varies from about 18 percent to about 35 percent. It is noteworthy that the widespread industrialisation at Spanish level required that more than one region experienced industrialising processes. Similarly, the role of the leading sectors is relatively small (about one fifth). From this last result, it can also be inferred that broad industrialisation demanded that traditional industries experienced large growth rates. Indeed, the contribution of Catalan industry to Spanish GDP is also small from about 9 percent to about 23 percent.

### 2.5. Conclusions

The main arguments can be re-stated as follows. First, I would stress that the results of the first section indicate the importance of quality in industrial growth during this period. Consequently, this paper provides a serious quantitative challenge to previous estimates of industrial output that did not take into account this issue. Second, I have made further revisions of the earlier estimates by means of the Törqvist indices in the course of the second section; these are generally fairly small in overall growth rates but tend to change the internal contribution of each sector. Third, I accept that the measurement of growth yields only a range of best guest estimates and that the coverage of the new index is not complete. However, it is important not to exaggerate the degree of scepticism. Fourth, I point out that Catalonia experienced the beginnings of industrialisation during this period. Finally, I demonstrate that despite the impressive growth rates in several modern industries, early industrialisation in Spain remains a regional phenomenon. On the whole, during this early period of industrialisation, rapid growth rates in Spanish GDP were only possible when traditional sectors experienced similar growth rates to those found in the modern industries.[154]

[154] See chapter 7.

# Chapter 3

# Capital as a Factor of Production

In this chapter I investigate the role of capital accumulation in Catalan manufacturing growth during early industrialisation. Traditional interpretations of the early Catalan industrialisation have underlined (1) the importance of the previous accumulation of commercial capital for the spurt of industry, (2) the existence of some sort of capital-supply constraint in the development of Catalan manufacturing. In sharp contrast, this chapter highlights that the main role in the process of industrialisation was not played by capital accumulation and that the record of Catalan investment in manufacturing correlates quite well with the experiences of other industrialising countries. Therefore, it is unlikely that the capital-supply constraint was larger in Catalonia than in other industrialising European regions.

## 3.1. Introduction

Economic historians have long been interested in determining the role of capital accumulation in industrialisation: whether the shift to a high rate of investment was a characteristic of the early part of industrialisation, and whether machinery investment is the strategic factor in economic growth. It is generally accepted that capital was important for growth, but there is disagreement on the part of economic growth that can be directly attributed to capital accumulation.

One extreme position in the debate is represented by the authors who postulate the strong association between investment in fixed assets and growth.[155] According to this school of thought, capital accumulation must precede rapid growth rates. For example, W.W. Rostow postulates that an investment boom for a number of years will cause a spurt in the short-run growth rate, and shift it to a new, higher growth path.[156] A corollary for economic policy is that a pro-investment policy leads to higher capital formation and to a higher level of income.

A variant of this argument is provided by academics who conjecture that the rate of investment affects the rate of technical change in a positive manner.[157] Thus, machinery investment and productivity growth are strongly associated, since technical progress is due primarily to improvements in the design of new capital. Therefore, changes in the capital to labour ratio may lead to a long-term increase in the rate of growth of productivity. The corollary for economic policy is that favouring the acquisition of machinery (e.g., subsidising imports of the most modern machinery ) induces higher growth rates.

Finally, the other extreme of the debate is occupied by the authors who suggest that growth induces subsequent capital formation more than capital formation induces subsequent growth.[158] Similarly, shifts in productivity, and hence technological innovation, precede high investment rates. The economic policy consequences of this posture are also strong. Simply raising saving and investment rates will not increase growth levels. Economic policies must encourage changes in institutions, the economic climate, education, direct investment, the population structure and make efficient the use of available resources.

Recently there seems to have an upswing in interest in the subject of capital in Catalonia, primarily because of its profound implications for the understanding of early industrialisation. However, relatively little has been written on the relation between investment and economic growth. The (implicit) assumption of almost all Catalan literature on capital is

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[155] The two classic references are Rostow (1960) and Lewis (1955).

[156] Rostow (1956)(1960).

[157] For example, Rosenberg (1963), Landes (1969), Landau (1989), De Long (1991) and De Long and Summers (1991).

[158] See, for example, Blomström *et al.* (1996).

that investment in fixed assets (especially in machinery) must cause economic growth. In other words, it is the rate of investment which decides growth rates and, hence, an increase in the amount of capital invested in industry will positively affect the rate of output growth. Consequently, the tendency in the literature has been to look for external factors that determined the supply of capital rather than those internal factors which determined the demand for capital.

A large group of writers have tended to highlight the constraints on the supply of capital to industry. The truth is, that since the beginning of the twentieth century many authors have worried about the weak links between banking and industry. Furthermore, these authors have alleged that Catalan banks failed to properly finance industrial enterprises. The seminal work in this area is Guillem Graell.[159] He pointed out that Catalan banks were less active than other Spanish banks because of the reduced size of the home market for financial instruments. More recently, Gabriel Tortella[160] come back the issue following the ideas of Cameron.[161] He found that banks were important for the construction of the railway network in Spain, but not for Catalan industry. Furthermore, he pointed out that the large demand for funds from the Spanish government and railways crowded out industry investment. Tortella's book spawned a series of works which, using banking data examined the relationship between banks and industry in Catalonia. Similar conclusions were reached in all these studies: the relations between banks and industry were scarce since the banking system was mainly devoted to financing the development of the railway network and other public works.[162]

Some studies based on data drawn from industrial firms arrived at similar conclusions to those articles based on banking sources; that is, the lack of direct involvement of banks in industrial business. The pioneering work in this area is Jordi Nadal and Enric Ribas,[163] who

[159] Graell, ed. (1908).

[160] Tortella (1972a)(1972b).

[161] Cameron (1967) and Cameron, ed. (1972)(1992). See a critical review of the methodology and arguments of Cameron at Checkland (1968).

[162] Castañeda et alt (1991) and Pascual (1990).

[163] Nadal and Ribas (1992).

found that cotton entrepreneurs relied mainly on their own reserves (either personal wealth or, more commonly, plough-back profits) and the wealth of family and relations for long-term finance. However, recent studies cast doubts on this view since it was found that industrialists required outside funds on some occasions (e.g., during the downward periods of the business-cycles or when they wished to increase the size of their firms) and that, in practice, long-term loans could easily arise out of the continual renewal of short-term accommodation.[164]

The evidence for a lack of involvement in industrial finance by the banks could be taken as evidence for either the absence of an active demand for funds from industry, or a supply constraint. In other words, the evidence of a lack of involvement cannot distinguish between demand and supply. Furthermore, it must be said that no direct evidence on the refusal of banks to finance new industrial projects has been produced. Moreover, even if there was a fringe of dissatisfied borrowers, one cannot presuppose market failure in bank lending. To sum up, the evidence collected does not serve to discriminate between autonomous demand and supply factors.

A variant of the supply-side constraint argument is provided by two studies which blame monetary restrictions. Carles Sudria holds that the restrictive monetary policy conducted by the Banco de Barcelona, the main note-issuer in Catalonia, reduced the supply of money.[165] He offers evidence that this bank maintained a large amount of money in cash and reduced note-issuing during the downward periods of the business cycle. Similarly, Carles Sudrià and his associates have pointed out that the loss of the American colonies at the beginning of the nineteenth century, combined with the large exports of gold and silver to pay for imports, provoked a money-supply restriction in the Catalan economy.[166] Although, recently, Xavier Cuadras and Joan R. Rosés have shown that macroeconomic evidence does not correspond to a situation of currency shortage. Since there was rapid economic growth, an important commercial deficit which was offset with exports of metals, and price stability.[167] Then, they

[164] Rosés (1993).

[165] Sudrià (1994b).

[166] Sudrià *et al.* (1992).

[167] Cuadras and Rosés (1998).

argue that the explanation of this puzzle lies on the use of bills of exchange and other privately issued documents as means of payment, probably due to the shortage of other alternative exchange media.

Evidence on the nature of the demand for capital is much scarcer. The major results on this issue have been accomplished by the recent work on the formation of companies. According to the collected data, the constitution of companies in Barcelona showed that capital invested in the service sector was twice the amount of capital invested in industry.[168] In other words, the absolute levels of industrial investment appear to have been quite modest when compared to the other sectors of the economy. Although, it should be noted that this kind of indicator is not exempt from problems. First, it is biased in favour of investment in industry, since most of the new factories were constituted in the form of companies whereas agricultural and small shops were not registered. For example, 0.22 percent of the total of capital invested in companies in Barcelona corresponds to agriculture. Which at that time covered about two thirds of the active population. Second, the number of registers is strongly affected by the changes in the commercial legislation or custom. Third, since companies were registered when they constituted, reformed, or closed, increases in capital after the constitution are difficult to discover. Fourth, companies were sometimes registered with fictitious capital figures and, hence, resulting capital figures are unbelievable. Finally, the resulting figures are not adequate for developing macroeconomic estimations since it is impossible to distinguish between the sources of the investment (machinery, buildings, inventories and circulating). Consequently, depreciation rates cannot be obtained or computed.

To sum up, unfortunately, the empirical work on capital has not used standard macroeconomic measures of capital input and, hence, it can only offer an incomplete view of the role played by investment during industrialisation. Moreover, the results obtained are rather inconclusive. Banks were relatively less important for Catalan industry than in other backward countries, like Germany or Italy, but it is not clear if this was a consequence of supply-restrictions or demand characteristics. For that reason, this chapter attempts to fill some of this void by providing direct measures of capital input for the main Catalan industries.

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[168] Sudrià *et al.* (1992), table 4, pp. 197.

Employing the standard methods of the theory of capital. There are two general reasons why this alternative approach might be useful: (1) macroeconomic figures can be used to establish the relations between investment and growth rates (that is, to study the contribution of capital accumulation to industry growth), (2) it can serve to discriminate between the supply and demand arguments since it is possible to establish with these figures whether Catalan experience on industrial investment correlates well with the experience of other European countries during early industrialisation.

The rest of the chapter proceeds as follows. Section 3.2 reviews concepts, methodology and historical sources for the measurement of capital. Section 3.3 presents the results of the estimation of capital for the main Catalan industries. Section 3.4 addresses the debate with the evidence from the Catalan experience.

### 3.2. Definitions, Methodology and Historical Sources

Before proceeding further, it is necessary to narrow the definition of capital and describe the measure that will be employed in this section. Capital here comprises (considering that this dissertation only refers to industry) non-residential structures (industrial buildings), producer durable equipment (machinery and other industrial equipment), and inventories (stocks of raw materials, semi-manufactured and finished goods, here, in the hands of industrialists). It differs from the concept of capital employed in business and accounting (the financial resources available for an enterprise; what is put into a project). Since the accounting concept also includes some non-tangible assets and the financial capital required to cover trade debts and the depreciation of tangible assets. Two final points about the composition of buildings. The measures of land for industrial uses are embodied in the measures of buildings, and industrial buildings were sometimes also used as residential buildings. Or, as was more often the case, that residential buildings were also employed as industrial buildings.

The correct measure of capital as a factor of production is the flow of services emanating from capital. It is customary to assume that the flow of services from capital is proportional to the measured net capital stock at T-1; in other words, previous capital investments minus depreciations and retirements.[169] It is also convenient to adjust these figures for underutilisation. One simple solution to this problem is to compute energy consumption instead of physical capital stock.[170] However, in this period, this does not seem the optimal procedure because the growth of energy consumption did not correlate well with the increase of the capital stock. In effect, the relationships between capital services and energy changed during the period since the new technologies introduced employed more energy per unit of capital.[171] Specifically, at the beginning of the period, machinery was hand, horse or water powered. In the 1830s and 1840s the first steam engines were introduced, and then in the 1850s the low pressure steam engines were replaced by high pressure engines.[172] To sum up, since data on capital utilisation is not available for all years, and cannot be computed from energy consumption, the flow of capital services is assumed to be proportional to the measured capital stock. This requires the condition that $Ki_t = \lambda_{Ki}Ci_t$, where $\lambda_{Ki}$ is a constant, K is capital input, and C the measured capital stock.[173]

The first step in developing measures of capital input is to construct estimates of net capital stock for the benchmark years at current prices. The perpetual inventory method was not used to extend these estimates from the benchmark years to annual for two main reasons: (1) this methodology requires several stringent assumptions that do not correlate well with the early industrialisation experience, (2) data on annual investment and retirements is not readily available for the studied period. There are three main assumptions behind the perpetual inventory method: the firms are not free to retire old capital as economic conditions dictate, maintenance and repair activities do not influence efficiency, and a higher rate of utilisation does not cause asset efficiency to decline more rapidly.[174] These three assumptions are highly implausible for the scenario of early industrialisation.

[169] Hulten (1990), pp. 123.

[170] This solution was proposed by Costello (1993), pp. 211.

[171] The classical reference is Von Tunzelmann (1978). On Catalonia see Carreras (1983) and Maluquer (1990).

[172] Nadal (1974), pp. 197-201.

[173] It should be noted that this is a common assumption in this kind of exercises.

[174] Hulten (1990), pp. 126-127.

The second step consisted of transforming the current estimates of capital stock into *real* figures. In this case, I employ the same methodology as Mark Blaug and Kenneth Sokoloff, deflating current values by an index of capital goods prices.[175] I do not deflate each industry by its price index as Sokoloff did, but each kind of capital good in each industry by its corresponding price index.[176] Therefore, I employ capital goods indices for each type of asset. Considering four sectors (the cotton industry, the metal industry, the paper industry and other textile industries),[177] and up to six different types of assets (workshops, factories, hand-machinery, steam and water driven machinery, engines, and inventories).[178] For workshops and factories I employ the same price index. In machinery, I use two different price indices: one for domestically produced machinery and one for imported machinery. Finally, when I computed the price index for inventories the assumption was that they were composed of equal values of outputs and raw materials.[179]

Unfortunately, no index of capital goods has already been constructed for that period in Spain and, therefore, I must develop previous the price indices.[180] Due to the scarce information in the rest of industries, I preferred to construct buildings and machinery indices employing only price data on cotton spinning and weaving. And, then assumed that the rest of the industries' prices experienced the same trend. Therefore, the prices of bergadanas (handspindles), steam-driven mule-jennies, steam engines, handlooms, powerlooms and factories have been computed for the two benchmark years (1840 and 1861). An unweighted average of the price of bergadanas, handlooms and steam engines generated the national machinery price index. Similarly, an unweighted average of mule-jennies, powerlooms and

[175] Blaug (1961), and Sokoloff (1986).

[176] Since the price indices vary across industries according to the industry-specific composition of capital goods this method is equivalent to deflating industry figures by a Törqvist price index.

[177] As was mentioned in the previous chapter, I do not separate other textile industries into their individual components because looms were employed to produce cloth with different fibres.

[178] In the case of other textile industries assets are also divided between machinery for spinning and weaving.

[179] This is the same assumption as Sokoloff (1986), pp. 693.

[180] Prados (1997) furnishes a series of deflators but only from 1850 onwards.

steam engines generated the imported machinery price index.[181] A further problem was provoked by the fact that the average size of factories rose during the period. To avoid this problem the price of new factories was divided by the number of spindles that were in the factory, using the assumption that spindles occupied the same space during the period.[182] The results of these calculations are in the following table:

**Table 3.1** Capital Goods Prices, 1840-1861(in Pta.)

| | 1840 | 1861 |
|---|---|---|
| (1) Factories (per spindle) | 20.34 | 19.41 |
| (2) Bergadanas (per spindle) | 2.00 | 2.00 |
| (3) Mule-jennies (per spindle) | 26.53 | 25.00 |
| (4) Powerlooms (per loom) | 1000.00 | 840.00 |
| (5) Handlooms (per loom) | 100.00 | 100.00 |
| (6) Steam Engines (per C.V.) | 1500.00 | 1240.00 |
| **Indices** | | |
| (a) Buildings | 100.00 | 95.43 |
| (b) Imported Machinery | 100.00 | 86.97 |
| (c) National Machinery | 100.00 | 93.28 |

**Notes and sources:** The prices of factories corresponded to cotton spinning steam-driven factories. The prices of mule-jennie and powerlooms are the prices of steam-powered machinery. The prices included all ancillary equipment, except the steam engine. The prices of steam engines corresponded to low pressure steam engines of less than 12 CV. The prices are drawn from: (1) Factories: for 1840 Comisión del gobierno (1841) and for 1861 Comisión especial arancelaria (1867); (2) Bergadanas for 1840, M.M. Gutiérrez (1837) and for 1861 Gimenez Guited (1862); (3) Mule-jennies for 1840 Comisión del gobierno (1841) and for 1861 Comisión especial arancelaria (1867); (4) Powerlooms for 1840 Madoz (1846) and for 1861 Comisión especial arancelaria (1867); (5) Handlooms the same sources than powerlooms; and (6) Steam engines for 1840 Figuerola (1968) and for 1861 Comisión especial arancelaria (1867).

Note that the prices computed show the same downward trend is present in the prices for the United States, England and France.[183] However, the prices of imported machinery declined faster than the prices of national capital goods (buildings and machinery). It should

[181] Note the biases introduced for the system are larger in the case of national machinery than foreign machinery.

[182] The technical handbooks in spinning technology published in Catalonia provided a list of formulas to establish the space required for each spindle. Therefore, one can assume that all factories were constructed taking these requirements into account. Arau (1855) and Calvet (1857).

[183] Blaug (1961), pp. 375; Sokoloff (1986), pp. 692; Feinstein (1988), Appendix, table XII, pp. 470; and Lévy-Leboyer (1978), pp.278.

be underlined that national prices of machinery are composed of three goods, two produced by the woodwork industry and one by the metal industry, and that the good produced by the metal industry experienced a declining trend in prices as rapid as imported goods. This result shows that the metal industry increased productivity whereas the woodwork and construction trades suffered from productivity stagnation.

The third step in developing sectoral measures of capital input is to construct rental prices for each category. Using the assumption of perfect competition and constant returns to scale I take the aggregate share of capital by industry to be simply one minus the estimated share of labour and intermediate inputs. I employ rental prices to allocate capital income by asset type. Here depreciation rates are very important because they decide the price.[184] In capital literature there are three main depreciation rates: one-hoss shay form, straight-line and geometric decay. I prefer the geometric pattern since modern productive measurement tends to support the use of geometric depreciation rates in estimating rental rates.[185] However, it should be underlined that the geometric rate is likely to exaggerate rental prices because of the rapid loss of efficiency in the first years of asset life. Consequently, when computing the rental prices with geometric rates one increases the differences among the different types of capital goods (and the effect of capital quality on output growth).[186]

The estimated lives of the different assets are: 50 years for workshops, 40 years for factories, 20 years for engines, 25 years for hand-machinery, 14 years for steam or water-powered machinery and zero years for inventories.[187] The corresponding geometric depreciation rates are: 4 percent for workshops, 5 percent for factories, 10 percent for engines, 8 percent for hand-machinery, 14.3 percent for steam or water-powered machinery and, obviously, 0 percent for inventories. Workshops are given a longer life than factories because workshops were sometimes used as housing. Similarly, hand-machinery was employed during

[184] Moreover, in the case of the perpetual inventory method they also determine the quantity index.

[185] Hulten (1990), pp. 125.

[186] Therefore, I also exaggerate the rate of growth of the capital input index.

[187] These asset lives are based on Von Tunzelmann (1978) and Lyons (1987). However, Catalan sources displays the same asset lives see, for example, Nadal and Ribas (1992) or Arau (1855).

more years than modern machinery because it was simple to repair.[188] Furthermore, by assuming these different lives of the assets in the proto-industry and factory system I try to capture the effects of embodied technical change.

In perfect markets the rental rate must be equal to the arbitrage condition. Thus:

$$p_k(T) = p_i(T-1)r(T) + \delta p_i(T) - [p_i(T)-p_i(T-1)] \tag{3.1}$$

Where $p_k$ (T) is rental rate, $p_i$ (T) is price, $\delta_i$ is the geometric depreciation rate for a capital good type i, and r (T) is the nominal rate of return between (T) and (T-1) years. The price of the input capital is the sum of the nominal price and depreciation less revaluation. Under the customary assumption that all assets obtain the same rate of return I vary r(T) until total payments to capital equal the aggregate share of capital. Implicitly, this equation assumes that the transition from long duration to short duration capital goods is an increase in the quality of input capital. Therefore, the capital goods with larger amortization rates had larger weights in the input capital index, and machinery had a higher weight than buildings in the input capital index.

The final step in constructing the data on capital input was to combine price and quantity data into price and quantity indices of capital input. Employing the Törqvist index, capital input is computed as follows:

$$lnK_t - lnK_{t-1} = \sum_i [\overline{\Theta}_{K_i}(\ln Ci_t - \ln Ci_{t-1})] \tag{3.2}$$

where Ki designates capital input, C designates capital (observable) stock, n kinds of capital inputs (1..i..n) are being considered, the two time periods are t and t-1, and the value share weights $\Theta_{ki}$ are computed as:

$$\overline{\Theta}_{K_i} = 1/2[\theta_{ki}(T) + \theta_{ki}(T-1)], \quad (i=1,..i,..n).$$

The $\Theta_{ki}$'s denote the share of each in the value of sectoral property compensation. The exponential of this logarithmic change yields an index number.

[188] Gutiérrez (1837).

A subsequent difficulty is the adaptation of contemporary data to the requirements of these measures. Notice that, in almost all nineteenth century studies, capital was measured according to the narrow definition of the Spanish industrial tax. Industrial taxes were collected with principles very similar to the concept of net capital stock and were adjusted for underutilization since taxes were only paid on the machines in use.[189]

For the first benchmark year (1840) the main data source is the industrial survey conducted during the period. For this census a Royal Commission, which was formed of several outstanding Spanish economists and was directed by Esteban Sayró, visited all the villages and towns in Catalonia where the cotton industry were located. The objective of the census was to evaluate the importance of the Catalan cotton industry, and other ancillary industries, and to decide if they merited tariffs. The census has never been fully published but two books gathered the main results. The first book, which was edited by the same Sayró, collected the total figures and gave details on the methodology and sources of the survey.[190] In addition, Pascual Madoz, who took part in the Royal Commission, published a great part of the results in his geographical dictionary.[191] The dictionary presented detailed information on the cotton industry and other minor industries by districts, provinces and towns.

The debate during the period over cotton industry spindles gives some insight into the quality of Sayró's census. As it was submitted to severe scrutiny by many contemporaries that, finally, certified the veracity of the data. In particular, Figuerola, in his very detailed study on the cotton industry disputed the figures in hand-machinery but, by contrast, confirmed the rest.[192] A reduction in the amount of hand-machinery cannot challenge the overall results since hand-machinery represented a small proportion of the stock of capital. Moreover, the figures of the census are confirmed indirectly by the anterior and posterior estimations of the cotton industry.[193]

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[189] An alternative estimation with the perpetual inventory method shows that stock estimates in different censuses are likely to be net.

[190] Sayró (1842).

[191] Madoz (1846), especially the article, in the volume III, devoted to Barcelona.

[192] Figuerola (1968), pp. 302-320.

[193] See following pages for a description of these sources.

In this census, capital was divided in three types: buildings, machinery and circulating capital. The two first components were net of depreciation and retirements, and were also adjusted for capital utilisation. Since the Royal Commission excluded all machinery and buildings which wer not in in-use, obsolete, in-construction or newly installed but not effectively employed. Moreover, part-time firms were registered only on the basis of their machinery in use.[194] For example, during the visit of the Sayro's commission, the Junta de Fabricas (the cotton industry employers' organisation) claimed, without any success, that in-construction, part-time and stopped factories and workshops must be included as full-time factories in the census. Arguing that a 'strong crisis' had reduced the real productive capacity.[195] The truth is that the Junta de Fábricas was interested in exaggerating size of cotton industry to prove its importance. Therefore, the Royal Commission estimated the adequate measure of buildings and machinery for the purposes of this chapter.

Nevertheless, the measure of circulating capital is not the most suitable for these purposes since they computed a 'rough' measure aggregating money values. Thus measure not only includes raw materials, semi-manufactured goods, and stored goods, but also provisions for wages. However, it is important to appreciate that provisions for wages might be necessarily reduced since wages were paid on a weekly basis and piece-rates were paid immediately after the goods were finished.[196] Therefore, the biases produced by using circulating capital instead of inventories can be considered small.

Further problems could have been caused by the low quality of the price data but this does not seem the case. According to the procedures associated with the analysis of capital as a factor of production, capital stock must not be valued at new prices but at 'the amount that would be obtained from selling each piece of capital at its market price'.[197] Evidence seems to suggest that the census values were based on actual prices of capital goods (i.e.,

[194] Sayró (1842) describes the methodology of the survey. One of the authors of the survey, who did not agree with the methodology and preferred a gross capital measure, considers that almost 10 percent of the (gross) capital was not computed. Madoz (1846), III, pp. 462-473.

[195] Junta de Fábricas (1841).

[196] Sayró (1842).

[197] Hulten (1990), pp. 129.

historical acquisition prices minus depreciation plus revaluations) and, therefore, fit quite well with the requirements of this kind of study. Sayró explains how the values of buildings were computed by capitalizing the actual rental values, but gives little information on the method that was employed when computing machinery and equipment values.[198] Nevertheless, some indications of the method employed to estimate values of machinery can be indirectly obtained by looking at some of the data published by Madoz. For several Catalan towns he published the complete census sheets. In these sheets the information was disaggregated to unit-of-production level. From this evidence, it can be inferred that the Royal Commission gave different values to the same models of machinery in different cotton mills and workshops and, therefore, considered depreciation. For example, in the small village of Malgrat in the Province of Barcelona, 30 dandy looms were valued at Rv. 300 each in the factory of Francisco Sanllehí, 24 dandy looms were valued at Rv. 500 each in the factory of Gispert and Cia, and 8 dandy looms were valued at Rv. 412.5 each in the factory of José Maria Mandri.[199]

Unfortunately, Sayró's census only covered the cotton, mixed fabrics and metal industries. The rest of the main Catalan industries (paper, linen, wool and silk) were practically ignored or the figures were simple speculations made by the members of the Royal Commission. Consequently, capital estimates for these industries must be based on alternative sources.

With regard to the paper industry, the main sources are the two studies on this industry conducted during the period.[200] At first glance both estimates were based on the concept of gross stock of capital since they tried to estimate the amount of value-added generated by the industry, and the return on capital. Moreover, the evidence presented in both studies is non-conflicting. Therefore, I convert from gross to net figures by assuming 30 percent depreciation.[201]

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[198] Sayró (1842), pp. 36.

[199] Madoz (1846), pp. 75.

[200] Gutiérrez (1837), pp. 142 and the report cited by Delgado (1991), pp. 213-215.

[201] Gutiérrez (1837) and Delgado (1991).

For the linen industry, the gross stock of capital was estimated for 1846 in an article in Madoz's dictionary. This article also contains production figures from 1840 to 1846.[202] Employing these output figures, one can estimate the gross stock of capital in 1840, using the assumption that there were no changes in the capital to output ratios during the period. Furthermore, because linen weaving was practically new in Catalonia, the gross capital figures for 1840 are practically equivalent to net figures and, consequently, they do not require further adjustments.

From the available data on machinery and buildings for the wool industry in Sabadell and Tarrassa,[203] one can estimate the overall capital stocks using the assumption that Catalan capital to output ratios were the same in Sabadell and Tarrassa. In this period these two towns contained a large part of the Catalan wool industry. Therefore, it can be postulated that the biases involved in using this data for computing the net stock of capital in the wool industry are likely to be small.

To complete the set of calculations for 1840, I move to the silk industry. Due to the scarce information on this textile industry, it was necessary to draw on the capital to output ratio (in this case the number of looms divided by the metres of cloth) of the mixed fabrics industry.[204] Silk weaving and finishing employed almost the same type of equipment as mixed fabrics weaving and finishing. Furthermore, in the early 1840s, Catalonia was not involved in the early phases of the production of silk cloth. The silk yarn needed had to be imported from other Spanish sites, usually Valencia and Grenada.[205] Therefore, the biases introduced by using the mixed fabrics ratios in computing the net stock of capital in silk are likely to be minimal.

With regard to the last benchmark year (1861), the main sources are: for cotton textiles the survey of the Comisión especial arancelaria, and for the other industries the Gimenez

[202] Madoz (1846), pp. 555.
[203] Benaül (1991), pp. 117.
[204] Sayró (1842), pp. 17.
[205] Figuerola (1968), pp. 225-226.

Guited industrial guide.[206] Several academics, and influential nineteenth century experts, have considered the survey as the best source of information on the cotton industry in the nineteenth century.[207] It contains detailed information for all types of assets in spinning, weaving and finishing and very detailed reports on three firms in each of these sub-sectors. The data was collected on the same basis as the Sayro's census; machinery and buildings were net of depreciation and retirements and circulating capital included provisions for wages. Moreover, figures are given for 1860, the best year of the industry, and 1865.[208] In Gimenez Guited (1862) the stock of capital was divided into only two types, aggregated buildings and circulating capital, but stock was net of depreciation and retirements.

A sceptical reader would argue that the estimations of Gimenez Guited (1862) might be biased downwards since they were based on tax data and, therefore, tax evasion might reduce overall figures.[209] In particular, evasion of the direct industrial tax (*Contribución Industrial*) would reduce equipment figures because this tax was paid according to the number of machines. Furthermore, the errors contained in the number of machines were transmitted to the value of buildings and circulating capital since their amount was estimated considering data on machinery.[210]

To estimate the amount of tax evasion, and hence the undervaluation contained in Gimenez Guited's figures, I can only use cotton industry data this is because other industries' alternative figures are not already available or are not suitable for this purpose. Consequently, I must assume that the level of tax evasion in the other industries was equal to the level in the cotton industry.[211]

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[206] Comisión especial arancelaria (1867) and Gimenez Guited (1862).

[207] Nadal (1974), pp. 11-12.

[208] The figures employed here have been adjusted to 1861 levels.

[209] By contrast, Sayró's census was not conducted for tax reasons and, consequently, it is probably more exact.

[210] In Gimenez Guited (1862) only information on machinery capital appeared at firm level, whereas buildings and inventories appeared aggregated at industry and province levels.

[211] In this period taxes had to be paid on machinery as soon as it was installed. However, in the 1860s the Spanish parliament passed several laws that gave exemption from industrial taxes to factories that employed water energy. Carreras (1983), pp. 54-55.

It should be highlighted that in the cotton industry, particularly in spinning, to establish the reliability of the figures is relatively simple. One can check the figures by calculating the physical production per unit of machinery. The quantity of raw cotton consumed by each spindle varies according to four factors: the quality of the yarn, the type of spindles, the age of machinery, and the underutilisation of the machinery. During the 1850s in Catalonia, the first two factors remained stable since yarn was produced by a constant combination of mule-jennies or self-acting mules and throstles (since 1852-1853 proportions were nine spindles of selfactings to one spindle of the other two types of machinery).[212] Furthermore, the quality of yarn remained constant during the 1850s[213] and all the machinery, except a few handspindles and mule-jennie spindles, was relatively new. Therefore, underutilisation is the unique varible that affected physical productivity. The following table collects data on the physical productivity of spindles:

**Table 3.2** Physical Productivity of Cotton Spindles: Catalonia, 1849-1861

| **Source** | **year** | **scope** | **Spindles (thousands)** | **Raw Cotton (Tons)** | **Kg. per spindle** |
|---|---|---|---|---|---|
| Figuerola | 1849 | Self-actings | | | 20.0 |
| Figuerola | 1849 | Mule-jennies | | | 20.0 |
| Figuerola | 1849 | Throstles | | | 15.0 |
| Ronquillo | 1850 | Catalonia | 704 | 13,934 | 19.8 |
| Instituto Industrial | 1860 | Catalonia | 1,050 | 21,920 | 20.9 |
| España Industrial S.A. | 1860 | Sans | 42 | 876 | 20.9 |
| José Ferrer & Cia | 1860 | Vilanova | 19 | 298 | 15.7 |
| Jové, Ascacibar & Cia | 1860 | Barcelona | 15 | 323 | 21.5 |
| Gimenez Guited | 1861 | Spain | 1,017 | 23,024 | 22.6 |

**Notes and sources:** numbers are subject to rounding errors. Kg. per spindle is tons of raw cotton divided by the amount of spindles. Figuerola (1968), pp. 314. Ronquillo (1851-1857), pp. 129; Instituto Industrial: Comisión Especial Arancelaria (1867), pp. 27-28. España Industrial S.A., José Ferrer and Cia and Jové, Ascacibar and Cia: Comisión Especial Arancelaria (1867), pp. 11-26. Gimenez Guited (1862), pp. 204.

Figuerola's figures refer to the full-capacity of the Catalan machinery in 1849.

[212] See in the table 3.2 that, according to Figuerola (1968), mule-jennies and selfactings consumed about 20 Kg. of raw cotton per year whereas throstles only 15 Kg.

[213] See chapter 9.

Ronquillo's figures, which are corrected for underutilisation,[214] are based on the cotton industry census conducted by the Junta de Fabricas de Cataluña in 1850. However, in 1850, many hand-spindles (about 26 percent of in-use spindles), with very low productivity, were still active. The Instituto Industrial's figures were not adjusted for underutilisation. The next figures correspond to three firms that replied to the comisión especial arancelaria: the España Industrial S.A., the largest Catalan cotton mill, Jové, Ascacibar & Cia, and José Ferrer and Cía. The output of two first companies is representative of the average output produced by Catalan mills, whereas the output of the third firm was finer than the average.[215] Furthermore, the first two worked at full capacity during 1860, whereas production at José Ferrer and Cía. was halted for several months. However, it should be noted that even when the mills worked at full capacity some machinery was stopped for repairs during the year. For instance, Cerdà reports that machinery was stopped about 9 to 10 weeks per year (about 17 percent of the year for repairs).[216]

Comparing the productivity of cotton spindles derived from Gimenez Guited with other sources, I find that these values are only about 8 percent higher than the Instituto Industrial's figures. Since data on raw cotton imports seems very accurate, this high productivity value is probably due to the different treatment of the machinery stopped for repairs. This impression is confirmed by the fact that industrial taxes in Spain were only paid on machinery in-use. Therefore, Gimenez Guited's figures seem accurate, and the major differences are probably due to the different treatment of idle machinery.

Another important question is the reliability of the prices employed by Gimenez Guited and the distribution of the sample errors. As has been mentioned above, capital goods must be valued at acquisition prices minus revaluations and depreciations. Like in the Sayró census, in Gimenez Guited's guide the same machinery was valued at different prices in different factories, which suggests that depreciation rates were considered. By looking at the

[214] According to the source, about 26 percent of the spindles were idle.

[215] See a description of the quality of Catalan yarn output in chapter 9.

[216] Cerdá (1968), pp. 595-598.

surviving records of two cotton firms,[217] this supposition can be investigated in detail. In Gispert, Soucherion and Cía. (Vilanova) the real value of machinery was 25 percent higher than the value Gimenez Guited reported while in Miguel Puig and Cía. (Esparraguera) the reported and the real values were practically identical. This puzzling evidence can be solved by looking at the amount of machinery in Gispert, Soucherion and Cía. According to the company's reports, 70 very old powerlooms, which worked at 75 percent of capacity, and other 132 new powerlooms (acquired after 1853) which worked at full capacity, were in the factory. Whereas only 142 mechanical looms were declared to the guide.[218] Therefore, the managers maintained some old looms on the accounting books to artificially increase the value of their assets. To sum up, according to the evidence on these two cotton firms, the prices seem correct. Concerning the question of the distribution of the errors in Gimenez Guited (1862), two statistical tests show that the errors were randomly distributed among all the industries and provinces.[219]

In the cotton industry but not in other industries, the capital input has been estimated for two more benchmark years (1830 and 1850). The main sources for 1830 are the figures of Figuerola and Gutiérrez.[220] Both estimates were not based on census data but were the direct estimations of the authors. Therefore, it is likely that the margins of error were larger than in the census. By contrast, the main source for 1850 is more reliable since it is a cotton industry census conducted by the Junta de Fabricas de Cataluña.[221] There are two main problems with the 1850 figures: the finishing figures do not comprise the whole finishing industry since they only take into account printing but not bleaching, and the weaving figures also include the mixed fabrics industry. To deal with the first problem, the capital tooutput ratios of the other finishing operations in 1840 to 1850 were extrapolated using the

[217] The firms are Gispert, Soucherion and Cia and Miguel Puig and Cia. The data on the first was studied by Nadal and Ribas (1992) whereas the records of the second firm are in Sedó (1861-65)

[218] Nadal and Ribas (1992), pp. 220-221.

[219] For example, the data observations have a log-normal distribution at 99 percent and they also passed the alpha-test of data reliability. See Greene (1993) on the mathematical grounds.

[220] Figuerola (1968), pp. 311 and Gutiérrez (1834), pp. 131-141, and Gutiérrez (1837), pp. 22.

[221] Junta de fábricas (1850). The results were published by Ronquillo (1851-1857), pp. 129 whereas the whole census was reproduced, with several small errors, by Graell (1910), pp. 442-492.

assumption that these operations underwent no important technological innovations. Then, the resulting figures have been added to printing figures to obtain the net stock of capital in finishing. Similarly, the capital to output ratios of the 1840 mixed fabrics industry were extrapolated. These figures were then used to estimate the capital levels of the 1850 mixed fabrics industry. These capital amounts were then subtracted from the weaving totals to obtain the level of capital used in the cotton weaving industry.

### 3.3. Empirical results

Table 3.3 shows the evolution of the stocks of capital of nine industries: cotton spinning, cotton weaving, cotton finishing, metal, paper, linen, silk, wool, and mixed fabrics. These industries account for 84.22 percent of the stock of capital reported by Gimenez Guited in Catalonia and probably a similar proportion of 1840 stocks.[222] Capital input growth rates range from about 2 percent to about 9 percent. Net capital stock[223] rates (hereafter raw capital) were smaller than capital input rates, which shows that capital quality rose during the period.

The interpretation of capital quality has provoked a large debate among economists. Many academics have argued that the quality change in investment goods could be attributed to embodied technical change, which can be defined as the technical progress due to improvements in the design of new capital.[224] Others have argued that the embodiment hypothesis was substantially unimportant, because changes in the composition of capital stock have only a small impact on output growth.[225] Finally, a third group of authors has rejected the concept of embodiment with the argument that the procedure used to compute quality in capital goods 'is no more than an extension of the standard two-factor analysis to the consideration of more numerous inputs'.[226]

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[222] Gimenez Guited (1862) tables of the provinces of Barcelona, Gerona, Lérida and Tarragona.

[223] Net capital stock is equal to previous investments minus depreciation and retirements.

[224] Hulten (1990).

[225] Denison (1964).

[226] Young (1995), pp. 649.

**Table 3.3** Growth Rates of Capital Inputs and Sectoral Output: Modern Industries, 1840-1861

| | Capital Input | Raw Capital | Quality | Sectoral Output |
|---|---|---|---|---|
| Cotton spinning | 5.97 | 5.47 | 0.50 | 5.32 |
| Cotton weaving | 4.72 | 1.02 | 3.70 | 6.04 |
| Cotton Finishing | 9.03 | 8.26 | 0.77 | 5.95 |
| Cotton Industry | 6.27 | 4.92 | 1.35 | 5.80 |
| Metal Industry | 6.77 | 6.14 | 0.63 | 6.82 |
| Other Textiles | 2.72 | 2.20 | 0.52 | 4.28 |
| Paper Industry | 1.90 | 0.98 | 0.92 | 2.07 |
| Total | 5.92 | 4.70 | 1.22 | 5.29 |

**Notes and sources:** Numbers are subject to rounding errors. Total figures computed according to the method described in the equation 3.2. For capital sources see text above. Sectoral output figures are drawn from table 2.8 and 2.9.

Whether the numbers in the above table reflect the trend of capital input in Catalonia between 1840 and 1861,[227] I may justifiably infer from them that the country was accumulating industrial capital at respectable rates throughout the process of early industrialisation: roughly 5 percent per year in net stock and 6 percent in capital input. Even the lower rate is well above the growth of the manufacturing labour force in those years.[228] In other words, the capital to labour ratio in Catalan manufacturing must have increased in those years. More interesting, however, is that total capital rates were very close to output rates in all industries, and even in the other textiles and paper industries they were below the output growth rates.

There are grounds for pursuing this question somewhat further. In particular, sceptics might argue that investment booms preceded any kind of industrial expansion within the period. This means that the balance between capital and output growth might be disturbed during the first decades (the 1830s or the 1840s) in one or several industries. During these short spans Catalan industry might receive large transfers of capital from the rest of the economy and it is certainly possible that these funds found their way into the Catalan cotton

[227] It should be noted that the sample of industries is biased in favour of modern industries and, hence, overall industry capital growth rates were likely to be lower.

[228] See the next chapter.

industry.

The sequence of capital stock growth offers a convenient point for discussing the first question. The procedure is to concentrate on the cotton industry data by comparing capital and output by decades. Table 3.4 presents a set of estimates of capital input, raw capital (ie., net stock), capital quality and gross output growth rates.

**Table 3.4** Growth Rates of Capital Input and Sectoral Output: Cotton Industry 1830-1861

| Period | Sector | Capital Input | Raw Capital | Quality | Sectoral Output |
|---|---|---|---|---|---|
| 1830-1840 | Spinning | 3.45 | 2.41 | 1.04 | 7.02 |
| | Weaving | 7.19 | 5.17 | 2.02 | 8.57 |
| | Finishing | 9.10 | 8.43 | 0.67 | 8.29 |
| | **Total** | **5.01** | **3.74** | **1.27** | **8.22** |
| 1840-1850 | Spinning | 7.89 | 7.42 | 0.47 | 7.65 |
| | Weaving | 4.58 | 1.40 | 3.18 | 9.68 |
| | Finishing | 8.61 | 7.62 | 0.99 | 10.48 |
| | **Total** | **6.92** | **5.47** | **1.44** | **10.41** |
| 1850-1861 | Spinning | 5.41 | 3.70 | 1.71 | 3.29 |
| | Weaving | 2.11 | 0.67 | 1.44 | 2.93 |
| | Finishing | 10.47 | 8.84 | 1.64 | 2.12 |
| | **Total** | **5.63** | **4.02** | **1.61** | **2.15** |
| 1830-1861 | Spinning | 4.88 | 4.48 | 0.39 | 5.90 |
| | Weaving | 7.67 | 2.36 | 5.31 | 6.93 |
| | Finishing | 9.21 | 8.31 | 0.90 | 6.81 |
| | **Total** | **6.41** | **4.65** | **1.77** | **6.77** |

**Notes and sources:** Numbers are subject to rounding errors. Total figures computed according to the method described in the equation 3.2. For sources see text above. Sectoral output growth rates computed with the figures of the tables 2.2 and 2.4.

In the 1830s and 1840s, production had grown more rapidly than investment; in the 1850s the reverse was the case. Moreover, during the whole period, the capital stock experienced a quite stable growth pattern. Indeed, this result confirms the picture resulting from table 3.3. Note that individual sub-sectors evolved differently in the short-run, weaving experienced the largest investments in the 1830s, spinning in the 1840s, and finishing in the 1850s. This result may indicate flows of capital among sectors throughout this early phase of industrialisation and structural changes in the composition of capital. It should also be noted that it gives little support to arguments based on the large transfers of capital towards industry.

However, the aggregate quantitative unimportance of capital growth may conceal significant shifts in the composition of capital stock through these years. Changes in the composition of capital can be of two types: alterations in the relative importance of the different industrial sectors, and changes in the composition within the sectors of capital stock.

Moving to the question of the changes in the share of each industry in the net capital stock, table 3.5 provides a detailed statement on the trends from 1830 to 1861. In cotton textiles the share is presented for four benchmark years whereas in the rest of industries only two years are given.

**Table 3.5** Net Stock of Capital: Modern Industries, 1830-1861 (thousand Pta.)

| | 1830 | 1840 | 1850 | 1861 |
|---|---|---|---|---|
| Cotton spinning | 26,460 | 33,664 | 70,701 | 106,220 |
| as % cotton | 55.65 | 46.89 | 56.85 | 53.87 |
| as % total | | 35.50 | | 44.43 |
| Cotton weaving | 16,833 | 28,238 | 32,481 | 34,970 |
| as % cotton | 35.40 | 39.33 | 26.12 | 17.73 |
| as % total | | 29.78 | | 14.63 |
| Cotton Finishing | 4,257 | 9,887 | 21,189 | 56,000 |
| as % cotton | 8.95 | 13.77 | 17.04 | 28.40 |
| as % total | | 10.43 | | 23.42 |
| Cotton Industry | 47,550 | 71,790 | 124,371 | 197,190 |
| as % total | | 75.70 | | 82.48 |
| Metal Industry | | 3,988 | | 14,489 |
| as % total | | 4.21 | | 6.06 |
| Other Textiles | | 11,140 | | 17,673 |
| as % total | | 11.75 | | 7.39 |
| Paper Industry | | 7,912 | | 9,730 |
| as % total | | 8.34 | | 4.07 |
| **Total** | | **94,830** | | **239,083** |

**Notes and sources:** numbers subject to rounding errors. For sources see text.

Throughout the period the cotton industry absorbed the lion's share of capital stock, its share fluctuated between roughly 76 percent and 82 percent. Within the cotton industry, weaving lost importance whereas finishing gained positions and the share of spinning remained quite stable. The evolution of cotton finishing is the most remarkable, the share in 1861 was triple the share of 1830. After cotton finishing, metal was the industry that most rapidly increased its share in the net stock. This rapid growth can be associated with the creation of several modern companies that produced modern machinery with foreign patents. In spite of the rapid growth of these new factories, the small workshops did not disappear because they participated in the new business as sub-contractors of the large firms.[229] The counter-examples of the cotton and metal industry are the other textiles and paper industries. These industries showed a declining participation in the net stock of capital during the period. It is well known that the widespread use of cotton textiles damaged the rest of the textiles industries, reducing their market share. Moreover, the mechanisation of weaving in mixed fabrics and wool encountered many problems because the powerlooms used were not profitable until the 1850s.[230] More complicated is to explain the slow growth of capital in the paper industry. Certainly, the establishment of new factories took place in the 1840s and 1850s. Meanwhile, the traditional paper industry based on small water-mills, which produced high quality products, survived without important changes. It is likely that this dual aspect of the paper industry slowed down the total growth rates since new investment in the traditional sector was probably small.

The changes not only affected the distribution of the net stock of capital among the different industries, but also the shares of their components (buildings, machinery and equipment, and inventories) within each industry. Accounts for several countries have shown the relative increase of machinery with respect to industrial buildings during early industrialisation.[231] Similarly, some economic historians, of whom the most famous is the Nobel winner Sir John Hicks, predicted that fixed investment during industrialisation benefited from the decrease of circulating capital.[232] The next table displays these changes in Catalonia:

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[229] See Nadal (1974) and (1991b).

[230] For mechanisation in the wool industry see Benaül (1991), pp. 105-158.

[231] However, the reader must not be confounded by this phenomenon since the share of machinery in total net capital stock remained small during the whole period. For example, Field (1985), pp. 380-381 shows that in the United States in 1850 machinery (producer durable) represented only about 9 percent of total reproducible tangible assets.

[232] Hicks (1965)(1969).

**Table 3.6** Changes in the Composition of Net Stock of Capital: Modern Industries, 1830-1861(percent)

| | Year | Buildings | Machinery & Equipment | Inventories |
|---|---|---|---|---|
| Cotton spinning | 1830 | 63.78 | 13.86 | 22.36 |
| | 1840 | 48.90 | 22.20 | 28.89 |
| | 1850 | 30.13 | 32.89 | 36.97 |
| | 1861 | 23.05 | 56.27 | 20.68 |
| Cotton weaving | 1830 | 27.42 | 9.41 | 63.16 |
| | 1840 | 31.13 | 11.95 | 56.93 |
| | 1850 | 31.92 | 20.61 | 47.48 |
| | 1861 | 46.05 | 39.65 | 14.30 |
| Cotton Finishing | 1830 | 45.89 | 25.13 | 28.98 |
| | 1840 | 65.18 | 19.11 | 15.71 |
| | 1850 | 35.62 | 17.65 | 46.74 |
| | 1861 | 48.91 | 28.77 | 22.32 |
| Cotton Industry | 1830 | 49.31 | 13.29 | 37.40 |
| | 1840 | 44.15 | 17.74 | 38.11 |
| | 1850 | 31.53 | 27.09 | 41.38 |
| | 1861 | 34.47 | 45.51 | 20.02 |
| Metal Industry | 1840 | 43.18 | 26.74 | 30.08 |
| | 1861 | 41.23 | 33.77 | 25.00 |
| Other Textiles | 1840 | 50.93 | 13.94 | 35.13 |
| | 1861 | 53.55 | 22.50 | 23.95 |
| Paper Industry | 1840 | 37.45 | 27.16 | 35.39 |
| | 1861 | 34.57 | 30.85 | 34.57 |
| **Total** | 1840 | 44.35 | 18.46 | 37.19 |
| | 1861 | 35.90 | 42.24 | 21.86 |

**Notes and sources:** numbers subject to rounding errors. For sources see text.

The outstanding feature of the classification by type of capital is the increase of the share of machinery in the net stock. At the beginning of the period under review machinery accounted for 18 percent of the total; by the end its share was 42 percent; that is, its relative importance had doubled. It is also important to appreciate the downward trend in inventories: in 1840 they accounted for 37 percent of the total and by 1861 their share had fallen to 21 percent; that is, their relative importance had halved. The proportion of net stock of capital as industrial buildings also decreased significantly from 44 percent in 1840 to 36 percent in 1861.[233] A further consequence of these trends is the sharp rise in the ratio of fixed to circulating capital. Thus, the ratio of fixed to circulating capital was 1.6:1 in 1840 and by 1861 it had climbed to 3.6:1. This latter result is similar to british figures where the ratio of fixed to circulating capital within the commercial and industrial sectors also experienced a sharp rise; from 1.5:1 in 1800 to 3.3:1 in 1860.[234]

The first part of table 3.6, in which the changes in the cotton industry are displayed, is in some ways the most interesting. It again shows a marked upswing in the importance of machinery, with an increase from over 13 percent of the total in 1830 to over 45 percent in 1861. The table also shows the falls in inventory levels, with a decline from 35 percent of the total in 1830 to 20 percent in 1861. The increase of machinery showed a constant increase. In current values, the amount of machinery grew from about 6 million Pta. in 1830 to 90 million Pta. in 1861. By contrast, the downward trend of inventories was not constant as it was affected by business cycles. In particular, in 1850 the share of inventories grew due to the special characteristics of that year.[235] However, it should be noted that this decrease in the share does not correspond to a similar decline in their current value. In 1830 inventories amounted to about 18 million Pta. and in 1861 about 39 million Pta. (i.e., more than twice the 1830 figure). Moreover, this reduction in the share of inventories is almost entirely due to cotton weaving. Inventories in cotton weaving fall in importance, with a decline from 63 percent in 1830 to only 14 percent in 1861. These results imply that their current value in weaving was reduced from over 10 million Pta. in 1830 to only 5 million Pta. in 1861. This result does not mean that spinning and finishing did not save capital in inventories but that the reallocation of inventories among the different sectors strongly benefited weaving.[236]

[233] This change in the structure of net capital implies that 57 percent of net investment was exclusively devoted to machinery whereas buildings received about 31 percent and inventories only 12 percent.

[234] Feinstein (1978).

[235] For example, in the cotton company studied by Nadal and Ribas (1992), pp. 237 the value of inventories in 1850 were double that of 1849 and 1852.

[236] See chapter 8.

Another aspect of the structure of the net stock of capital is set out in the first part of the table 3.6. The wider differences in the composition of capital among the different sub-sectors of the cotton industry. My contention is that the changes in the structure of capital were mainly decided by the point of departure and the different stages in the transition towards the mechanized factories.

For the period studied, spinning is the unique sub-sector of the cotton industry that completed the transition from proto-industry to factory system. In 1830, it was a putting-out industry with many units of production and very low investments in machinery.[237] For example, an observer at that time emphasised the low amount of capital necessary to acquire a jenny.[238] Then, the spread of the new cotton mills reduced the relative importance of buildings by decreasing the number of workshops. Furthermore, competition among the new entrants helped the rapid succession of new vintages of machinery, every time more complicated and consequently more expensive. Thus, the buildings to machinery ratio plummeted from 4.6:1 in 1830, to 0.4:1 in 1861.[239] Initially, in the 1830s, new steampowered factories constituted a small portion of the industry, and water and horse-powered mills constituted the large part. For example, in 1840, the total number of CV installed in the industry was 2,014. Of which only 14 percent corresponded to steam engines. During the 1840s the process accelerated with the introduction of the self-acting mules. These new spinning machines benefited from the reduction of power costs through the adoption of high-pressure and compound steam engines.[240] This reduction in running costs was accompanied by a progressive increase in the amount of capital invested in machinery. This was because the new machinery was more expensive but also more efficient and competitive with respect to alternative sources of energy. By the 1850s, the standard factory in spinning was steampowered and employed a combination of self-acting mules and throstles. Through this process the industry saved on capital invested in buildings by reducing the number of

[237] See chapters 7 and 9.

[238] Gutiérrez (1837), pp. 152-153.

[239] Furthermore, the net investment in buildings from 1830 to 1861 was equal to about 45 percent of the value of the net stock of buildings in 1830.

[240] Von Tunzelmann (1978), pp. 206-208.

productive units, but not the amount devoted to inventories.[241] Moreover, it should be noted that the previous investments in fixed capital were never wasted since old buildings were prepared to adopt the new machinery and old mules were scrapped only at the end of their working lives.[242]

Contrary to spinning, cotton weaving did not complete the transition to the factory system in the period. Moreover, handloom weaving was not heavily damaged by the use of the new machinery until the 1850s. For example, in 1850 eight handlooms were in service for each mechanical loom.[243] In spite of the survival of handlooms during the period, the changes in the capital structure had a marked parallelism with that of spinning. Thus, the buildings to machinery ratio decreased from 2.9:1 in 1830 to 1.15:1 in 1861, while the fixed capital to inventories ratio rose from 0.58:1 in 1830 to 6:1 in 1861. Indeed, the change in the buildings to machinery ratio can be associated solely with the process of mechanisation, but the fall in inventory levels was also associated with other factors. In weaving, the impulse towards mechanisation came from spinning mills that integrated forward into the production of cloth and also, sometimes, the finishing processes. These new vertically integrated factories were responsible for large inventories savings.[244] For example, the management of España Industrial estimated that without the vertical integration of spinning, weaving and finishing the firm would have been forced to increase the amount of grey cloth in the storehouses from 7,000 to 25,000 pieces (i.e., vertical integration saved about 70 percent of inventories of semi-finished products).[245]

The finishing industry did not experience the strong alterations in the composition of capital that took place in spinning and weaving. The differences between the organisation of the proto-industry in finishing and the other two sub-sectors of the cotton industry were

[241] These building were mainly devoted to putting-out.

[242] For example, many mule-jennies were transfomed into self-acting mules through modifications. Maluquer, (1976).

[243] Ronquillo (1851-1857), pp. 129.

[244] See chapter 8.

[245] Comisión especial arancelaria (1867), pp. 45.

wider.[246] The proto-industry in finishing was organised in manufactories but not into putting-out webs. This is perhaps the major reason why the changes in the structure of capital were small. Any changes in inventory levels was due to business cycles.

### 3.4. Conclusions

This chapter has revisited the role of capital in the early phase of Catalan industrialisation. The main empirical conclusion is that the rate of growth of industrial capital was important during early industrialisation in Catalonia, but less impressive than the rate of output growth. The Catalan experience correlates very well with the experience of other European countries during early industrialisation, such as Britain, France, Germany, or the United States.[247] Where the absolute levels of industrial investment appear to have been quite modest. In contrast, the Catalan experience differs strongly from Twentieth Century growth experiences. For instance, in the last twenty years the growth rates of industrial capital in the Asian newly industrialised countries were twice or thrice the historical Catalan rates.[248]

The extent of the industrial production in Catalonia in a hypothetical world without supply restrictions on capital cannot, of course, be confidentially gauged. However, the comparison of Catalonia with the other industrialising European countries probably provides the best indicator of the extent of capital supply constraints. Since comparisons suggested that the growth rates of Catalan industrial investment were normal for Europe. It seems very difficult to argue that supply side constraints largely decided the amount of industrial investment. By contrast, several demand-side characteristics that were common to all early industrialising regions can explain the low requirements of capital by the Catalan industry. First, the gradual nature of industrialisation reduced the simultaneous quantity of capital put into new projects. For example, the construction of new factories in the cotton industry took place throughout the period and was not concentrated in a few years, and only towards to the

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[246] See, Thomson (1992), chapter 9 and Sánchez (1989)(1992) and (1996).

[247] Feinstein (1978)(1981), Tilly (1978), Lévy-Leboyer (1978) and Davis and Gallman (1978)(1994).

[248] For instance, in South Korea manufacturing the capital stock grew at 15 percent per year; in Taiwan at 13 percent; and in Singapore at 10 percent. See Young, (1995), tables VI, VII and VIII.

end of the period were the major cotton mills constructed. Another aspect was that during the emergence of the factory system putting-out remained important. This tended to slow the aggregate rate of growth of the stock of capital since the reduced rate of investment in the putting-out system affected the total rates. Third, the low fixed capital requirements in absolute terms of Catalan industries. All Catalan industries during the early industrialisation, even the metal industry that was mainly devoted to the production of machinery, can be in though of as light industries; that is, industries with low fixed capital requirements. Finally, many historians have pointed out that the factories economised on the substantial working capital associated with putting-out and domestic manufacturing.[249] These savings were then spent on the plant and equipment of the mill. The rationality of this substitution is easy to explain in a neoclassical context since the marginal productivity of inventories (i.e., the rental rate) was lower than that of fixed capital. In other words, the savings in working capital increased the marginal productivity of the total stock of capital. In the Catalan case, these savings appear to be important, especially in the case of cotton textiles where the share of inventories with respect to total stock of capital decreased substantially.

Given the demonstrated slow increase in the net stock of manufacturing capital, the next logical question concerns the supposed relationship between the previous accumulation of capital and the beginnings of industrialisation. My results make it difficult to support the primitive accumulation argument suggested by Marxists. Likewise, the explanations of the early phase of Catalan industrialisation based on the accumulation of capital during the Colonial Era or through the exports of wines and spirits are rejected. I would suggest that there is at least as much evidence to support productivity improvement within the manufacturing sector after 1830 as the major source of capital. In other words, Catalan industry produced enough surplus to sustain further increases in industrial capital.

Moreover, it has been shown that the failure to adjust capital for quality change has the effect of reducing the rate of growth of capital input. On average, the embodied technical change was about 20 percent of input capital, but varied strongly from industry to industry. This leads to the conclusion that changes in the quality of capital had a nontrivial impact on

[249] Von Tunzelmann (1995), and Field (1985).

the growth of capital input from 1830 to 1861. However, these results also cast serious doubts on the relevance of the embodiment hypothesis for explaining a large part of output growth. The data presented in this chapter suggest that Denison (1964) was correct in his emphasis on the unimportance of the quality of capital. It seems likely that the machinery supposition fails to explain the essence of economic growth during early industrialisation. In other words, it appears to be difficult to explain the Continental industrialisation only in terms of the transference of the modern machinery from Britain to the Continent.

In summary, this chapter has established the inappropriateness of the argument that capital accumulation played the main role in the early phases of Catalan industrialisation. Consequently, future chapters should be directed towards discovering the main sources of growth. Only two possible explanations remain: (1) a very elastic supply of labour allowed the Catalan industries to grow without large investments, (2) gains in productivity due to non-capital embodied innovations were the key element in early industrialisation.

# Chapter 4

# The Transformation of the Labour Market in Manufacturing

The goal of this chapter is to throw light on the changes in the labour market in the early industrialisation of Catalonia. The first half of the chapter is devoted to contrasting the two basic hypotheses on the role of labour during early industrialisation: the Dual-growth model and the Goldin-Sokoloff hypothesis. Employment and wages in manufacturing are then analysed. On the whole, the evidence does not support an explanation based on the former and gives only partial support to the arguments of the latter. The second part of the chapter is devoted to discussing new evidence in capital-skills p-complementarity and to formulating a simple partial equilibrium model. This model tries to explain the evolution of labour markets after the adoption of the factory system. An important corollary of the discussion is that from 1830 to 1861 the overall contribution of labour to growth rates was small.

## 4.1. Introduction

It has long been stressed that cheap and abundant labour was important at the beginning of industrialisation. In particular, many authors have linked the success of some European regions during the first half of the nineteenth century with this kind of competitive advantage.[250] This chapter will not resolve this question definitively. Its purpose is much more modest. Its starts with the proposition that this is an empirical question, and that accurate answers depend on the peculiarities of each region.[251] Furthermore, I attempt to go

[250] See, for example, Mendels (1972) and Mokyr (1974)(1976).

[251] A review on labour markets history is available in Grantham (1994).

behind the common belief that only the quantity of labour was crucial, to see what can be learned by considering not homogeneous but heterogeneous labour.[252] This sounds trivial and unimportant; it is not. For example, if physical and human capital (skills) are relatively p-complementary, any process of capital-labour substitution would affect the demand for the different types of labour differently. It would increase the demand for skilled labour and depress the demand for unskilled labour.

This chapter will explore the changes in the manufacturing labour market during the early industrialisation of Catalonia. My contention is that labour had a limited role in explaining output growth because of the Catalan industries desire to economise on labour. The Catalan labour market in the eighteenth century was characterised by many artisans in several towns, who were grouped into powerful guilds.[253] There was a scarce supply of men labour for labouring tasks since small to medium landholdings predominated in the countryside.[254] Furthermore, the Catalan farms grew many agrarian products reducing the seasonality of the agrarian employment. Which affected the amount of men labour that would be interested in participating in manufacturing work. Thus, in Catalonia, the most scarce supply of labour was unskilled men (labourers) whereas skilled artisans were relatively abundant.

At the beginning of industrialisation Catalan modern manufacturing used a lot of skilled men, women and child labour. Therefore, it can be argued that there was a first phase of Catalan industrialisation up to 1850; a phase during which a large amount of women and child labour was used. The period post-1850 was market by an increase in the employment of men and a decrease in the use of women and children. However, men were mainly employed in the new skilled jobs created by the spread of the factory system. Thus, in this second phase, Catalan manufacturing also economised on women and child labour.

The rest of the chapter is organised as follows. Sections 4.2 to 4.4 compare the

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[252] A review of the literature on heterogeneous labour is in Hamermesh (1993).

[253] Molas (1970).

[254] Vilar (1962).

Catalan case and the received wisdom. The first section describes the literature on the topic at international level. Then, the amount of employment in the modern industries is analysed by means of industry-based data. Section 4.4 provides data on the evolution of wages. From this section emerges the conclusion that wages grew with productivity increases and that earning differentials between men and women decreased. Basically, the result from these two sections is that the Catalan case does not correlate well with the received wisdom, especially after the 1850s. For that reason, section 4.5 presents evidence on capital-skills complementarity, which is not habitually considered in the analysis of the early industrialisation. Evidence on the dispersion of wages and labour demand elasticities is provided. Employing the evidence from the previous sections, a novel (stylized) model of the labour market is sketched in section 4.6. Finally, the last section summarises the major findings and presents conclusions.

## 4.2. The Literature on the Contribution of Labour to the Early Industrialisation

The standard interpretation is that the contribution of unskilled and cheap labour to early industrialisation was important and decisive. However, there appear to be two broad views. The largest group of economic historians places greater emphasis on the release of labour from agriculture, while others have emphasised the role of women and child employment. For the first group, early industrialisation can be explained with the labour surplus model whereas for the other with the so-called relative productivity hypothesis.

The two-sector growth model, which is sometimes called the dual or labour-surplus model, is the most widespread interpretation of the early phases of European industrialisation. Arthur W. Lewis developed the primitive dual model in the 1950s.[255] He used explanations based on economics with a surplus of labour producing an elastic supply. Several leading economic historians, such as Habakkuk, Kindelberger and Herric, agree with

[255] Lewis (1955)(1963). However, the model has its roots in the classical economists, such as Malthus or Marx, though the definitive fomalisation is due to Lewis. The early version of Lewis was further refined and improved by several leading economists such as Fei and Ranis (1964), Sen (1966) and Dixit (1973).

him because they consider that the elastic supply of labour is the 'engine of growth' of capitalist development.[256] They believe that the elastic supply of labour makes it possible for *real* wages to grow more slowly than productivity. This helps the accumulation of capital that forms the basis of modern growth. Therefore, they think that if *real* wages grow at the same rate as productivity the incentives for investment are damaged and that economic growth will stop.

In the Lewis model the economy is divided into dual sectors of traditional and modern parts, and it is argued that the traditional parts of the economy are absorbed into the modern parts during the process of modernisation. The main characteristics of the traditional sector are a low labour productivity, which remains stagnant for long periods and a large supply of labour. The traditional household is a small farm. In these households there is a lot of hidden unemployment because the labour force does not work at full capacity.

The main characteristic of the modern sector is that it has higher labour productivity than the traditional sector. As the traditional sector has a surplus of labour, it can export part of the labour force to the modern sector. The modern sector can grow with this new workforce while maintaining the high productivity of labour. Inevitably, the institutional constraints decide the wage level, and workers in both sectors usually obtain low wages. Accordingly, capital accumulation is produced in a 'natural way' because the gains of labour productivity in the modern sector are transformed, simultaneously, into new savings and investments in the hands of capitalists. In other words, the capitalists obtain a 'quasirent' because the rise of labour productivity has no repercussions on wages.

The Lewis model has a major implication for the understanding of the role of labour during early industrialisation. The main extension of this model is that during the first phase of the process of industrialisation, *real* wages fall because prices rise. Whereas *nominal* wages remain constant. Obviously, the decrease of *real* wages has consequences for workers' living standards because it produces an impoverished labour force and an increase in

[256] Habakkuk (1962), and Kindleberger and Herric (1977).

inequality.

Fei and Ranis have expressed doubts about the Lewis model because, they argue, the traditional sector does not operate in isolation from the modern sector. The co-existence of the old and the new is important, and the interaction of the two sectors does not only affect the wage level. Therefore, they think that the traditional sector is capable of improving its productivity because the marginal return of the traditional family is permanently zero. In other words, they reject the hypothesis that labour productivity stagnation is the main characteristic of the traditional sector. Moreover, these authors argue that it is possible that the traditional sector was not only formed by family farms. There was a large rural proletariat that worked as wage earners receiving monetary and non-monetary remunerations. The simultaneous existence of surplus labour and positive wages in the traditional and modern sectors is theoretically possible. Therefore, the surplus of labour is not a sufficient condition for unlimited supplies of labour.[257] At this point, the basic concept of the Lewis model, the unlimited supplies of labour, appears too vague to sustain a dual explanation for economic growth.

Joel Mokyr, in his work treating industrialisation in the Low Countries, adapts the Lewis model to the historical reality.[258] He suggests a pseudo labour-surplus model, in which the superabundance of a labour force is unnecessary for 'dual' growth. Thus, he argues that during the 'transitional' phases of industrialisation, a 'growing up' process occurs that is basically a disequilibrium of the 'classical stationary state'. In his model, the wage level is fully determined by technological and economic parameters because wages are based on the opportunity cost of labour in the traditional sector. In the Neoclassical model wages and profits are decided by the marginal productivity (assuming perfect labour markets) of labour and capital. In the Lewis model wages are determined by the institutional parameters. Mokyr also supposes that, *ceteris paribus*, technological change was almost independent of factor prices. Consequently, the capitalists obtained a 'quasirent' because wages were not fully

[257] Fei and Ranis (1964).

[258] Mokyr (1974)(1976).

determined by marginal labour productivity.

Another pivotal element in Mokyr's reasoning is the coexistence of two techniques, 'old' and 'new', in one industrial sector. Modern technology and entrepreneurs are exogenous to the model because he assumes that both were mobile and were available from the most developed countries, Britain and France, during these early phases of industrialisation. In the modern industries the labour force essentially came from workers who were previously employed in the traditional sector. This labour did not receive a rise in wage level when the capital to labour ratio grew with the accumulation of capital. Therefore, modern entrepreneurs obtained a 'quasirent' that they reinvested or consumed. Consumers, on the other hand, benefited from the lower prices of industrial goods and, therefore, the demand curve shifted as fast as demand elasticity. These two forces explain the process of industrialisation.

A secondary element of the model is that the absence of capital markets, during this early phase of industrialisation, meant firms had to self-finance investment. The capital accumulation necessary for the growth of the modern sector had to be provided by each firm or to flow among the firms within the sector. Therefore, capital flows from extra-sectoral savings were empirically insignificant. In the modern sector, the rate of growth was decided by the rate of profit and by the proportion of profits ploughed back into the firm. Profits will diverge from the marginal productivity of capital because the coexistence of two techniques, one relatively more inefficient than other, implies that the more efficient technique earns a 'quasirent'. So, the rate of profit cannot fall with the increase of the capital to labour ratio, and could fall only if wages were rising. In other words, if the rate of profit accelerates, the 'transitional' process does so as well. The process finishes when the traditional sector disappears.

To sum up, the Mokyr model has two main conditions: that during the 'transitional' period the wage level should not rise, and that the capital required for modern industry development had to come from inside the modern sector. Therefore, the model is valid only if labour costs did not grow and if *real* wages did not rise.

The increasing participation of women and children compared with men in manufacturing during early industrialisation, i.e., the second broad interpretation, has been pointed out by Claudia Goldin and Kenneth Sokoloff.[259] They argue that early industrialisation was associated with an extraordinary rise in the demand for women and children as labour force, because the expansion of the new methods of production promoted the substitution of unskilled for skilled labour. The low relative productivity of women and children in agriculture in some regions established a relatively low opportunity cost for their labour.[260] Consequently, regions where the productivity of women and children in agriculture was the lowest had a competitive advantage at the start of industrialisation.

According to Goldin and Sokoloff this increase in the demand for women and children meant that they had up a large proportion of the entire manufacturing labour force. However, they were not represented in the same amount in all sectors since their employment was closely associated with the production process used by large establishments both mechanised and non-mechanised. Note that this last statement is very important since it separates this interpretation from the classical proto-industrialisation model.[261] In the proto-industrialisation model, women and children lived in the countryside were paid low salaries because industrial work is complementary to typical agrarian activities. Therefore, an increase in their participation in manufacturing could not result in an increase in their relative wages.

Briefly, the Goldin-Sokoloff model specifies two major conditions: that during industrialisation the relative women and child wage should rise, and that the new workforce required for modern industry development has to be formed by women and children. However, note that the Goldin-Sokoloff model fails to predict some features of the evolution of labour markets from 1850 onwards in the United States. Thus, it is unable to explain why

[259] Goldin and Sokoloff (1982)(1984). Recently, the model has been tested against new evidence, and confirmed, by Craig and Field-Hendrey (1993).

[260] In sharp contrast, the unskilled men labour was not redundant in these regions. Consequently, the substitution of unskilled men for skilled men could not result in any gain for manufacturing development.

[261] Mendels (1972).

after peaking near 40 percent in the 1850s, the share of the industrial labour force in the American North-east composed of women and children began a secular decline which continued into the second half of the nineteenth century.

Goldin-Sokoloff's hypothesis and Mokyr's model agree that the role of the transference of labour within manufacturing was crucial during early industrialisation. However, the Goldin-Sokoloff hypothesis is more optimistic than Mokyr's thesis since it argues that the wages of women and children rise during this phase. Furthermore, in a more recent paper, the widespread gains in *real* wages that happened during the industrialisation of the United States have been pointed out by Sokoloff and Villaflor.[262] In the next two sections I will contrast the two major features of the Mokyr and Goldin-Sokoloff models: employment and wages. Thus first I will discuss the evidence available on manufacturing employment and then I will analyse the evolution of labour costs, *real* wages, and the relative wages of women and children.

### 4.3. Evidence on Manufacturing Employment

New evidence on changes in modern manufacturing employment during early industrialisation is presented in this section. The first area of interest is the growth of the amount of workforce. Note that Mokyr's thesis can explain why the growth rates of the labourforce in Catalonia were faster than output growth rates; that is, they were above 4 percent per year. The reason is that since wages were below the equilibria wage level entrepreneurs found it more profitable to contract more workers than to increase their investment in capital and therefore productivity. The second area of interest concerns the effect of the arrival of the factory system on the composition of employment, specifically sex-age composition of the workforce. Here the expected result according to Goldin-Sokoloff's model is a large increase in the women and child workforce during industrialisation. Note, however, that this fast increase in the employment of women and children is not incompatible with Lewis-like models. One could advance a slightly weaker

[262] Sokoloff and Villaflor (1991).

version of Lewis' model by asserting that, while it was a condition of superabundance of labour, entrepreneurs in manufacturing preferred to contract women and children because of their low wage levels.

The available figures cover the manufacturing sectors analysed in the two previous chapters, i.e., the cotton industry, the metal industry, other textiles comprising mixed fabrics and the linen, silk and wool textiles, and paper industries. The figures for cotton spinning, weaving and finishing were adjusted to full-time employment (FTE) according to the procedure described in the following pages. Finally, it should be noted that the cotton industry's figures are presented for four benchmark years (1830, 1840, 1850, 1861) whereas in the rest of modern manufacturing there is only data for two years (1840 and 1861).

Lacking good sources on employment adjusted to work-hours, it was necessary to develop an indirect method for calculating these numbers. The total number of FTEs in the year t was computed by multiplying the amount of functioning machinery in the year t by the positions per machine. Each FTE is equivalent to 3185.5 hours (11.5 hours x 277 working days per year).[263] It should be noted that positions are different for each type of machinery and they were derived directly from different historical sources. Thus, for example, I actually estimate the 1850 FTEs in mechanical looms using the number of functioning mechanical looms in 1850 and the positions per mechanical loom. For my overall FTE estimates, I then sum across different types of machinery. The main advantage of this method is that the number of hours obtained is adjusted for periods when factories were at a standstill, so the FTEs are correlated with movements in output. Therefore, the figures obtained do not reflect the number of workers, on the contrary, they represent the *real* hours worked.[264]

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[263] The number of work-days during the year is furnished by several sources see Cerdà (1968) and Ferrer Vidal (1875).

[264] The data on positions per machine are drawn from Madoz (1846), Cerdá (1968), Comisión especial arancelaria (1867), and Ferrer Vidal (1875). It is important to appreciate that different sources give very similar positions per machine. Finally, Figuerola (1968), Sayró (1842), Junta de Fábricas (1850), and Comisión especial arancelaria (1867) provided, respectively, the data on functioning machinery for 1830, 1840, 1850 and 1861.

As was mentioned above, jobs in the rest of industries are not adjusted to full-time employment. Indeed, this can introduce unknown biases into the results to the extent that industry relied on part-time work. In the mixed fabrics and metal industries, Sayró's survey is the source of the working population for the first benchmark year (1840).[265] By contrast, the paper, linen, wool and silk industries were practically ignored in the census or their figures were simple speculations made by the census officials. Therefore, I must compute their employment figures using alternative sources. Regarding the paper industry, the main sources are the two studies on this industry conducted during the period.[266] These works display figures for men, women and children. For the linen industry, employment was estimated for 1846 in an article in Madoz's geographic dictionary, which also contains production figures from 1840 to 1846.[267] Using these output figures, employment can be easily estimated for 1840 by assuming that there were no changes in the labour-output ratios. The total workforce in the wool industry can be estimated using the 1849 data for Sabadell and Tarrassa.[268] I thus assume that Sabadell-Tarrassa labour-output ratios were equivalent to the same ratios for Catalonia. To complete the set of calculation for 1840 I must go to the silk industry. Due to the scarce information on this textile industry, it was necessary to draw on the labour-capital ratio (here the number of workers divided by the number of looms) of the mixed fabrics' industry.[269] However, it should be noted that the biases introduced by this method are likely to be small because the technology and productivity in both industries was very similar. Furthermore, in this early period, the silk industry in Catalonia was concentrated in the weaving phase. Finally, with regard to the last benchmark year (1861), the main source is the Gimenez Guited industrial guide.[270] The next table presents the evidence on the evolution of the labour force in the main Catalan manufacturing sectors:

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[265] Sayró (1842) and Madoz (1846), especially the article devoted to Barcelona in the volume III.

[266] Gutiérrez (1834), p. 142 and the report cited by Delgado (1991), p. 213-215.

[267] Madoz (1846), vol. III, p. 555.

[268] Benaül (1991) , tables 17 and 18, p. 114-115.

[269] Sayró (1842), p. 17.

[270] Gimenez Guited (1862).

**Table 4.1** Evolution of Labourforce: Modern Industries, 1830-1861

| | | 1830 | 1840 | 1850 | 1861 |
|---|---|---|---|---|---|
| Cotton Spinning | Men | 982 | 1,295 | 3,631 | 3,632 |
| | Women | 11,292 | 14,774 | 8,409 | 6,262 |
| | Children | 6,046 | 7,915 | 4,599 | 2,630 |
| | Total | 18,320 | 23,984 | 16,640 | 12,524 |
| Cotton Weaving | Men | 18,597 | 22,185 | 29,024 | 26,088 |
| | Women | 8,335 | 9,944 | 10,253 | 6785 |
| | Children | 3,160 | 3,769 | 3,038 | 1052 |
| | Total | 30,092 | 35,898 | 42,315 | 33924 |
| Cotton Finishing | Men | 2,101 | 3,470 | 4,045 | 6650 |
| | Women | 315 | 520 | 535 | 800 |
| | Children | 1,209 | 1,997 | 1,004 | 200 |
| | Total | 3,626 | 5,987 | 5,584 | 7,650 |
| Cotton Industry | Men | 21,680 | 26,950 | 36,700 | 36,370 |
| | Women | 19,943 | 25,238 | 19,968 | 13,847 |
| | Children | 10,415 | 13,681 | 8,642 | 3,882 |
| | Total | 52,038 | 65,869 | 64,538 | 54,098 |
| Metal Industry | Men | | 1,067 | | 1,497 |
| | Women | | 0 | | 0 |
| | Children | | 0 | | 0 |
| | Total | | 1,067 | | 1,497 |
| Other Textiles | Men | | 5,700 | | 15,022 |
| | Women | | 5,935 | | 4,766 |
| | Children | | 3,246 | | 1,684 |
| | Total | | 14,881 | | 21,476 |
| Paper industry | Men | | 3,360 | | 1,126 |
| | Women | | 1,462 | | 490 |
| | Children | | 578 | | 445 |
| | Total | | 5,400 | | 2,061 |
| Total | Men | | 37,077 | | 54,015 |
| | Women | | 32,635 | | 19,103 |
| | Children | | 17,505 | | 6,011 |
| | Total | | 87,217 | | 79,128 |

**Notes and sources:** see text

The outstanding feature of the previous table is the decrease in the total number of workers in Catalan industry. The decrease in the number of workers was mainly concentrated in the cotton and paper industries whereas others sectors experienced a relatively sharp increase in their labour. In particular, the metal and other textiles industries increased their workforce by about 50 percent from 1840 to 1861. Moreover, with a more detailed observation of the data, it is possible to appreciate that the decline in the total figures is only because women and child labour plummeted. Whereas the adult male workforce rose of about 46 percent from 1840 to 1861.

One can further explore these changes by analysing the more detailed and probably more exact data on the cotton industry. At first glance, the evolution of the total number of workers in the cotton industry had the typical bell structure. FTE was 52,038 in 1830 and in 1840 it was 65,869. It then slightly decreased in the 1840s, 64,538 in 1850, and then plummeted to 54,098 in 1861.[271] The evolution of the different components of the workforce was divergent, the men workforce increased until the 1850s, whereas the number of women and children decreased after the 1840s. These results reflect the great transition in the methods of production since the increase in the men labour force and the rapid decrease in women and child labour occurred over the consolidation of the factory system. Note also, that the anomalous behaviour of men employment in the 1850s was exclusively due to weaving where the workforce increased from 30,092 FTE in 1830 to 42,315 in 1850. There was then a decrease to 33,924 FTE in 1861. In weaving during the 1840s the expansion of the labour force took place by incorporating new handweavers, who were mainly young males. This process was clearly the result of the cheaper yarn produced by the new mechanical spindles. This spillover process between the innovation in spinning and the increase of the labour force in weaving was similar to that which occurred in Lancashire.[272] By the 1850s the great decrease in the number of weavers was due to the irruption of the powerlooms that began to substitute handlooms. Interestingly, the number of handweavers that abandoned cotton weaving is almost equal to the increase in handweavers in the other textiles industry. This result could suggest that handweavers only had to change fibre when their market was occupied by the new powerlooms.[273]

In spite of the sharp decrease in the employment of women and children within the modern industries from 1840 to 1861, the share of this type of labour in Catalan

[271] It should be emphasised that these changes occurred during a period of growth. Consequently, labour productivity must have increased rapidly (see chapter 5).

[272] See Timmins (1993) and Bythell (1978).

[273] Cerdá (1968), pp. 610-615 presents evidence on the capacity of handweavers to weave with different fibre according to the changes in fashion and season.

manufacturing workforce was high throughout the period.[274] The extent to which modern manufacturing drew on women and children in recruiting workers during the initial period of industrialisation can be better appreciated in the next table:

**Table 4.2** Proportion of Men, Women and Child Labour: Industry, 1840-1861(percent)

| | Adult Men Percent | Adult Women Percent | Children Percent |
|---|---|---|---|
| **Catalonia, 1840** | | | |
| Cotton Spinning | 5.40 | 61.60 | 33.00 |
| Cotton Weaving | 61.80 | 27.70 | 10.50 |
| Cotton Finishing | 57.95 | 8.69 | 33.36 |
| Cotton Industry | 40.91 | 38.32 | 20.77 |
| Metal Industry | 100.00 | 0.00 | 0.00 |
| Other Textiles | 38.30 | 39.88 | 21.81 |
| Paper industry | 62.22 | 27.08 | 10.70 |
| All of these industries | 42.51 | 37.42 | 20.07 |
| **Barcelona, 1856** | | | |
| Modern Industries | 50.83 | 32.35 | 16.82 |
| Artisanal Trades | 63.18 | 24.60 | 12.22 |
| Construction | 92.83 | 0.00 | 7.17 |
| Total Industries | 58.29 | 27.12 | 14.59 |
| **Catalonia, 1861** | | | |
| Cotton Spinning | 29.00 | 50.00 | 21.00 |
| Cotton Weaving | 76.90 | 20.00 | 3.10 |
| Cotton Finishing | 86.93 | 10.46 | 2.61 |
| Cotton Industry | 67.23 | 25.60 | 7.18 |
| Metal Industry | 100.00 | 0.00 | 0.00 |
| Other Textiles | 69.96 | 22.20 | 7.84 |
| Paper industry | 54.63 | 23.77 | 21.59 |
| All of these industries | 68.43 | 23.91 | 7.66 |

**Notes and sources:** (1) **1840:** for cotton industry Madoz (1846) and Sayró (1842); Metal industry: Madoz (1846); Other textiles: Madoz (1846), Sayró (1842) and Benaül (1991); Paper industry: Gutiérrez (1834) and Delgado (1991). (2) **1856:** Cerdá (1968) considering modern industries as mentioned above and under the assumption that half the apprentices were adults and half child labour. (3) **1861:** for cotton industry, Comisión especial Arancelaria (1867), and for the rest, Gimenez Guited (1862).

[274] The proportion of women and children in Catalan manufacturing workforce was higher than the proportion in the north-east of the United States. For example, Goldin and Sokoloff (1984), p. 748 report figures of roughly 40 percent in 1832 and 30 percent in 1850. Whereas in Catalonia in 1840 the percentage was about 60 percent in 1840 and 30 percent in 1860.

The table reveals that women and children made up a large proportion of the industrial workforce throughout the second third of the nineteenth century. The historical peak of women and child employment in manufacturing occurred around 1840 when they were 57.5 percent of modern manufacturing workers, but this percentage had dropped to 31.6 percent by 1861. A similar pattern is apparent in Barcelona, where Cerdá's study provided the data for my 1856 figure. In that town the share of the labour force consisting of women and children is around the average of the figures for 1840 and 1861. It should also be underlined that women and children were more abundant in modern industries than in artisanal trades, and that their share is not sensitive to the reduced share of domestic production in Cerdá's figures. This result gives some support to the argument advanced by Goldin and Sokoloff that the emergence of the factory system substituted unskilled women and children for men.[275] Although, it should be underlined that the Catalan case does not resemble to the north-east of the United States. In the United States outworking was less common than in Catalonia.[276] Therefore the number of women and children in manufacturing before the coming of the factory system was larger in the latter than in the former.

With the help of the figures on the cotton industry it is possible to distinguish two broad phases in the evolution of the workforce in Catalan manufacturing. Until the 1840s the labourforce grew at respectable rates by using women and child labour. After 1840 the overall labour figures decreased or remained stagnant because the employment of women and children plummeted. The sharp decrease in women and child employment in the 1850s is difficult to explain with the Goldin-Sokoloff's model. They have underlined that this was because the full available women and child workforce was employed at its market price. At equilibrium, one would not expect any new incorporation of women and children within the manufacturing labourforce. However, this explanation is not very convincing since the women and child workforce decreased in the 1850s, instead of remaining constant as they predict.

[275] Goldin and Sokoloff (1982) and (1984). See also Sokoloff (1986).

[276] See the evidence on the United States furnished by Sokoloff and Dolar (1997).

### 4.4. Evidence on Labour Remuneration

This section deals with the Mokyr and Goldin-Sokoloff models' predictions of wage movements. The prediction of the first model is decreasing *real* wages. Note, however, that this prediction can be accomplished in two ways: directly if productivity did not rise during the period, and indirectly if productivity gains were not transmitted to wages. Only in the second situation is Mokyr's model supported since the labour surplus model predicts wage decreases throughout industrialisation and, therefore, that productivity gains did not imply wage increases. As mentioned above, Goldin-Sokoloff's model predicts that the women-men and child-men wage gap decreases throughout early industrialisation.

Obviously, to discuss the evolution of labour remuneration, it is essential to establish a correct measure for wages, bearing in mind that this measure has to be correct for the type of question asked.[277] To be precise, the technically correct calculation of labour costs must include the part of value-added that workers effectively received. In the next paragraphs four types of methodological problems will be discussed: the choice of *nominal* or *real* wages, the methodology used to estimate *real* wages, the spatial biases, and the choice between job wages and average wages.

A major problem is the choice between nominal and *real* wages. The choice of nominal wages has a main risk: sometimes the increase or decrease in nominal wages is not due to increases or decreases in the price of labour but changes in living costs.[278] Therefore, although *nominal* figures are useful, *real* wage estimates provide a richer picture of the change over time of labour markets.

Although some scholars have doubted its efficacy, *nominal* wages deflated by a cost

[277] On the history and methodology of wages see: Bothan and Hunt (1987); Crafts (1985b); Crafts and Mills (1994); Hunt (1986); Feinstein (1990a) and (1990b).

[278] If one assumes that the labour market is perfectly competitive then the changes in the price of labour parallel changes in the marginal productivity of labour.

of living index is by far the most widely used method to measure *real* wages.[279] Unfortunately, no cost of living index for Catalonia covering the whole period studied here is available.[280] Therefore, two other price indices must be considered: the Sardà, which is a wholesale index based on the prices at the Port of Barcelona, and the Reher-Ballesteros, which is a cost of living index for Castilia.[281] The main difference between the two indices is that in the Sardà index fluctuates more than the other during the period considered here. Both indices have their problems. Since the Sardá index is based on wholesale shares it may not reflect the expenditure pattern of the Catalan population. Similarly, the basked of goods on which the Reher-Ballesteros index is based may be not representative of the patterns of consumption among Catalan industrial workers. It is reasonable to believe that new estimates of a consumer price index might revise the pattern presented here. The two indices are in the next table:

**Table 4.3** Alternative Price Indices, 1830-1861 (1830=100)

| Type | Scope | 1830 | 1834 | 1840 | 1846 | 1856 | 1861 |
|---|---|---|---|---|---|---|---|
| Wholesale | Barcelona | 100.0 | 118.4 | 107.3 | 109.2 | 126.8 | 125.5 |
| Cost-of-living | Castilia | 100.0 | 107.0 | 130.5 | 120.9 | 131.0 | 134.2 |

**Notes and sources:** (1) wholesale: Sardá (1948), p. 302-305 and (2) cost-of-living: Reher and Ballesteros (1993), p. 131-136.

Thirdly, serious problems of interpretation may arise when there are substantial differences in wages by zones. In particular, historians have pointed out that there were strong spatial differences in agricultural and road labourer wages[282]. According to Ramón Garrabou and his associates, these differences in wages may be not only due to differences in living costs but also to be attributable to the inadequate integration of the Catalan labour

[279] See a technical review of criticisms at Nordhaus (1996).

[280] Maluquer (1994b) presented an index of cost-of-living for Barcelona but, unfortunately, began in 1855.

[281] Reher and Ballesteros (1993) and Sardà (1948).

[282] An agricultural worker was paid a daily wage of 8.5 Rv in Barcelona and only 6.0 Rv in Lleida (Garrabou *et al.* (1991), p. 40). Similarly, in the same year, a labourer that was employed in the construction of roads received money wages of 8.2 Rv./day in Barcelona, 7 Rv./day in Lleida, 6.9 Rv./day in Tarragona and only 6.4 Rv./day in Girona. The source is Madrazo (1984), p. 208.

market.[283] The question that remains, however, is if these differences were also important in manufacturing since Catalan industries were not spread across Catalonia but concentrated in a few zones. These zones were characterised by, comparatively speaking, high agrarian and unskilled wages. Furthermore, the labour demand equations in section 4.3 support the view that spatial segmentation did not significantly affect manufacturing wages.

Another problem is the choice between job-based wages and average wages. Both choices have their pitfalls.[284] In the first case, given the absence of complete information for all groups of workers, the choice could be biased. Furthermore, sometimes the increase or decrease in *real* wages is not due to changes in the remuneration of the given job but alterations in its nature. In the second case, to say average *real* wages have risen does not mean that all groups of workers have benefited. For example, the rise or fall in average wages can be exclusively due to changes in the skills composition of the workforce or changes in the location of the industry. In other words, it can be possible that individual wages remain constant while average wages rise or fall.

An idea of the trend of nominal wages can be obtained by computing yearly earnings for several Catalan modern industries. Raw data for 1840 and 1861 serve to calculate average annual earnings cross-classified by industry, sex and age. An important problem in the survey of 1840 is that it did not give information on annual days worked, but only offered the information on a monthly basis. Thus, the assumption was that workers worked all months of the year. This is likely to overestimate the *real* value of average wages for 1840, reducing, in turn, the growth rate of wages from 1840 to 1861.

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[283] Garrabou *et al.* (1991), p. 33-34.

[284] The discussion is based mainly on O'Brien and Engerman (1981), p. 167-171.

**Table 4.4** *Nominal* Yearly Earnings: Modern Industries, 1830-1861(in Pta.)

| | | 1840 | 1861 |
|---|---|---|---|
| Cotton Spinning | Men | 750 | 1004 |
| | Women | 311 | 585 |
| | Children | 126 | 255 |
| | Weighted average | 274 | 637 |
| Cotton Weaving | Men | 554 | 745 |
| | Women | 242 | 453 |
| | Children | 138 | 187 |
| | Weighted average | 424 | 669 |
| Cotton Finishing | Men | 794 | 788 |
| | Women | 395 | 488 |
| | Children | 192 | 300 |
| | Weighted average | 558 | 743 |
| Cotton Industry | Men | 595 | 778 |
| | Women | 286 | 515 |
| | Children | 139 | 239 |
| | Weighted average | 382 | 672 |
| Metal Industry | Men | 773 | 1350 |
| | Women | | |
| | Children | | |
| | Weighted average | 773 | 1350 |
| Other Textiles | Men | 712 | 975 |
| | Women | 251 | 450 |
| | Children | 145 | 300 |
| | Weighted average | 404 | 806 |
| Paper industry | Men | 536 | 900 |
| | Women | 166 | 278 |
| | Children | 29 | 159 |
| | Weighted average | 381 | 592 |
| Total | Men | 612 | 863 |
| | Women | 274 | 489 |
| | Children | 136 | 252 |
| | Weighted average | 390 | 727 |

**Notes and sources:** for the cotton industry in 1840 Sayró (1842) and Madoz (1846) and for 1861, Comisión especial arancelaria (1867). In metal industry, the same sources than in cotton. In other textiles: for wool Benaül (1991), for linen Madoz (1846) and Comisión especial arancelaria (1867), for silk Comisión especial arancelaria (1867) and Cerdá (1968); finally for mixed fabrics the same sources than for cotton industry. In paper industry: Gutiérrez (1834) and Delgado (1991) for 1840 and for 1861, Cerdá (1968).

According to this table nominal yearly earnings grew quickly from 1840 to 1861. On the next page I present evidence on *real* wages. However, since there are salient discrepancies between the alternative price indices (see table 4.3), the picture varies with the choice of index.

**Table 4.5** *Real* Yearly Earnings: Modern Industries, 1840-1861(1840=100)

| | | 1861 Cerda | 1861 Reher | Growth rates (percent) Cerdá | Reher |
|---|---|---|---|---|---|
| Cotton Spinning | Men | 114.44 | 130.13 | 0.64 | 1.25 |
| | Women | 160.81 | 182.86 | 2.26 | 2.87 |
| | Children | 172.96 | 196.68 | 2.61 | 3.22 |
| Cotton Weaving | Men | 114.87 | 130.62 | 0.66 | 1.27 |
| | Women | 160.18 | 182.15 | 2.24 | 2.86 |
| | Children | 115.98 | 131.88 | 0.71 | 1.32 |
| Cotton Finishing | Men | 84.82 | 96.45 | -0.78 | -0.17 |
| | Women | 105.64 | 120.12 | 0.26 | 0.87 |
| | Children | 133.64 | 151.96 | 1.38 | 1.99 |
| Cotton Industry | Men | 111.94 | 127.29 | 0.54 | 1.15 |
| | Women | 154.16 | 175.30 | 2.06 | 2.67 |
| | Children | 147.08 | 167.25 | 1.84 | 2.45 |
| Metal Industry | Men | 149.30 | 169.77 | 1.91 | 2.52 |
| Other Textiles | Men | 117.16 | 133.22 | 0.75 | 1.37 |
| | Women | 153.38 | 174.41 | 2.04 | 2.65 |
| | Children | 177.22 | 201.52 | 2.72 | 3.34 |
| Paper industry | Men | 143.67 | 163.37 | 1.73 | 2.34 |
| | Women | 143.67 | 163.37 | 1.73 | 2.34 |
| | Children | 464.71 | 528.42 | 7.32 | 7.93 |
| Total | Men | 120.48 | 137.00 | 0.89 | 1.50 |
| | Women | 152.62 | 173.54 | 2.01 | 2.63 |
| | Children | 157.87 | 179.51 | 2.17 | 2.79 |

**Notes and sources:** Price indices are in table 4.3 and nominal earnings in table 4.4.

In spite of the large differences between the estimations made with the different price indices, and further differences between industries, the wage figures are consistent with a substantial improvement in *real* wages from 1840 to 1861. For men, the average is about the 1 percent per year whereas for women and children it is around 2 percent. However, not all employees gained during the period. For instance, the men workers in cotton finishing registered large losses. The lower earnings of men workers in finishing were due to the adoption of new machinery in calico printing (perrotin and cylinders), which reduced the skills required to perform the process of printing.[285]

[285] For a full description of this transition see chapter 7.

I now discuss the predictions of the Goldin-Sokoloff model about the women-men and child-men wage gap. Then, I compare the men, women and child wages in the cotton industry and agriculture.

**Table 4.6** The Sex-age Wage Gap: Cotton Industry and Agriculture, 1840-1861

| | cotton spinning | | cotton weaving | | cotton fininshing | | cotton industry | | Agriculture Barcelona | Agriculture Lleida |
|---|---|---|---|---|---|---|---|---|---|---|
| | $W_w/W_m$ | $W_{ch}/W_m$ | $W_w/W_m$ | $W_{ch}/W_m$ | $W_w/W_m$ | $W_{ch}/W_m$ | $W_w/W_m$ | $W_{ch}/W_m$ | $W_w/W_m$ | $W_w/W_m$ |
| **1840** | 41.46 | 16.80 | 43.68 | 24.91 | 49.75 | 24.18 | 48.07 | 23.36 | 51.28 | 45.77 |
| **1861** | 58.27 | 25.40 | 60.81 | 25.10 | 61.93 | 38.07 | 66.20 | 30.72 | 58.82 | 40.98 |

**Notes and sources:** $W_w/W_m$: women wage divided by men wages multiplied by 100. $W_{ch}/W_m$: children wage divided by male wages multiplied by 100. (1) **1840:** for cotton industry and mixed fabrics Madoz (1846); for agriculture Garrabou *et al* (1991). **1861:** for cotton industry and mixed fabrics, Comisión especial Arancelaria (1867).

In the table 4.6 there is clear evidence of the narrowing of the women-men and child-men wage gap in the cotton industry and in agriculture in Barcelona. By contrast, the wage gap increased in the mostly agrarian province of Lleida. Obviously, these results are compatible with the predictions of the Goldin-Sokoloff model.

The difference between the Catalan experience and industrialisation based on the Lewis-like dualisms which Mokyr describes for Belgium is large.[286] The above results show that growth rates of manufacturing labour were slow and that wages did not stagnate but rose. Exactly the contrary of Mokyr's model. On the other hand, some evidence seems to support the Goldin-Sokoloff's model[287] since the share of women and children in the manufacturing workforce increase until the 1840s. Their wages also experienced sharp increases in the 1840s and 1850s. Moreover, women and children were employed more in the modern industries than in the artisanal trades. However, since the 1850s the events cannot be explained by either of the models. Total employment in modern manufacturing decreased, and many women and children were replaced by men, simultaneously wages experienced notable gains. Evidently these issues require further investigation.

[286] Mokyr (1974)(1976).

[287] Goldin and Sokoloff (1982)(1984).

### 4.5. Evidence on Capital-skills Complementarity

Labour is treated in the Goldin-Sokoloff and labour-surplus models as a skills-homogenous input. It is noteworthy, though, that literature on labour markets has recognised the importance of accounting for the differences in skills among the types of workers.[288] These differences in skills have a pervasive influence on the substitutability and complementarity among the different types of workers and different inputs; that is, in the evolution of the demand for labour. In particular, many economists have emphasised the notion of capital-skills p-complementarity.

The concept of capital-skills complementarity was originally proposed by Zvi Griliches.[289] He argued that in the production function capital and skills (human capital) are more complements than substitutes; that is, an increase in the amount of capital was accompanied by an increase in the amount of human capital employed in production. More recently, Claudia Goldin and Lawrence F. Katz point that capital-skill complementarity occurred in the aggregate economy as particular technologies spread; that is, the emergence of capital-skills complementarity is a historical fact.[290] They also relate the appearance of capital-skill complementarity with the development of the batch and continuous-process methods of production, but not with the emergence of the factory system which they consider as de-skilling. In the next few pages four different tests of the emergence of capital-skills complementarity in Catalonia during the development of the factory system will be discussed.

Note that the simplest way to detect the emergence of capital-skills complementarity is to analyse the wage structure. The theory predicts that, in the presence of capital-skills complementarity, the periods of rapid technological advance serve to widen the wage structure. The wage structure should then narrow in the next period when the state or individuals have invested in the skills associated with the new technology, as they can obtain

[288] See the review of the literature in Hamermesh (1993).

[289] Griliches (1969).

[290] Goldin and Katz (1996a)(1996b).

large returns from this investment in human capital.[291] For instance, the boom in the demand for clerical labour at the beginning of the twentieth century not only increased the salaries of these employees but also the demand for that kind of education. Consequently, after a period of adjustment, the structure of wages narrowed again. At this point, I will present evidence on the widening of the wage structure in Catalonia during early industrialisation.

A simple procedure to study the changes in the unskilled/skilled workers wage gap is to compare nominal wages among different jobs. It would be convenient, to avoid the effect of market failures, if these wages corresponded to the same industries and same towns. The next table presents nominal wages for different occupations within the cotton industry in Barcelona. The maximum wages for each job were chosen to eliminate the effects of age and experience. Finally, several jobs that significantly changed over the time period were eliminated of the sample.

**Table 4.7** The Skills Wage Gap: Cotton Industry in Barcelona, 1830-1861 (Rv. per day)

| Job | Sex | 1830 | 1834 | 1840 | 1846 | 1856 | 1861 |
|---|---|---|---|---|---|---|---|
| Carders | young male | | | | 8.0 | 9.3 | 10.0 |
| | women | | 4.5 | 4.5 | 4.6 | 6.3 | 6.3 |
| Minders Spinning | men | | 8.0 | | 10.0 | 12.1 | 14.2 |
| | women | | 8.0 | | 10.0 | 12.1 | 14.0 |
| Mechanical weavers | men | | | | | 12.0 | 12.0 |
| | women | | | | | 12.0 | 12.0 |
| Handweavers | men | 8.0 | 8.0 | 8.8 | 10.0 | 11.0 | 12.5 |
| Jacquard weavers | men | | | | | 13.0 | 16.5 |
| Labourers in factories | men | | | | 9.1 | 10.0 | 10.0 |

**Notes and sources:** maximum *nominal* wages in each job. Numbers subject to rounding errors. Sources: for 1830: Junta de Fábricas (1830); for 1834, Junta de Fábricas (1834a); for 1840 Comisión del Gobierno (1841) and only the wages for handweavers Madoz (1846), vol. III, p. 462; for 1846 Comisión de Fábricas (1846), p. 48 and only the wages for handweavers Madoz (1846), vol. III, p. 555; for 1856 Cerdá (1968); and for 1860, Comisión especial arancelaria (1867).

The picture that arises from this table, in spite of some differences among the

[291] The wage gap effect of capital-skills complementarity is discussed in many studies see, for example, the seminal work of Griliches (1969), a review of the literature in Hamermesh (1993), chapter 3, and the recent empirical studies of Osterman (1986) and Autor *et al.* (1997).

different occupations, is that nominal wages remained constant during the 1830s, and grew in the 1840s and 1850s. The shift in the 1840s implies that the wage level increased by about 20 percent. In the 1850s the increase in wages was between 10 and 40 percent. It must be pointed out, however, that skilled workers' wages grew more than unskilled ones. Furthermore, on the whole, the results presented here are similar to the figures for the wool industry in Sabadell, where skilled wages rose and unskilled wages fell.[292] To summarise, the wage gap between skilled and unskilled workers grew. This first impression can be confirmed, or rejected, by looking at the available data on the wages of unskilled workers in agriculture. The next table presents the evidence collected:

**Table 4.8** Daily *Nominal* Wages: Agriculture, 1830-1860

| Scope | Sex | 1830 | 1834 | 1840 | 1846 | 1856 | 1860 |
|---|---|---|---|---|---|---|---|
| Province of Barcelona | males | 8.0 | 7.9 | 7.8 | 8.0 | 8.0 | 8.5 |
| | females | 4.0 | 4.0 | 4.0 | | 4.0 | 5.0 |
| Province of Lleida | males | 6.0 | 5.0 | 4.4 | 5.5 | 6.6 | 6.0 |
| | females | 2.1 | 2.0 | 2.0 | 2.1 | 2.5 | 2.4 |

**Notes and sources:** In Rv. Numbers subject to rounding errors. Wages corresponded to periods without harvest. The male wage of Barcelona in 1840 is an average of those of 1839 and 1841; the female wage of Barcelona in 1830 is an average of those of 1829 and 1831; and the female wage of Lleida in 1840 is an average of those of 1839 and 1841. The source is Garrabou *et al.* (1991), pp. 40 and 43.

In the 1830s and the 1840s male agrarian wages in Barcelona were stable while from 1856 to 1860 they only grew about 6 percent. Consequently, the trend of agrarian wages in Barcelona was very similar to that of unskilled workers. In Lleida the male agrarian wages were even more stable since the money wage in 1860 was the same as in 1830. Moreover, in spite of a delay, the wage gap between male and female workers in Barcelona shrink. The same is not true for Lleida. Therefore, this table tends to confirm the results presented in the previous one and, obviously, the above statements on the existence of capital-skills complementarity. In other words, early industrialisation boosted *real* wages for skilled workers. Unskilled workers benefited less from economic progress. Occasionally, namely agricultural labourers, there were not net benefits but clear losses. For instance, the *real*

[292] Estimations made by Camps and cited by Benaül (1991), table 19, p. 115.

male agrarian wage was lower in 1861 than in 1830.

Another test for the consistency of the hypothesis of capital-skills complementarity is to examine the relationship between average earnings per wage earner and capital-intensity and firm-size variables.[293] The data to perform this test is drawn from the survey of the Catalan industry, which was conducted by the Sayró's commission in 1840.[294] Survey officials collected information on establishments and not on firms. The published tables describe the value and quantity of one month output, the amount of inputs, the number of employees, and their wages (broken down into men, women and children). But do not give the number of days worked. They also describe the number of engines (broken down by type), their power, the number of other machines (looms, powerlooms, mule-jenny spindles, handspindles, and so on), and the value of machinery, building and circulating capital. The original schedules of the survey have been not conserved and only a published table that records information aggregated by towns and small districts remains. This may introduce a serious drawback since the use of aggregate data in labour demand studies can introduce unknown biases into the results.[295] Anyway, to control for these biases, equations are estimated with the weighted least squares instead of the ordinary least squares procedure. The required data is only available for the cotton, mixed fabrics and metal industries but this does not appear to be a major problem. Since the purpose of this exercise is to measure the effect of the new technologies on labour demand and these three industries were greatly affected by the introduction of the new technologies.

In the first regression the dependent variable is the total wage bill divided by the quantity of labour. The variable capital intensity is the total amount of capital divided by the number of workers. The variable establishment size is the result of dividing the number of workers in each observation by the number of establishments in the same observation. The capital-skills hypothesis implies a positive correlation between the capital to labour ratio and wages and, similarly, a positive relation between wages and average firm-size.

[293] This test was proposed by Goldin and Katz (1996a).

[294] The data that I employ here is collected in Madoz (1846), vol III, p. 164ff.

[295] Hamermesh (1993), pp. 64ff.

**Table 4.9** Determinants of Wages, 1840

| **Dependent variable:** | **Log (Average monthly earnings)** | |
|---|---|---|
| **Independent variables:** | **Coefficients** | **(Standard error)** |
| Constant | 2.719050 | (0.196909) |
| Log (K/L) | 0.279878 | (0.026598) |
| Log (Establishment size) | 0.128162 | (0.029777) |
| % women | -0.790337 | (0.090312) |
| % children | -1.345922 | (0.134450) |
| Number of observations | 81 | |
| R2 adjusted | 0.8873 | |
| F | 158.45 | |

**Notes and sources:** See text. The equation has been estimated with weighted least squares with weights given by the number of workers in each observation. All coefficients are significative at 99 percent.

The estimated equation gives the expected result. For instance, an increase of 10 percent in the capital to labour ratio would lead an increase of about 2.79 percent in average wages. A caveat here is that the measured wage premia may be due to compositional effects. A greater proportion of more skilled workers were found in industries with more capital per worker and large average size. A possible alternative interpretation may be that wage differentials reflected premia for identically-skilled individuals working under factory discipline.[296] However, it has been credibly argued that in Catalonia workers organised their own production and administered their own time in the factories. The fact is that the firms preferred to employ an incentive more than a coercive system.[297] Another explanation would be that the more capital-intensive and largest establishments were in zones where the cost-of-living was highest, for example in Barcelona, or the quality of life was poorest. For that reason, differentials in average wages may reflect compensation for the high rents and poor sanitation of urban locations.[298] However, the impact of any location variable on the dependent variable is not statistically significative.

Another quantitative strategy to discuss capital-skills complementarity would be to

[296] The best treatment of the issue is furnished by Clark (1994).

[297] See, for example, Comisión Especial Arancelaria (1867), Camps (1995) or Cerdá (1968). The latter displays evidence on the existence of incentives to avoid shirking and increase effort at work. For example, the work groups had to pay for lighting if they were behind schedule.

[298] See on this aspect see Brown (1990) discussing workers in the north-west of England.

estimate labour demand equations.[299] The simplest are the traditional conditional factor demand equations developed from Cobb-Douglas technology. These equations are first-order approximations of the economy. The number of equations that will be estimated here is four:

(4.1) $\log(\text{Workers}_i) = \beta_0 + \beta_1 \log(\text{Output}_i) + \beta_2 \log(\text{Wages}_i) + \beta_3 \log(\text{Machinery}_i) + \text{dummies}_{ei} + \varepsilon_i$ ,

(4.2) $\log(\text{Men}_i) = \beta_0 + \beta_1 \log(\text{Output}_i) + \beta_2 \log(\text{Wages}_i) + \beta_3 \log(\text{Machinery}_i) + \text{dummies}_{ei} + \varepsilon_i$ ,

(4.3) $\log(\text{Women}_i) = \beta_0 + \beta_1 \log(\text{Output}_i) + \beta_2 \log(\text{Wages}_i) + \beta_3 \log(\text{Machinery}_i) + \text{dummies}_{ei} + \varepsilon_i$ ,

(4.4) $\log(\text{Children}_i) = \beta_0 + \beta_1 \log(\text{Output}_i) + \beta_2 \log(\text{Wages}_i) + \beta_3 \log(\text{Machinery}_i) + \text{dummies}_{ei} + \varepsilon_i$ .

Where on the left-side workers, men, women and children represent, respectively, a measure of workers, men, women and child employment. On the right-side wages are average wages (respectively for all workers, men, women and children), output is a measure of one month output, machinery is the value of the stock of machinery, and i indexes observations and e industries. Equation 4.1 assumes that labour is homogeneous whereas the other three equations assume that each category is homogeneous. It should be noted that this latter assumption seems more plausible for women and children than for men.

These equations may be viewed as traditional demand curves with 'machinery' acting as a shift variable.[300] Thus, the 'machinery' coefficcient summarizes the substitution and complementarity relations between the different components of the labour force and machinery. Because output is controlled for in the equation the channel of impact through lower product price, and greater production, is not reflected in the coefficient of 'machinery.' In other words, the equation only measures the direct effect of the introduction of

[299] For a complete discussion of the literature on labour demand see Hamermesh (1993), especially the chapters 2 and 3.

[300] Basically,.this is the same method that was employed by Osterman (1986) to estimate the impact of computers on the employment of clerks and managers.

machinery, but not the demand-shift effect produced by productivity growth.

This straightforward and traditional method is not without problems. It is likely that the most important fault is that machinery stock might not be fully employed. Failure to control for business-cycles will tends to reduce any displacement effect. Since complete controls are very difficult, the best solution may be to introduce industry-specific dummy variables into the estimating equations.

Data limitations prevented computing the model for several years, but a range of enough observations is available for 1840. This year seems a good choice since in that year a mixture of production techniques were used.[301] The database is the same employed in the previous regression on the wage determinants.

[301] Chapter 7 for a full description of the industrial structure of the cotton industry in1840.

**Table 4.10 Cobb-Douglas Labour Demand Equations, 1840**

| Dependent variables: | Log(workers) | Log (men) | Log(women) | Log(children) |
|---|---|---|---|---|
| Independent variables: | | | | |
| Constant | 3.651055* | -1.59478** | -5.166685* | -2.40480** |
| (S.E.) | (0.718661) | (0.657925) | (0.775823) | (1.134170) |
| Log (output) | 0.663097* | 0.524208* | 1.050924* | 1.025919* |
| (S.E.) | (0.097034) | (0.085944) | (0.146519) | (0.192802) |
| Log (average wage) | -1.652376* | -0.614943* | 0.302068** | 0.656025* |
| (S.E.) | (0.191109) | (0.128813) | (0.157700) | (0.234402) |
| Log (machinery) | 0.22421** | 0.321709* | -0.429070* | -0.565719* |
| (S.E.) | (0.114728) | (0.096270) | (0.160557) | (0.206702) |
| Dummy spinning | -0.967231* | -2.287887* | 2.850639* | 0.70879** |
| (S.E.) | (0.222741) | (0.153955) | (0.266132) | (0.350295) |
| Dummy weaving | -0.296206" | 0.202153" | 1.229303* | -1.328665* |
| (S.E.) | (0.228809) | (0.202153) | (0.358336) | (0.470183) |
| Dummy metal industry | -0.481553" | -0.67612** | -3.032134* | -3.522448* |
| (S.E.) | (0.404534) | (0.341043) | (0.887931) | (1.20146) |
| Number of observations | 81 | 81 | 81 | 81 |
| R2 (percent) | 90.85 | 96.93 | 88.60 | 74.04 |
| F | 133.425 | 416.747 | 104.674 | 39.021 |
| P-value | 0.000 | 0.000 | 0.000 | 0.000 |

**Notes and sources:** See text fo sources. *significative at 99 percent; ** significative at 95 percent; " not statistically significative. Equation estimated with the weighted least squares method with weights given by the number of establishments in each observation. The finishing industry is the industry which is omited in the dummies. Alternative estimations without dummies offered fewer statistically reliable results.

The results for the four equations are presented in table 4.9. Some signs of the coefficients are as expected, with increases in output having a positive effect upon all kinds of employment, but the wage variable does not always show the expected sign. The expected sign (negative) was obtained in the total and men employment equations, but the coefficcients were positive in the women and child equations. The major variable of interest for the objective of this chapter, the machinery coefficient, is positive and highly significant. The magnitude of the coefficients implies that, other things equal, a 10 percent increase in the stock of machinery led to a 3.2 percent increase in men employment, and a 4.3 percent decrease in women employment and a 5.6 percent decrease in child employment. Note that the nature of the estimation procedure mean that these elasticities represent marginal changes.

In broad terms, these Cobb-Douglas equations show that the demand for men was strongly and positively correlated with the introduction of more machinery. The opposite holds for women and children. An unexpected result is that the demand for women and children grew with their wages, although this latter result was predicted by the Goldin-Sokoloff's hypothesis.[302]

One source of concern is that the Cobb-Douglas function is quite uninteresting when one wishes to discover the cross-price elasticities or how the substitution between pairs of inputs is affected by the amount of inputs used.[303]

An alternative procedure to estimate labour demand equations is based on the Translog approximation of production. In this case, the choice is between cost functions and production functions. The Translog cost function is preferred when the data used is collected at firm-level since, then factor prices rather than factor quantities are treated as exogenous. On the other hand, production functions are employed for large observation units as then factor quantities are more exogenous than factor prices. Since the units of observation in the data used for this study are towns and districts I employ the production function instead of the cost function. Specifically, after taking logarithms, the translog production function has the form:

$$\ln Q = a_0 + a_m \ln M + a_w \ln W + a_k \ln K + a_r \ln R + \frac{1}{2} b_{mm} (\ln M)^2 + \frac{1}{2} b_{ww} (\ln W)^2 + \frac{1}{2} b_{kk} (\ln K)^2 + \frac{1}{2} b_{rr} (\ln R)^2 + b_{mw} \ln M \ln W + b_{mk} \ln M \ln K + b_{mr} \ln M \ln R + b_{wk} \ln W \ln K + b_{wr} \ln W \ln R + b_{kr} \ln K \ln R. \tag{4.5}$$

Where Q is total output, M is men employment, F is women and child employment, K is capital and R materials.[304] The data source and variables are the same as in the Cobb-Douglas demand function with the only difference being that here I introduce a new variable (raw materials) and the variable machinery has been expanded by introducing the other

[302] Goldin and Sokoloff (1982)(1984).

[303] Hamermesh (1993), pp. 38-39.

[304] The use of this number of variables is not casual. In the process of computation this group of variables offered by far the best model. Moreover, due to problems of correlation, women and children variables have been split within a single variable by means of a translog quantity index. This is because the variables are practically perfect complements.

components of capital input (buildings and inventories). This is the common physical production function. It is estimated using the weighted least squared method.[305] Output shares have been employed to compute the production function and, therefore, the implicit assumptions are the presence of constant returns of scale and that firms were price-takers in factor markets.

Using this production function, the questions of substitutability and complementarity of inputs can be considered. Two measures of elasticity, the Hicks partial elasticities of complementarity (HEC) and factor price elasticities, will be employed.[306] For the Translog function the own HEC is defined as:

(4.6) $C_{ii} = ( b_{ii} + S_i^2 - S_i) / S_i^2,$

and the cross-elasticity of complementarity as

(4.7) $C_{ij} = ( b_{ij} + S_iS_j) / S_iS_j.$

Where $b_i$ are parameters obtained from the Translog equation and $S_i$ is the mean output share of factor i. Finally, the standard errors for the elasticities evaluated at the mean shares are:[307]

(4.8) $S.E. (C_i) = S.E. ( b_i )/ S_i,$

(4.9) $S.E. (C_{ij}) = S.E. ( b_{ij} )/ S_{ij}.$

Equations 4.6 and 4.7 measure the *ceteris paribus* effect on relative factor prices of

[305] See a similar application of Translog production in Field (1988).

[306] Note that the Allen elasticity of substitution is a more common measure but that this concept is inappropriate if we are interested in considering the effects of exogenous changes in factor quantities on factor prices. See Grant and Hamermesh (1981).

[307] See on this method Griffin (1996).

changes in relative factor quantities, holding output price and other input quantities constant. Factors i and j are quantity complements (q-complements) when $C_{ij} > 0$ and quantity substitutes (q-substitutes) when $C_{ij} < 0$. Associated with $C_{ij}$ are the factor price elasticities ($\eta_{ij}$), which show the change in the price of factor i given a 1 percent change in the quantity of factor j, holding output price constant. These were computed by multiplying the HEC by the appropriate factor share. Factors i and j are price complements (p-complements) when $\eta_{ij} < 0$, whereas they are price substitutes (p-substitutes) when $\eta_{ij} > 0$.

Some examples may help to show the use of these definitions. When women labour and capital are p-substitutes one may infer that a rise in the cost of capital will increase the fraction of women workers at each level of production. These two factors may also be q-complements. If so, an increase in the supply of capital will raise the relative wage of uneducated workers by making them more productive.

**Table 4.11** Translog Labour Demand Elasticities, 1840

| | Elasticities of factor Complementarity | | Elasticities of factor Prices | |
|---|---|---|---|---|
| | Value | S.E. | Value | S.E. |
| **Own-Elasticities** | | | | |
| Men | -2.176 | (0.52) | -0.213 | (0.05) |
| Women and children | -12.174 | (0.25) | -0.693 | (0.01) |
| Capital | -10.070 | (0.50) | -1.501 | (0.07) |
| Raw Materials | -0.218 | (0.03) | -0.151 | (0.02) |
| **Cross-Elasticities** | | | | |
| Men - Women and Children | -5.484 | (0.54) | -0.312 | (0.08) |
| Men -Capital | 0.182 | (0.33) | 0.027 | (0.08) |
| Men - Raw Materials | 0.531 | (0.08) | 0.369 | (0.06) |
| Women & Children - Capital | 8.625 | (0.50) | 1.285 | (0.10) |
| Women & Children - Raw materials | 0.200 | (0.06) | 0.139 | (0.04) |

**Notes and sources:** see text.

The elasticities of table 4.11 display several important findings. First, all of the own HECs are negative, which is consistent with convexity and, therefore, with equilibrium in labour markets.[308]

Second, men, the most skilled labour group, on average, was the labour group with the lowest own-price elasticity and was least p-substitutable for capital. Less skilled labour groups, women and children, are found to be strong p-substitutes for capital.[309] For instance, looking at elasticities of factor prices, the own elasticity of men is -0.213 whereas the own elasticity of women and children was -0.693. This means that an increase of one point in the supply of men decreased their wages by 0.2 points, whereas the same increase in the supply of women and child labour decreased their wages by 0.6. That is, three times the reduction in men wages. It should be emphasised that, according to the labour demand literature, this is a consequence of the existence of capital-skills p-complementarity. In effect, many present-day empirical studies on labour demand have agreed that own-price demand elasticities are inversely correlated with the amount of human capital held by the group of workers. Similarly, they have also concluded that skilled groups of workers are more p-complementary with capital than unskilled workers.[310]

Third, the own-price elasticities are quite small, which implies that relative increases in the supply of one type of labour could be absorbed with only a small decline in its relative wage. This result casts strong doubts on the elastic labour-supply explanations. On the other hand, the large own-price elasticity of capital implies that the market responded strongly to fluctuations in interest rates. In other words, the capital market worked quite well.[311]

Finally, men and women were q-substitutes and p-complements. This implies that an increase in the wages of men might reduce women and child employment. Similarly, an increase in the amount of men labour might depress women wages. The reason is simple: the supply of men was less elastic than that of women and children since there was no

[308] Field (1988), p. 657.

[309] The skills differences between men, women and children are discussed in chapter 6.

[310] Hamermesh (1993), pp. 134ff., and Griffin (1996), p. 894.

[311] This result reinforces the arguments of chapter 3.

hidden men unemployment.[312] Similarly, it can be argued that this is because, on average, men were more skilled.

This section has proved the robustness of the capital-skills p-complementarity hypothesis in the early industrialisation framework. The results of the different elasticities also imply that general and skilled wages might grow during early industrialisation, as occurred, even when total employment decreased.

At this point, many readers may be intrigued about the nature of capital-skills complementarity in this early period and how the transition to the factory system produced this phenomenon? For example, Claudia Goldin and Lawrence Katz state that the emergence of factories was de-skilling (i.e., there was no capital-skills complementarity) because it narrowed the knowledge employed by shop floor workers (blue collars).[313] In other words, before the increase in the division-of-labour, each artisan was trained in all the different operations.[314] In sharp contrast, I argue that the emergence of factories increased the demand for skills since it created new skilled tasks unknown in the previous decentralized system of production. Furthermore, despite the fact that some jobs were simplified (for example, the reparairs were done by specialized workers instead of by the same artisans), the use of the new machinery required a different types of skills.

To accumulate the details that I needed I ignored the rest of the industries and concentrated on the metal industry, which evolved from small workshops to factories during the period. Before the advent of the factories each metal artisan with one or two assistants and one or two apprentices, produced metal goods in a small shop.[315] The spares were collected by merchants who commercialised the product or were produced to order.

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[312] Active population censuses of the period supports the belief that the participation rates of males were very high (see Nicolau (1990), Table 10, p. 46).

[313] Goldin and Katz (1996a).

[314] Leijonhufvud (1986).

[315] See a description of the salaries of the different workers in the metal industry in Cerdá (1968). There is also a description of the factories and workshops in Comisión especial arancelaria (1867).

Consequently, the masters owned and repaired the machinery. However, note that the machinery was usually simple and easy to repair.

In the new metal factories skilled workers with assistants produced the spares. However, their work was not essentially simpler since the rhythm of the new machinery was controlled by the skilled worker. More precisely, the skilled worker had to develop a new level of dexterity since a good master had to run his power-driven machinery faster than the old hand-driven machines. Also, they had to be capable of managing their work team, which was probably larger than in the artisanal shop. More prominently, the final product had to be homogeneous and the skilled worker had to simultaneously control the quality and amount of production. In other words, the shop-floor tasks in the mechanical metal-industry were not simple and routine. Furthermore, skilled workers repaired the small problems of the machinery, which was certainly more difficult than the typical reparations of the old hand-machines. To sum up, the emergence of factories in the metal industry did not result in the de-skilling the shop floor skilled workers. The main effect was that it separated the skilled from the unskilled tasks.

In addition, the factories created some new jobs that were absolutely skilled. For instance, the number of clerks and accountants grew exponentially because of the complication of management tasks, accounting systems and business relations.[316] Within the new factories the commercial tasks performed by merchants in the proto-industry were performed by clerks who need schooling. Similarly, new jobs were created on the shop floor. The unpredictable and sometimes dangerous steam-engines were controlled by new engineers. The spares were designed by groups of designers and the workers were controlled by managers. Up to this point the evidence seems clear-cut that the transition to the factory increased the demand for skilled workers. In part, the increase was driven by the new machinery increasing and creating a new demand for metal goods. But a close look at the factories would suggest that the development of many new jobs was associated with the development of accounting and other management system. As well as the design of new

[316] Pollard (1965).

goods, the control of the new machinery and, more prominently, the control and organisation of the labourforce. The history of the metal industry suggests that the transition to the factory system was more than just a change in the skills employed on the shop floor. It suggests that the increase in skilled tasks created a demand for skilled workers.

### 4. 6. A Simple Model of the Early Industrialisation Labour Market

To complete the discussion of the changes in the labour market I develop a simple labour model. This model is basically an adaptation of the models outlined by Hamermesh and Goldin-Sokoloff.[317] The objective of this model is to formalise some arguments discussed previously. The model is based on two main ideas: (1) the scarce factor during early industrialisation was human capital (skills),[318] (2) industrial production is efficient at any moment in time given the scarcity of production factors. In other words, the technologies used in early industrialisation appropriately reflected existing factor prices.

For simplicity, I will consider two stages in early industrialisation: the proto-industry (which was comprised of handicrafts and outworking production) and the factory system. Each of these stages is defined by different levels of skills (human capital). Three inputs (unskilled labour Lu, skilled labour Ls, and physical capital K) are used to produce goods in manufacturing. Women and children were unskilled labour and could substitute men once division-of-labour and technology allowed this process.[319] The supply of unskilled labour is more elastic than the supply of skilled labour.[320] Finally, for simplicity, I assume that

[317] Hamermesh (1993), pp. 383-385; and Goldin and Sokoloff (1982)(1984).

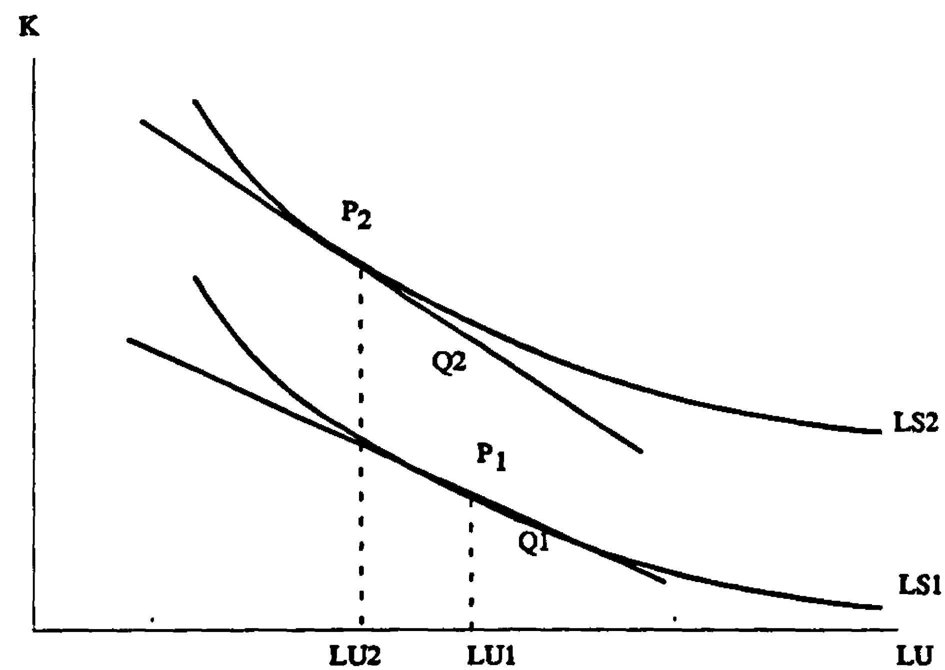
[318] Note that here the term skill is used in a broad way since the skills are the knowledge necessary to organise production and deal with industrial technology. However, when I measured capital-skill complementarity in the past section I narrowed the definition of skill to the quantity of human capital employed by the labour force. See charter 6 for a detailed definition of the terms human capital and knowledge.

[319] On the importance of the physical aptitudes and education of females for their position in the labour market during early industrialisation see Burnette (1997). See also a complete discussion on the human capital factors in chapter 6.

[320] This model does not require the assumption of unlimited supplies of labour. Therefore, it is unnecessary to agree with the Lewis' model to formulate the model.

entrepreneurs could choose the quantities of physical capital and labour with the main constraint being the available input of skills.[321]

**Figure 4.1** Capital-Unskilled Labour Substitution and Skill Endowments: Early Industrialisation




**Notes and sources:** Modified from Hamermesh (1993), p. 384.

First, consider the behaviour of the typical entrepreneur in the proto-industry, shown in Figure 4.1. The available quantity of skills was constrained to be Ls1, so that the firms operate on the isoquant Q1. Given the relative prices of the services of physical capital and unskilled labour the firm chooses to produce P1. Using P1 unskilled hours. Then the total amount of labour employed is L1 = Ls1 + Lu1. Labour productivity is Qo/Lo.

There then follows a process of innovation propelled by local conditions, for example

[321] Note that this does not mean that I assume elastic supply of labour but simply that entrepreneurs make an efficient choice given the relative prices of factors.

the size of the market for the locally produced goods.[322] The entrepreneurs then found it profitable to introduce the factory system. The factory system is characterised by an increasing division-of-labour and, in the second phase, by using new capital goods (machinery). The new establishments and machinery were larger and therefore more expensive than the proto-industry shops and machinery. Hence, the total amount of fixed capital increases. Consequently, capital-skills complementarity is more evident. Furthermore, the division-of-labour allowed women and children to participate more actively in manufacturing since the need for physical strength was reduced.[323] However, it should be noted that in some industries, such as cotton spinning, there was previously some initial division-of-labour and women and children were already used for manufacturing tasks. In other words, the argument is that the process of employment of women and children in unskilled tasks was intensified, not originated, in this period. There was a shift in the price of skilled labour and private and public investors found it profitable to invest in the acquisition/diffusion of the new skills associated with the new machinery because they realised skilled workers received higher wages.[324] Thus, the supply of skill increases to Ls1. The isoquant shifts outward to Q2, where Q2 >> Q1. At the new maximizing point, P2, there is a decline in the demand for unskilled labour, even a decline in total labour input, and an increase in the demand for physical capital.[325] It should be noted that with the new amount of skilled workforce output per worker and per unit of capital rises substantially.

This transition did not affect all industries in the same way since in many industries in the middle of the nineteenth century hand-trades still cohabited with factories in all the industrialising regions. Although it should be noted that manufacturing as a whole progressed in this fashion, the transition in each industry was decided by the extent of market for their products.[326]

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[322] A discussion of this issue in chapter 7.

[323] Burnette (1997).

[324] See chapter 6 for a full discussion of the methods of informal education and on-the-job-training.

[325] However, in the long run, the total amount of employment grew again according to the Marshall's derived demand laws (see, Hamermesh (1993), pp. 24-25).

[326] See chapter 7.

In spite of the fact that this simple model obviously ignores important issues in the development of the labour market, it predicts the growth of endowments and returns in a three-factor world during early industrialisation. Briefly, the predictions of this model are: (1) a rise in wages in the transition from the proto-industry to the factory system because the marginal productivity of labour rises due to the increase in skills endowments; (2) a decrease in employment in the same period because of the labour-saving effect of capital-skills complementarity and because consumers' demand for manufacturer goods grew slower than labour productivity (instead, if demand growth was perfectly elastic to price changes one would expect employment to grow at a faster rate); (3) the growth in the skilled-unskilled wage gap because of the shift in capital and technology; (4) a large number of women and children performing unskilled tasks; (5) a decrease in the women-men and child-men wage gap. All these events occurred in Catalonia during the industrailisation.

### 4.7. Conclusions

This chapter sets out some empirical findings about the evolution of the labour market in manufacturing during the early phase of Catalan industrialisation. These findings come from the fragmentary evidence on wages, employment and labour demand. In sharp contrast to much of the existing literature on the process of industrialisation, the evidence points to the conclusion that Catalan industrialisation was not based on the use of a large supply of (cheap) labour. Quite the contrary, the evolution of manufacturing employment and wages supports the view of changes promoted by the demand-side of the labour market. Until the 1840s, the extent of the division-of-labour allowed women and children to enter the manufacturing workforce and then to decrease their wage gap with men. After the 1840s, the existence of capital-skills complementarity in the new factories depressed the demand for unskilled labour while simultaneously increasing the demand for skilled workers. Who benefited from the widening of the gap between their wages and the wages of the unskilled workers. As a consequence, many women and children who occupied unskilled jobs were displaced from manufacturing towards other occupations. The outcome of all these successive and rapid changes was an increase in the overall wage level accompanied by a slight decrease in total employment in manufacturing.

# Chapter 5

# The Contribution of Productivity Growth

The purpose of this chapter is to provide a careful analysis of the contribution of factor accumulation and productivity growth to the output growth of the main Catalan industries. This study covers the period 1830-1861 for the cotton industry and as much of this period as is feasible for each of the remaining six industries (metal, wool, linen, silk, mixed fabrics and paper).[327] The main conclusion is that neither capital accumulation, nor the transference of labour within modern manufacturing appear to be as important as productivity improvement. In other words, growth in modern manufacturing from 1830 to 1861 was mainly due to shifts in total factor productivity.

## 5.1. Introduction

There is a large intellectual disagreement among economic historians on the roles played by factor accumulation, such as labour and physical capital, and technical progress in early industrialisation.[328] Some have argued that increasing investment rates and the transfer of labour into manufacturing can explain a great part of manufacturing output growth. Others have insisted on the main role played by machinery investment; that is, the diffusion and adoption of new machinery.[329] In these explanations technology is usually

[327] There are few growth accounting studies for this early period. See, for Britain, McCloskey (1981), Feinstein (1981), Crafts (1985a)(1995) and, for the United States, Abramovitz (1993), Sokoloff (1986), and Tchakerian (1994).

[328] See, for example, Rostow (1960), Gerschenkron (1962), Landes (1969) or Pollard (1981).

[329] Landes (1969).

embodied in the stock of capital goods and the so-called adopters and users of technology play no role in developing or changing the technologies they choose and use. Therefore, the followers can benefit from the diffusion of industrial technology without incurring the costs of technological innovation. Finally, others have underlined the crucial importance of innovations that were non capital-embodied and affected the organisation of labour, firms and markets.[330] According to this line of reasoning productivity improvement is partly independent of factor accumulation, and especially from investment in machinery.

The rest of the chapter is organised as follows. A survey on the literature on growth accounting, including the major shortcomings and recent innovations, forms the next section of the chapter. The following section describes the methodology used in the chapter and provides a quick overview of the generation of the variables. The fourth section examines labour productivity. The fifth section investigates total factor productivity, underlines some stylized facts, and discusses the main biases of the measures computed. The results of sections four and five imply that most manufacturing industries realised large gains in labour productivity and total factor productivity. Therefore, productivity improvement seems the main 'engine' of growth in the early phases of Catalan industrialisation. The last section summarises.

### 5.2. An Overview to the Literature on Productivity Measurement

This section presents information about the origins and developments of the literature on growth accounting. Little of the content claims to be original. The first part, on the history of the method, could readily be omitted by those familiar with the subject. Compared to the usual surveys on the topic, it does devote less attention to mathematical points. It would have to be complemented by a thorough study of the technical side to give a full picture of the methodology.[331] Lack of space and opportunity precludes that here. The objectives of this section are: (1) to prove that the growth accounting methodology is

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[330] Clark (1984) and Sokoloff (1984a)(1986).

[331] There are numerous surveys of growth accounting see, for example, Gollop (1983), Kohli (1990), Jorgenson (1990) and Dean *et al.* (1996).

rigorous, (2) that many measuring choices are the result of previous debates.

Growth accounting is the most widespread method of measuring the contribution of the different inputs and productivity improvements to growth. Growth accounting is a framework that purports to distinguish the separate contributions of innovation, capital accumulation and labour in raising output. Consequently, standard growth accounting provides some quantitative descriptions of the 'proximate' sources of growth. Innovation in growth accounting is assumed to be equal to the 'residual' of the growth equation left by all factors of production when they are weighted accordingly.

The early growth accounting methodology was based on the concept of an aggregate production function.[332] Paul H. Douglas developed the original concept of the production function before the Second World War.[333] A few years later, a Dutch economist, Jan Tinbergen, established one of the earliest formulations of what we now call the neo-classical theory of growth. His innovation consisted of adding a time trend to the function of capital and labour inputs (i.e., to the production function) using this to represent the level of 'efficiency.' The work of Tinbergen was ignored in the United States, where his research was not rediscovered until the mid-1950s. Meanwhile, George J. Stigler had independently introduced the idea of efficiency or total factor productivity.[334] In the following years, the National Bureau of Economic Research developed a major research programme on this subject. In the framework of this project, Moses Abramovitz, John W. Kendrick and Solomon Fabricant published several important articles that contained the first true growth accountings.[335] The programme culminated in 1961 when John W. Kendrick published his path-breaking monograph on the United States. In his analysis of the productivity trends in the United States, Kendrick employed an explicit system of national accounts to generate

[332] This paragraph is based on Jorgenson (1990), pp. 19ff.

[333] Douglas (1948).

[334] Stigler (1947).

[335] Abramovitz (1956), Fabricant (1959), and Kendrick (1956).

to capital stock if capital inputs were homogeneous, while labour input would be proportional to hours worked if labour inputs were homogeneous. However experience shows that, in fact, inputs are enormously heterogeneous. Therefore, an implication of the early growth accounting was that, because all inputs were undifferentiated, one hour of work of an unskilled worker was the same as one hour of a skilled worker.

Third, in primitive growth accounting the part of the growth equation explained by factors of production was of only one-quarter of all growth of net output per capita. Obviously, this introduced a major source of concern in the quality and usefulness of the new methodology. It was commonly argued that the "residual" contained too many different things. Consequently, Abramovitz spoke of the residual as 'the measure of our ignorance'.[339]

Finally, many held that growth accounting was only useful in describing long-term growth but not short-term fluctuations in growth rates. It was also commonly argued that the very aggregate early growth accounting offered little room for the analysis of the sources of invention or innovation. Such as new and improved products or processes, or organisational and structural change. For instance, the highly aggregate production models used by the early growth accountants were a serious obstacle to understanding the causes of the slowdown in economic growth in the OECD countries during the period 1973-1979.[340] Thus, the general impression was that the assumptions underlying the aggregate model were inconsistent with the empirical evidence and that growth accounting analysis, which was based on broad models, was too vague and imprecise.

Since the early 1970s, however, the importance of the unexplained part and the main shortcomings of the method have been reduced. This is mainly due to improvements in the methodology that have led to a much more analysis of productivity. The main improvements have been: (1) the use of superlative indices and their derived production functions; (2) the substitution of industry-based analysis for aggregate or economy-wide analysis; (3) the

[339] Abramovitz (1993).

[340] Jorgenson (1990), pp. 26.

analysis of inputs other than labour and capital (i.e., intermediate inputs); (4) considering the heterogeneity of capital and labour inputs.

In growth accounting, such as in output measurement, the choice of index number strongly effects the results. Broadly, two great families of index numbers can be distinguished: the non-superlative and superlative indices. The most common and best-known non-superlative indices are the Laspeyres, Paasche and Geometric. Empirically, Paasche indices tend to reduce the rates of growth whereas Laspeyres indices tend to increase these rates. Moreover, the Laspeyres and Paasche indices are exact for the Leontief production function while the Geometric indices are exact for the Cobb-Douglas production function. Both production functions are first-order approximations of an arbitrary neo-classical production function that assumes a constant elasticity of substitution among the factors of production. If a nonsuperlative index is chosen the analysis of the interrelations among the factors of production is biased, because a correct measure of growth must consider that sometimes the innovation implies changes in the elasticities of substitution. For this reason, modern growth accounting has abandoned this type of index and introduced superlative indices. These indices are a second-order approximation of an arbitrary neo-classical economy because they assume multiple elasticities of substitution among the factors of production. The best-known superlative indices are the Fisher *ideal* and the Divisia (also so-called Törnqvist). The first fits a quadratic production function and the second a Translog production function. Both production functions assume, obviously, multiple elasticities of substitution among the factors of production.[341]

The second major innovation consisted of the analysis of the sources of economic growth at the level of the industrial sectors. The pioneering work in this area was due to John W. Kendrick, although Dale W. Jorgenson and his associates have dominated this topic since the 1970s.[342] Later, the same Jorgenson developed a new framework to integrate the results for the individual sectors into an analysis of the sources of growth for the economy

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[341] Diewert (1976)(1987), Diewert and Nakamura, eds. (1993), and Hill (1993).

[342] See, Kendrick (1961), Kendrick and Grossman (1980), and Jorgenson *et el.* (1987).

as a whole.[343] Aggregate productivity growth can be represented by a weighted sum of sectoral productivity growth rates. The weights given by the ratios of the value of output, or value added, in each sector to value added in all sectors. This improvement makes it possible to attribute aggregate growth rates with their sources in individual industries. Another major accomplishment of this methodological improvement was that overall growth can be decomposed into sources at individual industry level and the effects of resource reallocation. Consequently, the assumption of perfect competition has been largely relaxed (e.g., the economy can misallocate resources) and it is possible to measure the effects of structural changes in the economy (e.g., the effect of the reallocation of labour from agriculture to industry).[344]

The introduction of intermediate inputs into growth accounting was due to Dale W. Jorgenson.[345] Previous studies had modelled economic growth using the concept of value added, eliminating the effect of increases in the quantity and quality of intermediate inputs on overall growth rates.[346] Jorgenson also introduced the concept of symmetry by treating all inputs into the accounts symmetrically. All inputs must be computed with the same index number methodology and all inputs, including intermediate inputs, were heterogeneous.

However, the most pathbreaking advance in productivity measurement was the development of heterogeneous measures for inputs. The development of heterogeneous measures for inputs was strongly related with progress in the application of index number theory to productivity measurement.[347] In 1961 Edward F. Denison introduced the concept of heterogeneous labour.[348] Hours worked are cross-classified by age, sex, education, and employment status, and weighted by wage rates. The development of similar (heterogeneous)

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[343] Berndt and Jorgenson (1973).

[344] This major accomplishment also makes it possible to measure the effects of market failures on overall growth rates, and analyse the consequences of structural reforms on the use of inputs and total factor productivity.

[345] Berndt and Jorgenson (1973).

[346] Kendrick (1961).

[347] Diewert (1976) and Caves *et al.* (1982a)(1982b).

[348] Denison (1961).

measures for capital input generated a large and intense debate that started in the 1960s. Space restrictions prevent the summarising of this debate.[349] In 1980, Gollop and Jorgenson published the work that shaped the subsequent literature.[350] The basic objective was to divide capital into homogeneous components, and weigh each by its rental rate. Note that the introduction of the heterogeneity of inputs makes it possible to separate the contribution due to changes in the quantity and quality of inputs. Quality changes in labour input are associated with increases in the use of human capital.[351] Whereas quality changes in capital input are associated with the effect of embodied technical change.[352] The effect of this was a considerable reduction in the amount of total factor productivity. For example, Jorgenson has shown that changes in quality account for two-fifths of the growth of capital input and for more than one-third of the growth of labour input for the United States between 1947 and 1985 .[353]

The major consequence of all the recent developments in growth accounting methodology was a reduction in the unexplained part. State-of-the-art growth accounting makes it possible to decompose overall growth into the growth of capital, labour and intermediate inputs. One can also compute the effect of the reallocation of inputs (production factors) among the different sectors, and measure the changes in the quality of inputs. Strong assumptions have been relaxed and, in broad terms, the methodology has become more useful in explaining short-term fluctuations. However, it should be noted that the new improvements do not serve to reject the results of the early methodology. They have been able to narrow the size of the residual by explaining part of their composition. In other words, early accounting included in the residual not only 'pure' (disembodied) innovation, but also the innovation embodied in capital goods (capital quality), human capital accumulation (labour quality) and the improvements in markets (resource allocation).

[349] See chapter 3 and Hulten (1990).

[350] Gollop and Jorgenson (1980).

[351] See chapter 6.

[352] Hulten (1992).

[353] Jorgenson (1990), pp. 24-25.

There are numerous studies on economic history that are based on the growth accounting methodology. Furthermore, many of the early works in growth accounting were historical accounts. However, many economic historians are still sceptical of the explanatory capacity of the growth accounting methodology and the related econometric methods.[354] It is useful to be fairly sceptical of the explanatory capacity of growth accounting methodology, but mistrust must not be exaggerated. Macroeconomic growth accounts helped us to focus attention on long-term growth and permitted economic historians to examine the "big picture" of what was happening in the economy without being confused by obscure details that they could not measure. I already noted that recent improvements in the methodology have expanded its explanatory capacity towards the level of individual industries. Modern growth accounting requires fewer assumptions and, for example, is very consistent in its treatment of market failures and related problems. Finally, it should be emphasised that this framework does not include a theory of growth, it only describes the process of growth.[355] Therefore, it is compatible with economic theories even if they are different from standard neo-classical growth theory (for example, growth accounting would be used to analyse New Growth Theory models).

There are a large number of studies based on the growth accounting methodology for the period after the Second World. In sharp contrast, the literature on the early phases of industrialisation using this method is remarkably thin. Several economic historians have studied the British Industrial Revolution. The most macroeconomic approach is the work of Feinstein.[356] This work was replicated by Donald McCloskey and Nicholas F.R. Crafts.[357] McCloskey's growth accounting worried about the effects of the reallocation of resources and estimated productivity through prices instead of quantities. The pioneering and innovative work of McCloskey was refined and corrected by Crafts, who decreased the growth rates of the whole economy, individual industries and TFP. Recently, he has also

[354] See, for example, the review of the British debate on this aspect in Crafts and Harley (1992).

[355] Barro and Sala-i-Martín (1994).

[356] Feinstein (1981).

[357] McCloskey (1981) and Crafts (1985a). See, also, Crafts and Harley (1992).

introduced the concept of human capital input in his growth accounting exercises.[358] Indeed, these works have helped to change opinions on the Industrial Revolution. In broad terms, these three authors have arrived at similar conclusions: structural changes were very important, but that the British Industrial Revolution cannot be completely explained by the accumulation of production factors (capital, labour or human capital). In other words, the perspective given on the British Industrial Revolution by these studies is that it was due to a sharp increase in productivity.[359] However, according to Crafts' results innovation was concentrated in few sectors, whereas McCloskey supports the view that it was a broad phenomenon.[360]

The early phase of industrialisation in the United States was studied with the growth accounting methodology by two economic historians. Kenneth Sokoloff developed labour productivity and total factor productivity measures for 13 major industries in the north-east of the United States for the period from 1820 to 1860.[361] This work was recently replicated for the south of the United States by Vicken Tchakerian.[362] These two studies emphasised that a broad range of manufacturing industries enjoyed substantial gains in productivity throughout the early nineteenth century, and that the major source of growth during early industrialisation was productivity improvement (i.e., innovation). Furthermore, they have underlined the importance of the changes in labour organisation.

There are two basic findings that impede us in generalising the results of these five studies for other early industrialisation cases in Europe. First, the British and the United States cases seem exceptions to the norm more than universal models. Great Britain was the first country to industrialise and experienced large structural changes that not were replicated in European countries. The United States enjoyed a large home market and an unparalleled

[358] Crafts (1995).

[359] See the recent debate of Crafts and Mills (1997) versus Greasley and Oaxley (1997).

[360] McCloskey (1981). See, also the recent criticism on the arguments of Crafts by Temin (1997).

[361] Sokoloff (1986).

[362] Tchakerian (1994).

abundance of resources. Second, unfortunately, these five studies did not incorporate many of the recent improvements in growth accounting methodology, and considered all outputs and inputs as homogeneous. At this point, a sceptical and informed reader could not accept the relevance or importance of the results, claiming that these large TFP growth rates are spurious due to, for example, a failure to account for changes in the quality of capital.

A knowledge of the productivity improvement in manufacturing is clearly of great value in studying the early phases of European industrialisation. Turning now to the Catalan case, a really accurate productivity analysis of Catalan industrialisation, something which currently does not exist, must take into account changes in the quality of outputs and inputs. Furthermore, changes in the quality of capital, for overall manufacturing and for individual industries, is very useful in studying the importance of the transference of British technology (machinery) for the industrialisation of the followers. For instance, if a large part of growth rates are explained by improvements in the quality of capital, the success of the early industrialisation regions must be attached to the adoption of British machinery. Conversely, if productivity improvement is relatively independent of productive factors one must underline the importance of local knowledge and innovative capacity as major sources of industry growth.

### 5.3. Methodology

This section is devoted to describing the methodology employed to estimate labour and total factor productivity. Interested readers can find more detailed accounts on the methodology used to estimate output and capital input in the respective chapters. The labour input methodology is contained in the appendix to this chapter.

This study of the sources of growth at the industry level is based on the economic theory of production. Beginning with a production function, giving output ($Q_i$), as function of capital input ($K_i$), labour input ($L_i$), intermediate input ($X_i$) and time (T). The contribution of each input is the product of the value share of the input in total outlay multiplied by its growth rate. It may be useful here to give a quick analytic overview of the approach. The point of departure is that each industry has a homogeneous production function ($F_i$), given by:

$$Q_i = F_i\,(X_i, K_i, L_i, T), \qquad (i = 1,2, \ldots n) \tag{5.1}$$

We can approach this production function by means of the Translog production function, which gives the theoretical justification for the use of factor shares to weight growth rates.[363] Specifically, the Translog production function in the case of three inputs is:

$$\begin{aligned} \ln Q &= a_0 + a_x \ln X + a_k \ln K + a_l \ln L + \tfrac{1}{2} b_{xx} (\ln X)^2 \\ &+ \tfrac{1}{2} b_{kk} (\ln K)^2 + \tfrac{1}{2} b_{ll} (\ln L)^2\; b_{xk} \ln X \ln K + b_{xl} \ln X \ln L + b_{kl} \ln K \ln L \end{aligned} \tag{5.2}$$

In the case of two discrete periods of time, and after differentiating and taking logarithms:[364]

$$\begin{aligned} \ln Q(T) - \ln Q(T-1) = \theta_X[\ln X(T) - \ln X(T-1)] + \theta_K[\ln K(T) - \ln K(T-1)] + \\ \theta_L[\ln L(T) - \ln L(T-1)] + TFP_{T-1,T}, \end{aligned} \tag{5.3}$$

$$\theta_i = 1/2[\theta_i(T) + \theta_i(T-1)]$$

The $\Theta_i$ denotes the elasticity of output with respect to each input. Weights are given by the average share of each component in the total outlay for the two periods.[365] Note that the share of each factor of production in the total inputs relies exclusively on its relative price (elasticities) and, moreover, under constant returns to scale the value shares sum to unity. The Translog index of TFP ($TFP_{T-1,T}$) is the difference between the growth rate of output and a weighted average of the growth rates of intermediate, capital, and labour inputs. It is, thus, a measure of the increase in output attributable to a time-related shift in the

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[363] Christensen *et al.* (1971)(1973).

[364] For reasons of space the mathematical development of the Translog index is not complete; it appears in Christensen *et al.* (1980) and Jorgenson (1990).

[365] Total outlay is practically equivalent to the total payments received for outputs. However, in some cases, these payments can be adjusted for direct taxation and monopoly gains to obtain the total outlay. In this case, I make no adjustments and I assume that total outlay is equivalent to total payments (it should be noted that adjustments would reduce the share of capital in total payments and, hence increase the TFP growth rate).

production function.

A major innovation adopted in this production account is that output and inputs are not treated as homogeneous.[366] Therefore, the rate of growth of output and each input between two periods is a weighted average of the growth rates of its $n$ components. Weights are given by the share of each component in the corresponding payments for each input. In the case of output, intermediate inputs, capital and labour, the respective equations are:

(5.4) $$lnQ_t - lnQ_{t-1} = \sum_i [\bar{\theta}_{Q_i}(\ln Qi_t - \ln Qi_{t-1})]$$

(5.5) $$lnX_t - lnX_{t-1} = \sum_i [\bar{\theta}_{X_i}(\ln \Xi_t - \ln \Xi_{t-1})]$$

(5.6) $$lnK_t - lnK_{t-1} = \sum_i [\bar{\theta}_{K_i}(\ln Ci_t - \ln Ci_{t-1})]$$

(5.7) $$lnL_t - lnL_{t-1} = \sum_i [\bar{\theta}_{L_i}(\ln Li_t - \ln Li_{t-1})]$$

Where value shares are computed as:

(5.8) $$\bar{\theta}_{n_i} = 1/2[\theta_{ni}(T) + \theta_{ni}(T-1)], \quad (i=1,..i,..n).$$

The methodology used for computing output, intermediate, capital and labour inputs has already been full described in the respective previous chapters, but two critical points should be mentioned: the procedure used to distinguish among the components of inputs and output and the assumptions behind the methodology used in computing the input shares.

We can approach the different components with two different techniques: (1) break down each input, or output, by class and, then, multiply each by its share in factor payments; (2) construct a Törnqvist price index then deflate the total value of each input or output with this price index. Note that if the price and quantity indices are properly

[366] See Jorgenson (1990), pp. 22ff. for a complete discussion of the importance of this issue.

constructed the results with both techniques are equivalent.[367] The latter technique was used to obtain an *exact* approach for output and intermediate inputs for the period 1840-1861. The former technique was employed for capital and labour inputs for the period 1840-1861, and the cotton industry outputs and inputs for 1830-1861. Obviously, where they are comparable (e.g., in the cotton industry), the results of both techniques are practically equivalent. Basically, the choice of technique was dictated by availability of sources; where it was possible the quantity technique was used.

In order to estimate the share of labour and capital in value added it is necessary to measure output from the point of view of the producer. This requires removing all indirect business taxes on the value of output, while retaining all the taxes on factors of production. Here this is simple because indirect taxes were small and only direct taxes on factors of production (capital) were paid. Consequently, the value of the output can be employed to estimate the share of the different inputs. The first step consists of calculating the proportion of output devoted to physical intermediate inputs. This is derived directly by multiplying the quantities of physical inputs by their respective prices. Then, each factor share is calculated using equation 5.8. Next, the labour share was computed in two steps: (1) estimates of the workers' hourly incomes cross-tabulated by sector, sex, age and skills were constructed, (2) the implicit labour income and, therefore, its share in total payments was computed by multiplying hourly incomes by the previous estimates of yearly hours of work cross-tabulated by sector, sex, age and skills. Finally, the remuneration of capital was computed as the residual of the total output value. Note that this method to compute capital's share is common to many growth accountings and that the result is biased against total factor productivity growth rates. Each industry has its own shares for each benchmark year. The next table reports these shares from 1840 to 1861:

[367] Diewert (1976) and Hill (1993).

**Table 5.1** Shares of Inputs in Total Payments: Modern Industries, 1840-1861(percent)

| | Intermediate | Labour | Capital |
|---|---|---|---|
| Cotton Spinning | 63.14 | 16.31 | 20.55 |
| Cotton Weaving | 66.73 | 28.51 | 4.77 |
| Cotton Finishing | 71.95 | 18.23 | 9.82 |
| Cotton Industry | 34.93 | 40.34 | 24.72 |
| Metal Industry | 67.21 | 28.79 | 4.00 |
| Other textiles | 66.73 | 14.85 | 18.42 |
| Paper | 41.45 | 27.57 | 30.98 |
| **Total** | **42.77** | **34.06** | **23.16** |

**Notes and sources:** Numbers are subject to rounding errors. Total figures computed according to the method described in the equation 5.8.

Note that we can also compute labour productivity (LP), which can be defined as the difference between the growth rate of sectoral output and labour input. Specifically:

(5.11) $$\ln Lp(T) - \ln Lp(T-1) = [\ln Q(T) - \ln Q(T-1)] - [\ln L(T) - \ln L(T-1)]$$

A further problem, but not minor, is how aggregation over sectors should be conducted. I formulate two different models: one model of production for manufacturing as a whole and another by aggregating over models of production for individual industrial sectors.[368] In the first model I adopt the restrictive assumption that a unique value-added function exists for all sectors; in other words, there is an aggregate production function. Note that the concept of an aggregate production function is highly problematical, requiring the very stringent assumption that the technology of each sector must contain a replica of the whole economy production function.[369] Under this assumption, I can combine sectoral value added functions for all industrial sectors with market equilibrium conditions for each factor of production to obtain an aggregate model of production.

In the second model, value added is the sum of the quantities of value-added in all

[368] Basically, I adopt the methodology proposed by Jorgenson (1990), pp. 64ff.

[369] This question provoked a large debate. Initiated by Samuelson (1962) and summarised in Burmeister (1980).

industrial sectors. This formula was originally proposed by John W. Kendrick.[370] A closely related approach to aggregate productivity measurement uses sectoral productivity growth rates based on output rather than value added.[371] Thus, in the case of value-added, transactions in intermediate goods do not appear at the aggregate level. Measures of aggregate capital and labour can be constructed by weighting the individual components of these inputs in each industry by the weighting of that industry in total value added. Finally, sectoral productivity growth rates are weighted by ratios of the value-added in the corresponding sector to the sum of value added in all sectors. According to the theory, the difference between the growth rates of the model that is based on an aggregate production function, and the resulting growth rates of the model that is a weighted model, is the effect of the reallocation of factors among sectors.[372]

### 5.4. Empirical Results: Labour Productivity

The results for labour productivity for the period 1840 to 1861 are shown in table 5.2.. The numerator is based on the concept of sectoral output while the denominator is a measure of labour input obtained by weighting men, women and children by their relative wages. Alternative labour productivity figures with value-added instead sectoral output can also be computed. However, it should be noted that generally these figures offered lower labour productivity estimates and are less recommended by the technical literature.[373] Similarly, a broad measure of labour (hours worked) can be used instead of the more sophisticated measured employed here, but the procedure can be highly misleading due to the large differences in the marginal productivity of the different types of labour.[374]

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[370] Kendrick (1956).

[371] See, for example, Jorgenson (1990), p. 67.

[372] This approach is full discussed by Jorgenson (1990), pp. 66-67.

[373] See, for example, Dean *et al.* (1996).

[374] See chapter 6 for a full discussion of this topic.

**Table 5.2** Labour Productivity Growth: Modern Industries, 1840-1861

| | Sectoral Output | Labour Input | Labour Productivity |
|---|---|---|---|
| Cotton Spinning | 5.32 | -1.50 | 6.82 |
| Cotton Weaving | 6.04 | 0.24 | 5.80 |
| Cotton Finishing | 5.95 | 2.15 | 3.80 |
| Cotton Industry | 5.80 | 0.02 | 5.78 |
| Metal Industry | 6.82 | 1.61 | 5.20 |
| Other textiles | 4.28 | 3.48 | 0.80 |
| Paper | 2.07 | -5.58 | 7.65 |
| **Weighted model** | **5.29** | **0.61** | **4.68** |
| **Aggregate model** | **5.13** | **0.57** | **4.57** |

**Notes and sources:** Numbers are subject to rounding errors. Total figures computed according to the method described in the equation 5.10. Sectoral output figures drawn from table 2.8 and 2.9 and labour input figures from table 5.6. The weighted model has been computed using value added weights.

The first point to note is that labour productivity increased substantially between 1840 and 1861. All of the industries registered significant advances in 'real' sectoral output per labour input (equivalent worker).[375] Obviously, this result tends to confirm the belief presented in chapter 2 on the historical importance of this period as the early phase of Catalan industrialisation.

The second point to note is that there was a considerable degree of variation in growth rates among the different sectors. In particular, the leadership in labour productivity growth corresponded to the paper industry and cotton spinning, whereas the other textile industries experienced the slowest trend. In the paper industry, the growth of labour productivity can be explained by the spectacular decrease in the labour input index since the output index experienced a slow growth trend. Obviously, this result can introduce some concern about the quality of the paper industry figures. However, a simple comparison between these estimates and similar estimates for manufacturing in the north-east of the United States show that the paper industry experienced very similar productivity growth

[375] Obviously, this result confirms the figures discussed in section 2.3 in the second chapter. These labour productivity increases are also indirectly confirmed by the gains in *real* wages that are displayed in chapter 4 (see, in particular, table 4.8).

rates in both regions in this early period.[376] In cotton spinning, fast labour productivity growth seems to be provoked by the combination of two effects: the rapid growth of output and the remarkable decrease in labour input (fortunately, both changes are remarkably well documented in the historical sources).

The third point of interest is the high growth rates in overall productivity. Some sceptical readers could argue that these productivity estimates may exceed what might have been expected. However, it should be noted that this result is partly due to the combination of industries and partly due to the specialisation of Catalonia in high labour productivity industries.

At this point, it is interesting to discuss what the effect of these industries was on the overall performance of Catalan manufacturing. Note that the industries of the sample cover about 56.8 percent of Catalan manufacturing value added.[377] Therefore, under the assumption that in the sectors without data productivity rates were not negative, one can establish that the minimum labour productivity growth in Catalan manufacturing was about 2.6 percent per annum (i.e., 56.8 percent x 4.57). Moreover, in broad terms, labour productivity rates seem quite reasonable by other historical standards. For example, Sokoloff has computed rates of productivity growth for thirteen industries in the north-east of the United States during that region's initial phase of industrial development, 1820-1860. His calculations suggest that the U.S. record of advance was similar to that observed in Catalonia.[378] Similar statements can be derived by comparing the estimates of McCloskey for four manufacturing industries in Britain during that country's early period of industrial development (1780-1860)..[379] Of perhaps even greater interest, the labour productivity rates of each Catalan industry are very close to the corresponding industries in the north-east of the United States. Except in the other textiles industries (wool, linen, silk and mixed fabrics)

[376] The U.S. data is available at Sokoloff (1986), table 13.6. I compare the Catalan estimates with the GQLP (gross output per equivalent worker) estimates for the U.S.

[377] See section 2.3 in chapter 2.

[378] Sokoloff (1984), table 13.6., p. 698.

[379] McCloskey (1981).

where Catalan growth rates were lower than in the United States.[380]

The last point to consider is that the evidence seems to support the conclusion that labour productivity growth in Catalan manufacturing during this early phase of industrialisation was faster than labour productivity growth in Spain.[381] This result is not unexpected since it is the obvious outcome of the results that were obtained in the previous chapter. Thus, I would like to step back for a short period and look at chapters 2 and 4. Chapter 2 shows clearly that the growth rates in Catalan manufacturing surpassed the Spanish manufacturing and economy growth rates. In sharp contrast, chapter 4 shows the sluggish labourforce growth rates in Catalonia, well below the natural growth rates of the Spanish population. These two factors lead to Catalonia having a higher level of growth of labour productivity than Spain.

### 5.5. Empirical Results: Total Factor Productivity

It is well known that the estimates of labour productivity growth display a very poor picture of the process of growth, and therefore of productivity change. In particular, labour productivity growth cannot be related to increases in overall efficiency because it would be caused by the accumulation of capital. Consequently, the most methodologically consistent approach to productivity growth must consider the interaction between inputs and productivity. In Table 5.3 the results for TFP and physical inputs accumulation are presented for each industry for 1840 to 1861.

[380] See the data on United States in Sokoloff (1986), table 13.6, p. 698.

[381] Bairoch (1982) and Prados (1988).

**Table 5.3** Contribution of Factor Accumulation and TFP to Sectoral Output Growth: Modern Industries, 1840-1861

| | Growth Sectoral | Contribution Intermediate | Contribution Labour | Contribution Capital | TFP |
|---|---|---|---|---|---|
| Cotton Spinning | 5.32 | 2.71 | -0.25 | 1.23 | 1.63 |
| Cotton Weaving | 6.04 | 3.87 | 0.07 | 0.23 | 1.88 |
| Cotton Finishing | 5.95 | 3.91 | 0.39 | 0.89 | 0.76 |
| Metal Industry | 6.82 | 2.47 | 0.46 | 0.32 | 3.57 |
| Other textiles | 4.28 | 1.98 | 0.52 | 0.70 | 1.08 |
| Paper | 2.07 | 0.38 | -1.54 | 0.94 | 2.29 |
| **Weighted model** | **5.29** | **1.86** | **0.07** | **1.32** | **2.04** |
| **Aggregate model** | **5.13** | **1.69** | **0.19** | **1.33** | **1.91** |
| Reallocation of resources | -0.16 | -0.17 | 0.12 | 0.01 | -0.13 |

**Notes and sources:** Numbers are subject to rounding errors. Figures computed according to the method described in the equations 5.9 and 5.10. Sectoral output figures drawn from table 2.10 and 2.11, intermediate input figures from table 2.10 and 2.11, labour input figures from table 5.6, and capital input figures from table 3.3. The weighted model has been computed using value added weights. The reallocation of resources is computed as the difference between the difference of the growth rates of the weighted model and the respective rates in the aggregate model.

The table above displays several findings of particular interest. First, the general conclusion is that the driving force behind the expansion of manufacturing output during the early industrialisation of Catalonia was the growth of total factor productivity. The annual total factor productivity growth rates range from 0.76 percent per year for cotton finishing to 3.57 percent per year in the metal industry. Total factor productivity disparities among industries are important, but it confirms that the modern manufacturing industries in Catalonia benefited from relevant TFP gains. More specifically, TFP is the main source of growth of value-added (that is, sectoral output minus the contribution of intermediate inputs) in all sectors except cotton finishing.

However, if we focus attention on the contribution of intermediate inputs to sectoral output growth, examining equation 5.3, we find that the intensification in the use of intermediate inputs is a more important source of growth that changes in productivity. This result does not mean that productivity growth was lower or unimportant during the period but that technological innovation saved relatively little in intermediate inputs.[382] For instance, coal consumption expanded greatly during the period in all manufacturing industries.

Second, note that the contribution of TFP to growth was practically double the contribution of the accumulation of physical factors (labour and capital) in the total measures.[383] The labour force had a reduced role in the growth of total output, even though it accounted for an important share in the total payments (see table 5.1). This was because working hours remained practically constant in all the industrial sectors considered.[384] More specifically, in the cotton spinning and paper industries, labour input accounted for a negative figure. In the rest of the industries the contribution of labour to growth was small and only in the metal industry was it larger than capital.

The disparities in the rates of contribution of physical capital to output growth are larger. The minimum was 0.23 percent in cotton weaving, and the maximum was 1.55 percent in the cotton industry. In the total models (aggregate and weighted), capital contributes to about 35 percent to 39 percent of value-added growth. Moreover, these results are not modified to take into account the changes in the quality of capital. Changes in the quality of capital account, on average, for about 20 percent of the growth of capital input (i.e., they contributed about 8 percent of growth rates).[385] Since many authors have argued that capital embodied innovation (i.e., the innovation embodied in the use of the most modern machinery) can be measured by computing capital quality, one can argue that their role in value-added growth was relatively minor.[386] In particular, capital embodied innovation accounted for, at best, 14 percent of total factor productivity growth. This result has two

[382] For example, Catalan TFP rates were in the range of the rates found for the north-east of the United States by Sokoloff (1986), table 13.11, pp. 719 and, on the whole, higher than those found by Jorgenson (1990), table 3.2., p.27 for the United States industries from 1947 to 1985.

[383] Note that labour input does not reflect human capital accumulation. However, chapter 6 demonstrates that human capital accumulation only accounts for a small proportion of growth in cotton spinning and weaving (see table 6.5.). Therefore, it is likely that overall results would not be greatly altered by taking into account human capital accumulation.

[384] A very detailed discussion of the evolution of labour is available in chapter 4.

[385] See in chapter 3, table 3.3.

[386] Jorgenson (1989), Hulten (1990)(1992).

important consequences. First, it casts doubt on the work of scholars who view the diffusion of mechanisation across manufacturing industries during 1840s and 1850s as the crucial development behind early Catalan industrialisation.[387] In effect, according to the figures above, the perspective that relates industrialisation with mechanisation contributes little to understanding how and why the striking progress between 1840 and 1860 was achieved. Second, this result confirms indirectly the robustness of previous TFP studies for Britain and the United States. Studies which did not consider capital quality.[388]

Third, table 5.3 depicts some differences between the weighted and the aggregate model. We can see that the divergence between both models in TFP growth rates is relatively important (about one fifth). As was mentioned above, this means that the market imperfections reduced actual growth rates by 20 percent. If value added and all components of capital and labour inputs were to grow at the same rate for all industries, there would be no reallocation. Interestingly, the market failures were due to the reallocations of intermediate inputs, and labour input, but not capital input. In other words, the major market failures were concentrated in the labour and intermediate products markets. In contrast, the capital market appears to have been quite competitive.[389] It is also relevant that the amount of the misallocation of resources is practically the same as found in a similar study, but with 37 sectors, for the United States from 1947 to 1985.[390]

There are grounds for pursuing TFP measures somewhat further. In particular, sceptics could argue that fast TFP rates are a consequence of the election of the benchmark years.[391] In other words, they are the result of the biases introduced by the election of one

[387] See Nadal (1974) or Maluquer (1976).

[388] Feinstein (1981), McCloskey (1981), Crafts (1985a), Crafts and Harley (1992), Crafts (1996) in Britain; and Sokoloff (1984) and Tchakerian (1994).

[389] Pollard (1981) and Hudson (1986)(1989) argue that early industrialising regions were characterised by regional capital markets that efficiently channelled funds from the traditional to the modern sectors and industries.

[390] Jorgenson (1990), table 3.1., p. 22.

[391] It should be underlined that the Divisia index employed in the elaboration of the index is not additively consistent. See, for example, Diewert (1976), Hill (1993) or Dean *et al.* (1996).

bottom year of the business cycle as an initial year and a peak year as the last year. However, it should be noted that whereas 1840 can be considered as a peak in the business cycle, 1861 was not.[392] Then, according to the arguments put forward by Abramovitz, TFP productivity measures can be biased downwards, but not upwards, since productivity of factors is not fully exploited.[393] Anyway, the most detailed data on the cotton industry allow me to discuss in detail this question.

**Table 5.4** Contribution of Factor Accumulation and TFP to Value-added Growth: Cotton Industries, 1830-1861

| | Value Added | Labour | Capital | TFP |
|---|---|---|---|---|
| **Spinning** | | | | |
| 1830-40 | 3.27 | 0.60 | 0.92 | 1.76 |
| 1840-50 | 3.15 | -0.18 | 1.55 | 1.79 |
| 1850-61 | 1.26 | -0.18 | 0.90 | 0.54 |
| 1830-61 | 2.58 | -0.02 | 1.15 | 1.45 |
| **Weaving** | | | | |
| 1830-40 | 4.46 | 0.65 | 0.54 | 3.27 |
| 1840-50 | 4.88 | 0.71 | 0.35 | 3.81 |
| 1850-61 | 0.71 | -0.40 | 0.16 | 0.95 |
| 1830-61 | 3.09 | 0.22 | 0.56 | 2.31 |
| **Finishing** | | | | |
| 1830-40 | 0.12 | 0.21 | 0.15 | -0.24 |
| 1840-50 | 1.21 | 0.03 | 0.19 | 0.99 |
| 1850-61 | -0.39 | 0.20 | 0.42 | -1.01 |
| 1830-61 | 0.39 | 0.15 | 0.32 | -0.07 |

**Notes and sources:** Numbers are subject to rounding errors. Total figures computed according to the method described in the equation 5.10. Sectoral output figures drawn from table 2.2, intermediate inputs from table 2.3, labour input figures from table 5.7, and capital figures from table 3.4.

In broad terms, table 5.4 confirms the picture emanating from table 5.3 and bolsters confidence in the robustness of the qualitative interpretation derived from it. First, TFP was the main factor in the growth of cotton spinning and weaving but not cotton finishing. Second, the TFP growth rates differed strongly from one decade to another. Moreover, they also indicate that the 1850s was not a period of spectacular TFP growth rates. In other

[392] See table 2.5. For example, 1840 was the best year of the 1830s while the best year of the 1850s and early 1860s was 1857, but not 1861.

[393] Abramovitz (1993).

words, I may justifiably infer from them that results of table 5.4 are not biased upwards but downwards.

It is noteworthy that the mean annual aggregate productivity growth rates are similar to what was found for similar exercises developed for the north-east of the United States for the same early industrialisation period.[394] However, the main problem of TFP is that it computes the absolute changes in the efficiency of the sectors and not the relative changes with respect to other sectors; that is, it describes the pace of growth but not the level of efficiency.[395] For example, industries at different technological levels could have the same TFP growth rates but this does not mean that they have the same level of efficiency. For this reason, Catalan and U.S. TFP growth rates are not directly comparable (it could be that the U.S. was at higher level and consequently the same TFP growth rates have different meanings). However, it should be underlined that the pace of growth was similar in both countries during the early phases of industrialisation. Moreover, U.S. results tend to confirm the view expressed in this paper and show that, probably, early industrialising regions had more resemblances than differences in their development paths.

Finally, the next table presents estimates of the importance of quality growth in the sectoral growth of the Catalan cotton industry. The Translog indices aid the decomposition of the growth rates into quantity and quality growth rates. The quantity rate is simple to calculate because it is the difference of successive logarithms, and is derived directly from the quantity produced. The quality growth rates can then be computed by subtracting the quantity rates from the Translog rates.[396]

[394] Sokoloff (1986).

[395] Allen (1991).

[396] Christensen *et al.* (1980) and Gollop and Jorgenson (1980).

**Table 5.5** Quantity and Quality Decomposition of Growth Rates: Cotton Industry, 1830-1861

| | Sectoral Output | Decomposed in Quantity | Quality | TFP 1 | TFP 2 |
|---|---|---|---|---|---|
| 1830-1840 | 8.22 | 6.15 | 2.07 | 3.27 | 2.31 |
| 1840-1850 | 10.41 | 5.56 | 4.85 | 4.29 | 2.77 |
| 1850-1861 | 2.15 | 3.80 | -1.65 | -0.91 | 0.41 |
| 1830-1861 | 6.77 | 5.13 | 1.65 | 1.77 | 1.59 |

**Notes and sources:** Quantity is an unweighted index of cotton industry production where quantities are directly added. Quality growth rates are the difference between the Törqvist quantity index growth rates and the unweighted index growth rates. TFP 1 refers to the aggregate model and TFP2 to industry model (see text).

This table contains a number of important results. The periods of large TFP growth were coincident with periods of large shifts in quality and sectoral output. Therefore, the changes in the market for cotton goods can be associated with the development of innovations that affected quality. It is clear that this is a question worth addressing in the next chapters.[397]

To end this section, it is important to consider whether there may be some biases in the estimates of total factor productivity. I will discuss three main points: (1) the biases in the sample of industries; (2) the possible bias in the data as a consequence of business cycles; (3) the assumptions behind the construction of the weights for each input.

It is necessary to remember that this exercise does not cover the whole Catalan manufacturing sector, but only nine industries (cotton spinning, cotton weaving, cotton finishing, linen, metal, mixed fabrics, paper, silk and wool). The main absences in this exercise are the flour, cork, and liquors industries, where there was not enough data for 1840. Therefore the sample is biased in favour of the most modern, capital intensive and rapid growth industries and, obviously, against the sectors with low rates of growth and productivity stagnation.

[397] See chapters 8 and 9.

Special mention should be given to workforce figures because they are very volatile over the business cycle and, hence, are the perfect candidates for estimation errors. However, there are several ways to test the quality of the data. For example, the workforce in the cotton industry was estimated with the alternative method of multiplying the machinery in use by a coefficient of full-time jobs, which is different for each kind of machinery. Despite this more sophisticated method, the new results are only slightly different from the data reported in the original sources.

Inventories also varied strongly through the business cycle. In particular, during the peaks of the cycle inventories tend to decrease, while the contrary holds for the bottom years. Indeed, this pro-cyclical movement of inventories tends to exaggerate the cyclical movements in productivity. Furthermore, during the period there is a large transference of inventories from one sector to another. At this point it would be worth explaining in detail what happened in the cotton industry. In 1830 the cotton industry was formed by three sub-sectors: spinning, weaving and finishing. Inventories of raw materials and semi-finished goods were rather equally distributed among the sub-sectors; that is, no sector was able to transfer semi-finished goods to other sectors. However, the integration process in the 1840s and 1850s was not equally intense in all sub-sectors. Moreover, many cotton spinning firms integrated vertically into cotton weaving.[398] The outcome of these changes was the reduction of the inventories in spinning and weaving but an increase in the inventories of semi-finished cloth in finishing. What effects had this change on the measures proposed here? It decreased the amount of capital in spinning and weaving, whereas the contrary holds for finishing. Consequently, *ceteris paribus*, it increased the efficiency (TFP) of spinning and weaving and decreased TFP in finishing.

A last source of bias could be the share of the factors in output. It is worth addressing the interesting question that the main source of error could be the absence of perfect competition. Habitually, the absence of perfect competition tends to benefit capitalists more than workers (it should be take into account that at the time the Catalan

[398] See the further chapter 8.

trade unions were very feeble in manufacturing).[399] Therefore, capital's share will be overstated. Basically, since the capital input is the fastest growing input, this bias tends to reduce the TFP figures.

Although there is a possibility of biases in TFP measures, it is likely that the impact of these biases was relatively minor in the overall results. Neither the biases introduced by the coverage of the sample, nor the bias in the labour force figures, nor the bias in inventories, nor the overstatement of capital's share seem capable of altering the overall conclusions. Furthermore, it should be noted that many biases acted against my main argument, the importance of TFP growth, since they tended to reduce the 'residual'.

**5.6. Conclusions**

Sceptics could argue that the approach of this paper is vulnerable to measurement error, but this does not seem plausible because the main assumptions are derived from standard methodology and are consistent with the historical data. Different historical sources and growth accounting studies for other countries seem to indirectly confirm the results obtained. Moreover, any kind of correction in the capital and labour shares is not likely to produce spectacular changes in the productivity estimates. Consequently, the conclusions and implications of this research seem to be largely consistent.

Some general interpretation of Catalan industry growth can be derived from the results. The first implication is that innovation in the light industries in the nineteenth century had strong multiplicative effects. In other words, the adoption of some innovations in these industries produced larger effects in the growth of output. Contemporary experience is quite different, to increase growth long research projects and extensive human capital are required. In the nineteenth century the effects of innovation were larger.

A second implication is that direct machinery investment and larger TFP growth rates

[399] Izard (1979).

did not correlate well. In other words, the non capital-embodied innovations had a leading role in the productivity improvement. This chapter emphasises the importance of active involvement in technical change and the role played by local innovations. In particular, Catalan industry was not only successful because of its ability to import technologies from abroad. Consequently, it can be argued that the achievement of high rates of productivity was strongly related to the local conditions and capabilities. In this environment, the presence of market pressures and opportunities, the rivalry among firms, the local knowledge, and the social capabilities emerge as the main factors in economic development.

**Appendix to Chapter 5: The Indices of Labour Input**

The objective of this appendix is to develop measures of labour input by combining into a single measure the quantities of men, women and children. This new labour input measure is employed to compute TFP and the labour productivity figures in chapter 6.

The first step in developing sectoral input measures is to construct employment matrices. Cross-classified by men, women and children. These employment matrices are presented in table 4.4. The second step is to construct labour compensation matrices for each year. Table 4.7 displays this data. Differences in labour remuneration reflect differences in average marginal product. The last step in constructing data on labour input is to combine price and quantity data, cross-classified by men, women and children, into price and quantity indices of labour input. Employing the Törqvist index, labour input is computed as follows:

$$lnL_t - lnL_{t-1} = \sum_l [\bar{\Theta}_{L_l}(\ln li_t - \ln li_{t-1})] \qquad (5.12)$$

Where Li designates labour input, I designates labour, three types of labour (men, women, and children) are being considered, the two time periods are t and t-1, and the value share weights $\Theta_{Li}$ are computed as:

$$\bar{\Theta}_{L_i} = 1/2[\theta_{li}(T) + \theta_{li}(T-1)], \qquad (i=1,..,n).$$

Where the $\Theta_{Li}$'s denote the share of each in the wage bill. The exponential of this logarithmic change yields an index number. The results for the main manufacturing sectors are displayed in the table below:

**Table 5.6** Growth rates of labour input and its components, modern manufacturing, 1840-1861

| | Male | Females | Children | Labour Input |
|---|---|---|---|---|
| Cotton Spinning | 4.91 | -4.09 | -5.25 | -1.50 |
| Cotton Weaving | 0.77 | -1.82 | -6.08 | 0.24 |
| Cotton Finishing | 3.10 | 2.05 | -10.96 | 2.15 |
| Cotton Industry | 1.43 | -2.86 | -6.00 | 0.02 |
| Metal Industry | 1.61 | | | 1.61 |
| Other textiles | 4.61 | -1.04 | -3.13 | 3.48 |
| Paper | -5.21 | -5.21 | -1.24 | -5.58 |
| Total | 1.79 | -2.55 | -5.09 | 0.57 |

**Notes and sources:** Numbers are subject to rounding errors. Labour input index computed according to the method described in the equation 4.6. For labour sources see text above.

Finally, in the case of the cotton industry because data is available for more periods it is possible to elaborate the labour index for four benchmark years. The results are presented in the next table:

**Table 5.7** Growth rates of labour inputs and its components, Cotton industry, 1840-1861

| Spinning | Male | Female | Children | Labour Input |
|---|---|---|---|---|
| 1830-40 | 2.77 | 2.69 | 2.69 | 2.70 |
| 1840-50 | 10.31 | -5.64 | -5.43 | -1.18 |
| 1850-61 | 0.00 | -2.68 | -5.08 | -1.76 |
| 1830-61 | 4.22 | -1.90 | -2.68 | -0.15 |
| **Weaving** | **Male** | **Female** | **Children** | **Labour Input** |
| 1830-40 | 1.76 | 1.74 | 1.75 | 1.76 |
| 1840-50 | 2.69 | 0.31 | -2.16 | 2.18 |
| 1850-61 | -0.97 | -3.75 | -9.64 | -1.51 |
| 1830-61 | 1.09 | -0.66 | -3.55 | 0.74 |
| **Finishing** | **Male** | **Female** | **Children** | **Labour Input** |
| 1830-40 | 5.01 | 4.99 | 5.00 | 5.01 |
| 1840-50 | 1.53 | 0.27 | -6.87 | 0.69 |
| 1850-61 | 4.52 | 3.67 | -14.67 | 3.72 |
| 1830-61 | 3.72 | 3.01 | -5.81 | 3.07 |
| | **Male** | **Female** | **Children** | **Labour Input** |
| 1830-40 | 2.18 | 2.35 | 2.73 | 2.27 |
| 1840-50 | 3.09 | -2.74 | -4.59 | 1.14 |
| 1850-61 | -0.08 | -2.97 | -7.28 | -0.94 |
| 1830-61 | 1.67 | -1.18 | -3.18 | 0.76 |

**Notes and sources:** Numbers are subject to rounding errors. Total figures computed according to the method described in the equation 4.6. For labour sources see text above.

# Part II. Inside the 'Black Box': Explaining Productivity Growth

# Chapter 6

## The Contribution of Human Capital

The objective of this chapter is to investigate: (1) how large the accumulation of human capital was prior to the emergence of the factory system, (2) what the role of human capital was during this process. In other words, my aim is to study the level and growth effects of human capital. The chapter argues that for a region adopting a technology from elsewhere, an existing stock of (relevant) human capital was essential to the rapid and successful adoption of the technology. But once the technology has been fully assimilated, you would not expect increments in human capital to be important in its further growth. Catalan industrialisation was possible because the level of human capital present in industry was enough to adopt and modify new technologies. The human capital stock was mainly the result of past investments in on-the-job-training, and children's informal education took place in the workplace rather than the schoolroom. Therefore, the level of human capital present in the workforce was higher than literacy and schooling rates showed. However, evidence is also presented on the low contribution made by human capital to growth rates.

It should be noted that the topic of this chapter is strongly related with several of the arguments presented in chapters 4 and 5. On the one hand, in chapter 4, it was proved that there was a shift in technology. This resulted in the intensification of the capital-skills complementarity and the widening of the unskilled-skilled workers wage gap. Two main questions were left without an answer in that chapter. How Catalonia was capable of adopting the new British and French machinery? How and where the new skilled workers were trained and recruited? Obviously, this issue can only be resolved by examining empirically the level effects of previous human capital accumulation and the system for educating and training the workforce. On the other hand, the growth accounting exercise of chapter 5 showed that the 'residual' is the major source of the Catalan industrialisation. Nevertheless, the measure of total factor productivity of chapter 5 was based on the original Solow formulation (sectoral output is function of intermediate, capital and labour inputs). This formulation includes in the residual not only gains in productivity but also improvements in human capital. It is obvious that the question of how much of the residual is explained by human capital accumulation (i.e., the growth rate of human capital) is critical for further analysis of Catalan industrialisation.

**6.1. Introduction**

A certain level of human capital accumulation is almost universally regarded as a prerequisite for economic growth. In other words, the level of human capital is important in determining future growth rates and explaining differences in income *per capita* among countries. For example, Sandberg argues that the lack of human capital limited the opportunities of backward countries to grow rapidly during the last century.[400] Several studies have also underlined the role played by the comparative low levels of literacy and schooling in the relative backwardness of the Mediterranean basin.[401] In a similar vein, many empirical studies for the twentieth century have also shown that the level of human capital is one of the major influences determining the capacity of nations to innovate and the speed of convergence.[402]

In contrast, there is much discussion of whether the rate of growth of human capital explains actual growth rates. Thus, several economic historians have argued that human capital growth is less of an explanatory factor for the growth rates of the nineteenth century than of the twentieth.[403] However, it should be stressed that in their accounts these authors have considered schooling and literacy, and not on-the-job-training. This is more likely to

[400] Sandberg (1979)(1982).

[401] See, for example, Reis (1993) and Tortella (1994).

[402] See, for example, Barro and Sala-i-Martin (1992), Benhabib and Spiegel (1992)(1994), Lucas (1988)(1990), Mankiw *et al.* (1992) and Romer (1986).

[403] Abramowitz (1993) and Crafts (1995).

reduce estimates of human-capital during the nineteenth century when an important part of the workforce was illiterate but skilled. It will simultaneously raise the estimates for the twentieth century, when formal education is universally adopted and widespread. More prominently, during the early phases of industrialisation, training played a leading role in the development of skills among industrial workers and was widespread within proto-industrial households, workshops and factories.

Before to proceeding further, two clarifications on terminology should be useful. First, here, the human capital term is not treated as a synonym for knowledge. According to Mankiw's definitions: 'Knowledge refers to society's understanding about how the world works. Human capital refers to the resources expanded transmitting this understanding to the labour force'.[404] Second, throughout this chapter, the term 'informal education' is treated as a synonym for training received before adult age.

The motivations for this chapter are twofold. First, as yet, no scholar has considered human capital as a prerequisite for Catalan industrialisation and a broad inspection of schooling and literacy data seems to support this view. For example, in 1860, Catalonia showed all the characteristics typical of countries with low levels of education: low literacy and primary schooling rates, large differences between the male-female levels of literacy and schooling, a strong concentration of schools in urban zones, low public investment in education, and many students at secondary and higher levels.[405] Finally, in the debate over proto-industrialisation, the transmission of skills from proto-industry to factory system has still not received adequate attention, while the contribution of cheap (unskilled) labour has been considered elsewhere.[406]

The remainder of this chapter is organised as follows. Section 6.2 presents a simple framework to understand this methodology. The next section gives qualitative evidence on the levels of human capital present in the labour force. In addition, it describes the methods of

[404] Mankiw (1995), p.35.

[405] Nuñez (1992), pp. 135, 292 and 298.

[406] See section 4.2 in chapter 4.

education and training in the factories and verifies whether workers' earnings were correlated with past investments in human capital. Section 6.4 discusses the effect of the spread of the factory system on the skills required for production. The subsequent section discusses the contribution of human capital to growth. Finally, section 6.6 summarises and gives new perspectives on the role of human capital in the early phases of Catalan industrialisation.

### 6.2. A Methodology to Estimate Human Capital

In order to evaluate the contribution of human capital during the past century, a measure for the effects of both schooling and training is necessary. An alternative approach suggested by recent growth accounting exercises gives a simple solution to this problem through computing the quality of the labour force; that is, the set of skills employed during production.[407] There are two basic ideas behind this: (1) the quality of the labour force is enhanced by past investments in human capital, (2) differentials in individuals' earnings are the consequence of these same investments. These two ideas are derived directly from the seminal arguments of human capital theory.[408] Put simply, the argument is that the income employed in enhancing human capacities raises the worker's earnings because it increases productivity per worker.

This argument is widely debated. Some authors have maintained that earnings differentials, even during the nineteenth century, are due to institutional constraints.[409] As a result, human capital accumulation cannot be measured by computing individual earnings since they do not imply a direct relationship between age, experience, skill and productivity. For instance, Michael Huberman has argued that in the Lancashire cotton industry, where standstill had higher costs and monitoring tasks were difficult, workers were paid 'efficiency' wages. In other words, they were paid higher wages at the end of their working lives to compensate them for the lack of job security, for monitoring tasks, and to stop them shirking. Therefore, employers and workers established a long-term and implicit contract where

[407] For example, Jorgenson (1990), and Young (1995).

[408] Becker (1962), Schultz (1962), and Mincer (1974).

[409] See, for example, on Catalonia, Camps (1995); and, on Lancashire, Huberman (1996).

seniority criteria were employed to settle workers' earnings. The contract was stipulated by means of piece-rate lists. These were public documents where a relation was established between the age of the worker, the type of output, and the piece rate obtained by each unit of output (in this case, pound of yarn) produced. These piece-rate lists regulated the salary structure in the Lancashire spinning industry by paying workers according their age (the older the worker, the higher the piece rate).[410] Obviously, according to this argument, the increase in wages with age cannot be associated with any increase in human capital but it is consequence of the contract that regulated how the labour market worked.

It should be underlined that the evidence on Catalan cotton firms demonstrates that payment of 'efficiency' wages is unlikely to have affected average earnings significantly. The fact is that in the largest Catalan cotton firm (the *España IndustrialS.A*), which had about 1700 workers, the wages of skilled workers at the end of their working lives were significantly lower than at the peak of their physical strength.[411] In Barcelona factories, during periods of crisis, no seniority criteria were employed to fire workers[412] and piece-rates were different for each worker according to the quality and quantity of their production and not according to their age. For example, in mechanical weaving, there were many different piece rates according to the productivity of the firm, the quality of workers' production, the number of pieces per hour, and so on.[413] Furthermore, employers repeatedly rejected any kind of agreement with workers to establish piece-rate lists, with the argument that 'every worker must be paid according to his individual productivity and dexterity'.[414] Working in the same cotton mill for long periods was unusual since the cotton companies were constituted for only short periods. In effect, movements of the labourforce were common and workers migrated from one zone to another in search of better jobs and salaries.[415] Finally, the reduced size of the

[410] Huberman (1986)(1991a)(1991b)(1995)(1996).

[411] Camps (1995), table 7, pp. 204-205.

[412] Cerdá (1968), pp. 575-576.

[413] Cerdá (1968), pp 607-609.

[414] Junta de Fábricas (1830), (1834a) and (1835). However, in the 1870s several piece-rate lists were agreed. Where payments were regulated according to the distance of the factory from Barcelona and the age of the worker. See Nadal (1991a), pp. 55-58.

[415] Camps (1995).

Catalan cotton mills, in comparison, for example, with Lancashire's mills, made the monitoring tasks relatively simpler for entrepreneurs and bosses.[416]

However, it is true that all pay structures in the Catalan cotton industry contained elements which hindered the perfect labour market. For instance, during short periods workers formed powerful trade unions and obtained substantial gains in *real* wages.[417] Similarly, employers collaborated to avoid increases in wages and the establishment of regulated work conditions.[418] For the most part, however, these imperfections affected the difference in earnings between industries, rather than within a given industry. That is, some differences of salaries among industries could be difficult to completely explain within the framework of human capital theory. In any case, it should be noted that a human capital explanation is not inconsistent with the presence of some imperfections in labour markets. For instance, over time earnings can increase with investment in human capital; but at one moment in time the labour market can exhibit imperfections, like monitoring or shirking problems.

### 6.3. The Levels of Human Capital in the Labour Force

It is commonly accepted that certain levels of skill and technical competence are needed in the recipient country of new technologies.[419] Moreover, it is pointed out that the rapid production or large scale importation of skills is very inefficient, at least compared to the production or importation of machinery.[420] In other words, countries without a skilled labourforce encountered many problems to starting any process of industrialisation. Moreover, in the nineteenth century technological innovation had some peculiarities made the

[416] For example, in 1850, Catalonia cotton factories had on average 86 workers whereas those in England had 171 workers. The sources are: for Catalonia, Junta de Fábricas (1850) and for England, Sicsic (1994). Furthermore, there were very few factories in Catalonia with more than 500 workers (for example, in 1861 only 6, see chapter 9 the table 9.2) whereas in Lancashire they were very common (see, for example Gatrell (1977) or Lloyd-Jones and LeRoux (1980)).

[417] See, for example, the references of Cerdá (1968) to the associations of powerweavers and the work of Izard (1979) on the organisation of the first trade unions.

[418] See Graell (1910) on the history of the Junta de Fábricas.

[419] Rosenberg (1982), pp. 246ff.

[420] Sandberg (1982), p. 696.

transmission of knowledge difficult. In particular, many of the technical procedures were not codified or based on science and, therefore, experience and tacit knowledge played a central role in the acquisition of the human capital necessary to manage any technology.[421]

In Catalonia during this period a large part of the cotton production shifted from domestic production, artisan shops and non-mechanised factories, to mechanised factories that employed inanimate sources of energy instead of animal strength.[422] The new mechanised factories in Catalonia were as sophisticated as the most advanced British and French factories.[423] A puzzling question is that, in spite Catalonia's overall low education and literacy levels, its cotton industry showed itself to be surprisingly efficient in embracing and rapidly adapting foreign technologies. For example, from 1836 to 1840 the imports of modern cotton machinery from Britain and France were increased 600 percent and the horsepower of steam engines from 1832 to 1848 increased 8000 percent.[424]

In the first stages of the transition to the modern industry, the 1830s and the early 1840s, foreign technicians and workers played a leading role in the adoption of new machinery since they installed and maintained new machinery and trained native workers.[425] But by the 1840s native workers had completely substituted foreign workers in this field. Thus, from about 1850s onwards, Catalan factories could replace their machinery with new vintages, which were more sophisticated than the previous ones because they ran faster and operated with high pressure steam engines, without needing to appeal to foreign technicians.[426] Therefore, after the initial period, Catalans developed the capacity to maintain their own machinery, adopted the new technologies and, obviously, ran them without any foreign help. Moreover, in the post-adoption phase, Catalan firms incorporated a stream of incremental

[421] On the differences between the present-day and the past century technological diffusion. See Nelson and Wright (1992). Furthermore, chapter 7 contains a description of the technological peculiarities of the Catalan cotton industry.

[422] See chapter 8.

[423] See Arau (1855) and Calvet (1857).

[424] The data comes from Madoz (1846) and Figuerola (1968).

[425] Ronquillo (1851-57), p. 128.

[426] Comisión especial arancelaria (1867), Ferrer Vidal (1875), Figuerola (1968).

developments and modifications to improve and adapt foreign technology to local requirements.[427]

The stock of metal artisans and the active involvement of the Catalan entrepreneurs were the two main factors that helped this rapid development of native technicians. During the proto-industrial period, in Barcelona and other Catalan industrial towns, many handicraft workshops made and repaired spares, small metal pieces, and machinery, including cotton industry machinery.[428] The artisans in these workshops were relatively (highly) skilled since they could perform many different tasks (i.e. the division of labour was not particularly important) under the supervision of the master.[429] With the spread of new cotton factories, cotton entrepreneurs recruited many metal artisans to fill the new machinery-maintenance posts. For instance, a contemporary commentator said: 'All cotton, silk or wool establishments had their own machinery workshop, which had its master and skilled workers ready to repair any sudden machinery breakdowns. These workers have been educated in metal-industry workshops and factories (....) and they all are actually (1849) natives of the country'.[430] Thus, it can be argued that foreign technicians did not train uneducated native workers but converted the artisans and former apprentices of the metal workshops. Who could become factory technicians with only a short period of training.

The Catalan entrepreneurs participated actively in the development and enlargement of this native highly-skilled workforce because the cost of recruiting and employing foreign workers was higher. An interesting example of this active involvement of Catalan entrepreneurs is given by the first modern cotton mill, the Bonaplata factory (established in 1832), which not only produced cotton goods with the most modern technologies but also trained many young Catalans. These trainees were then rapidly recruited by other new factories for the repair and maintenance of their new machinery. For example, in 1833, the

[427] Arau (1855), Calvet (1857).

[428] Madoz (1846), Sayró (1842), Comisión especial arancelaria (1867), Figuerola (1968), Nadal (1991b).

[429] Comisión especial arancelaria (1867), Cerdá (1968), Figuerola (1968).

[430] Figuerola (1968), p. 299.

employers' organisation congratulated Mr. Bonaplata 'for the efficiency of teaching so many young Catalans the theory and practice of modern machinery in his factory. As this creates the seedbed of the new mechanic artisans that will replace the foreign artisans and spread their skills to the whole cotton industry'.[431] It is intriguing why Mr. Bonaplata preferred to use local workers, who could abandon the factory after their training, and not foreign workers. If one assumes that Mr. Bonaplata was not a philanthropist there are two possible reasons. Local workers had to pay for their education (for example, they were not paid during the months of training), which is highly plausible, and/or the costs involved in importing foreign workers were so high than Mr. Bonaplata found it profitable to lose some money training some national workers. An idea of the high wages of the foreign workers is given by the next example. In 1861, an Alsatian chemist of the España Industrial S.A. had a daily wage of Rv. 275, whereas a male adult unskilled worker in the same production section received a daily wage of only Rv. 10.[432]

Contrary to the machinery-maintenance sector, in the productive sector native workers performed all the productive tasks from the beginning.[433] Despite the fact that labour was still heterogeneous, factories preferred to employ workers from the proto-industry, especially in weaving, because they were more productive than other workers.[434] According to contemporaries, their higher standards were the consequence of the many years of training they had had from when they were children.[435] It should also be stressed that the proto-industrial workers could retain this advantage over other workers during the first stages of factory transition because there were more similarities than differences between the proto-industrial and factory machinery. For example, a contemporary comments that 'in mechanical weaving there are not apprentices since former handweavers can manage the new mechanical looms after a short explanation'.[436]

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[431] Junta de Fábricas (1833).

[432] Comisión especial arancelaria (1867).

[433] Camps (1995), p. 123.

[434] Junta de Fábricas (1835).

[435] Junta de Fábricas (1830).

[436] Cerdá (1968), p. 568.

However, not all workers in the proto-industry were as skilled as the handweavers. Thus, the differences in skills between handweavers and handspinners were wide. Handweaving was usually a high-skilled, full-time, male occupation with higher piece rates. Whereas handspinning a low-skilled, part-time, female and child occupation had lower earnings.[437] In handspinning, the proto-industrial household was the key element in the informal education of children whereas in handweaving apprenticeships were widely diffused, especially in towns. Briefly, handweavers corresponded very well to the image of skilled artisans while proto-industrial handspinners were more akin to cheap labour.

A new system to educate the workforce was developed within the new mills. The necessity of a stable and skilled factory workforce, the low public investments in primary and technical education, and the decrease of proto-industrial workers who might be recruited by factories were the three main causes behind this innovation. In particular, the same spread of factories reduced the available stock of (skilled) proto-industry workers since they destroyed the old putting-out districts and jeopardised the survival of artisan workshops. Problems provoked by the cheap goods of new mills encouraged young proto-industrial workers to migrate to the new factories.[438]

It should be noted that the rise of informal education within factories was more rapid in spinning than in weaving because the survival of handweaving during the period made the recruitment of skilled weavers for new mills easier.[439] Moreover, it seems that the training system of handweavers, which was based on apprenticeship, was very flexible and showed itself to be highly efficient. In particular, in the period of prosperity of cotton handweaving, the 1840s, the amount of handweavers increased rapidly, but without appreciable effects on quality and productivity and with relatively small consequences for wages.

The key element in the informal education of the new factory workers was the work

[437] Sayró (1842), Gutiérrez (1834) and (1837), Madoz (1846). See also the discussion in chapter 4 and in chapter 7.

[438] Camps (1995), chapters 3 and 4.

[439] Cerdá (1968), p. 568.

of children and youth within the factories.[440] Children entered the factories at the age of eight or nine, doing preparatory and auxiliary jobs (blowing, carding and rowing). Over the following years, they worked beside a parent, relative or other experienced worker receiving little pay and sometimes changing occupation or even factory. In this way, many children gained a wide knowledge of the factories and their machinery. By the age of 15 or 16, the most proficient children were still attached to a work group receiving fixed weekly wages. At the age of 17 or 18, many had acquired a high degree of dexterity and were ready to supervise their own work group as main mule-spinners.[441] Therefore, during their time in the factories children not only worked but also received an informal education. As adults, they were able to obtain further increases in their earnings as their skills continued to improve. In spinning, for example, spinners began with throstles, afterwards moving to longer mules, and some of them finished their careers in the well-paid supervisory posts.[442] Apprenticeships were also common in factories among the highly skilled workers who filled the machinery maintenance jobs. For example, in 1856 in Barcelona, apprentices were 30 per cent of the workers in factory machinery-maintenance sections.[443] Contrary to the other factory children, these apprentices specialised in a specific job from their entry and did not receive any wages for their work.

The evidence on posts, earnings, opportunity costs and returns of informal education shows that human capital investment was made during the period in which children and young worked in the factories. Former factory children filled the skilled posts in the factories because the workers who had not received any training as children could not develop these skills and were limited to unskilled jobs throughout their lives.[444] However, this does not mean that unskilled workers did not have opportunities to increase their earnings throughout their lives because they were given some sort of training within the factory and, therefore, were

[440] There are many references to child labour in the contemporary sources; see for example, Sayró (1842), Madoz (1846), Cerdá (1968), and Comisión especial arancelaria (1867).

[441] Cerdá (1968), p. 568.

[442] This system of child training was very similar to the system employed in the cotton mills of Lancashire. On Lancashire, see Boot (1995).

[443] Cerdá (1968), pp. 590-591.

[444] Junta de Fábricas (1834b), and Cerdá (1968), p. 568.

sometimes promoted from the simplest to semi-skilled tasks.[445]

**Table 6.1** Male Yearly Earnings: Selected Cotton Factory Jobs, Barcelona, 1856

| | Skills | Child Education | Minimum Earnings | Maximum Earnings | Difference |
|---|---|---|---|---|---|
| Machinery-maintenance | HSK | AP | 2791 | 4996 | 2205 |
| Mechanical-weavers | SK | PR | 1016 | 3853 | 2837 |
| Hand-weavers | SK | PR | 1210 | 3574 | 2364 |
| Jacquard-weavers | SK | PR&AP | 1694 | 3570 | 1876 |
| Mule-Spinners | SK | CH | 2384 | 3829 | 1445 |
| Factory labourer | USK | NO | 2286 | 3218 | 934 |
| Carding-machines | USK | NO | 1814 | 2694 | 880 |

**Notes and sources:** Values in Reales de Vellón (hereafter Rv); Skills: HSK (highly skilled), SK (skilled), USK (unskilled). Informal education: PR (children working in proto-industry households); CH (children working in factories); AP (apprenticeships) and NO (any informal education). Minimum earnings corresponded to young workers and maximum earnings to experienced workers. The data source is Cerdá (1968, pp. 629-640).

Table 6.1 shows the earnings in diverse jobs in Barcelona cotton mills and the informal education and skills associated with these jobs. It can be seen that the largest maximum earnings and largest differentials between maximum and minimum earnings correspond to skilled jobs. Unskilled workers with no childhood education, in spite of the fact that they performed occupations with a considerable degree of physical exertion, expected to get lower earnings which would not increase much. Former apprentices obtained the largest minimum and maximum earnings because they received many specific skills and invested heavily in their education. However, a puzzling feature of these figures is the difference between the earnings of the former proto-industry and factory boys. The minimum earnings of former factory boys were higher than those of boys formerly in the proto-industry, whereas in maximum earnings, these differences were not significant. This apparent anomaly can be explained by the fact that, at the beginning of their adult life, factory boys had more training in specific factory tasks than proto-industry boys. But proto-industry boys were able to catch-up on factory boys' skills and earnings during their lifetime work in the factories. In other words, the evidence shows that the proto-industry trained workers for the factories and the

[445] See interesting references to unskilled lifetime earnings in Cerdá (1968) and Camps (1995), p. 204.

new machinery.

The work of children in factories had large opportunity costs for them and their families. Comparing the earnings of shoeshine boys with factory boys makes the analysis simple. Shoeshining was the typical unskilled job with absolute free-entry. For example, many factory boys also worked at shoeshining on Sundays because the factories were closed.[446] The shoeshining earning was on average Rv. 3.5 per day while in the factories boys received an average wage of Rv 2.5 per day. Moreover, for a large part of this period, factory children were only paid Rv 2 per day and only at the age of fifteen or sixteen were they promoted to work in work groups, receiving wages of Rv 3 per day. If we assume (1) that children began to work at eight years of age; (2) that the number of days of work in the factories was 227 while shoeshine boys worked for 349;[447] (3) that the discount rate was 6 per cent; (4) that the wages remained constant, as the sources indicate for 1855.[448] Then the actual opportunity cost of working within the factories at the age of sixteen is equal to the difference between shoeshine and factory wages plus discount rate. Thus, the total opportunity cost of the period in the factories from eight to sixteen years was equal to three years of young adult (minimum) mule-spinners earnings[449] and the opportunity costs of apprenticeship in machinery-maintenance, which was not paid, was equal to about four years of young adult (minimum) machinery-maintenance earnings.[450]

Lifetime earnings may also be used to estimate the net returns of informal education within the factories.[451] To compute the net returns of informal education, the adult yearly earnings of skilled workers in cotton factories were compared with the yearly earnings of

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[446] Cerdá (1968), p. 599.

[447] As Cerdá (1968) indicates.

[448] Under the assumption that factory boys did not have other jobs during the days when factories were closed. For example, they could work as shoeshiners on sundays to cover part of the opportunity costs of their work in factories.

[449] Sources of data: Cerdá (1968).

[450] Under the same assumptions but considering the wage of apprentices equal to zero.

[451] Recently, Boot (1995), p. 283, suggested that by observing the lifetime earnings profiles of workers it is possible to measure skills formation during the nineteenth century in Lancashire.

unskilled workers, throughout their lives using the time series of Camps.[452] The net return to skills acquisition is the difference between skilled and unskilled occupation earnings discounted to their actual value. At the age of sixteen a skilled worker could anticipate earnings in present value terms of about Rv 206,556 from his life as factory worker, whereas a labourer could only expect Rv 126,176 Rv, that is to say 64 percent of what he would have earned as a skilled worker.

A different figure from that based on Camps' data can be obtained by using the cross-section series from Cerdá, which corresponds to the year 1855. Thus, the adult yearly earnings of mule-spinners and machinery-maintenance workers were compared with the yearly earnings of building labourers, which was an unskilled occupation, for all their lives.[453] At the age of sixteen, a mule-spinner could anticipate earnings in present value terms of about Rv 229,652 from his life as a factory worker and a machinery-maintenance worker about Rv 250,487. Whereas a construction labourer only about Rv. 129,632.

At this point, many readers may be intrigued about why the opportunity cost estimated with the cross-section series differs from that computed with the time-series. Obviously, one could argue that it is simply because the sample differed among the two series although a less evident answer could also be given. It can be argued that these differences are a consequence of the narrowing of the skilled-unskilled wage-gap (the time-series of Camps finished some years after 1855). Why did this wage-gap narrow? Simply because the new technology was fully assimilated and the supply of workers skilled in the new technology was firmly established. As was explained in chapter 4, after a period with a widening wage gap comes a period of narrowing since the individual finds it profitable to invest in acquiring the new type of skills. Therefore, the same market forces that shaped the labour supply were responsible for the narrowing of the skilled-unskilled wage gap.

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[452] The data is the time series from 1847 to 1887 computed by Camps (1995), table 7, p. 204.

[453] The source is Cerdá (1968). Note that it is assumed that wages remained constant, as the 1855 sources indicate.

## 6.4. The Effect of the Spread of the Factory System

Scholars have debated whether the emergence of the factory system increased or decreased the demand for skills among workers.[454] It is misleading to argue that all workers in the proto-industry were skilled since there was a division of labour such that some simple productive tasks were carried out separately by unskilled workers. And at least some artisanal jobs were relatively unskilled.[455] However, it is true that the division of labour increased with the spread of factories. In particular, in the proto-industry some workers could not only make the final goods but also produced, installed or maintained machinery. It was not true for the new factories, the machine-installation, machine-maintenance segment, and the production portion were composed of specialised groups of workers.[456]

The labour force in the cotton mills during this period was a combination of highly skilled, skilled, and unskilled workers.[457] In the preparatory section, where raw cotton was cleaned and prepared for spinning, unskilled workers (women and children) were monitored by some foremen, who were the only skilled workers in the section. On the shop floor of the spinning rooms, work groups were common and overlookers did not monitor the effort of the workers. In work groups, each spinner worked with one or two piecers, unskilled workers who mended broken threads during spinning operations. From around the 1850s, the rapid substitution of mule-jennies by self-actors did not reduce the importance of work groups and, according to the Catalan sources, did not alter the structure of labour.[458] On average, in spinning mills, which traditionally were comprised of preparatory and spinning sections, the proportions were one skilled worker (overlooker or spinner) to three or four unskilled

[454] Note that the evidence on capital-skills complementarity of chapter 4 reinforces the arguments that I will present in this section.

[455] See the data that appears in Cerdá (1968), p. 609-613.

[456] Goldin and Katz (1996a).

[457] The following description of cotton mills is based on several historical sources: Arau (1855), Calvet (1857), Cerdá (1968), Comisión de Fábricas (1846), Comisión especial arancelaria (1867), Comisión del Gobierno (1841), and Ronquillo (1851-1857).

[458] Cerdá (1968), pp. 595-598.

workers.[459] In weaving, the work group was less common than in spinning and many experienced weavers worked alone. Whereas unskilled workers (mainly women and children monitored by foremen) carried out the auxiliary tasks in the section. The increase in mechanical looms altered the relation between the number of weavers and auxiliary workers since in handweaving (with dandy or jacquard looms) the ratio was one weaver to two auxiliary workers. In mechanical-weaving it was one auxiliary worker to three or four weavers.[460] Machinery-maintenance and engine-control tasks were also carried out by work teams, which were normally composed of several artisans. Interestingly, the corps of machinists was highly skilled because the steam engines were very unpredictable. Furthermore, all factories had several labourers who did some general tasks. Finally, many factories also had their own group of clerks and other white collar workers such as accountants, designers and so on.

There are several procedures for investigating changes in workforce skills. The most simple is to compute the proportion of men, women and children. It was common during the period for women to receive less formal and informal education than men. Therefore, on average they were less skilled.[461] In Barcelona's workforce in 1856 about 75 percent of men were skilled, compared to only about 48 percent of women. Moreover, only 14 percent of apprentices were female.[462] Similarly, on-the-job training for women lasted less than for men because they tended to abandon the factory much earlier (sometimes after their marriage) and had more frequent and longer absences for illness. Although, these results might be different if there were strong differentials in shirking among men and women, but on this aspect the data is not available.

However, women's skills cannot be studied without a proper understanding of their heterogeneous situation within the cotton industry. In the proto-industry, women predominated

[459] According to Cerdá in Barcelona's mills (1856) there were 1450 spinners, 1450 piecers and 2110 workers involved the preparatory stages. Cerdá (1968), pp. 595-598.

[460] Comisión especial arancelaria (1867), pp. 45-46, Cerdá (1968), pp. 607-613.

[461] For example, this is the assumption behind some of the regressions in chapter 4.

[462] According to Cerdá (1968), pp. 562-570.

in handspinning and auxiliary tasks but not in handweaving (i.e. the fairly unskilled occupation). More to the point, women predominated in the domestic industry and men in the small shops. By contrast, in mills, in spite of their preponderance in low paid and unskilled jobs, many women were frequently to be found in skilled jobs such as mule-spinning or mechanical-weaving. Where they were paid the same piece-rates as men. In particular, Ildefonso Cerdá lists 16 jobs where he points out that women had the same competence as men. Only in three of 16, corresponding to mule-spinners, self-acting spinners and mechanical-weavers, did women have the same salary as men. This evidence proves that in cotton mills the labour market in skilled jobs was not generally segmented by sex. [463]

The main difference between men and women was that men filled the extra-paid posts in longer mules, monitoring, white-collar and machinery-maintenance. There was a large spectrum of variables that influenced this segregation of women from the extra-paid posts. Occasionally, for example in the longer mules, the physical exertion required was an unavoidable entry barrier for women.[464] The size of the spinning mule was extended until it made more efficient use of the adult male worker's physical capacities. Furthermore, in other posts, women had not been apprentices or had received no formal education (e.g. in machinist posts). It is well known that in Spain, at that period, the schooling rates of girls were lower than those of boys.[465] Finally, on other occasions, they were not recruited simply for social reasons (e.g. as overlookers). Here, since many women successfully monitored their own work group in spinning, it cannot be argued that they did managerial tasks worse than men.[466]

[463] Cerdá (1968), p. 646.

[464] Huberman, (1996), p. 35.

[465] Nuñez (1992).

[466] This contradicts the views of Lazonick (1979) and Huberman (1991b).

**Table 6.2** Composition of the Labour Force in Full-time Equivalent Employment: Cotton Spinning and Weaving , 1830-1861

| | Male | Female | Children | Total |
|---|---|---|---|---|
| 1830 | 19,579 | 19,628 | 9,205 | 48,412 |
| percent | (40.44) | (40.54) | (19.01) | (100.00) |
| 1840 | 23,480 | 24,718 | 11,684 | 59,882 |
| percent | (39.21) | (41.28) | (19.51) | (100.00) |
| 1850 | 32,655 | 18,662 | 7,637 | 58,955 |
| percent | (55.39) | (31.65) | (12.95) | (100.00) |
| 1861 | 29,720 | 13,047 | 3,682 | 46,448 |
| percent | (63.98) | (28.09) | (7.93) | (100.00) |

**Notes and sources:** Table 4.1.

In table 6.2 it is easy to appreciate the process of substitution of women and children by men. This process is related to two different facts On the one hand, the typical female occupations in the proto-industry, especially handspinning, disappeared more rapidly than male occupations, such as handweaving. On the other hand, many new jobs created with the arrival of factories were filled exclusively by men (e.g. engine-driver, overlooker, dockers). These new jobs were sometimes highly skilled jobs, which could not be filled by women for the reasons advanced above.

Data on sex, age, and skills was put together to establish the proportion of skilled and unskilled workers in the cotton industry, both factory and proto-industry. Here, eight categories have been established. Five categories correspond exclusively to factory workers: highly skilled male workers, skilled male workers, unskilled male workers, skilled female workers, and unskilled female workers. Proto-industry workers are divided into only two categories: men and women. Finally, the children category corresponds to workers under the age of 16.

The factory categories have been defined in the following way: highly skilled workers were workers employed in non-productive jobs (e.g. administration, maintenance) and had normally already received a formal education and/or an apprenticeship; skilled workers were those employed in the process of production that were in charge of machines (e.g. spinners, weavers) who had normally been trained within the same factories or in the proto-industry;

and unskilled workers were those employed in auxiliary tasks (e.g. carders, cleaners, dockers) and who were not trained in the cotton industry as children. Highly skilled and unskilled workers were wage-earners while skilled workers (and also proto-industry workers) were paid by piece-rate.[467] Moreover, skilled workers managed work groups while the unskilled were monitored by foremen or other workers.

My next task is to estimate the labour force cross-classified by up to seven skills attributes. First, I separate the workforce between proto-industry and factory workers. This separation has been established under the assumption that workers who used hand machinery were proto-industry workers and that workers who used other machinery were factory workers. Therefore, to obtain the number of full time equivalent workers in the proto-industry I multiply the amount of functioning hand machinery by positions per year per machine. Then, I make use of the information provided by the sources to divide the resulting figures into men, women and children.[468]

Second, I make use of the information provided by several historical sources on the occupations associated with each type of machinery to divide factory workers into several skills categories. Thus, for example, I actually estimate the FTE in 1861 self-actings cross-classified by sex and skills using available sources. For my final estimates I then sum across different machinery to derive a reduced table of the variables of interest to me.[469]

[467] Comisión especial arancelaria (1867) and Cerdá (1968).

[468] Gutiérrez (1834) and Figuerola (1968), Madoz (1846), Junta de Fábricas (1850), Gimenez Guited (1862) and Comisión especial arancelaria (1867), respectively, provided the data on hand-machinery for 1830, 1840, 1850 and 1861.

[469] Estimates of the working population cross-tabulated by class of machinery, sex, and skills were derived from Comisión de Fábricas (1846), Cerdá (1968), and from Comisión especial arancelaria (1867). Note that for 1830, skills by type of machine were assumed to be those reported in the 1840 data, the earliest year for which detailed data is available. Finally, it should be noted that, in weaving, factories were only important in the 1850s and that the different sources give very similar pictures of the skills composition of the workforce.

**Table 6.3** Skills Composition of Adult Workforce in Full-time Equivalent Employment: Cotton Spinning and Weaving, 1830-1861

| | Factory Highly Skilled Male | Factory Skilled Male | Factory Unskilled Male | Proto-industry Male | Factory Skilled Female | Factory Unskilled Female | Proto-industry Female |
|---|---|---|---|---|---|---|---|
| 1830 | 64 | 120 | 123 | 19271 | 1045 | 2493 | 16090 |
| percent | (0.16) | (0.31) | (0.31) | (49.15) | (2.67) | (6.36) | (41.04) |
| 1840 | 212 | 486 | 402 | 22381 | 3394 | 8049 | 13275 |
| percent | (0.44) | (1.01) | (0.83) | (46.44) | (7.04) | (16.70) | (27.54) |
| 1850 | 604 | 3128 | 1122 | 27803 | 2272 | 4629 | 11763 |
| percent | (1.18) | (6.10) | (2.19) | (54.18) | (4.43) | (9.02) | (22.92) |
| 1861 | 907 | 7915 | 1635 | 19261 | 2885 | 5073 | 5088 |
| percent | (2.12) | (18.51) | (3.82) | (45.04) | (6.75) | (11.86) | (11.90) |

**Notes and sources:** See text

The most outstanding result that emerges from table 6.3 is that in 1861, despite thirty years of factory workforce development with rapid growth rates (on average about 5 percent per year), proto-industry occupations were still important, with about 55 percent of the total. Until the 1850s, the development of the factory workforce was accompanied by a parallel increase in proto-industry labour. This was because in the first twenty years handweaving benefited from the expansion of mechanical spinning, which decreased the price of yarn, and increasing the markets for cotton goods. In effect, handweaving was only strongly damaged by the factory expansion of the 1850s, when mechanical looms took over coarse-medium cloth production, but handweavers remained numerous until at least the 1870s. When Catalan mechanical looms also began to produce fine cloth.[470] Therefore, due to this partial substitution of handweaving by mechanical weaving, highly skilled hours formed only 2 percent of the total hours in 1861 and skilled hours (male and female) formed 26 per cent. In response to these features, one might argue that human-capital supply bottlenecks restricted the development of the factory system. However, available evidence gives little support to this assertion. In weaving, the survival of a large number of artisans guaranteed the continuous availability of skilled workers. This was not true in spinning, where artisans had practically disappeared in only a few years (by the mid-1840s). Furthermore, the number of children trained at factories largely exceeded the demand for new skilled workers from the same

[470] Comisión especial arancelaria (1867).

factories.

A secondary result is that the growth of the skilled (highly skilled and skilled) workforce was more rapid than the unskilled one, which only represents a minor portion of the total workforce at the end of the period. This result gives strong support to the argument advanced in chapter 4; that is, the existence of capital-skills complementarity in the emergence of the factory system.

The final test concerning the demand for skills can only be made by computing the changes in the remuneration of productive factors (raw labour, human capital and physical capital). Two of the possible outcomes are related to changes in the demand for skills: (1) if raw labour and physical capital remunerations rose while human-capital dropped, the new machinery had a de-skilling effect, (2) if human and physical capital remunerations increased while raw labour diminished, the new machinery increased the demand for skilled labour.

Human-capital remuneration is assumed to be labour minus the part of raw labour. Raw labour remuneration is the result of the sum of the total of hours of male work multiplied by the male hourly wage of unskilled cotton workers between 16 and 20 years old, plus the total hours of female work multiplied by the female hourly wage of unskilled cotton workers between 16 and 20 years old, plus children's earnings. This measure of raw labour is based on three points: (1) unskilled cotton workers between 16 and 20 years were not trained, (2) the differences between males and females must be reflected in the account, (3) the measure of raw labour must be based on data from the same cotton industry to avoid distortions caused by labour market failures. In contrast, other economic historians[471] have established the remuneration of raw labour as the wage of agrarian labourers. It should be noted that, in this case, the average male agrarian wage in the province of Barcelona was about 90 percent of that of unskilled workers in the cotton industry. [472]

The human-capital share was also separated into two sub-shares. Specifically, the share

[471] Crafts (1995).

[472] See chapter 4.

improvements into the analysis by considering intermediate inputs, subdividing inputs by type, and then weighing each type by its imputed return.[475] Here the new theory is combined with the above methodological improvement to create a single growth accounting equation. This is done by dividing labour into raw labour and human capital parts, thus simultaneously considering changes in input quality. Specifically:

$$(6.1) \quad \ln Q(T) - \ln Q(T-1) = \Theta_X[\ln X(T) - \ln X(T-1)] + \Theta_K[\ln K(T) - \ln K(T-1)] + \Theta_L[\ln L(T) - \ln L(T-1)] + \Theta_H[\ln H(T) - \ln H(T-1)] + TFP_{T-1,T},$$

where:

$$\Theta_i = 1/2[\theta_i(T) + \theta_i(T-1)].$$

Here Q is output, X physical intermediate inputs, K capital, L labour, H human capital, TFP the Total Factor Productivity and $\Theta_i$ denotes the share of each input in total factor payments. The index of TFP ($TFP_{T-1,T}$) is a measure of the increase in output attributable to innovation; in other words, it is the increase in output triggered by a time-related shift in the production function.

The appropriate measure of physical capital, human capital and labour inputs is the flow of services emanating from these inputs. Moving to labour input, one can reasonably assume that the flow of services is proportional to the total hours of work. The contribution of the raw labour input is estimated as the arithmetic sum of hours worked, with no adjustment for labour quality, multiplied by its share in total payments. Likewise, the contribution of human capital is computed as an index of human capital, where the price part is the remuneration of human capital in each category of workers. The quantity part is the quantity of hours worked cross-tabulated by sex, age and skills. Moreover, each category is weighted by its earnings premium over the raw labour wage (i.e. the wage of unskilled workers from 16 to 20 years). Specifically, human capital rises if the components with higher flows of labour input per hour worked grow more rapidly, and falls if components with lower flows per hour grow more rapidly. For example, in this paper it is hypothesised that, because

[475] Jorgenson (1990). For a full discussion of these advances see chapter 5.

the average wage of a male highly skilled worker was higher than that of a male skilled worker, the direct substitution of a skilled male worker by a highly skilled male worker entails an increase in the use of human capital in the aggregate production function.

**Table 6.5** Augmented Solow-type Growth Accounting: Cotton Spinning and Weaving, 1830-1861

| | Contributions to growth (percent rates per year) | | | | | |
|---|---|---|---|---|---|---|
| | Output | Physical Inputs | Physical Capital | Human Capital | Raw Labour | TFP |
| **Spinning** | | | | | | |
| 1830-40 | 7.02 | 3.74 | 0.92 | 0.20 | 0.45 | 1.71 |
| 1840-50 | 7.65 | 4.50 | 1.52 | 0.04 | -0.38 | 1.96 |
| 1850-61 | 3.29 | 2.03 | 0.84 | 0.00 | -0.17 | 0.59 |
| 1830-61 | 5.90 | 3.32 | 1.12 | 0.11 | -0.15 | 1.45 |
| **Weaving** | | | | | | |
| 1830-40 | 8.57 | 4.11 | 0.54 | 0.13 | 0.36 | 3.43 |
| 1840-50 | 9.68 | 4.81 | 0.29 | 0.27 | 0.31 | 4.02 |
| 1850-61 | 2.93 | 2.22 | 0.09 | -0.16 | -0.29 | 1.07 |
| 1830-61 | 6.93 | 3.84 | 0.41 | 0.22 | 0.06 | 2.40 |

**Notes and sources:** See appendix.

Table 6.5 compiles the contributions to growth in the Catalan cotton industry. Two main conclusions emanate from these results: (1) TFP was the factor that grew more rapidly, (2) the growth of human capital was slow or, in some cases, even negative. Consequently, table 5 tends to confirm more than reject the results obtained previously with the descriptive techniques and the results of growth accountings of chapter 5. That is, the main source behind the Catalan industrialisation was total factor productivity growth. It is also interesting to see that there are very few connections between the human capital contribution and the TFP contribution. In other words, it is unlikely that the shifts in human capital could explain the shifts in total factor productivity.

Some interpretations of TFP growth in the Catalan cotton industry can be derived from these results. The first implication is related to the fact that TFP clearly appears to be the main ingredient in the years of output expansion. As mentioned above in chapter 5, these years of strong expansion of output and TFP were associated with important structural changes in the sector that altered the organisation of the firms, markets and labour. The main change during these years was, precisely, the emergence of the factory system. In other words, the substitution of putting-out with the factory system formed the basis of the development of industrialisation and the growth of industrial output.

The second implication is that innovation in the new industries in the first half of nineteenth century had strong multiplicative effects. For instance, the adoption of some innovations in the cotton industry produced large effects on the growth of output. Contemporary experience is quite different because to achieve greater effects, long-term research projects and extensive human capital are necessary. In the nineteenth century, the effects of innovation were greater and more immediate. Therefore, with relatively low investments in physical and human capital, leading European regions could grow.

### 6.6 Concluding Remarks

The overall balance-sheet of human capital in Catalonia during the emergence of the factory system is still uneven. On the one hand, the level of human capital present in the cotton industry was enough to adapt most modern foreign technologies and to fill the skilled posts in the new factories with native workers. For instance, after a short period of training for the new technologies, all machinery-maintenance posts were filled by Catalan workers. On the other hand, no less important is the fact that human capital appears to contribute little to output growth; in other words, the overall level of human capital in the cotton industry did not rise much during the period.

The presence of this initial stock of human capital is one major explanation for why the economic and political crisis of the first thirty years of the nineteenth century was not enough to impede Catalan industrialisation. In all likelihood, the main development advantage of Catalonia over other Spanish and European regions was, precisely, this stock of human capital.[476] Therefore, it is possible on the basis of the evidence presented to make some considerations as regards proto-industrialisation theory. In the original formulation by Frank Mendels the main contribution of proto-industry to the new industry was in terms of unskilled labour force.[477] In other words, the proto-industry furnished the new factories with abundant and cheap labour. On the contrary, the evidence for Catalonia suggests that the proto-industry provided the new Catalan factories with the necessary human-capital to introduce the new technologies. It was possible to adapt prior training to the technical requirements of the factories because there were more similarities than differences between proto-industrial and factory technologies. Furthermore, some new factory technologies were also adapted for proto-industrial use.[478]

A methodological corollary of this growth-accounting exercise is that it is easier to be sceptical about the restriction of the concept of human capital to that of formal education during almost all the nineteenth century. Thus, it is important to appreciate that the emergence of the factory system during the past century had the potential of filling some important gaps in the historical analyses of human capital. In truth, it shows that the 'educational' definition of human capital is very restrictive because the role of formal education (schooling) was limited in many proto-industrial households, factory jobs and, by extension, during the early phases of industrialisation. While a vast literature, accumulated over the last decades, contains a wealth of findings on the growth rates of schooling (enrolment and participation rates), corresponding estimates of on-the-job training and learning have not been constructed. Instead, the growth of participation or enrolment rates has been assumed to reflect human-capital accumulation during the nineteenth century.

Finally, the limitations of the model employed in the emergence of the Catalan factory system should also be stressed. In reality, this model was not able to sustain a new shift in

[476] Mitch (1990), p. 33 has said: 'Successful industrializers commonly drew on a stock of workers skilled in more traditional artisanal methods, while economies that had difficulty industrializing may have encountered problems because of the restricted supply of workers whose skills were acquired on the job'

[477] Mendels (1972).

[478] Berg (1985).

the output and in the quality of the production in the long-run because the Catalans were not able to produce original technology with their stock of human capital. Therefore, Catalan industrial firms were only capable of adapting and modifying foreign technologies with more similarities than differences with the technologies employed at that moment. Only with the development of formal technical training could the Catalans develop this innovative capacity in the long term. Entrepreneurs were aware of this problem and one of them said to a government commission in 1867:[479]

> Our managers had to make use of several technicians from foreign countries. The indifference in Spain towards the study of applied mathematical and natural sciences impedes our industrial firms in organising a numerous and sufficient national skilled workforce in order to satisfy all production requirements. It should be acknowledged that this (skilled workforce) is a main element in the development and the prosperity of any kind of industry and that it has to be found at any cost, even out of our borders where is abundant.

[479] Comisión especial arancelaria (1867), p. 83.

## Appendix to Chapter 6: Methods and Sources for Augmented-Solow Growth Accounting

**Output:** Divisia index of output with six homogeneous categories of product. Spinning quantities are based on yearly imports of raw cotton with variable wastage calculated according to the method of Huberman.[480] Weaving figures are yarn production minus yarn employed by the mixed fabrics and hosiery industries.[481]

**Physical inputs:** Divisia index of inputs with five homogeneous categories plus energy.[482]

**Physical capital:** Divisia index of real capital with six homogeneous categories (factories, workshops, modern machinery, hand machinery, engines, and inventories) weighted with rental rates (with geometric depreciation). The results are robust to changes in depreciation rates and alternative rental rates.[483]

**Human capital:** Divisia index of real human capital with 56 categories (cohort x sex x skills) weighted with relative incomes exceeding the raw labour wage.

My first task is to estimate the working population, cross-classified by up to three attributes, i.e. sex, age and skills. Under the assumptions that the life expectancy of all kinds of workers is the same and that they remained in the industry all their lives, I derive an approximation of the age distribution of the workforce for each benchmark year (1830, 1840, 1850, 1861). Because age-specific mortality was higher for unskilled than skilled workers, my first assumption will produce an underestimate of human capital. By contrast, the second assumption will produce an overestimate of human capital to the extent that workers left the cotton industry.

I use three sets of numbers: the total number of FTEs in each benchmark year, the age

[480] Huberman (1996), pp. 107-109.

[481] For a full description of the sources and methods see chapter 2.

[482] For a full description of the sources and methods see previous chapter 2.

[483] See chapter 3 for a description of the sources and methodology.

distribution of the Catalan cotton industry workforce, and the survival tables for Catalonia. The total number of FTEs is in table 4.1. The age distribution of the Catalan cotton industry workforce is drawn from Camps (1995, table 10, p. 166), Barnosell *et al.* (1994) and Ferrer (1994). It should be noted that the age distribution is different for proto-industry and factory workers. Finally, the survival tables are drawn from Muñoz (1991).

The second task is to estimate the remuneration of human capital in each category of workers. I begin by constructing estimates of the average hourly incomes of employees cross-tabulated by industry (proto-industry and factory, spinning and weaving), adult-child, sex, and skills. I then use the figures of Camps (1995), pp. 198-204 on wage profiles for highly skilled, skilled, and unskilled male and female workers to estimate the variation in incomes of employees due to age. Therefore, relative incomes by worker age are assumed to be constant at the levels reported in Camps (1995). Finally, I deduct the part of remuneration that corresponds to raw labour (initial hourly wages of workers; that is, the minimum wage at each occupation).[484]

**Raw Labour:** Unweighted hours worked (see text).

**Shares:** Current values at wholesale prices minus taxes. Capital share has been computed as the residual of total value minus physical inputs, human capital, and raw labour values.

[484] The sources are: for 1830 Madoz (1846) and Comisión de fábricas (1846), for 1840 Madoz (1846) and Comisión de fábricas (1846), for 1850 Cerdá (1968) and for 1861 Comisión especial arancelaria (1867).

## Chapter 7

## The Emergence of the Factory System

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This chapter examines the gains in efficiency associated with the emergence of the factory system in an attempt to explain how total factor productivity improvement took place in Catalonia during the period of early industrialisation. Three major conclusions will be reached. First, there was a connection between the enlargement of the size of industrial establishments (i.e., the adoption of the factory system) and the substantial productivity gains in the early phase of Catalan industrialisation. Second, in modern industries, such as the cotton industry, the emergence of factories and associated productivity gains were previous to the adoption of the new machinery. Therefore, some productivity improvement was independent from the adoption of the sources of central motive power (i.e., it was non-embodied in capital goods). Third, some of the superior productivity of the Catalan industry can be explained by the larger than average size of the Catalan industrial establishments.

For different reasons the questions of this chapter are not without interest. The question is not confined to whether one type of firm was more efficient than another. The main issue is whether substantial economic growth was realised by industrialising economies prior to the diffusion of new machinery, and to what extent this early phase of industrialisation was driven by increases in productivity achieved through changes in the organisation of the manufacturing labourforce. This reorganisation of labour gives an empirical explanation for the large total factor productivity rates of the early industrialisation period in Catalonia. Recently, Kenneth Sokoloff and Gregory Clark have linked the productivity gains of early industrialisation to the development of new forms of organisation.[485] However, as on other occasions, evidence has been circumscribed to the U.S. and British cases. Therefore, this study can throw light on the influence of this kind of innovation on other process of industrialisation, especially those that took place in Mediterranean regions.

### 7.1. Introduction

The story of early industrialisation has often been explained around the theme of technical innovation in machinery. The discovery of new spinning and weaving techniques, the innovations in iron making and power generation, the improvements in freight transportation and so on have been considered the most spectacular outcomes of these early years.[486] However, if one looks at these technological innovations from the present-day, all these inventions have capitulated to the passage of time with the arrival of new discoveries. For example, the ring spinning substituted the spinning mule, the automatic loom substituted the powerloom, electrical motors and Diesel engines replaced the steam engine. Instead, the major innovation in business institutions of early industrialisation, the factory system, has not only survived until the present-day, but still has the control over the production of industrial goods.

The term factory has been defined in several different ways. Some have chosen a narrow technical definition. Thus, according to A. Ure, 'the term Factory, in technology, designates the combined operation of many orders of work-people, adult and young, in tending with assiduous skill a system of productive machines continuously impelled by a central power.'[487] Others have emphasised the type of authority relationship prevalent in factories. Viewing the presence of wage-earners controlled by bosses and the ownership division between labour and capital characterising the factory.[488] Note that this definition is rather restrictive since, according to this view, some present-day large establishments that

[485] Clark (1984)(1994) and Sokoloff (1984a)(1986).

[486] Ashton (1962), Pollard (1965), Landes (1969), and Mathias (1969).

[487] Ure (1836), pp. 13.

[488] See, for example, Clark (1994).

sometimes use sub-contracting must not be considered factories. Less restrictive definitions have also been adopted. In particular, Williamson defined factories in terms of ownership. Thus, the capitalist mode of production (factories) involves that 'inventories of all kinds (raw materials, intermediate product, finished goods) as well as plant and equipment are owned by a single party.'[489] He also distinguishes two sub-categories: inside contracting and authority relation. 'Under the system of inside contracting, the management of a firm provided a floor space and machinery, supplied raw material and working capital, and arranged for the sale of the final product. The gap between raw material and finished product, however, was filled not by paid employees arranged in [a] descending hierarchy ... but by [inside] contractors, to whom the production job was delegated. They hired their own employees, supervised the work process, and received a [negotiated] piece rate from the company.'[490] Instead, the authority relation implies capitalist ownership of equipment and inventories combined with an employment relationship between entrepreneur and worker.[491]

In this chapter, two strong reasons have decided the choice of the less restrictive definition that was proposed by Williamson. First, this definition is the most useful in discussing the reasons behind the emergence of the factory system since it does not directly imply the technology answer. Second, for those involved in industry in Catalonia, the term factory usually referred to premises in which several people (habitually, ten or more) worked for an entrepreneur who possessed the various inventories.[492] Some had machinery and central motive power and some had not. Moreover, in some Catalan factories the authority relation dominated, in others inside contracting was common, and many others combined these the systems. In other words, Williamson's definition correlates more with the contemporaries' view than the other restrictive definitions.

[489] Williamson (1986), pp. 218.

[490] Buttrick cited by Williamson (1986), pp. 218.

[491] Williamson (1986), pp. 218.

[492] For example, the Catalan census (e.g. Junta de Fábricas (1850)) registered all establishments with more than 10 workers independently from their source of motive power or the existence or not of an authority relation within the shop floor.

Before the arrival of the factory system, the family-firm craftshop and the putting-out or outwork system were the only forms of business organisation in the industry. These two business institutions were based on decentralised small units and little division of labour. Under artisanal production, a master craftsman with a few assistants, who were sometimes members of his family, ran a small unit-of-production. In these shops the extent of the division of labour was little and, hence, the same worker performed several different tasks and could make the whole product. The putting-out system was characterised as a decentralised production organisation where the producers used their own tools, and where work was localised to their own homes. Two main types of putting-system can be found. In the *verlag-system* the putter-out puts out raw materials or semi-finished goods to a producer and, at least to some extent, plays a supervisory role. In the *kauf-system* the entrepreneur only collects the finished wares and sometimes supplies the producer with credit.[493]

The rest of the chapter is organised into three main parts. Section 7.2 discusses the literature on this topic. In section 7.3 I estimate scale economies to demonstrate that large establishments were more efficient than small establishments. Section 7.4 presents three different case studies: cotton spinning, mixed-fabrics and cotton weaving, and cotton finishing. Here, I show that there was a tendency for plant sizes to grow. Furthermore, I show that factories existed before the adoption of centralised sources of motive power. The rest of the chapter is devoted to comparing Catalonia with the rest of Spain. Thus, in section 7.5, I present evidence for 1861 on the average size of the Catalan establishments. The subsequent question discusses why were manufacturing establishments larger in catalonia than in other Spanish regions? Finally, the last section summarises and concludes.

### 7.2. The Emergence of the Factory System in the Literature

As mentioned above, the major innovation in business institutions during early industrialisation was the emergence of the factory system. Many economic historians and

[493] This division into two major categories is based on Kriedte *et al.* (1981).

economic theorists have discussed the effects, the nature, and the causes of this innovation. In the next pages I review the debate, underline some stylized facts, and present the implications for our understanding of the early phase of Catalan industrialisation. This section will confine itself to the discussion of theory rather than historical and empirical issues, since these will be examined in further sections.

In broad terms, there are three views on the emergence of the factory system. Some authors reject the arguments that the emergence of the factory system was associated with efficiency gains. Others argue that the emergence of the factory system resulted in efficiency gains. But do not accept that the development of the nonmechanised factories represented a significant technical or organisational advance over previous forms of organisation. In other words, they associate the efficiency gains of the factories with the adoption of central sources of motive power. Finally, the last group considers that the development of both mechanised and nonmechanised factories provided a more efficient method of producing manufactured goods.

To marxists, the factory represents a further decisive step in the divorce of the worker from control over the means of production. The leading proponent of this view is Stephen Marglin. He argues that the capitalist division of labour was not the result of a search for a technologically superior organisation of work. But for an organisation that guaranteed the entrepreneur an essential role in the production process, as the integrator of the separate efforts of his workers into a marketable product.[494] Marglin is arguing that the emergence of factory system was due to social determinants. Note that according this view productivity improvement was not a necessary outcome of the emergence of more centralised and hierarchical forms of production, such as the factory system, and that the entrepreneur was unnecessary.[495]

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[494] Marglin (1974), pp. 62ff.

[495] In the following paragraphs I only discuss the implications of the efficiency argument and not the debate on the role of entrepreneurs. A severe critique of Marglin's statements on the role of the entrepreneur is furnished by Landes (1986). See, also, a review of the debate in Berg (1991b).

Others see the emergence of the factory as 'the necessary outcome of the rise of machinery'. This view came from the pioneering economic historians and was broadly accepted by subsequent scholars such as Sidney Pollard, David Landes, Peter Mathias and S.R.H. Jones.[496] They argue that the low thermal efficiency and large size of early steam engines required the collection of a labourforce under one roof. The basic argument is that the new technologies introduced obvious economies of scale, and that this led to factory production. For example, Landes stresses that it was 'the muscle: the machines and engines'[497] that made the factory system in Britain successful. While, in the words of Jones, 'the pace of technological change appears to have been a major determinant of the speed with which factory production was adopted.'[498] Chandler takes the extreme position on this argument arguing that the division of labour and the introduction of the factory system into nonmechanised industries only accounted for minor increases in efficiency.[499]

Note that the 'machinery argument' has a strong implication for our understanding of Catalan industrialisation. If machinery innovations were the cause of widespread organisational innovations. Then in the follower countries (such as Catalonia) the introduction of the British machinery led to the development of the factory system. In other words, organisational innovations were as 'exogenous' as machinery innovations and the path of the development of the factory system must follow the chronology of the adoption of the British machinery. However, this does not seem the case because, before the adoption of the steam engine the spinning mule and the powerloom in the 1830s, the Catalan cotton industry developed some forms of organisation that allowed a concentration of the workforce and increased the scale of firms. For instance, in the eighteenth century, without central sources of motive power (i.e., the steam engine and the water wheels), calico printing was centralised in some large concerns.[500]

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496 Ashton (1962), Pollard (1965), Landes (1969), Mathias (1969) and Jones (1982)(1987)(1992).

497 Landes (1986), pp. 606.

498 Jones (1987), pp. 94.

499 Chandler (1977).

500 See, for example, Thomson (1992) and Sánchez (1989)(1996).

Thermal economies of scale were evidently one facet of the history. It is regarded as beyond dispute that in some industries, such as iron foundries, centralisation was directly connected to the discovery of technologies characterised by economies of scale and indivisibilities. However, thermal economies of scale are not the whole story. Many authors see the adoption of machinery as a consequence, not the cause, of the innovations in business institutions.

The position that the gains from the division of labour were previous to the adoption of the new machinery can be traced back at least as far as Adam Smith. In his account of the causes of the wealth of nations, Adam Smith considers the role of machinery as important. But secondary and subsidiary to the increasing division of labour. Basically, Smith did not theorise but attempted to explain the world around him. Since the division of labour was common in manufacturing when he lived, some years before the triumph of the machinery innovations.[501] He emphasised the benefits of the division of labour with the famous example of pinmaking. In pinmaking, each worker specialises in a particular operation and this produces a large increase in productivity.[502] Note that technology in pinmaking is extraordinary simple; consequently, machinery plays practically no role in deciding the forms of work organisation. In other words, since the tasks and tooling are relatively uncomplicated, and successive stages are technologically separable, pinmaking is suitable for centralised and decentralised business institutions. However, the example as it was originally discussed by Smith is unconvincing. As Stephen Marglin and Oliver E. Williamson have recently emphasised. The separate elaboration (batch-processing) of each pin is quite absurd.[503] Marglin argues that: 'It appears to have been technologically possible to obtain the economies of reducing set-up time without specialization. A workman, with his wife and children, could have proceeded from task to task, first drawing out enough wire for hundreds or thousands of pins, then straightening it, then cutting it, and so on with each successive operation, thus realizing the advantages of dividing the overall production process

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[501] Szostak (1989), pp. 350.

[502] Jones (1987), pp. 71. discusses the opportunity of the pinmaking example. He argues that this was an irrelevant industry in early industrialisation.

[503] Marglin (1974), pp. 38; and Williamson (1980), pp. 9.

into separate tasks.'[504] It seems that Smith missed something in his pinmaking example.

Marglin's and the machinist's arguments have been disputed by Oliver E. Williamson.[505] In particular, Williamson argues that the hierarchically organised factory was better at quality control, reduced inventories, saved transport costs and allocated work more efficiently than decentralised forms of work organization. At least when compared to putting-out or the workshop. Furthermore, the rationalisation of production within the factory enables entrepreneurs to perceive where technological improvements might be made, thus reducing the costs of innovation. In a few words, Williamson sees the emergence of the factories as a consequence of their transaction-cost advantages and efficiency superiority, not a result of class criteria or thermal economies.

Recently, Williamson's arguments have been repeatedly discussed. On the one hand, Jones and others emphasise the problems of empirically testing Williamson's theory. Jones convincingly argues that the adoption of the factory system took place in a framework where all kinds of costs were important, not only transaction costs.[506] Moreover, he underlines that putting-out was sometimes superior to the factory as a form of organisation in terms of transactions costs. For example, when markets fluctuate severely or when there is great seasonality of labour supply, putting-out has shown itself to be superior to the factory system.

On the other hand, Leijonhufvud and Szostak have refined some aspects of the original transaction-cost thesis. Leijonhufvud recovered Adam Smith's division-of-labour hypothesis by discussing the economies achieved by switching from crafts to factory production. He argues that the switch is capital-saving because the factory system gives the opportunity to economise on work-in-progress inventories. Moreover, it also saves on human capital since no worker need possess all the skills required to make the complete product. The skills needed to perform each single operation can be quickly acquired whereas, under

[504] Marglin (1974), pp. 38.

[505] Williamson (1980)(1983).

[506] Jones (1997), pp. 15.

crafts production, each individual had to spend years of apprenticeship before becoming a master of all the different operations. Equally important is that skilled workers can employ their whole time in skilled operations, because they do not have to spend time in unskilled tasks.[507] Szostak claimed that factories were not inherently more efficient than cottage production. Factories only became the best method of production when transport improvements increasingly favoured factories.[508]

Yet it is clear from our previous discussion that the choice between decentralised and centralised forms of production is far from clear cut. The substitution of the factory system for putting-out and craft workshops was mainly due to the advantages of the former in terms of transaction costs. But not exclusively, in several industries machinery and scale considerations might also have played a role. The inherent advantages of the division of labour and the extent of markets are two major ingredients. However, there is general agreement on the fact that the emergence of the factory increased the efficiency of production and helped the adoption and development of technological innovations. It saved on human and physical capital and then allowed a more efficient allocation of these scarce resources.

The arguments of Williamson, Szostak and Leijonhufvud have clear repercussions on our perception of early industrialisation in Catalonia. First, because they define organisational innovations as independent of machinery innovation. That is, they explain part of the disembodied component of productivity growth. Secondly, because they give a list of conditions under which the adoption of factories was more likely to happen. In particular, the efficiency hypothesis appears to be highly relevant and merits detailed attention. And, finally, because they provide a framework to understand why and how organisational innovations affected productivity and industry growth.

It should be noted that several Catalan economic historians devoted some attention

[507] Leijonhufvud (1986).

[508] Szostak (1989)(1992).

to the development of business institutions in Catalonia during early industrialisation. Jordi Nadal and Jordi Maluquer de Motes agree with the 'muscle' argument of Landes; that is, organisational innovation was a consequence of the adoption of British machinery.[509] A different view emerges from the works of Alex Sánchez since he shows that the adoption of centralised forms of production was previous to the introduction of steam engines.[510] However, none have considered the importance of innovation in business institutions for productivity growth. This is precisely the argument that I would like to develop in the further sections.

### 7.3. Testing the Efficiency of the Factories: Estimates of Returns to Scale

The most straightforward method of investigating whether productivity (efficiency) was influenced positively by the presence of factories (mechanised or nonmechanised) is the estimation of production functions. In other words, if large establishments (factories) were indeed more efficient than artisanal shops and domestic units-of-production (putting-out), production functions should furnish evidence of returns to scale.[511] Moreover, the presence of scale economies must be widespread in the modern sectors, even if they were not mechanised. Finally, one should also expect that economies of scale in the industries with small establishments (traditional industries) would be exhausted a moderate level of output.

Several alternative tests of the existence of economies of scale are possible. The estimation of either cost of production functions provides the necessary and sufficient information for a test of the previous argument. In the absence of knowledge about the appropriate cost of capital and wages, this chapter relies upon the estimation of production functions. Specifically, Cobb-Douglas and Translog production functions can be tested. The main advantage of the Translog over Cobb-Douglas is that it allows the estimate of the scale

[509] Nadal (1974), Maluquer (1976)(1998).

[510] Sánchez (1989)(1996). See also Grau and López (1975) and Thomson (1992).

[511] See, on the methodological aspects Griliches and Ringstad (1971). Similar exercises have been already performed for the United States by Atack (1977)(1987) and Sokoloff (1984a), and for France by Nye (1987) and Sicsic (1994).

coefficient to vary over firms.[512] In other words, the conventional estimation technique of the logarithmic transformation of the standard Cobb-Douglas only provides information on the conditions facing the median firm.

The only datasource available for the period that furnishes enough evidence to estimate these functions for several industries is Gimenez Guited's *Guia fabril e industrial de España*.[513] It collects data for the year of 1861 in 13 different industries at provincial and national level.[514] Moreover, the most important establishments were all enumerated in the respective provincial sections; thus the source describes establishments and not firms. The published tables report the value of annual output and the number of employees (broken down into men, women, and children), but do not give the number of days worked. The physical quantities of outputs (tons of yarn, yards of cloth, pounds of flour, and so on) are also often reported along with the number of machines, establishments and engines (broken down by looms, spindles, windmills, and other machines). But their power is only reported at the industry-level. The amount of capital reported was not only function of the size of buildings, but also of the machines and engines in the buildings.[515]

Unfortunately, the data is only furnished at provincial levels since the establishments data enumerated only the number of workers (without distinguishing men, women, children), the amount of machinery (broken down by class) and the capital invested in machinery (in the source called *capital representado*). Furthermore, not all establishments were recorded, since in several provinces, especially those with a small number of establishments, many small establishments were included in collective observations although the source clearly stated the total number of establishments in each collective observation. Data at provincial level is not furnished for the provinces of Navarre, Alava, Guipuzcoa, and Vizcaya but

[512] Griliches and Ringstad (1973).

[513] Gimenez Guited (1862).

[514] The quality of the data for Catalonia was already discussed in chapter 3. The conclusion was that the figures are acceptable.

[515] The description of the procedures to impute total capital from the value of machinery are given on Gimenez Guited (1862), pp. 8ff.

several national enumerators include them. A major problem is that the transference of intermediate inputs among provinces is not recorded since output data is based on the concept of sectoral output. It is obvious that this problem calls for adjustments when calculations.

In order to estimate returns to scale, I begin with the conventional formulation of the Cobb-Douglas production function:

$$(7.1) \qquad VA = AK^{\gamma}L^{\beta}.$$

Where VA is value-added, A is the intercept, L is labour input, and K is capital. From this form one can easily derive the following more operative form:

$$(7.2) \qquad \ln VA/L = \ln A + s\ln L + \beta \ln K/L$$

This equation has the advantage that the coefficient on labour ($s$) yields a direct test of economies of scale since:

$$(7.3) \qquad s = (\gamma + \beta) - 1$$

Habitually, this function is estimated with ordinary least squares. In this case this does not seem convenient because each province-based observation corresponded to the aggregation of many plant-level observations.[516] Consequently, I prefer to perform weighted least squares estimation with the weights given by the number of establishments in each cell. In addition, I also estimated two more equations by including industry (i.e, 12 dummy variables) or regional dummies (i.e., 6 dummy variables). These help control for effects such as: unobserved quality of labour inputs, seasonal unemployment, and unrecorded variation in the value of output or value-added. All of which might be correlated with the locality or/and industry.[517] The results of these three equations are presented in the table 7.1.

[516] See Greene (1993).

[517] This solution was implemented by Sokoloff (1984a) and Sicsic (1994).

**Table 7.1** Estimation of Cobb-Douglas Production Functions: Spanish Manufacturing, 1861

| | without dummies | | with industry dummies | | with region dummies | |
|---|---|---|---|---|---|---|
| | Coeff. | t-stat. | Coeff. | t-stat. | Coeff. | t-stat. |
| Constant | -0.413 | -0.348 | 0.188 | 5.198 | -0.030 | -0.238 |
| log(labour) | 0.136 | 8.980 | 0.073 | 4.152 | 0.102 | 6.352 |
| log(capital/labour) | 0.258 | 10.148 | 0.028 | 7.487 | 0.269 | 11.120 |
| N observations | 333 | | 333 | | 333 | |
| R2 adjusted | 0.360 | | 0.566 | | 0.453 | |
| MAE | 2.700 | | 2.164 | | 2.581 | |
| F-test | 94.529 | | 34.385 | | 35.433 | |

**Notes and Sources:** The dependent variable is the natural logarithm of value-added divided by labour. Coeff. is the coefficient of the variable and t-stat is the t-statistic. All equations are estimated by weighted least squares with weights given by the number of establishments in each observation. To derive from the original sectoral output figures the value-added figures it has been employed the coefficients of Prados (1988), except where I already estimated my own coefficients (see the previous chapter 2). Labour figures are a weighted aggregate of the male, female and children figures with the weights of the appendix of the chapter 5 plus the entrepreneurial input. A complete description of the regions is available in table 7.11.

The results are striking. First, and most important, all three regressions yield a statistically significant finding of economies of scale, with the scale coefficient ranging from 1.07 to 1.13.[518] This result gives support to the argument that there were gains in increasing establishment-size and, hence, that factories were indeed more efficient. However, the explanatory power of the equation is strongly improved by including the industry dummies. Of course, this result gives some support to the existence of a differential in the scale economies between modern and old industries. In table 7.2 this argument will be directly tested.

[518] These scale coefficients are very similar to those computed by Sokoloff for the United States with data for 1820 (Sokoloff (1984a), table 5, pp.364) but smaller than those computed by Sicsic for France with data for 1850 and 1861-1865. Sicsic (1994), table 7 and 8, pp. 468-469 and 472-473.

**Table 7.2** Estimation of Cobb-Douglas Production Functions: Spanish Modern and Traditional Manufacturing, 1861

| | Traditional industries | | Modern sectors | |
|---|---|---|---|---|
| | Coeff. | t-stat. | Coeff. | t-stat. |
| Constant | 0.194 | 0.964 | 0.250 | 1.894 |
| log(labour) | 0.022 | 2.931 | 0.083 | 4.552 |
| log(capital/labour) | 0.096 | 4.179 | 0.452 | 14.074 |
| N observations | 183 | | 150 | |
| R2 adjusted | 0.153 | | 0.702 | |
| MAE | 2.428 | | 1.911 | |
| F-test | 5.113 | | 177.159 | |

**Notes and Sources:** See the previous table 7.1. Modern industries are textile, paper and metal industries, and the remaining industries formed the traditional sector. Traditional industries equation includes regional dummies to improve the quality of the results.

The econometric results presented in table 7.2 are even clearer than the result of table 7.1. In the case of the traditional industries, the scale coefficient is not significant, whereas in the modern industries it is highly significant. In other words, the small traditional sectors had exhausted their scale economies by 1861 whilst in the modern sectors there still scale economies. Note that this result supports the view that increasing the size of the modern industries, as happened in Catalonia in this period, achieved gains in efficiency.

I now move to the Translog equation. Whose main advantage is the relaxation of many of the implicit assumptions of the Cobb-Douglas function. However, in this case, it would not change the overall conclusion. After taking logarithms, the Translog production function has the form:

$$(7.4) \qquad \ln VA = \alpha_0 + \alpha_l \ln L + \alpha_k lnK + \frac{1}{2}\beta_{ll}(lnL)^2 + \frac{1}{2}\beta_{kk}(lnK)^2 + \gamma_{lk} lnL lnK.$$

Where the scale economies ($s$) can be solved for:

$$(7.5) \qquad S = \alpha_l + \alpha_k + 2\beta_{ll}L + 2\beta_{kk}K + \gamma_{lk}(L+K)$$

It should be noted that the scale coefficient varies with the size of the establishment.

Translog production functions for both traditional and modern industries are presented in table 7.3.

**Table 7.3** Estimation of Translog Production Functions: Spanish Modern and Traditional Manufacturing, 1861

| | Traditional industries | | Modern sectors | |
|---|---|---|---|---|
| | Coefficient | t-statistic | Coefficient | t-statistic |
| Constant | 0.9392 | 0.8487 | 0.6911 | 1.2526 |
| log(capital) | 0.0035 | 0.0093 | 0.7051 | 4.2663 |
| log(labour) | 1.0863 | 3.1191 | 0.1890 | 0.7214 |
| log(capital)2 | 0.0720 | 2.5494 | 0.0020 | 0.0849 |
| log(labour)2 | 0.0902 | 2.9491 | 0.0660 | 1.6742 |
| log(capital)*log(labour) | -0.1654 | -4.4812 | -0.0481 | -0.9003 |
| Number observations | 183 | | 150 | |
| R2 adjusted | 0.9265 | | 0.9745 | |
| MAE | 2.4348 | | 1.9113 | |
| F | 459.5240 | | 1415.2300 | |

**Notes and Sources:** The dependent variable is the log (value added) See the previous table 7.1 and 7.2.

The coefficients indicate the presence of scale economies in the modern industries and that these were exhausted in the traditional sectors. Moreover, scale economies in the traditional sectors disappear near the actual mean establishment size. In sharp contrast, in the modern sectors there is no flattening of returns to scale. In other words, there were persistent economies of scale.[519]

In brief, the econometric results about economies of scale reported above are clear. The modern sector, which had relatively large firms, had economies of scale to exploit whereas the traditional sector, which had relatively small firms, had exhausted its scale economies. Note that this result gives strong support to the arguments advanced in the previous sections. Suppose that the Catalan industry consisted of two sectors: modern and traditional. The modern sector producing with factories, the traditional sector producing with the small establishments. Production in the traditional sector took place with the given technology and economies of scale were exhausted. Only the emergence of the modern

[519] The same result was obtained by Sicsic (1994) for France.

sector increased the optimal plant size and increased total factor productivity. In other words, the substitution of traditional by the modern sector was the roots of Catalan industrialisation. An important corollary can be derived. Regions without modern sectors (factories) could expect to remain underdeveloped (in industrial terms) since no scale economies were available in the traditional industries.

### 7.4. The Emergence of Factories in the Cotton Industry

The main objective of this section is to provide a check upon the above results using the survivor technique for optimal plant size.[520] Thus, this section will give evidence on the evolution of average firm size and market structure in the cotton industry, for each of the three subsectors: cotton spinning, mixed-fabrics and cotton weaving, and calico printing. A secondary objective is to discuss the relation between the adoption of new technologies and the enlargement of plant size. In this sense, I will provide evidence that the emergence of factories was previous to the adoption of new machinery but that the adoption of sources of central motive power (steam engines and water wheels) resulted in an intensification and acceleration of this process.

The main argument of the survivor technique is that in the long-run the optimum plant sizes not only survived but also increased their share of total industry value-added. This is because they adjusted better to market conditions. Therefore, the ultimate assumption of this technique is the existence of competition in markets. Obviously, it is difficult to believe that the Catalan and Spanish markets were perfectly competitive in the nineteenth century. For instance, one could argue that transport costs provoked the existence of local monopolies or oligopolies and that factors of production did not move easily among regions. For that reason, the survivor analysis may not only reflect the changes in the efficiency of firms, but also alterations in the level of competition. For example, improvements in transport and other market conditions could cause sharp discontinuities in the pattern of plant

[520] See Stigler (1968) on the theoretical grounds. Two application of this principle to historical analysis are Lloyd-Jones and Le Roux (1980) and Atack (1987).

structure.[521] However, it is important not to exaggerate the degree of scepticism about the results of the survival technique. The existence of profit-maximising behaviour ensures the survival of lower-costs plants regardless of market structure. Moreover, the structure of the Spanish industries was, in that period, atomistic, which ensures a certain degree of competition and cost minimisation behaviour.

The cotton spinning industry completed the transition to central sources of power from 1832 to 1861. Thus, by 1861, practically all yarn was produced in water or power-driven mills. Therefore, at first glance, it can be considered as a perfect example of how the adoption of new technologies might influence the enlargement of establishment size.

The organisation of spinning production varied enormously in the proto-industry period in Catalonia; that is, from the last decades of the eighteenth century until approximately the 1830s. Many workers laboured individually at home (domestic production), or in family units, but others (and an increasing proportion over time) left home to perform their tasks in a centralised unit-of-production. However, according to the comments of the contemporaries, cotton spinning in Catalonia before the 1830s was overwhelming dominated by the putting-out system.[522] There were few factories operating in the cotton industry before the 1830s. Alex Sánchez proved that, from 1793 to 1808, almost 28 new spinning factories were built. These factories being equipped with water frames or jennies horse or water-driven.[523] Factories that were equipped with jennies averaged about 28 spinning machines whereas those equipped with water frames averaged about 14 machines. Since water frames employed about twice the workforce of jennies, which employed about 2.75 workers per machine,[524] one can argue that the average size of the spinning factories was about 80 workers. So before the French war the factory system must have contained about 2,000 workers. For example, the biggest spinning mill, which was erected by Joan Vilaregut in Barcelona, contained 46 jennies powered by horses. So it

[521] See Atack (1987) for a discussion of this question.

[522] Gutiérrez (1834)(1837), see also Thomson (1992).

[523] Sánchez (1996), table 1, pp. 162.

[524] These numbers are based on the information of Madoz (1846).

probably employed about 125 workers.[525] These factories were capable of competing with the domestic units because most of them could survive until the arrival of the steam-driven factories.

The final requirement to show that the factory system expanded is to certify that there was an increase in average plant size over the period. Some evidence for such a general increase in the scale of manufacturing establishments is presented in table 7.4.[526]

**Table 7.4** Establishment Size: Cotton Spinning, 1840-1861

| | 1840 | 1850 | 1861 |
|---|---|---|---|
| 1. Yarn Output (in Tons) | 6,874 | 11,989 | 18,214 |
| 2. Spindles | 1,159,979 | 803,936 | 766,960 |
| 3. Workers | 30,081 | 18,259 | 11,999 |
| 4. Establishments | 1,765 | 539 | 315 |
| 5. Yarn Output per establishment | 3.89 | 22.24 | 57.82 |
| 6. Spindles per establishment | 657.21 | 1491.53 | 2434.79 |
| 7. Workers per establishment | 17.04 | 33.88 | 38.09 |

**Notes and Sources:** Output: chapter 2. Establishments and Spindles: 1840: Madoz (1846); 1850: Junta de Fábricas (1850); and 1861: Gimenez Guited (1862). In vertically integrated mills, it has only been computed the spinning section. In 1861, in vertically integrated mills the number of workers is not divided by sections; consequently to establish the number of workers in spinning it has been multiplied each 1000 spindles per 13.1. (See the discussion of this coefficient in chapter 4).

The most striking feature of this evidence is the spectacular increase in the average output per establishment. In the period from 1840 to 1850, average output per establishment increased 600 percent. From 1850 to 1861 the increase was 250 percent. This implies that in 1861 the average establishment produced about fifteen times the output of the average establishment in 1840. In other words, the average output per establishment grew five times faster than output (measured in tons). Moreover, the measure of output in tons understates the gains in product per establishment since in 1861 Catalan spinning mills produced finer

[525] Sánchez (1996), table 1, pp. 162.

[526] An alternative methodology would be to demonstrate that labourforce decreased in the typical putting-out zones. See, for example, Camps (1995) who furnishes this kind of evidence.

counts. These counts weighed less but required more work.[527] This increase in output per establishment was accompanied by a parallel decrease in the amount of spindles, establishments and workforce. However, from this table, one cannot establish the reasons for the increase in output per establishment. Whether it was caused by the crisis of the small establishments, especially those units in the domestic system. By an increase in the average size of the pool of factories already established in 1840. Or by both factors interacting together.

More insights into the problem can be obtained by focusing upon the data for 1850 and 1861. Since for these two years data is available at establishment-level. Consequently, it is possible to develop table 7.5. Considering the changes in the size-distribution of cotton mills for the whole industry in Catalonia.

**Table 7.5** The Changing Size-distribution of Establishments: Cotton Spinning, 1850-1861

| Size | 1850 Workers | Mills | 1861 Workers | Mills | 1850 Workforce Share | 1861 Workforce Share |
|---|---|---|---|---|---|---|
| 1-10 | 1,804 | 191 | 438 | 83 | 9.88 | 3.65 |
| 11-49 | 5,917 | 232 | 4,368 | 159 | 32.41 | 36.40 |
| 50-99 | 5,406 | 81 | 3,382 | 50 | 29.61 | 28.19 |
| 100-199 | 3,654 | 29 | 2,090 | 18 | 20.01 | 17.42 |
| 200-299 | 1,166 | 5 | 725 | 3 | 6.39 | 6.04 |
| 300-399 | 312 | 1 | | | 1.71 | 0.00 |
| +400 | | | 996 | 2 | 0.00 | 8.30 |
| Total | 18,259 | 539 | 11,999 | 315 | 100.00 | 100.00 |

**Notes and Sources:** Share is based on labour figures. 1850: Junta de Fábricas (1850); and 1861: Gimenez Guited (1862). See notes to the previous table 7.4.

Table 7.5 gives a more detailed perspective on the situation of the industry by 1850 and the changes in cotton spinning in the 1850s. It becomes obvious that in 1850 the industry was mainly a factory-based industry. The once dominant putting-out system was surpassed in only twenty years (from 1830 to 1850). It is also possible to appreciate that, from 1850 to 1861, at all establishment-size levels, there was a reduction in the number of

[527] The chapter 9 discusses the relevance of the quality choice.

establishments and workers. Perhaps most interesting, however, it is to look at the parallel reduction of the share of the smallest units-of-production (1-10 workers) and the increase of the biggest mills (more than 200 workers). Decentralised units-of-production, which are represented by the former category. Already practically disappeared in eleven years. Simultaneously, the biggest firms practically doubled their share (from about 8 percent to about 14 percent). Given the short span of years (11) between the two figures the results are quite spectacular. One can conclude that it is likely that the increase in the average size of cotton spinning factories from 1840 to 1861 was accomplished through two phenomena interacting together. The elimination of the putting-out system and the development of new large firms. Obviously, both phenomena show the presence of economies of scale and increasing competition in the markets.

It is also interesting to debate the relation between centralized sources of energy and the emergence of the factory system. In effect, it could be claimed that the rapidly growing number of spinning factories in the 1840s was only the natural consequence of the adoption of the central sources of motive power (steam engines and water wheels). The next table tries to test this argument. The establishment data from the cotton industry's census of 1850[528] contains the basic information needed to compute table 7.6. This source provides reports, at the establishment level, of the type of machinery used, the number of employees, and the power source. However, unfortunately, the source does not contain, at establishment level, information on output and production costs and, therefore, it cannot be employed to compute establishment-based production functions.

[528] Junta de Fabricas (1850).

**Table 7.6** Establishment Size and Power Source: Cotton Spinning, 1850

| Size | Workers number | Workers percent | Mills number | Mills percent | Mainly powered by Hand | Horses | Water | Steam |
|---|---|---|---|---|---|---|---|---|
| 1-10 | 1,804 | 9.9 | 191 | 35.4 | 180 | 7 | 1 | 3 |
| 11-49 | 5,917 | 32.4 | 232 | 43.0 | 59 | 68 | 36 | 69 |
| 50-99 | 5,406 | 29.6 | 81 | 15.1 | 3 | 3 | 22 | 53 |
| 100-199 | 3,654 | 20.0 | 29 | 5.5 | 1 | 2 | 7 | 19 |
| 200-299 | 1,166 | 6.4 | 5 | 0.9 | | | | 5 |
| 300 or more | 312 | 1.7 | 1 | 0.2 | | | | 1 |
| **Total** | **18,259** | **100.0** | **539** | **100.0** | **243** | **80** | **66** | **150** |

**Notes and Sources:** Comisión de Fábricas (1850). In vertically integrated mills, it has only been computed the spinning section. Several water driven mills had, for ancillary tasks, a small steam engine.

Table 7.6 shows that in 1850 the distribution of the different power sources among the different size groups was not uneven. Small-size establishments were mainly hand-driven, and mills were usually horse, water or steam driven. It is likely that the small water or steam driven establishments shared their building and central motive power with other mills. More than 50 percent of labourforce and units-of-production were concentrated in the medium-size segment (from 11 to 99 workers). This segment was characterised by the dominance of central motive power. Finally, the most marked association between size and power source is found in the big mills (200 workers or more). These were all steam-powered. Consequently, one cannot deny the fact that water and power-driven firms tended to be larger than hand-driven factories. Confirming that there were more scale economies in the power and water-driven factories than in the hand-driven factories. For example, the use of central sources of motive power simplified the division-of-labour and the control tasks. Because in some operations the speed of work could now controlled directly by regulating the machinery speed.[529]

There were several strong differences between the technologies in cotton spinning, mixed-fabrics and cotton weaving. In particular, the triumph of the steam engine and water wheels in cotton weaving was slower than in cotton spinning. The main reason was that the

[529] See, for example, Cohen (1985)(1990) or Huberman (1996). Contemporary references at Ure (1836), Arau (1855), and Calvet (1857).

powerlooms consumed a large amount of coal, required many horsepower to be installed, and demanded consistent yarn quality. This quality was only available after spinning was mechanised. Furthermore, during the period, powerlooms could not be efficiently used to produce fine cotton cloth and mixed fabrics.[530] It should also be noted that the division of labour in cotton weaving was less attractive than in cotton spinning. The process of transforming the raw cotton into yarn was divided into many single operations and each operation was performed by specialised workers.[531] This contrasts with cotton weaving, where the number of different operations production could be divided into was relatively low. Handweavers practically controlled the whole phase since they required almost no assistance. The introduction of the powerlooms also served to reinforce this path since some single operations, which were performed by assistants, were done directly by the powerloom.[532]

There seem to be two further implications of these differences. First, the increasing size of cotton weaving establishments might be due more to 'pure' transaction costs than the economies associated with the division-of-labour. Certainly, one could expect that there were some gains in the concentration of cloth production. In terms of standardisation of output, savings in inventories and transport costs, co-ordination benefits and, obviously, economies of speed. Second, establishment size increases might not necessarily be associated with the diffusion of the new technologies since new technologies were not widespread in weaving until the 1850s.

Table 7.7 assembles evidence on the evolution of the establishment size in cotton weaving in Catalonia from 1840 to 1861. As in cotton spinning, there is no a clear correlation between increases in average output per establishment and the number of workers and looms per establishment. Thus, from 1840 to 1860, the number of workers and looms per establishment remained quite constant. The only exception being 1850 when the number

[530] VonTunzelmann (1978) see also Arau (1855).

[531] For a full description of the process and a description of skills associated with each operation see chapter 6.

[532] Cerdá (1968).

of workers experienced a sharp increase. This contrasts with the output per establishment, which increased 340 percent. Note that, by any measure, the average size in weaving was smaller than in spinning.

**Table 7.7** Establishment Size: Mixed-fabrics and Cotton Weaving, 1840-1861

| | 1840 | 1850 | 1861 |
|---|---|---|---|
| 1. Cloth output (Tons) | 6,810 | 12,279 | 18,624 |
| 2. Looms | 25,620 | 28,979 | 22,798 |
| 3. Workers | 40,364 | 54,082 | 29,251 |
| 4. Establishments | 2,514 | 2,501 | 2,021 |
| 5. Output per establishment | 2.71 | 4.91 | 9.22 |
| 6. Looms per establishment | 10.19 | 11.59 | 11.28 |
| 7. Workers per establishment | 16.05 | 21.62 | 14.47 |

**Notes and Sources:** 1840: Madoz (1846); 1850: Junta de Fábricas (1850); and 1861: Gimenez Guited (1862). In vertically integrated mills, it has only been computed the weaving section. To estimate the number of workers in that section the number of powerlooms has been multiplied by one and the number of handlooms by 1.5.

Evidently, from this table one cannot infer if the increase in the average output per establishment was due to the crisis in the decentralised forms of organisation or whether there were other reasons such as an increase in the average size of the factories. The evidence on the size distribution of the weaving establishments for 1850 and 1861 will help to discuss this question.

**Table 7.8** The Changing Size-distribution of Establishments: Mixed-fabrics and Cotton Weaving, 1850-1861

| | 1850 | | 1861 | | 1850 | 1861 |
|---|---|---|---|---|---|---|
| | | | | | Workers | |
| Size | Workers | Mills | Workers | Mills | Share | Share |
| 1-10 | 10,553 | 1,552 | 4,526 | 1,519 | 19.26 | 15.47 |
| 11-49 | 16,292 | 666 | 8,669 | 355 | 29.73 | 29.64 |
| 50-99 | 13,940 | 202 | 6,543 | 97 | 25.44 | 22.37 |
| 100-199 | 8,132 | 61 | 4,633 | 34 | 14.84 | 15.84 |
| 200-299 | 3,286 | 14 | 2,667 | 12 | 6.00 | 9.12 |
| 300-399 | 957 | 3 | 340 | 1 | 1.75 | 1.16 |
| +400 | 1,642 | 3 | 1,873 | 3 | 3.00 | 6.40 |
| Total | 54,802 | 2,501 | 29,251 | 2,021 | 100.00 | 100.00 |

**Notes and Sources:** 1850: Junta de Fábricas (1850); and 1861: Gimenez Guited (1862).

The resemblance with the result for cotton spinning is evident. During this period many mills disappeared from the market and there were changes in the size distribution of the industry at the top and the bottom of the range. Decentralised production (small establishments) decreased their share by about one-fourth. Simultaneously, the biggest establishments (more than 200 workers) increased their share by about 50 percent (from about 11 percent to about 17 percent). Note, also, that the reduced share of putting-out system in 1850 (only employing about one-fifth of the total number of workers) suggests that putting-out system was in its final crisis at that time. Note that this result supports Enriqueta Camps' view: that the putting-out districts specialised in cotton weaving lost population during this period.[533]

One could also study the relation between the emergence of the factory system in weaving and the irruption of the central sources of motive power. In Catalonia, central-driven establishments in weaving could not efficiently adopt water as a source of power until the advent of the turbine in the mid 1850s. This was because of the large power requirements of the powerlooms.[534] Consequently, in 1850 the only source of central motive power in weaving was steam engines.

**Table 7.9** Establishment Size and Power Source:
Mixed-fabrics and Cotton Weaving, 1850-1861

| Size | Workers | Percent | Mills | Percent | hand driven | steam driven |
|---|---|---|---|---|---|---|
| 1-10 | 10,553 | 19.26 | 1,519 | 61.55 | 1,519 | 0 |
| 11-49 | 16,292 | 29.73 | 666 | 26.99 | 657 | 9 |
| 50-99 | 13,940 | 25.44 | 202 | 8.18 | 182 | 20 |
| 100-199 | 8,132 | 14.84 | 61 | 2.47 | 48 | 13 |
| 200-299 | 3,286 | 6.00 | 14 | 0.57 | 12 | 2 |
| 300-399 | 957 | 1.75 | 3 | 0.12 | 2 | 1 |
| +400 | 1,642 | 3.00 | 3 | 0.12 | 1 | 2 |
| Total | 54,802 | 100.00 | 2,468 | 100.00 | 2,421 | 47 |

**Notes and Sources:** Junta de Fábricas (1850).

533 Camps (1995).

534 Nadal (1992b).

At first glance, this table reveals two main issues. First, there are some important weaving factories which are hand-driven. More to the point, these hand-driven factories constituted the core of the industry and employed more than half the workforce. On the other hand, a small number of weaving mills were power-driven. Generally, these mills were bigger than hand-driven mills, which could suggest the presence of some scale-economies in the adoption of powerlooms. Note also that it seems that a minimum efficient scale existed for powerlooms. Since no small establishment (1-10 workers) used that kind of machinery.

For many different reasons, cotton printing was an extraordinary industry within the Catalan context of the eighteenth century. Since its beginnings, the industry was concentrated in Barcelona.[535] Moreover, the industry was based on centralised units of production. Despite having several managerial structures, from capitalistic firms to artisans' co-operatives.[536] Thus, the typical unit of production was formed by several workteams, which were composed of several masters, artisans and apprentices, and labourers. Consequently, the industry was established on the basis of medium-large establishments and extensive division of labour.[537] In the workteams the workforce was highly skilled and practically all male. Despite the presence of skilled artisans the industry escaped the control of guilds and could be considered pioneer in the adoption of capitalist forms of organisation.[538]

The choice of centralised forms of production since the beginnings of calico printing is really simple to explain in the framework of the transaction costs theory. The production of calicoes was high in asset specificity.[539] Each factory tried to produce homogeneous products with had homogeneous colours and drawings. In this situation knowledge and experience played a major role in the market position of the firms. The bleaching of colours

[535] Thomson (1992).

[536] Thomson (1992).

[537] See Grau and López (1975), Thomson (1992) and Sánchez (1989)(1992).

[538] Thomson (1992).

[539] See, on this argument, Williamson (1986) and section 7.2.

and the process of printing was generally based on the knowledge of secret formulas and procedures that were difficult to transmit.[540] Consequently, old calico establishments possessed some sort of tacit knowledge that could not easily be acquired by the new entrants in the trade. Furthermore, the high price of raw materials, in particular natural inks, gave incentives to avoid sub-contracting and outworking. Since pilfering would be very costly for the company.

However, calico printing was scarcely mechanised before the 1830s because few establishments had adopted the new British and French machinery.[541] Over the next thirty years, the process of adoption of the new machinery in calico printing was as slow as it was in cotton weaving. Thus, by the 1860s, many hand-driven workshops and factories survived. It is necessary to underline that the new machinery in calico printing had large consequences for the skills of the labour force. In the hand-driven calico factories the quality of the final product was in the hands of the artisans. In particular, the homogeneity of colours and the perfect reproduction of drawings were a question of skills and experience. In sharp contrast, the new machinery simplified the process of printing and the skills required to obtain homogeneous coloration. With the new machines, colours were mixed before the process of printing and the drawings were stamped with metal plates. Thus, colours and drawings were more uniform and could be easily reproduced. Workers did not participate in the process but simply controlled the machines. One chemist with a few (unskilled) assistants prepared the colours for the whole factory.[542] In other words, the new machinery transformed the highly skilled printers into unskilled workers. Cerdá states that the old skilled printers were converted into simple labourers by the new printing machines.[543]

[540] Thomson (1992).

[541] On the mechanisation of calico printing see Turnbull (1951) and Nadal and Tafunell (1992).

[542] A description of a calico factory is available in Gimenez Guited (1862).

[543] Cerdá (1968).

**Table 7.10** Establishment Size: Calico Printing, 1840-1861

| | 1840 | 1850 | 1861 |
|---|---|---|---|
| 1. Output (tons of printed cloth) | 2,662 | 6,413 | 8,552 |
| 2. Workers | 3,223 | 2,368 | n.a. |
| 3. Establishments | 62 | 57 | 75 |
| 4. Output per establishment | 42.94 | 112.51 | 114.02 |
| 5. Workers per establishment | 51.98 | 41.54 | n.a. |

Notes and Sources: Output see chapter 2. Workers and Establishments: 1840: Madoz (1846); 1850 Junta de Fábricas (1850); and 1861: Gimenez Guited (1862).

According to table 7.10, it seems that these changes in machinery in the printing industry were accompanied by changes in the average firm size. But smaller changes than in cotton spinning and weaving. In the 1840s the firm size doubled whereas in the 1850s the average firm size remained quite constant.

At this point, readers should recognise that there is abundant evidence of increasing returns to scale in the modern industries in Catalonia. It has been proved that early industrialisation resulted in the demise of the putting-out system and other forms of decentralised production. The equilibrium of advantages between the two modes of production was undoubtedly sensitive to a range of factors. Note that putting-out offered workers the convenience of choosing their hours of work and, hence, to combine industrial production with household or agrarian activities. Instead the centralised production provided more opportunities for gains in productivity through division and intensification of labour. As well as economies in the use of fixed capital and inventories. However it is clear that the changes in these factors increasingly favoured the adoption of factory.

### 7.5. Establishment Size in Catalonia: a Comparison with the Rest of Spain

In the past two sections I assembled some quantitative evidence on the relation between changes in establishment size and scale economies and efficiency gains. Two corollaries can be derived from the results obtained above: (1) regions with the largest establishments must have benefited more from higher productivity than zones with smaller establishments, (2) regions with modern industries, which had some scale economies to exploit, could benefit from further efficiency gains. It is obvious that these two corollaries have profound implications for our understanding of the differences in regional industrialisation in Spain. More insight on this aspect can be obtained by comparing Catalonia with the rest of Spain. To do so, I present evidence on the relative average size of Catalan and Spanish firms.

Regional estimates of the average number of employees per establishment in 1861 are presented in table 7.11. They support the view that in almost all industries the average size of establishments in Catalonia was larger than the average of the Spanish regions. This pattern holds over mechanised industries such as silk textiles, as well as nonmechanised ones such as leather, and is representative of the manufacturing sector in general. Only in three industries, namely olive oil refining, the paper industry and the metal industry, was Catalan average firm size below the Spanish average (in the case of cotton textiles the figures of Catalonia are also lower but since it dominated the industry, the results would be not significant). Averaging across all industries, Catalan establishments employed twice as many workers as Spanish establishments. It should be noted that even in industries where Catalonia did not dominate the Spanish panorama, such as the linen industry, the average Catalan establishment was larger than the Spanish average.

**Table 7.11** Establishment Size: Spanish Manufacturing, 1861

| | Cat | And | Ebro | Cant | Med | NCa | Sca | Spain |
|---|---|---|---|---|---|---|---|---|
| Cork manufacturing | 9.7 | 8.6 | | | | | 9.4 | 9.7 |
| Cotton textiles | 16.0 | 11.3 | 16.0 | 34.8 | 4.1 | 8.8 | | 16.2 |
| Leather industry | 6.3 | 3.1 | 3.9 | 4.1 | 4.9 | 9.3 | 3.8 | 5.7 |
| Linen and Flax textiles | 5.0 | 5.3 | 6.5 | 2.6 | 1.8 | 2.8 | 3.4 | 4.4 |
| Metal industry | 23.0 | 64.8 | 12.9 | 32.1 | 20.4 | 23.9 | 10.9 | 25.9 |
| Mixed Fabrics textiles | 24.1 | | | | | | | 24.1 |
| Olive Oil refining | 1.6 | 2.5 | 2.4 | 2.0 | 2.4 | 1.8 | 2.9 | 2.6 |
| Paper industry | 12.3 | 31.8 | 5.8 | 18.7 | 13.9 | 36.3 | 12.9 | 16.4 |
| Silk textiles | 26.1 | 8.8 | 39.0 | | 6.2 | 1.5 | 11.9 | 20.4 |
| Soap industry | 2.5 | 1.7 | 6.1 | 2.1 | 2.0 | | 1.5 | 2.2 |
| Liquors industry | 2.6 | 2.4 | 2.3 | 3.0 | 2.6 | 2.0 | 1.6 | 2.6 |
| Wheat industry | 2.5 | 1.8 | 1.7 | 1.9 | 2.9 | 1.3 | 1.7 | 1.9 |
| Wool textiles | 26.7 | 11.7 | 15.1 | 15.4 | 21.2 | 6.4 | 8.9 | 15.5 |
| **Average** | **10.5** | **3.1** | **4.5** | **7.7** | **4.3** | **2.6** | **2.6** | **5.5** |

**Notes and Sources:** Numbers subject to rounding errors. Cat (Catalonia) comprises the Province of Barcelona, Gerona, Lerida and Tarragona. And (Andalusia) comprises the provinces of Almería, Cádiz, Córdoba, Granada, Málaga, Huelva, Jaén and Sevilla. Ebro (Ebro) comprises the provinces of Huesca, Logroño, Teruel and Zaragoza. Can (Cantabric) comprises the provinces of Asturias, La Coruña, Lugo, Orense, Pontevedra and Santander. Med (Mediterranean) comprises the provinces of Alicante, Baleares, Castellón,Murcia and Valencia. NCa (North Castilia) comprises the provinces of Avila, Burgos, León, Palencia, Salamanca, Segoria, Soria, Valladolid and Zamora. SCa (South Castilia) comprises the provinces of Albacete, Badajoz, Caceres, Ciudad Real, Cuenca, Guadalajara, Madrid and Toledo. Finally, note that Spain's figures also comprise the figures corresponding to the tax-exempt provinces of Alava, Guipuzcoa, Navarre and Vizcaya. These figures were computed from the industry data compiled from Gimenez Guited (1862). The figures presented refer to the number of employees, with men, women and children receiving equal weight. Empty cells correspond to industries which were not in these regions.

However, there are some puzzling results that require further discussion. In particular, the case of the metal industry, where the average employee per establishment in Catalonia was well below the Spanish average, merits some attention. Basically, this result is consequence of the heterogeneity of the metal industry.[544] The Catalan metal industry was mainly composed of machinery constructors whereas in the rest of Spain iron and other metals foundries predominated. Since there was a minimum operational size for foundries, (about 25 workers) whereas in engineering there was not, average size tended to be larger in regions where foundries predominated. However, it should be underlined that engineering

[544] Gimenez Guited (1862).

firms in Catalonia were larger than in the rest of Spain.

Although the finding that the average size of most manufacturing industries in Catalonia was larger than in the rest of Spain is well supported, this by itself does not imply that relatively more large establishments were located in Catalonia than in the rest of the country. For instance, it could be that Catalonia possessed many units-of-production only slightly above the Spanish average firm size but not an appreciable amount of the largest ones. The issue is relatively important since some authors have argued the adoption of organisational innovations happened after a certain size threshold. For instance, Jeremy Atack argues that 'specialization [of labour] cannot be practised extensively unless a mill had more than twenty-five workers.'[545] Unfortunately, the datasource makes it impossible to establish a threshold size of twenty-five workers. As mentioned above, in many provinces Gimenez Guited's guide only separately enumerated the most important (largest) industries. A detailed observation of the data allowed me to establish that only establishments with about 50 workers were recorded separately in all provinces and industries. For that reason, I decided to estimate the total and the proportion of the labourforce who were employed in establishments with 50 or more employees; a certain large threshold size. The results of that estimation are presented in table 7.12.

[545] Atack (1987), p. 288.

**Table 7.12** Workers in Establishments of Fifty or More Workers: Spanish Manufacturing, 1861

| | Cat | And | Ebro | Can | Med | NCa | SCa | Sample |
|---|---|---|---|---|---|---|---|---|
| (1) Employees that were employed in establishments of 50 or more workers | | | | | | | | |
| Cork manufacturing | 585 | | | | | | 0 | 585 |
| Cotton textiles | 24,090 | 770 | 0 | 634 | 456 | 790 | | 26,740 |
| Leather industry | 400 | 57 | 0 | 0 | 0 | 1,372 | 0 | 1,829 |
| Linen and Flax textiles | 228 | 0 | 285 | 0 | 0 | 52 | 0 | 565 |
| Metal industry | 480 | 2,133 | 0 | 2,506 | 0 | 620 | 0 | 5,739 |
| Mixed Fabrics textiles | 4,736 | | | | | | | 4,736 |
| Paper industry | 504 | 64 | 0 | 60 | 163 | 0 | 0 | 791 |
| Silk textiles | 1,815 | 0 | 0 | | 1,243 | 0 | 0 | 3,058 |
| Wool textiles | 4,227 | 52 | 1,306 | 115 | 919 | 354 | 288 | 7,261 |
| **Total** | **37,065** | **3,076** | **1,591** | **3,315** | **2,781** | **3,188** | **288** | **51,304** |
| (2) Share (percent) of all employees who were employed in establishments of 50 or more workers | | | | | | | | |
| Cork manufacturing | 12.95 | 0.00 | | | | | 0.00 | 12.38 |
| Cotton textiles | 61.26 | 78.01 | 0.00 | 95.92 | 19.15 | 66.16 | | 60.01 |
| Leather industry | 28.33 | 7.04 | 0.00 | 0.00 | 0.00 | 63.55 | 0.00 | 28.10 |
| Linen and Flax textiles | 7.86 | 0.00 | 39.42 | 0.00 | 0.00 | 12.35 | 0.00 | 10.09 |
| Metal industry | 32.06 | 86.57 | 0.00 | 56.92 | 0.00 | 68.36 | 0.00 | 54.38 |
| Mixed Fabrics textiles | 79.78 | | | | | | | 79.78 |
| Paper industry | 24.45 | 8.74 | 0.00 | 53.57 | 11.40 | 0.00 | 0.00 | 15.11 |
| Silk textiles | 62.03 | 0.00 | 0.00 | | 27.22 | 0.00 | 0.00 | 36.50 |
| Wool textiles | 43.46 | 3.15 | 40.18 | 53.49 | 25.79 | 10.74 | 19.33 | 31.31 |
| **Total for all industries** | 48.82 | 14.14 | 22.30 | 46.25 | 12.81 | 21.97 | 2.30 | 31.92 |

**Notes and Sources:** See the previous table 7.11. Industries without establishments with 50 or more workers are not represented in the table. The total does not comprise the Provinces of Navarre, Alava, Guipuzcoa and Vizcaya.

This data provides a solid empirical confirmation of the argument advanced above. In all industries, except the linen and the metal industries, the proportion of workers in establishments with 50 or more workers is larger in Catalonia than in Spain. Basically, the results from table 7.12 reinforce the results of table 7.10. In particular, it should be noted that only one region (the Mediterranean region) does not maintain the same position in the two tables. It is also interesting to note the large share of the biggest establishments within the Catalan industry (about half the overall employment). Also remarkable is the case of mixed-fabrics textiles, an industry which had not experienced the transition to the steam-driven factories where about 80 percent of the workforce was in establishments of 50 or more workers..

A second question relates to the uneven distribution of the modern and traditional industries among the different regions. It is clear from the previous discussion that regions with modern industries benefited from scale economies. Whereas regions with a traditional manufacturing sector could expect output and productivity stagnation. The next table assembles data on this aspect:

**Table 7.13** The Importance of the Modern Industries: Spanish Manufacturing, 1861

| | Cat | And | Ebro | Can | Med | NCa | SCa | Sample |
|---|---|---|---|---|---|---|---|---|
| (1) Distribution of the value added between modern and traditional industries (percent) | | | | | | | | |
| Modern | 89.17 | 42.31 | 55.82 | 85.10 | 67.00 | 38.96 | 31.53 | 71.87 |
| Traditional | 10.83 | 57.69 | 44.18 | 14.90 | 33.00 | 61.04 | 68.47 | 28.13 |
| (2) Share (percent) of each region in the overall value-added | | | | | | | | |
| Modern | 63.93 | 6.57 | 2.65 | 8.84 | 10.40 | 4.76 | 2.85 | 100.00 |
| Traditional | 19.84 | 22.88 | 5.37 | 3.96 | 13.09 | 19.04 | 15.82 | 100.00 |
| Total | 51.53 | 11.16 | 3.42 | 7.47 | 11.16 | 8.78 | 6.50 | 100.00 |

**Notes and Sources:** See the previous table 7.11. The total figures for Spain are based on the sample of Gimenez Guited (1862), which is biased in favour of the modern industries. The total does not comprise the Provinces of Navarre, Alava, Guipuzcoa and Vizcaya.

Despite the fact that the datasource is biased in favour of the modern industries, because many traditional industries were not recorded,[546] the results emanating from the table are striking. Catalonia not only is the region that accumulated a major proportion of its value-added in the modern industries but is also the region that dominated the modern sectors. For instance, about 64 percent of the value-added of the modern industries was produced in Catalonia. A structure comparable with Catalonia can only be found in the Cantabric region, but that region had a very small share in total manufacturing value-added.

[546] For instance, I proved in chapter 2 that modern industries were about 50 percent of Catalan manufacturing value-added whereas in the sample they represented about 90 percent.

## 7.6 Why Were Manufacturing Establishments Larger in Catalonia Than in Other Spanish Regions?

It was show earlier that the establishment sizes in Catalonia were quite different from the rest of Spain. It was also proved that this had strong consequences for further increases in manufacturing productivity. In other words, this appears to be an important issue for understanding the emergence of the income differences among the Spanish regions and why some regions (in particular, Catalonia) were more successful than others in industrialisation. Measuring the effects of establishment size at one point in time will certainly not tell us why some regions had larger establishments than others. The relevant question from the historian's point of view. Obviously, I will not try to resolve the question definitively, but some hypotheses will be discussed in the following pages.

Five different hypotheses can be advanced to explain this phenomenon. First, one can interpret the situation in terms of entrepreneurial failure. Industrialisation and the enlargement of establishments took place in Catalonia rather than the rest of Spain because the number or quality of available entrepreneurs was lower. The implicit assumption of this argument is that there were substantial economies of scale in plants located in the underdeveloped regions. However, it seems difficult, given the available evidence, to interpret the situation of the industry in some regions only in terms of entrepreneurial failure.[547] The fact is that in regions where the traditional industry predominated they had reached their efficiency limit; that is, the point where economies of scale vanish.[548] In other words, entrepreneurs had efficiently allocated their resources. Of course, it could be argued that entrepreneurs failed since they did not invest in the modern industries when factories were more efficient. Although I will show this is also a debatable argument.

One could also argue that there was some kind of human capital constraint on the

[547] The leading proponent of the entrepreneurial backwardness thesis is Gabriel Tortella. See, for example, Tortella (1994b).

[548] Note that in France, see Sicsic (1994), and in the United States, Atack (1977) and Sokoloff (1984a) there were still economies of scale in traditional, small-scale manufacturing.

development of large factories. In chapter 6, I proved that Catalonia enjoyed a large supply of skilled artisans who could be easily transformed into engineers for the new power-driven factories. Consequently, regions without this stock of skilled artisans encountered many problems in adopting large mechanised factories. Although this explains part of the story, it does not cover the whole story. Since it explains why Catalonia had large mechanised factories but does not explain why non-mechanised establishments were larger in Catalonia than in the rest of Spain.

The presence of large establishments could also be linked to the superabundance of labour.[549] According to this line of reasoning, regions that experienced the proto-industry had an advantage in developing large manufacturing establishments. However, Jeremy Atack recently argued that this could not be the case. He argues that to the extent that putting-out was successful, it was an impediment to the spread of the factory as it limited the scope of the market and the desirability of further investments. Furthermore, artisans were more efficient than factories in crisis periods since they could switch to part-time work or temporary close shop. Whereas the factories could not because they had to amortise the large investment in fixed capital.[550] Similarly, to compete with the factories, artisans and putting-out workers could squeeze their wages.[551]

Claudia Goldin and Kenneth Sokoloff relate the development of the factory in the United States with the relative availability of women and children for manufacturing in some regions.[552] They argue that the new technologies associated with the diffusion of the factories were intensive in the use of women and children. Consequently, one expects that regions with larger establishments also employed more women and children in manufacturing than regions with smaller establishments. Table 7.14 tries to test this argument for Spain.

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[549] See, Mendels (1972) and Mokyr (1974)(1976) on the argument of the superabundance of labour as a consequence of the proto-industry.

[550] Atack (1987), pp. 325-326.

[551] Lyons (1989).

[552] Goldin and Sokoloff (1982)(1984) and see also Sokoloff (1984a).

**Table 7.14** Women and Child Workers: Spanish Manufacturing, 1861

| | Cat | And | Ebro | Cant | Med | NCa | SCa | Spain |
|---|---|---|---|---|---|---|---|---|
| (1) Percentage of employees that were women | | | | | | | | |
| Cotton | 41.09 | 42.55 | 0.00 | 26.17 | 11.68 | 39.95 | | 39.30 |
| Paper | 23.77 | 42.90 | 40.95 | 26.79 | 30.42 | 28.05 | 22.99 | 30.34 |
| Silk | 17.05 | 13.37 | 10.26 | | 27.51 | 0.00 | 21.29 | 22.85 |
| Wool | 15.38 | 16.56 | 21.48 | 16.74 | 10.30 | 19.27 | 15.23 | 16.26 |
| Total of all industries | 24.56 | 4.94 | 10.50 | 3.33 | 10.76 | 8.50 | 2.93 | 16.75 |
| (2) Percentage of employees that were children | | | | | | | | |
| Cotton | 8.89 | 8.41 | 18.75 | 15.89 | 5.04 | 4.69 | | 8.95 |
| Paper | 21.59 | 11.07 | 9.52 | 23.21 | 19.58 | 19.08 | 26.32 | 19.23 |
| Silk | 3.69 | 2.40 | 0.00 | | 8.10 | 0.00 | 19.39 | 6.79 |
| Wool | 2.00 | 6.55 | 6.34 | 3.72 | 8.36 | 12.20 | 6.85 | 6.04 |
| Total of all industries | 5.59 | 1.31 | 3.07 | 1.94 | 4.92 | 3.73 | 1.98 | 4.66 |

**Notes and Sources:** See the previous table 8.10. Numbers subject to rounding errors.Included only the industries with female and/or children labourforce. It is likely that cork and mixed-fabrics industry employed female and children labourforce but the source did not furnish that information.

The results of table 7.14 give some support to the argument advanced above because Catalonia, the region with the largest establishment average size, employed relatively more women and children than the other Spanish regions. Moreover, it is interesting to note that there are some patterns among industries in the amount of women and children employed. For instance, women and children appear to be relatively more important in cotton textiles and the paper industry than in the rest. However, on closer inspection, one can see that the Catalan pattern cannot be used to explain establishment size in the rest of Spain. In particular, the Mediterranean and North Castilia regions, which had relatively small establishments, employed more women and children than the Cantabric region. Which had larger establishments than the Mediterranean and North Castilia regions. Furthermore, it was shown in chapter 4 that the emergence of the new technologies in the 1840s and 1850s did not result in an increase in the female and child labourforce in Catalonia. In contrast, the share of women and children with respect to men decreased in that period.

Finally, the most convincing explanation for the absence of large establishments is related to the extent of markets. Thus, regions where population was comparatively sparse, distances were great, means of transport poor, and/or there was little demand for manufactured goods discouraged large-scale manufacturing. The reason is that local markets were too small to sustain industry on a scale large enough to compete with outsiders. Who could draw upon wider markets.[553] The industries could survive in these regions as positive transport costs created protected markets for high-cost producers. In other words, when the cost of transport exceeded the production cost differential between low and high cost producers, the latter could survive.

The argument can be put in another way. According to the Heckser-Ohlin theorem regions labour-intensive regions specialised in labour intensive production. Whereas land-intensive regions specialised in land-intensive production. Thus, manufacturing might predominate in the relatively labour-intensive regions. Where manufacturing predominated the establishment tended to be larger. Therefore, the important variable is population density. The next table analyses this argument:

**Table 7.15** Establishment Size and Population Density: Spanish Manufacturing, 1860

| | Average establishment | Population (thousands) | km2 | Density (hab per km2) |
|---|---|---|---|---|
| Catalonia | 10.5 | 1652.3 | 31930 | 51.75 |
| Cantabric | 7.7 | 2515.8 | 45288 | 55.55 |
| Ebro region | 4.5 | 1054.4 | 52703 | 20.01 |
| Mediterranean | 4.3 | 1890.4 | 39636 | 47.69 |
| Andalusia | 3.1 | 2927.4 | 87268 | 33.54 |
| North Castilia | 2.6 | 2083.1 | 94147 | 22.13 |
| South Castilia | 2.6 | 2386.2 | 128823 | 18.52 |

Notes and Sources: See table 7.11. Average firm size from table 7.11; population for 1857 are drawn from Nicolau (1989), table 2.20, p. 80.

The results of table 7.15 are striking. The range of average firm size corresponds to the range of population density. However, there are some puzzling results that require further discussion. The relative low density of Catalonia is due to the inclusion of the province of Lleida, a province with few industries within the region. Eliminating this province from the region, the density grows to 83 habitants per Km2; that is, the density that one can expect

[553] See, for example, the French debate in Sicsic (1994) or the U.S. debate in Tchakerian (1994).

due to the largest average firm size of Catalonia. More puzzling is, however, the figure for the Ebro region. This can be explained by two facts. Firstly, the concentration of the industry in a few zones in that region which produce the overall densities give a very poor picture of the situation. Secondly, the existence of good communication with the relatively industrialised regions, such as Catalonia. This caused problems for the inefficient firms in the Ebro region.

### 8.8. Summary and Conclusions

This chapter offers a broad perspective on the emergence of the factory system in Catalan industrialisation. It also provides a framework for understanding the productivity effects of that emergence. The increase in the establishment size seems to have been helped by persistent, but small, productivity gains over more traditional production methods. These gains are similar to those estimated by other authors for the United States and France.

During early industrialisation, manufacturing by centralised plants grew rapidly, and began to displace putting-out and small workshops even before the widespread diffusion of the water and steam-driven machinery. This sharply depressed the earnings of domestic workers and virtually eliminated the old production system. This analysis accounts for this pattern of development by relating the expansion of centralised manufacture to its efficiency superiority, the size of markets for manufacturing goods and the existence of an industrial workforce.

Furthermore, this chapter also provides a comparative perspective of why early Catalan industrial development was characterised by the development of the largest, in Spanish terms, manufacturing plants. The development of the industry in Catalonia has relevance for our understanding of the causes of the industrial backwardness of other Spanish regions. The preliminary results obtained seems to indicate that Catalonia benefited: (1) from the presence of skilled labour; (2) from some sort of labour-abundance compared to other Spanish regions were there was abundance of land-abundant.

# Chapter 8

## The Vertical Integration of the Cotton Industry

This chapter will discuss the vertical integration of cotton spinning and weaving in Catalonia during the 1840s and 1850s. Here, I show that this phenomenon was very important for the consolidation of this industry. I argue that vertical integration helped the adoption of the new machinery, such as the self-acting mule and the powerloom. Assets with a high degree of asset specificity. Moreover, this vertical integration served to save transaction costs, to obtain scale economies, and to organise the production of cotton goods in Catalonia more efficiently.

In the context of the dissertation, this chapter serves to explain what kind of innovation in business institutions accompanied the development of the cotton industry after 1840. Furthermore, it should be underlined that the business institutions that were established in this period (i.e., the vertically integrated mills) dominated the sector for many years, probably until the crisis of the cotton industry in the 1980s. In a more broad context, the arguments developed in this chapter can be inserted into the debate on the role of vertical integration into the development of modern industries. Several authors have linked the demise of Lancashire's cotton industry with a lack of vertical integration. They argue that the superiority of the U.S. cotton firms over their British counterparts was due to the massive adoption of vertical integration in the United States.[554] Although not the main issue, the results of this chapter could serve to throw light on that debate. In particular, I show that market failures explain vertical integration. Consequently, regions with efficient markets for

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[554] See a review of the debate in Mass and Lazonick (1990).

intermediate inputs would not need to develop vertically integrated firms to efficiently develop their cotton industry.

### 8.1. Introduction

Since there is more than one definition of vertical integration, it seems convenient to clarify how this term should be interpreted throughout the chapter. Economists traditionally defined vertical integration as the elimination of trade or contractual exchanges within the borders of the firm.[555] By contrast, engineers consider that vertical integration takes place in successive phases within the same technological core.[556] I use here the economic definition and not the technological one. Consequently vertical integration may comprise not only successive production phases. But also the trade and commerce of inputs, intermediate, and final goods, as well as their transport and financing. Note that, due to practical reasons and the constraint of the available empirical evidence, it was assumed that the firm that possesses machinery of one production phase, is vertically integrated in that phase. However, this is not completely true since full vertical integration only takes place when the firm has not bought goods that it can produce.[557]

Jordi Maluquer has argued that in the Catalan cotton industry a kind of 'industrial district' predominated. Where some capitalists controlled the production and where firms co-operated.[558] He argues that the demand for textile goods in Spain, which was very volatile, provoked sub-contracting and that out-working was widespread. In other words, large-scale firms were not competitive. The industry was organised hierarchically since some capitalists

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[555] Perry (1989), p. 185.

[556] Intuitively, the technological core is composed of the successive phases of technologically similar production. In particular, in the cotton spinning and weaving industry the technological core is fomed by the process of production with mechanical cards, self-acting mules and powerlooms.

[557] Furthermore, it is very difficult to find a fim that contains all phases of production in the cotton industry. Therefore I will circumscribe my analysis to the vertical integration of the three successive industrial phases (spinning, weaving and finishing). Anyway, many Catalan cotton fims integrated into their structure other production and ancillary processes such as machinery workshops, wholesale warehouses and shops.

[558] Maluquer de Motes (1976)(1998).

controlled large putting-out and sub-contracting webs. According to Maluquer, this hierarchical structure served to avoid the fluctuations in the demand for cotton goods. At the peaks of the business cycle capitalists increased the number of sub-contractors, whereas the contrary held in the trough years. Note that, with this system, entrepreneurs were also able to maintain a low wage level. Finally, he argues that this system was very positive and efficient since it eased the development of the industry, the adoption of the new machinery, and did not reduce competition among firms.

Maluquer's arguments are debatable. First, the existence of an industrial district is difficult to document. It is true that Catalan industry developed some forms of collaboration and common institutions but it seems difficult that these few institutions were capable of organising a 'true' industrial district, like the Italian style. An industrial district requires that firms collaborate in the acquisition of technology and financing. There are contradictory examples to that type of collaboration in Catalonia. By the 1860s, some mutual banks were established to overcome the absence of industrial credit from the banking system.[559] The experience of these mutual banks was unsuccessful and short-lived. Another example of collaboration was the employers' organisation. Although, it should be noted that many Catalan industrialists, especially those devoted to mixed fabrics weaving, disagreed with the protectionist purposes of the institution.[560] A final example of collaboration was the participation of several entrepreneurs in the development of the industrial engineering school in Barcelona.[561] Therefore, it can be argued that there was some kind of collaboration among Catalan firms although it was less intense than in typical Italian districts. Second, Maluquer inferred from the data on the number of firms and some qualitative information that sub-contracting might predominate among cotton firms.[562] In this sense, the presence of many small firms does not imply that these firms might collaborated and functioned hierarchically. Third, he argues that, due to the conditions of the home demand for cotton goods, flexibility was more important than scale economies. But offers no evidence to

[559] Rosés (1997).

[560] Comisión especial arancelaria (1867).

[561] Garrabou (1982).

[562] Maluquer (1976).

support this. Similarly, he assumes that large firms are necessarily less flexible than small firms. Finally, he never discusses the high transaction costs and inefficiencies associated with a system based on out-working webs.

In the Catalan cotton industry, new business institutions being developed from the early 1830s.[563] By 1861, vertical integration predominated in the cotton industry. The main reason for the substitution of sub-contracting for vertical integration was that the latter was the best choice due to the peculiar conditions of the market for Catalan textile goods. These peculiar conditions posed difficulties for the adoption of technologies that were high in asset specificity. Such as self-acting mules and mechanical looms. For that reason, the system of production based on sub-contracting was circumscribed to mixed fabrics and fine goods industries. Where the self-actings and mechanical looms were not efficient. Whereas most of the industry, which was devoted to the production of medium-coarse goods, adopted vertical integration.[564]

The remainder of the chapter is organised as follows. The second section is devoted to the main issues of the economic theory and the literature on economic history referring to vertical integration. In the third section, the diffusion and the scope of vertical integration among the Catalan cotton firms is analysed by means of time-series and cross-section data. The subsequent section investigates the major determinants of vertical integration. Then, the consequences of the vertical integration are studied. Finally, the last section concludes and summarises.

[563] See chapter 7.

[564] See Von Tunzelmann (1978) and Lyons (1987) for the characteristics of the different types of machinery. Both authors pointed out that in high quality goods self-actings and powerlooms were not efficient due the cost structure of this kind of cotton good.

**8.2 The Theoretical Framework**

Recent literature on business institutions tends to support the view that vertical integration is a complex phenomenon which is the result of many causes. Which can act alone or interact.[565] In sharp contrast, many economic historians subscribe to the anachronic view that vertical integration is fully decided by the available technology. Since some technologies imply that two phases of the process of production come together within the industrial plant. Technically, this means that vertical integration is only the result of thermal economies in the two-phase plant and diseconomies in the single-phase plant. However, according to the recent literature on business institutions, technology would completely determine the structure of an concrete industry <u>only</u> when two restrictive conditions are satisfied: (1) in that industry there is only one available technology, (2) when this technology implies a singular form of organization.[566] In other words, two phases always come hand in hand when there is only one method of production that entails the integration both phases. These two conditions did not occur in the cotton industry of the mid nineteenth century. Firstly, different technological options were employed in the production of cotton yarn and cloth. For example, spinning employed mule or throttle spindles and, similarly, cotton weaving could employ jacquard looms or powerlooms. Furthermore, different forms of organisation (business institutions) predominated in each country.[567] It is well known that in Lancashire the extension of vertical integration was less than in New England or Germany.[568]

It should also be noted that the technology of the cotton industry was relatively simple, standardised was subject to continuous improvements (microinventions) throughout

[565] Perry (1989), p.187 classifies the determinants in three broad groups: (1) technological economies, (2) transaction cost economies, (3) market imperfections.

[566] Williamson (1986), pp. 86-87.

[567] On Lancashire see Gattrell (1977), Lyons (1985) and Temin (1988); on Great Britain Chapman (1987), Farnie (1979), pp. 277-323 and Mass and Lazonick (1990); on Germany, Brown (1992); on the United States, Temin (1988) and Chandler (1987); on Japan, Mass and Lazonick (1990).

[568] Temin (1988) and Brown (1992).

the period.[569] For that reason, there were no technological breakouts, or scale economies, which could not be achieved with a change in the organisation of labour, management, or remuneration of production factors. For instance, in England, many handweavers survived the competition of the new powerlooms, in spite of their inferiority in terms of productivity, by reducing their wages and working longer hours.[570] Similarly, as was shown in the previous chapter, many small firms survived by adapting their production to the characteristics of the local demand or labour force. Consequently, the vertical integration of the cotton firms for technological reasons was not obvious or essential. One can argue that the available technology in the cotton industry allowed the single-phase firms to obtain scale economies without having to vertically integrate into the next phase. Consequently, the entrepreneurial decision to integrate vertically was determined by a basic issue: the choice between whether to buy the intermediate goods in the market or to produce these goods within the firm. Of course, this decision is mainly the result of an economic calculation.

One of the first economists who emphasised the role of market failures as a major determinant of the scope of the vertical integration was George J Stigler. He argues that the intensity of vertical integration varies through the life-cycle of the industry. Thus, when the industry is young, or when it is in its maturity, the firms tend to be vertically integrated since demand is not high enough to sustain competitive intermediate input markets. Similarly, in the middle period of the development of industrial sectors vertical integration tends to be less important.[571] Porter and Livesay, and Chandler, have presented a somewhat different argument[572]. These three historians are agree, in broad terms, with the influence of the life-cycle of the industry on the extension of vertical integration. Although, conversely, they hold that vertical integration was not provoked by decrease in demand but by its expansion. In other words, vertical integration is predominant in the middle ages of industries.

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[569] Mokyr (1994) and VonTunzelmann (1994)(1995).

[570] Bythell (1978) and Timmins (1993).

[571] Stigler (1968).

[572] Porter and Livesay (1971), Chandler (1977).

A more recent approach to the problem is the work of Oliver Williamson.[573] According to this author, the evidence allows us to conclude that vertical integration is more related to saving in transaction costs than other factors. More specifically, he argues that the presence of asset specificity is the main factor that explains vertical integration. The concept of asset specificity refers to the extent to which a particular investment might be used for alternative purposes. The lack of alternative uses raising the scope for opportunistic behaviour amongst contracting parties. Asset specificity includes investment in physical capital, sites, human capital, brands and innovation. The ability to identify degrees of asset specificity enabled Williamson to specify the occasions when firms preferred to sub-contracting (putting-out). As a rule non-specific investment will result in market governance, (sub-contracting) while specific or idiosyncratic investment and recurrent transacting will result in firm governance. When a firm invests in assets which have a high degree of asset specificity they tend to integrate into the next phase in order to avoid opportunism in their transactions with other firms. Moreover, the firms tend to eliminate the intermediate markets when it is difficult to establish contracts that stipulate all the facets of the transaction. Williamson distinguishes two types of vertical integration. 'Mundane' vertical integration, which embraces the successive industrial phases within an industrial technological core, and forward or backward vertical integration, which embraces phases outside this technological core. The first type of vertical integration is more common since here savings in transaction costs are obvious and large.

Alfred D. Chandler Jr. was the first in to establish the relationship between vertical integration and innovation in organisations. He argues that the transport revolution that preceded the managerial revolution in the United States was accompanied by the diffusion of vertical integration in the production and distribution of goods.[574] In the same line of reasoning, William Lazonick underlined the central role played by vertical integration in the series of organisational innovations that characterised the second industrial revolution. Thus, vertical integration is relevant when one takes into account economies of speed. He pointed

[573] Williamson (1975), (1986), (1989) and (1991).

[574] Chandler (1977).

out that the growth of firms and markets made internal coordination of production and distribution necessary. Accordingly, vertical integration helps to increase the coordination and, as a result, to accelerate production. Moreover, with the process of vertical integration firms can transform the high fixed costs of one phase into low unitary costs for the final product. And sometimes the expensive innovations in one phase provoke spillover effects in the next. Finally, this process of growth generates the achievement of market power that reduces the competitive uncertainty that is present in every market. According to Lazonick, the reduction of this uncertainty helped the adoption of technological innovations.[575]

From a more theoretical perspective, Lewis and Sappington have maintained that the vertically integrated firms are comparable to the technologically innovative firms because they try to grow by increasing their internal efficiency. Conversely, the firms that sub-contract do not try to increase efficiency but try to gain monopolistic rents over subcontractors.[576]

The main criticism of the previous view, which supports the vertical integration, is that it tends to associate one type of organisational development that was common in the U.S. economy with a general pattern of development. On the one hand, scholars interested in small firms underlined their flexibility and efficiency in comparison with the big firms. On the other hand, many British economic historians have stressed the efficiency of the British firms which were not vertically integrated and were smaller than the U.S. firms.[577] Thus, recent literature casts doubts on the existence of one path to development and technological innovation, and the intrinsic superiority of vertical integration.

I believe that all these perspectives are not contradictories but complementaries. Important transaction costs give incentives to entrepreneurs to search for organisational innovations, such as vertical integration. This does not mean that I subscribe a deterministic

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[575] See Lazonick (1991), p. 132ff.

[576] Lewis and Sappington (1991).

[577] See, on the first perspective, Piore and Sabel (1985), Scranton (1991), Blackford (1991) and Sable and Zeitlin (1997); on the second, Berg (1994) and more specially Broadberry (1997).

and endogenous vision of innovation. Quite the contrary, I argue that innovations have an exogenous and unpredictable nature. However, sometimes business innovations are transmitted by the imitation of successful experiences. Consequently, it is likely that the Catalan entrepreneurs who adopted vertical integration imitated other previous entrepreneurs who had become successful with this kind of organisation.[578] It is also likely that other entrepreneurs who did not adopt vertical integration went bankrupt or obtained lower returns. Therefore, they were not imitated by their fellows. Note also that I am not arguing that vertical integration is the only route of growth in the cotton industry and the definite solution to the organisational problems of the Catalan industry. It also seems erroneous to relate the development of vertical integration to big industry as Chandler did. On any reckoning, the Catalan cotton firms were relatively small. Therefore, vertical integration is clearly possible within the context of small firms. As I show later. To sum up, I believe that there is a close relationship among technological innovation, organisational innovation and market imperfections. However, in the last instance, the decision to vertically integrate is usually due to stochastic (exogenous) factors.

### 8.3. The Scope of Vertical Integration in Catalonia

From the technical point of view, the production of cotton goods can be divided in three successive phases: (1) preparation and spinning, (2) weaving, (3) finishing. Finishing is not the last phase for all kinds of cloth since occasionally the yarn is coloured before being weaved. As was mentioned in the three previous chapters, at the eve of the Cotton famine, the three phases were partly mechanised in Catalonia. In other words, part of the cotton production in Catalonia was still in the hands of non-mechanised firms and domestic workers.[579]

Vertically integrated firms in cotton spinning and weaving existed in Catalonia from

[578] The first modem factory in Catalonia, the Bonaplata factory, vertically integrated spinning and weaving. The original model for the factory was copied by Bonaplata from Lancashire's coarse cotton mills. See Nadal (1985)(1992a).

[579] See in chapter 9 a description of the evolution of the technology in the Catalan cotton industry. Chapter 7 contains a description of the importance of the different power sources.

the end of the eighteenth century.[580] Although, it not was until the 1840s that they become relatively important. By 1850, vertical integration was relatively significant among mechanised cotton firms. In that year, there were 242 mechanised firms with more than 10 workers employing 20,844 workers. That is, they had about 28 percent of the total labourforce in cotton spinning and cotton and mixed-fabrics weaving. Among these mechanised firms, 176 firms with 9,726 workers were devoted exclusively to cotton spinning, 13 firms with 1,385 workers only to cotton weaving, and 53 firms with 9,720 workers had integrated vertically into cotton spinning and weaving.[581] Consequently, about 46 percent of the workers in mechanised factories were in vertically integrated firms. At this point, readers cannot be confounded by this evidence, I would not argue that vertical integration was a consequence of mechanisation.

However, only one decade later by 1861, the situation had changed radically in favour of the vertically integrated firms. Table 9.1 illustrates that vertical integration expanded faster in the 1850s. In particular, about 18 percent of Catalan cotton firms were vertically integrated. They had about 50 percent of labourforce and more than 60 percent of capital in machinery.

[580] See Thomson (1992) and Sánchez (1989)(1996).

[581] Note that these figures are not adjusted for full time employment (FTE) and therefore they can differ from the figures in chapter 3.

**Table 8.1** Vertical Integration: Cotton Industry, 1861

| Type | (1) Establishments (percent) | (2) Firms (percent) | (3) Capital (percent) | (4) Workers (percent) | (3)/(4) K per W (All = 100.00) |
|---|---|---|---|---|---|
| I | 157 | 154 | 35,291 | 5,799 | 6,085 |
| | (21.66) | (23.23) | (16.88) | (15.25) | (110.65) |
| II | 328 | 311 | 8,249 | 11,308 | 729 |
| | (45.24) | (46.91) | (3.95) | (29.74) | (13.26) |
| III | 81 | 76 | 33,553 | 2,575 | 13,030 |
| | (11.17) | (11.46) | (16.05) | (6.77) | (236.92) |
| IV | 112 | 90 | 55,749 | 10,971 | 5,081 |
| | (15.45) | (13.57) | (26.66) | (28.86) | (92.39) |
| V | 14 | 10 | 1,487 | 343 | 4,334 |
| | (1.93) | (1.51) | (0.71) | (0.90) | (78.82) |
| VI | 5 | 3 | 2,531 | 291 | 8,698 |
| | (0.69) | (0.45) | (1.21) | (0.77) | (158.16) |
| VII | 28 | 19 | 72,227 | 6,730 | 10,732 |
| | (3.86) | (2.87) | (34.54) | (17.70) | (195.14) |
| Vertically integrated | 159 | 122 | 131,972 | 18,335 | 7,198 |
| | (21.93) | (18.40) | (63.12) | (48.23) | (130.87) |
| All | 725 | 663 | 209,087 | 38,017 | 5,500 |
| | (100.00) | (100.00) | (100.00) | (100.00) | (100.00) |

**Notes and sources:** The table only comprises firms with ten or more workers. I: Preparation and spinning; II: Weaving; III: Finishing; IV: Vertical integration of spinning and weaving; V: Vertical integration of weaving and finishing; VI: Vertical integration of spinning and finishing; and VII: vertical integration of spinning, weaving, and finishing. Numbers subject to rounding error. Capital figures in thousands of Rv.

The diffusion of vertical integration was not equal among the phases of the cotton industry. It was more common in cotton spinning and weaving than in finishing. There were 109 firms that vertically integrated in cotton spinning and weaving whereas only 19 vertically integrated cotton finishing with cotton spinning and/or weaving. Therefore, cotton finishing was mainly done by specialised firms.[582] These firms elaborated a reduced range of products and were subcontracted by cotton weaving firms. They therefore did not participate in the distribution of finished cotton cloth. In effect, the wholesale market of finished cloth was in hands of vertically integrated firms, weaving firms and some major wholesalers in Barcelona. As example, the finishing firm Abelló, Santos and Cia of Grácia (Barcelona) advertised itself as the producer of cheap printed cloth for other companies.

[582] On the printing developments in Catalonia see Nadal (1991a), pp. 34-37; and Nadal and Tafunell (1992), pp. 39-50.

Jaumeandreu and Cía, of Sant Martí de Provençals (Barcelona) advertised itself as a printer and as subcontracted by four important weaving firms (Ferrer and Cía, Santacana, Sadurní and Cía, Rafecas, Marqués and Cía, and Gallifá and Argemí). Similarly, in the industrial exposition of 1860, many vertically integrated producers of cotton cloth exposed printed goods even though they did not have printing machinery in their factories.[583]

Catalan finishing firms, especially those in calico printing, were concentrated in Sant Martí de Provençals, then in the surroundings of Barcelona. In this town there were many external economies. Since there were many firms of the same kind, many ancillary industries (specially chemical and machinery firms), easy access to the Port of Barcelona, and abundant water.[584] Note that finishing firms were water and energy-intensive and, hence, their location was driven by geographical conditions.

I can present a stylized hypothesis to explain why in the finishing firms vertical integration was less important. The particular energy requirements hindered many spinning and weaving firms from integration into the finishing processes within their actual locations. For instance, some firms that integrated printing and other finishing processes with spinning and weaving had several factories. In particular, finishing factories were habitually located at Sant Martí de Provençals. Whereas the other spinning or weaving factories were located at the original site of the company.

It would be very useful to review what position vertically integrated cotton firms occupied within the Catalan cotton industry. If Maluquer was right one can expect that large firms were horizontal firms since sub-contracting the next phase would produce more gains than losses. Instead, if transaction costs matter, one can expect that the large firms were those that were vertically integrated. One simple way to approach this question is to compare their amount of labour and capital with the labour and capital in horizontal (single-phase) firms.

[583] Orellana (1860).

[584] On Sant Martí de Provençals and printing see Nadal and Tafunell (1992).

**Table 8.2** The Size of Vertically Integrated and One-Phase Firms: Cotton Industry, 1861

(1) Classified according to the number of workers

| Type | | 10- | 50- | 100- | 200- | 300- | 400- | 500- | 600- | 1000- |
|---|---|---|---|---|---|---|---|---|---|---|
| Spinning | Firms | 117 | 28 | 9 | | | | | | |
| | Workers | 2,917 | 1,841 | 1,041 | | | | | | |
| Weaving | Firms | 253 | 42 | 12 | 3 | 1 | | | | |
| | Workers | 5,736 | 2,920 | 2,647 | 640 | 365 | | | | |
| Finishing | Firms | 63 | 12 | | | 1 | | | | |
| | Workers | 1,540 | 735 | | | 300 | | | | |
| Integrated | Firms | 36 | 33 | 22 | 15 | 6 | 4 | 4 | 1 | 1 |
| | Workers | 1,080 | 2,477 | 3,124 | 3,454 | 2,002 | 1,625 | 2,183 | 600 | 1,790 |
| All | Firms | 469 | 115 | 43 | 18 | 8 | 4 | 4 | 1 | 1 |
| | Workers | 11,273 | 7,973 | 5,812 | 4,094 | 2,667 | 1,625 | 2,183 | 600 | 1,790 |

(2) Classified according to capital in machinery (thousands of Rv.)

| Type | | 0- | 50- | 100- | 200- | 300- | 400- | 500- | 750- | 1000- |
|---|---|---|---|---|---|---|---|---|---|---|
| Spinning | Firms | 26 | 21 | 35 | 29 | 17 | 10 | 12 | 3 | 1 |
| | Capital | 826 | 1,486 | 5,176 | 7,190 | 5,899 | 4,288 | 6,862 | 2,564 | 1,000 |
| Weaving | Firms | 280 | 13 | 7 | 7 | 2 | 1 | 1 | | |
| | Capital | 2,934 | 931 | 1,014 | 1,657 | 666 | 472 | 576 | | |
| Finishing | Firms | 11 | 8 | 7 | 7 | 6 | 4 | 25 | 4 | 4 |
| | Capital | 268 | 560 | 987 | 1,454 | 2,039 | 1,740 | 15,643 | 3,208 | 7,654 |
| Integrated | Firms | 15 | 11 | 11 | 9 | 8 | 11 | 22 | 8 | 27 |
| | Capital | 455 | 805 | 1,557 | 2,193 | 2,845 | 4,757 | 13,246 | 6,963 | 99,173 |
| All | Firms | 332 | 53 | 60 | 52 | 33 | 26 | 60 | 15 | 32 |
| | Capital | 4,483 | 3,782 | 8,734 | 12,494 | 11,449 | 11,257 | 36,327 | 12,735 | 107,828 |

**Notes and sources:** numbers subject to rounding errors. The source is Gimenez Guited (1862)

As shown table 9.2, the major Catalan cotton firms were vertically integrated by any of the measures considered. In particular, all the firms with more than 400 workers, and 27 of 32 firms with more than Rv 1 million of capital in machinery were vertically integrated. However, a sceptical reader could argue that this result is the obvious consequence of the fact that vertically integrated factories contained two or more phases. In other words, they had no more scale economies in each single phase than one-phase firms. The next table serves to discuss this question.

**Table 8.3** The Size of Vertically Integrated and One-phase Firms: Cotton Spinning and Weaving, 1861

(1) Number of mechanical spindles

| Type | | 0- | 500- | 1000- | 2000- | 3000- | 4000- | 5000- | 7500- | 10000- |
|---|---|---|---|---|---|---|---|---|---|---|
| Spinning | Firms | 34 | 21 | 37 | 27 | 22 | 7 | 3 | 3 | |
| | Spindles | 8,320 | 15,888 | 54,937 | 66,172 | 73,690 | 31,180 | 16,670 | 26,231 | |
| Integrated | Firms | 16 | 11 | 14 | 17 | 14 | 6 | 15 | 9 | 6 |
| | Spindles | 5,395 | 7,941 | 19,324 | 41,298 | 48,314 | 26,724 | 89,963 | 75,628 | 142,172 |
| All | Firms | 50 | 32 | 51 | 44 | 36 | 13 | 18 | 12 | 6 |
| | Spindles | 13,715 | 23,829 | 74,261 | 107,470 | 122,470 | 57,904 | 106,633 | 101,859 | 142,726 |

(2) Weekly production of pieces of cloth (estimated)

| Type | | 0- | 50- | 100- | 200- | 300- | 400- | 500- | 750- | 1000- |
|---|---|---|---|---|---|---|---|---|---|---|
| Weaving | Firms | 254 | 29 | 16 | 5 | 3 | 2 | 2 | | |
| | Pieces | 5,172 | 1,975 | 2,263 | 1,388 | 992 | 832 | 1,240 | | |
| Integrated | Firms | 47 | 12 | 13 | 13 | 5 | 12 | 8 | 6 | 3 |
| | Pieces | 979 | 839 | 1,892 | 3,056 | 1,628 | 5,380 | 4,732 | 5,052 | 7,512 |
| All | Firms | 301 | 41 | 19 | 18 | 8 | 14 | 10 | 6 | 3 |
| | Pieces | 6,151 | 2,814 | 4,155 | 4,444 | 2,620 | 6,212 | 5,972 | 5,052 | 7,512 |

**Notes and sources:** numbers subject to rounding errors. The source is Gimenez Guited (1862)

Not only were the vertically integrated firms the largest firms in the cotton industry but they were also the largest firms in each phase. Specifically, in cotton spinning, all firms with more than 10,000 spindles were integrated vertically. Similarly, in cotton weaving, all firms with a production of more than 750 pieces per week were vertically integrated.[585] Consequently, these figures suggest that the biggest Catalan cotton firms decided to expand vertically towards the other phases and not horizontally within one phase. It seems that large firms obtained more gains by avoiding intermediate markets than by fixing the prices for sub-contractors. More to the point, the pressures associated with asset specificity were more important than the expected gains of expanding a single phase up to the limits of capital resources.[586]

[585] To estimate the production of the looms I assume that powerlooms produced four pieces per week and handlooms one. See Von Tunzelmann (1978). Lyons (1987) furnished a different figure: five pieces for the powerlooms and one piece for hand-looms.

[586] See Bresnahan (1989) on the theoretical grounds.

The next few examples serve to clarify how vertical integration and sub-contracting worked among the Catalan cotton firms. Firstly, I refer to España Industrial S.A., the biggest firm in the Catalan cotton industry at that time. This firm integrated cotton spinning, weaving, finishing, machinery repairs and wholesale distribution. From this firm, a book has been preserved where all transactions and the movement of goods among the different warehouses of the company are registered. With the data of this book, I compute table 9.4. This table serves to establish the relative importance of working-out within the company in the period 1859-1860.

**Table 8.4** The Scope of Sub-contracting: España Industrial S.A., 1859-60

| 1st phase: Spinning (in libras catalanas) | Output | internal consumption | sold to other firms |
|---|---|---|---|
| 1859 | 2045377 (100,00 %) | 1918492 (93,80 %) | 126885 (6,20 %) |
| 1860 | 2392375 (100,00 %) | 2340502 (97,83 %) | 51873 (2,17 %) |
| 2nd phase: weaving (in grey pieces) | Output | own production | bought to external producers |
| 1859 | 148098 (100,00 %) | 136261 (92,01 %) | 11837 (7,99 %) |
| 1860 | 178685 (100,00 %) | 157793 (88,31 %) | 20892 (11,69 %) |
| 3rd phase: Bleaching and printing (in pieces) | Output | own production | Sub-contracted bleaching |
| 1859 | 148098 (100,00 %) | 132060 (89,17 %) | 16038 (10,83 %) |
| 1860 | 178685 (100,00 %) | 154286 (86,35 %) | 24399 (13,65 %) |

Notes and sources: España Industrial (1859)(1860).

At first glance, the table highlights the small amount of intermediate goods that the firm traded with other companies. In spinning, the small excess of production was partly sold and partly sent to a few sub-contractors of the firm.[587] The firm also produced less grey cloth than the consumption of its finishing phase. Thus, it bought small quantities of fabrics from other firms and from sub-contractors who had previously received yarn stocks from the same company. It must be highlighted that the firm acquired products which were very

[587] In 1859, the distribution (in libras catalanas) was: with contract 96,784, sold by money 16,432, and external sub-contractors 13,666; and in 1860: 18,538 with contract, sold by money 13,092, and external sub-contractors 20,243.

similar to its own production. Finally, in the bleaching process, España Industrial sub-contracted in peak periods. The evidence seems to suggest that España industrial employed the intermediate (external) markets and sub-contracting not to diversify its production but to complete its delivery requirements and eliminate its surpluses of yarn or grey cloth. Chandler argues that in this period many cotton firms in the United States encountered many problems to synchronising the production of the different phases and, therefore, had to buy and sell intermediate products in the market[588]

The problems faced by España Industrial when it tried to sub-contract a small portion of the bleaching process can serve to illustrate the transaction costs associated with sub-contracting. España Industrial decided to sub-contract bleaching because the process was very labour-intensive and without any technological sophistication. Thus, it was less subject to opportunism by sub-contractors.[589] Despite the fact that the characteristics of the process make its sub-contracting easy, the firm suffered many problems with sub-contractors and had to test many firms to find a suitable company. This test on several sub-contractors represented additional costs for the company and delays in the finishing of many orders; consequently, the process of sub-contracting resulted in transaction costs and diseconomies of speed.[590]

The main goal of España Industrial was to develop a system of production where not only could it gain advantages from scale economies but also maintain a system of flexible production. Scale economies could only develop by producing long editions of the same type of yarn or cloth. By contrast, flexible production involved producing a short edition of each fabric. Flexible production was required to overcome the relative small size of the home market and to adopt the supply to changes in fashion and consumers' preferences. To maintain a flexible production system without losing scale economies the company produced 38 different fabrics from only a few grey cloths. Furthermore, each type of grey cloth was weaved with two single measures of yarn. Thus, España Industrial only produced eight

[588] Chandler (1977).

[589] Klein *et al.* (1978) and Williamson (1986), chapter 3.

[590] España Industrial (1858a)(1859a).

counts of yarn, and five types of grey cloth, but thirty-eight final fabrics. Note that the editions of each different type of finished cloth were shorter than the editions of each type of yarn or grey cloth. For example, the medium quality grey cloth of 70 cm width was employed in ten different types of fabrics: género blanco cólera, madapolan E, and eight different calicoes. The price of the final products was disparate since the cheapest was sold for Rv 5.75 per cana catalana and the most expensive for Rv. 15 per cana catalana.[591] With this combination of longer editions of grey cloth and shorter editions of finished cloth, the firms could invest in highly specific assets obtaining a level of efficiency and maintaining the flexibility of production. As was required by the Spanish home market.

Another interesting example is the cotton spinning and weaving factory of Juan Güell and Cía of Sants (Barcelona). Which was among the ten biggest Catalan cotton firms. This firm was mainly devoted to the production of corduroy. The corduroy production was completely mechanised except for the process of cutting the nap. This latter process was the only process that the company subcontracted to households, where women and children cut the nap.[592] Why did the firm subcontract this phase and not the others? The reason was that the firm was not subject to opportunism from domestic system (sub-contractors) because this phase employed unskilled labour and embezzlement was very difficult. Note that domestic workers had many problems when negotiating their wages since the firm could easily replace them and domestic production was in crisis. Consequently, it was advantageous to cover the transaction costs involved in out-working and not introduce the process of cutting the nap into the plant. In other words, it was likely that the costs involved were larger than the return of integrating the process within the factory. However, it should be remembered that the rest of the production processes were vertically integrated within the firm's factory.

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591 España Industrial (1858b).

592 Orellana (1860).

### 8.4. The Determinants of Vertical Integration

As mentioned above, the determinants in the entrepreneurial decision to vertically integrate are very complex. In this section, I analyse the main determinants of the diffusion of vertical integration among the Catalan cotton firms. I argue that the vertical integration was chosen by the big firms in order to offset certain limitations inherent in the Spanish home market. Precisely, it was due to this innovation that these big cotton firms could adopt the more efficient technologies. Which contained more asset specificity than the previous technologies used in the Catalan cotton mills. The main characteristic of the home market that gave incentives to vertically integrated was its small size. Problems were also caused by fluctuations in the demand for cotton goods and high interest rates. These problems represented diseconomies of scale for the one-phase firms and an incentive for the vertical integration of two or more phases of the production of cotton goods.

The Spanish home market for cotton textiles was smaller than the markets in other countries. The main reason was that the per capita demand for textile products in Spain was inferior to the average per capita demand in European countries.[593] For this reason, asset specificity was a larger problem in Catalonia than in other European regions. Thus, for a Spanish cotton firm to invest in a technology with few alternative uses would be very risky if the firm could not guarantee a minimum demand for its production. A minimum demand for the production of yarn could be obtained by vertically integrating the production of grey cloth with powerlooms. In other words, the risk of expanding production horizontally with technology containing asset specificity was larger than the risk of expanding the production vertically.

In particular, by the 1850s the more efficient technology for the production of cotton cloth of coarse-medium quality had few alternative uses.[594] The most productive machinery

[593] Sánchez-Albornoz (1981) and Prados de la Escosura (1983).

[594] Note that, until now, economic theory has not developed an independent measure of asset specificity. Consequently, asset specificity is a relative argument. Thus, one can argue that self-actor mules contained more asset specificity than mule-jennies. Since the latter were able to efficiently produce more counts (qualities) of yarn than the former and, also, could change count easier.

was the self-acting mule in cotton spinning and the powerloom in cotton weaving. Their use was not universal due to their technological constraints. They could not produce all the different types of cotton goods because they were only suitable for the medium and coarse yarn and cloth. Moreover, they were most efficient when they could produce long editions. That is, their productivity increased when they could produce large amounts of the same count (quality) of yarn or cloth. The old technologies (i.e., the mule-jennie and the hand-looms) were more efficient in the production of fine cloth and mixed-fabrics.[595]

Specifically, the self-acting was not flexible since it could not produce yarn of different counts, fine quality yarn, or easily change count.[596] Furthermore, the initial investment in plant and motive power for self-actings was relatively important. Consequently, to invest in self-actings would be very risky if the industrialists had not found enough demand for the relatively large quantity of yarn that this spinning machine was capable of producing. Moreover, the presence of many cotton mills with self-actings in the market should push down the price of yarn in the market. Due to this, it was a good idea for firms with self-actings to vertically integrate into the next phase, weaving with powerlooms, instead to grow horizontally by acquiring more self-actings.

Likewise, the powerlooms were complementaries of the self-actings. To work efficiently powerlooms required a long quantity of very homogeneous yarn. Mule-jennies and other primitive spinning machines were unable to produce this homogeneous yarn. Unlike self-actings which produced a long quantity of homogeneous yarn.[597] Note that powerloom technology was not more flexible than self-acting technology; in other words, powerlooms contained asset specificity. Obviously, this drove the vertical integration of the firms that employed self-actings and powerlooms since, as Oliver E. Williamson argues,

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[595] Von Tunzelmann (1978) and Lyons (1987).

[596] Cohen (1990) exaggerates the flexibility of the self-acting mule. The Spanish technical handbooks refer to problems with the self-acting mule and the advantages of maintaining the use of mule-jennies. See, for example, Arau (1855). However, the self-acting were more flexible than the throstle as the latter could not be modified to change count and efficiently produced only a very limited range of counts.

[597] Von Tunzelmann (1978) and Lyons (1987).

successive phases with similar technologies and important asset specificity are integrated more easily.[598] If we also consider the intrinsic problems of the home market, it is not strange that most of firms that employed self-actings in spinning integrated forward into weaving with powerlooms.

**Table 8.5** The Relationship Between Cloth Quality and the Type of Firm: Cotton Industry, 1860

| Type of firm | Number of firms showing in the exhibition: Coarse cloth | Medium cloth | Fine & Mixed cloth | total firms in the exhibition |
|---|---|---|---|---|
| Hand Weaving | 1 | 2 | 14 | 16 |
| Power weaving | 1 | 0 | 0 | 1 |
| Printing | 2 | 12 | 6 | 14 |
| Spinning + Weaving | 4 | 10 | 0 | 12 |
| All phases | 2 | 9 | 1 | 10 |
| Total | 9 | 34 | 21 | 53 |

**Notes and Sources:** Some firms produced more than one quality of cloth, therefore the last column does not add up. Coarse cloth: Curados, cutíes, driles, empesas and percalinas bastas. Medium cloth: Brillantinas, elefantes, empesas finas, guineas, hamburgos, indianas normales, madepolan, muselinas, panas, percalinas, retores, ruanesas and semi-retores. Fine cotton cloth and mixed fabrics: Batistas, cashmires, castores, chalecos, florentinas, guatas, indianas finas, mantones, pañuelos, and piqués. The source is Orellana (1860), the classification of the quality of products is based on Ronquillo (1851-1857) and the classification of firms is based on Gimenez Guited (1862).

Table 8.5 confirms part of the proposition. According to the arguments presented above, one can expect that firms producing coarse-medium cloth had to employ powerlooms.[599] In contrast, hand-weaving firms tended to produce fine and mixed-fabrics cloth since powerlooms were not effective in that type of production. Here it is likely that vertical integration was less important. Printing firms produced the whole range of qualities of cloth since they could buy all types of cloth.

The fluctuations in demand affected the market for intermediate and final goods. It

[598] Williamson (1986), pp. 85ff.

[599] It is likely that these firms also employed self-actings but the evidence for 1861 is not readily available. However, it should be noted that in 1850 practically all establishments which vertically integrated cotton spinning and weaving employed self.-actings in spinning. See Junta de Fabricas (1850).

is well known that the demand for textile products in Spain was relatively small, in comparison with the Western European countries and the United States. Demand was also very irregular, in comparative terms, throughout the year and from one year to another.[600] the result of this was that the wholesalers and shops rarely settled the date at which they would pay their debts, or signed credit documents.[601] They preferred to send payments to their suppliers when they decided to settle their debts.[602] It is obvious that firms could finance themselves by means of accommodation bills, although this involved higher financial costs due to the high interest rates in Spain.[603] Thus, the fluctuations in demand were difficult (costly) to avoid by external financing and cotton factories could not get credit on the products sold since they did not know when the debt would be settled.

According to the theory, when markets fluctuate the firms in the initial phases of the process can protect themselves by adopting flexible production techniques. With flexible production firms can adapt the quantity and quality of their production to the changes in the final demand for goods.[604] In Catalonia, the cotton firms combined vertical integration and flexible production. Thus, the majority of production took place in firms which vertically integrated cotton spinning and weaving and sub-contracted finishing. Thus, as shown in a previous example, the firms could produce a reduced range of grey cloth and finish them with different kinds of colours and textures. The price of finishing was very varied and, therefore, products could be directed to many different markets and consumers. To summarise, the cotton firms reduced the number of intermediaries, reducing transaction costs but maintaining a system of flexible production.

[600] Sánchez-Albornoz (1981) and Prados de la Escosura (1983).

[601] Graell (ed)(1908) and Sudrià (1987).

[602] Cuadras and Rosés (1998).

[603] The common interest rate in Spain was about 6 percent, although in some occasions this would be raised up to 9 percent. In sharp contrast, British interest rates were habitually below 4 percent. Furthermore, when Catalan firms issued accommodation bills they incurred other expenses such as negotiation and rediscounting costs. Which could double the cost of borrowing.

[604] On flexible production see Milgrom and Roberts (1990) and Eaton and Schmitt (1994).

**Table 8.6** The Relationship Between the Number of Products and the Type of Firm: Cotton Industry, 1860

| Type | Firms | Fabrics | Mean per firm | Standard Deviation |
|---|---|---|---|---|
| Only weaving | 17 | 24 | 1.4 | 0.79 |
| Only printing | 14 | 25 | 1.8 | 1.05 |
| Vertically integrated | 22 | 77 | 3.5 | 2.44 |

**Notes and sources:** The source is Orellana (1860).

The previous table was computed using data on the cloth presented by several firms participating in the industrial exposition that took place in Barcelona in 1860 in homage to the Queen. Each firm was asked to send to the exposition some fabrics from its warehouses.[605] This table serves to confirm the previous arguments. Vertically integrated firms were capable of producing a wider range of products than the specialised spinning or weaving firms. Furthermore, it shows that finishing firms and weaving firms were specialised in a small range of products.

Recently, imperfections in financial markets have been considered important in explaining the level of concentration in industrial sectors because they act as entry barriers to new firms.[606] Furthermore, this kind of imperfection can give an incentive to vertical integration. Vertical integration works as an internal capital market and, therefore, it represents the elimination of financial intermediaries.[607] In other words, the absence of external financing, or high interest rates, can give an incentive to firms to buy the next phase and to employ their money invested in circulating capital (i.e., the money used for credit to customers) within the firm. In this case, vertical integration has three main consequences for the financial situation of firms: it reduces risk, it increases control over their own business, and it diminishes the amount of circulating capital. In other words, vertical integration reduces the financial costs of firms.

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[605] Orellana (1860).

[606] Haber (1991).

[607] Williamson (1975) and Mowery (1992).

In Spain, the final and intermediate markets were organised into networks where personal contacts determined the reputation of firms. In other words, transactions were based on a system of reputation. For example, España Industrial asked for two recommendations from old customers to give credit to a new customer. Thus, the firm was more interested in the reputation of the future customer (e.g., if he were a devout catholic, a good father or a trustworthy entrepreneur) than his assets or credit record.[608] Furthermore, the small size of the market and its unstable character caused difficulties for financial institutions trying to develop an impersonal system of money lending. Thus, the Catalan cotton firms used an important part of their resources financing their own customers since credit from banks and other financial intermediaries was scarce. Any unexpected increase in the demand for cotton goods might be financed by the same cotton industry that had to finance all the distribution from the factory to the final customer. It was rare that wholesalers or shops paid in advance or amortised their debts over short periods. Similarly, weaving firms could not easily obtain credit from banks. It was also common for spinning firms to finance weaving firms. Consequently, for mechanised spinning firms it could be very convenient to vertically integrate into the weaving process because they already indirectly financed this phase. Thus, they could convert the circulating capital lent to other companies into fixed capital, which was directly owned by the company.

An example can help us to understand this situation. The firm Miquel Puig and Cia produced yarn and cloth in its factory in Esparraguera (Barcelona). This society sold yarn to weaving firms and coarse and medium counts of cloth (percalinas, empesas, and hamburgos) to printing firms. The company received some credit from its suppliers, but it was not enough to finance the cycle of production within the firm and the credit that the firm conceded to its customers. Furthermore, the firm rarely received credits or discounted bills-of-exchange in banks. More commonly, the firm asked its owners for more money or delayed the payment of dividends in order to finance the new requirements of capital. The result was that a growing quantity of capital was continuously employed to finance the market of its products. In other words, new increases in demand simultaneously required

[608] España Industrial (1858b)(1859c).

new capital. After some years of existence, the firm decided to buy the next phase of production: the printing of cotton goods. Thus, it reduced its financial costs since the amount of capital devoted to financing its customers who were printers was larger than the cost of producing printer cloth in the new factory. The acquisition of the next phase was possible because the company had access to new sources of external financing.[609]

To sum up, there were many incentives to vertically integrate the production of cotton goods. The small size of the markets, the fluctuations in demand and the absence of external financing all gave incentives to vertically integrate the production of cotton goods. Furthermore, this vertical integration was more intense in the cases where 'mundane' vertical integration was possible. This hypothesis can be formalised in the next model:

(8.Vertical Integration (PROB=1) = F (Size, Machinery, Capital Intensity, Subcontracting)

Where I assume that the probability of a cotton firm being vertically integrated is a positive function of: the size of the firm, especially in the spinning phase; the level of adoption of new technologies containing asset specificity (mechanisation); and capital intensity. Whereas it is negative function of subcontracting. I test two alternative models: one considering all kinds of vertical integration and the second only vertical integration of cotton spinning and weaving. In the first model I consider all Catalan cotton firms with 10 or more workers in 1861. Whereas in the second model all Catalan firms in cotton spinning or weaving with 10 or more workers.[610]

The methodology used in the analysis is the logit analysis. This procedure allows the estimation of the probability of an event occurring given a sample of different explanatory variables. Specifically, given that the dependent variable is binary (the variable takes the value 1 when the firm is vertically integrated and 0 when not), the logit estimates a non-linear equation that indicates which are the determinant factors of the dichotomic event. I

[609] Sedó (1850-1855)(1856-1860)(1861-1865)(1866-1870).

[610] The data is drawn from Gimenez Guited (1862).

use this method instead of linear discriminant or multiple regression analysis because it requires far fewer assumptions than these alternative methods. These two techniques pose difficulties when the dependent variable can have only two values. On the one hand, the assumptions necessary for hypothesis testing in regression analysis are necessarily violated and the predicted values cannot be interpreted as probabilities. On the other hand, linear discriminant analysis allows direct prediction of group membership. But the assumption of multivariate normality of the independent variables, as well as equal variance-covariance matrices in the two groups, is required for the prediction rule to be optimal. Instead, the logit method performs well even when the assumptions required for discriminant analysis are satisfied[611]

In logistic regression one directly estimates the probability of an event occurring. The parameters of the model are estimated using the maximum-likelihood method. The regression coefficients give the amount of change in the dependent variable for a one-unit change in the independent variable. The Wald statistic is just the square of the ratio of the coefficient to its standard errors. There are different ways to asses whether or not the model fits the data. First, one looks at the likelihood, which is the probability of the observed results given the parameter estimates. To test the null hypothesis that the observed likelihood does not differ from one (the value of the likelihood for a model that fits perfectly), I used the value of -2 Log Likelihood. This is a measure of how well the estimated model fits the data. Second, I used a chi-square test that is comparable to the F test for linear regression. The chi-square tests the null hypothesis that the coefficients for all of the terms in the current model, except the constant, are zero. Finally, I present the goodness-of-fit statistic of the model, which compares the observed probabilities to those predicted by the model.

I consider the following variables. Three independent variables refer to size as a determinant of vertical integration. The first refer to preparation, the second to spinning, and the third to the number of factories. The variable 'cards' is the number of card machines in each firm. The number of cards is a very good proxy for the amount of output since most

[611]A logit model was preferred to the alternative specification, probit, due to the particular characteristics of the sample. See Hosmer and Lemeshow (1989) for a discussion of this point.

firms employed the same type of card. The variable 'mechanical spindles' is the number of mechanical spindles in each firm. Finally, the variable 'factories' refers to the number of industrial establishments owned by each firm. Two variables refer to the level of mechanisation: the variable 'spinning mechanisation' is the share of mechanical spindles in the total number of spindles in each firm; the variable 'weaving mechanisation' is the share of powerlooms in the total number of looms in each firm. The variable 'K/L' (capital/intensity) is the amount of capital in machinery of the firm divided by the number of workers. Finally, the variable 'sub-contracting' was computed according to the next equation:

**(6.1)**

$$P_{Sx} = \frac{\sum_{i=1}^{n} Wt}{\sum_{i=1}^{n} QE}$$

**i= 1,2,3 ...n.**

Where the probability of sub-contracting X ($P_{Sx}$), is equal to the number of workers in the workshops (establishments with less than 10 workers) in the *n* districts (Wt) where the firm has factories, divided by the number of firms in the n districts (QE) where the firm has factories. The expected outcome of our analysis is that the probability that vertical integration takes place is a positive function of the variables 'cards', 'mechanical spindles', 'K/L', 'factories', 'mechanical spinning' and 'mechanical weaving', and a negative function of 'sub-contracting'. The results of the model are presented in table 8.7.

**Table 8.7** The Determinants of Vertical Integration: Cotton Industry, 1861

Estimation procedure: Logit method

| Dependent Variables / Independent Variables | | Any kind of vertical integration β (S.E.) | Wald (Sig.) | | Vertical integration of spinning and weaving β (S.E.) | Wald (Sig.) |
|---|---|---|---|---|---|---|
| Constant | | -7.0237 | 78.6678 | | -8.4902 | 54.9531 |
| | | (.7919) | (.0000) | | (1.1453) | (.0000) |
| Cards | | .0323 | 10.3300 | | .0456 | 16.2436 |
| | | (.0100) | (.0013) | | (.0113) | (.0001) |
| Mechanical Spindles | | | | | .0002 | 4.3033 |
| | | | | | (.0001) | (.0380) |
| K/L | | .0002 | 7.3264 | | .0005 | 22.0636 |
| | | (6.09E-06) | (.0068) | | (.0001) | (.0000) |
| Factories | | 3.2204 | 39.9386 | | 3.0783 | 22.8121 |
| | | (.5096) | (.0000) | | (.6445) | (.0000) |
| Mec. Spinning | | .0338 | 55.4721 | | .0595 | 49.9469 |
| | | (.0045) | (.0000) | | (.0084) | (.0000) |
| Mec. Weaving | | .0390 | 84.1651 | | .0586 | 52.9006 |
| | | (.0042) | (.0000) | | (.0081) | (.0000) |
| Subcontracting | | -.1246 | 5.2814 | | -.1669 | 5.4849 |
| | | (.0542) | (.0216) | | (.1.1453) | (.0192) |
| Observations | 663 | | | 587 | | |
| | | | Signif. | | | Signif. |
| -2 Log Probability | | 273.126 | 1.0000 | | 166.154 | 1.0000 |
| Chi$^2$ of the model | | 359.937 | .0000 | | 397.264 | .0000 |
| Goodness-of-fit | | 1736.718 | .0000 | | 3103.547 | .0000 |

**Notes and sources:** see text.

The size of spinning is one of the determinants of vertical integration because the market imperfections and transaction costs provoked diseconomies of scale in the spinning firms. Moreover, spinning firms invested more in assets with asset specificity since, for example, at the end of the 1860s about 80 percent of spindles were in self-acting mules and throstles.[612] Investments which were high in asset specificity. This explains why integration was from spinning towards weaving and finishing more than from weaving or finishing towards spinning. The number of factories is also a determinant of the degree of vertical integration. As many vertical integrations consisted of the takeover of already established

[612] Comisión especial arancelaria (1867).

factories and because many firms that integrated into the finishing phase maintained the finishing factory at Sant Martin de Provençals and the other factories in other locations.

The level of mechanisation in spinning and weaving are determinants of the level of vertical integration. Consequently, the 'mundane' hypothesis (i.e., that vertical integration is more common within the technological core) of Oliver Williamson is corroborated in the case of the Catalan cotton industry. Furthermore, it can be assumed that high levels of mechanisation corresponded to the use of self-actings and powerlooms and that, as was demonstrated in table 9.6, these firms produced coarse-medium cloth.

Capital intensity positively affected the probability of vertical integration. The reason is that the vertically integrated firms had opted for a more intensive technology: self-acting mules in spinning and powerlooms in weaving. Note that self-actings and powerlooms required less labourforce per Pta of capital that the old technologies (mule-jennies and handlooms). Furthermore, as was repeatedly argued previously, this more capital-intensive option was only possible in the vertically integrated firms. Note then that the vertical integration was a way to intensify the substitution of capital for labour and to increase the labour productivity of the cotton industry. Consequently, one can argue that in the Catalan case there is a strong relation between organisational innovations and the adoption of the most efficient machinery.[613]

The relationship between the probability of sub-contracting and the probability of vertically integrating cotton production is negative. This means that the tendency was that vertically integrated firms did not locate in the same districts as the workshops that could sub-contract. As I have already stated vertically integrated firms produced a different cloth than the small workshops and domestic industry. Moreover, vertically integrated firms sub-contracted less than one-phase firms and, obviously, eliminated the intermediate market for cotton yarn. Thus, vertically integrated firms did not collaborate with workshops but competed with them for natural resources and labourforce. In particular, the vertically

[613] Lazonick.(1991), p. 132ff has argued that there is a strong correlation between organisational innovation and the development of gains in productivity and scale economies.

integrated firms could offer higher salaries since their labour was more productive. Thus, it was likely that the wage level was higher in districts with many vertically integrated firms. Consequently, workshops that employed cheap labour encountered many problems recruiting cheap labour and tended to disappear from the districts of the vertically integrated firms.

### 9.5. The Consequences of Vertical Integration

Finally, it is worth addressing to the consequences of vertical integration. Here, four main questions will be considered: (1) the effect on the productivity of the industry; (2) the consequences on its structure; (3) the effects on the international competitiveness; (4) if it had monopolistic consequences, that is, if the vertical integration reduced the level of competition among the Catalan firms.

In chapter 5,[614] it was shown that total factor productivity in the cotton industry did not expand as fast as in the 1850s than in the previous periods. Thus, one could argue that this type of institutional innovation had limited effects on productivity growth. However, two questions must be considered. Firstly, the rate of productivity growth from 1850 to 1861 was hampered by the overproduction problems in the industry at the end of the 1850s. Secondly, as was noted in the past section, the diffusion of vertical integration was accompanied by the adoption of new machinery. Consequently, some productivity improvements associated with the adoption of vertically integrated firms were included in the capital measures as capital quality increases.

The dualistic character of the Catalan cotton industry (this was not unique to Catalonia) was strongly reinforced by the spread of the vertical integration. An important part of the industry was organised into centralised, power-driven, highly mechanised, vertically-integrated factories that produced coarse-medium cotton goods. With their vertical integration these big cotton firms (in Spanish terms) avoided some imperfections of the Spanish market and augmented their efficiency. On the other hand, the rest of the industry

[614] See table 5.4.

was formed of many small firms. These firms were less intensive in capital, smaller than vertically-integrated firms, and produced fine cotton cloth and mixed fabrics. The printing firms were between the two groups: they were sub-contracted by the vertically-integrated firms or, alternatively, controlled their own web of small weaving firms or domestic weavers. Small firms survived because of their flexible production and the human capital of their employees.

The development of the integrated firms altered the nature of the production of cotton goods in Catalonia. During the 1830s, the industry had a democratic character since it was very easy to enter the business.[615] However, the irruption of the more capital-intensive vertically-integrated firms raised large entry barriers. Thus, the initial requirements of capital rose substantially and the separation between ownership and labour became more clear cut. In spite of the movements towards centralisation, the external economies were still very important for the Catalan industries. In particular, during this period there was a spectacular increase in the number of ancillary industrial services available in Catalonia. This represented a strong competitive advantage of that region compared to the rest of Spain.[616]

Note that, due to the market imperfections of the Spanish market, which were caused by its small size, one can expect that the relative importance of vertical integration in Catalonia was larger than in England. Table 8.8 compares the relative importance of vertical integration in Catalonia and England. To correctly compare Catalonia and England it was necessary to convert the Catalan evidence to the British standards.[617] To construct the next table, only power and water-driven factories with more than 10 workers were considered. This implies 25,366 workers of the 42,631 in Catalonia. Note also that the British sources did not report all the workforce because, for example, hand-weavers were not included.[618]

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[615] Thomson (1992), pp. 235ff.

[616] See chapter 7.

[617] Gatrell (1977) offers a detailed description of the British sources.

[618] Timmins (1993).

**Table 8.8** Share of the Vertically Integrated Mills: Cotton Spinning and Weaving, England and Catalonia, 1861 (percent)

| | Workers | Power Looms | Mechanical Spindles |
|---|---|---|---|
| England | 52.9 | 63.9 | 41.8 |
| Catalonia | 65.8 | 80.2 | 55.2 |

**Notes and sources:** England: Farnie (1979), p. 317 and Catalonia: Gimenez Guited (1862).

The result of this comparison is very persuasive. By any measure, vertical integration was more important in Catalonia than in England. The hypothesis of the relation between market size and vertical integration seems warranted. Note that this result is not a consequence of the fact that Britain exported a large quantity of its yarn. Since in England and Catalonia powerlooms were important in vertically integrated firms. Extending this result to the United States, one can expect that vertical integration was more important than in England since market costs were likely to be larger in the U.S. As the U.S. market was smaller and its integration was hindered by the high transport costs.[619]

In terms of international competitiveness, the principal consequence of vertical integration was to considerably reduce the disadvantages provoked by the size of the Spanish home market. Thus, by vertically integrating the production of cotton yarn and cloth many Catalan firms increased their average size and achieved some scale economies. The next table shows how vertical integration helped the efficient development of the Catalan cotton firms.[620]

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[619] See, for example, Atack (1987).

[620] This international comparison is based in the same conversion effectuated to compare Catalonia with England.

**Table 8.9** Average Number of Workers per Mill: England, France, United States, and Catalonia Cotton Industries, 1850

| Type | England | France | United States | Catalonia |
|---|---|---|---|---|
| Spinning | 106 | 110 | n.a. | 55 |
| Weaving | 98 | 136 | n.a. | 108 |
| Vertically integrated | 327 | 160 | n.a. | 183 |
| **All** | 171 | 77 | 98 | 86 |

**Notes and Sources:** See text. Sicsic (1994) and for Catalonia Junta de Fábricas (1850). The sample of weaving(mechanical) mills in Catalonia is little representative given the small number of observations.

The single-phase cotton mills in Catalonia are smaller than comparable cotton mills in France and England. In particular, in the spinning factories, where scale economies were very important, the average number of workers per cotton mill in Catalonia was about half that of England or France. In sharp contrast, vertically integrated cotton mills in Catalonia were larger than in France, but smaller than in England. Necessarily, it should be underlined that, since in England markets were more efficient and larger than in other countries, average firm size was larger. Similarly, the threshold size for vertically integrating was larger than in other countries. Note also that without vertical integration Catalan cotton mills could be even smaller and the difference in scale economies with their competitors would be more important.

Finally, it is commonly accepted that with low or moderate levels of concentration the vertical integration *per se* did not result in oligopoly situations. As the vertically integrated firms could not gain enough market power to successfully collude. In 1861, the level of concentration in the Catalan cotton industry was low: in spinning it was 14.89 percent and in weaving 17.46 percent. To compute the levels of concentration I estimate the market share (by means of the output) of the biggest four firms in each phase. One phase became an oligopoly since it reached the 70 percent concentration level.[621] Consequently, in the short-run vertical integration resulted in an increase in the efficiency of the industry. However, it should be noted that in the long-run the situation was not so clear because the

[621] Williamson (1986), pp. 100ff.

vertical integration increased entry barriers into the industry. In particular, to create a new competitive firm it was necessary to collect a larger initial capital than before. Since the Spanish home market was relatively small and highly protected from foreign competition the entrance of a large firm could decrease the level of competition, provoking oligopolistic tendencies in the industry. Furthermore, collusion among firms could become simpler since the number of participants in the market decreased rapidly and the share of the larger participants increased.

### 8.5. Summary and Conclusions

In this chapter, I analysed some changes that occurred in the Catalan cotton industry after the adoption of the factory system. In the 1850s, sub-contracting was abandoned as the main organisational form of the Catalan cotton industry. It was substituted by vertical integration. The vertical integration helped the Catalan firms to save in transaction costs, to overcome some market failures, and to introduce machinery containing asset specificity. Consequently, vertical integration was one of the secrets of the success of the Catalan cotton industry because it resulted in increased efficiency.

From the point of view of economic theory, this chapter has checked the explanatory power of the theory of transaction costs in economic history. Thus, the hypothesis of Oliver E. Williamson on the relation between transaction costs and vertical integration is fully confirmed by this research. As vertical integration was more intense when the technology was high in asset specificity.

Finally, from the point of view of the debate on economic history, it is necessary to underline the fact that the size of the market matters. The development of vertical integration is strongly related to local market imperfections. Obviously, this result casts doubt on arguments that claim that the problems in Lancashire's cotton industry were due to organisational failures.

# Chapter 9

## Technology and International Competitiveness

The purpose of this chapter is to investigate the differences between the technological choices of the Catalan and the two major cotton textile industries of that period. Which were located in Lancashire and New England. From this I derive the implications for the international competitiveness of the Catalan cotton industry. In the second third of the nineteenth century the Spanish, the British and the U.S. cotton industries differed in industrial structure and technology. This was caused by differing histories, product choices, levels of technological sophistication, markets, factor prices, workforce skills, managerial performance and tariffs.

This chapter finds that the choice of quality, technology, and factor endowments are intimately connected in the cotton industry in the first half of the nineteenth century.[622] In particular, I show that, on average, Catalan cotton mills produced a type of cloth that was in the middle of the extreme choices: between the unskilled and raw-materials intensive production of New England mills and skills-intensive and raw-materials saving choice of the Lancashire cotton mills. However, it also proves that, in spite of the fact that technological choices and product-mix were adapted to local endowments, the Catalan cotton industry could not survive without the help of tariffs. The Catalan cotton industry was not

[622] Saxonhouse and Wright (1984) argue the contrary for the last decades of the nineteenth century.

competitive because of the high cost of raw materials and its efficiency inferiority with respect to the British cotton industry. Consequently, this chapter is also concerned with modern debates about nineteenth century Catalan and Spanish economic development. Specifically, I seek to shed new light on the reasons for the almost complete absence of Catalan manufacturing products in foreign markets.

Finally, this study could also serve to confirm some of the beliefs expressed in the previous chapters. First, it shows that, as was underlined in chapter 3, the alleged low capital investment in industry explains little of the Catalan historical experience during the early phase of industrialisation. In particular, the uncompetitiveness of the Catalan cotton industry in international markets, and the comparative low levels of productivity, cannot be explained by appealing to low levels of capital intensity. Second, it also serves to confirm the argument, which was advanced in chapter 6, that the level of human capital in the Catalan industry and the system-of-training of the labour force was similar to that in Lancashire. Third, I pointed out previously in chapters 5 and 6 that productivity improvement was the main engine of growth in the early phase of industrialisation. This chapter verifies this since it proves that productivity improvements in Catalonia explain the reduction of the price gap between Catalonia and, at that time, the most advanced cotton industries in the world, Britain's and New England's.

### 9.1. Introduction

A knowledge of the choice of technique in the early period of factory cotton textiles is clearly of great value in studying the early phase of European industrialisation. By any reckoning, the cotton industry is one of the most spectacular and earliest examples of the widespread diffusion of new technology.[623] In many European countries and in the United States, the cotton industry represented the first large-scale application of modern technology and the factory system. In the beginnings, the new cotton mills followed the British model but in few years each country had developed its own practices and adapted the British

[623] See, for example, Landes (1969) and Pollard (1981).

technology (machinery) to its own needs. Therefore, it seems that there is a strong case for placing primary stress on the cotton industry as the first example of how technological choice is influenced by local conditions.

Economic historians tend to support the view that the technological constraint is not exogenous because technology is relatively malleable. Thus, one expects that regional differences in technology emerged as a consequence of differences in the relative factor prices, factor endowments, economic policies, and home demand. Furthermore, in the nineteenth century, the particular characteristics of innovation and the low integration of international markets was likely to exacerbate the differences in technology among countries. Specifically, technologies of the past century needed a large amount of learning-by-doing and were improved by a continuous process of trial-and-error. In other words, since technical progress was local and incremental, the universal diffusion of the best-practices was more difficult than nowadays. When technology is often related to common science knowledge.[624] It should also be noted that barriers to free trade and transport costs were important. Therefore the competitive pressures exerted by foreign countries, with different technical choices, were less pronounced than in present-day global markets.

A striking feature of the cotton industry was that the choice of technique was closely connected with the choice of quality. Cotton cloth is not a homogeneous product because cotton mills employed different quantities of physical and human capital, labour, energy and raw cotton to produce the different kinds of cloth. Furthermore, some types of machinery were more adept than others in the production of some kinds of cotton goods. For instance, the throstle employed more energy, less skilled labour and was better at spinning coarse yarn than the mule. Therefore, a detailed analysis of the quality-mix of the cotton industry can throw light on the influence of relative prices and factor endowments on the choice of technique.

Equally important are the implications of quality-mix for the competitiveness of

[624] Nelson and Wright (1992).

cotton industries and, therefore, their position in the world market. From 1845 Great Britain has gradually lost its share of the world market, being replaced the new European and United States cotton industries.[625] However, Great Britain continued to export high-quality goods to the American and Western European markets while very cheap goods went to the rapidly expanding Asian markets.[626] Therefore, the British cotton industry lost almost of all the market for coarse and medium quality cloth in Europe. The evident question is why the British lost the market for low-quality but not the market for high-quality cloth. Was it because the new producers became rapidly competitive in the low or medium-quality products or was it because tariffs were higher on this kind of good? On this point, only a detailed account of the prices of different quality cotton goods can furnish us with the correct answer.[627]

The chapter is organised as follows. Section 9.2 introduces the main differences in technology, skills and organisation among the cotton industries in Catalonia, New England and Lancashire. Section 9.3 discusses the product-mix. Here, I develop a framework to understand how quality choices were decided by factor endowments. The rest of the chapter is devoted to discussing the international competitiveness of Catalan firms. Then, evidence on the prices of the main Spanish, U.S. and British cotton products is presented. Section 9.5 measures the cost of the main inputs and the impact on the international competitiveness of the Catalan industry. The subsequent section provides measures of comparative productivity. Finally, the last section concludes and summarises.

### 9.2 Technical Choice: Machinery, Workforce Skills, and Organisation

For the sake of comparison, it is useful to know how large the cotton industries of Catalonia, New England and Britain were. To answer this question, I rely on cloth produced

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[625] Ellison (1968), pp.97ff.

[626] Sandberg (1968).

[627] To my knowledge, only the study of Harley (1992) has been able to furnish detailed evidence on the price differentials between the British and one new cotton industry, in this case the U.S. cotton industry.

more than on spindles or raw cotton import figures. The number of spindles is not a good indicator of the size of the cotton industry because the productivity of spindles varies strongly with yarn quality (count). Similarly, the level of raw cotton consumption does not furnish information on the real amount of production since, for example, wastage and the weight of production vary according to yarn quality.[628] For the reasons above, my choice was to compare cloth produced in square metres. Table 9.1 shows the results.

**Table 9.1** Production of Cotton Cloth: Catalonia, New England and Britain, 1830-1860 (In thousands of m2, average per year)

| | Catalonia | New England | Britain |
|---|---|---|---|
| 1830-40 | 21,291 | 229,440 | 680,614 |
| 1840-50 | 51,430 | 414,972 | 1,140,804 |
| 1850-60 | 109,132 | 612,815 | 1,852,892 |
| 1830-60 | 60,500 | 420,345 | 1,233,122 |
| | Catalonia (%) of New England | Catalonia (%) of Britain | New England (%) of Britain |
| 1830-40 | 9.28 | 3.13 | 33.71 |
| 1840-50 | 12.39 | 4.51 | 36.38 |
| 1850-60 | 17.81 | 5.89 | 33.07 |
| 1830-60 | 14.39 | 4.89 | 34.09 |

**Notes and sources:** Numbers subject to rounding errors. New England's data is drawn from Davis and Stettler (1966), table 4, p. 221. The procedure to compute the Catalan and British figures was the following. First, according Huberman's (1996) method, a disaggregated yarn output series was constructed for Catalonia and Britain. Then, under the assumption that yarn exports and yarn inventories had the same distribution as yarn production, I derived the amount of yarn consumed in the weaving industry (the figures on British yarn exports are drawn from Ellison (1968), table 2). That is, total yarn production minus exports of yarn, inventories, and wastage (5 percent) during weaving. To arrive at output in m2, I multiply the weight of the yarn consumed by a fixed coefficient. The coefficients are different for each quality also different for Catalonia and Britain. The Catalan coefficients are derived from Comisión especial arancelaria (1867) and the British coefficients from the figures on cotton fabrics from the *Economist* (1845). Then I sum across qualities to compute total estimates.

This table immediately reveals that, in spite of its relative progression, the Catalan cotton industry was relatively small in all the periods. On average, the British cotton industry was about twenty times as large as the Catalan cotton industry. The cotton industry

[628] See, for example, Blaug (1961), Huberman (1996) or Comisión especial arancelaria (1867).

of New England was on average eight times as great as the cotton industry in Catalonia but did not progress like the cotton industry in Great Britain. Finally, it should be noted that the cotton industry in Spain grew faster in the 1850s than the Catalan figures show due to the incorporation of the Basque Country and Andalusia into the production of cotton textiles.[629] Similarly, in the United States, national figures may differ from New England's because of the development of the cotton industry in the Southern and the mid-Atlantic region of the United States.

During the first half of the nineteenth century technological leadership remained in the hands of the British cotton industry. It is well known that a great part of the progress in cotton technology during the period was due to British engineers.[630] At the very beginnings of the nineteenth century the fine-spinning branch was the most technologically advanced because, for example, it was the first in applying steam-power to the new textile machinery. These substantial improvements cheapened finer yarns, which had noticeable effects on both exports and cloth fashion in Britain.[631] It should also be noted also that the first factories also appeared in fine-spinning. On the shop floor of these factories sub-contracting dominated other forms of labour management.[632] Furthermore, these cotton mills were prepared to produce many different counts of yarn. In other words, they developed a flexible specialisation where the labour force, machinery and production could quickly adapt to the volatile demand of foreign and high-quality cloth markets. By the 1830s, however, technological leadership moved to the production of coarse cloth.[633] The improvements in the application of power to cotton textiles production had large consequences on the costs of production of coarse cloth because coarse spinning was very power-intensive.[634] In particular, the new high pressure steam engines helped the adoption of the self-acting mule

[629] Gimenez Guited (1862) gives national figures on cotton industry production. Also see Nadal (1974) for a brief description of Malaga's experience.

[630] On the British advances during the period see, for example, Chapman (1987), VonTunzelmann (1978), Ellison (1968), and Mann (1968).

[631] Von Tunzelmann (1978), p. 224.

[632] Cohen (1990), pp. 35ff and Huberman (1996).

[633] Von Tunzelmann (1978), pp. 184ff..

[634] Von Tunzelmann (1978), pp. 186ff.

and the development of powerlooms, cheapening the production of coarse cloth. In sharp contrast with the fine spinning mills, British coarse spinning mills often vertically integrated into the production of cloth with powerlooms. Moreover, it should be underlined that their labour force was less skilled, which went hand in hand with the adoption of foremanship.[635]

The first modern spinning machinery (i.e., Arkwrights' water frames) appeared in the U.S. during the last years of the eighteenth century.[636] The embargo and the war with Great Britain had favoured the settlement of the cotton industry in the United States. But the first great expansion of the industry took place from the end of the War of 1812. When the industry was protected by high tariffs.[637] In this early period, U.S. cotton-textile mills, which were known as the Rhode Island type, were comparable to British coarse spinning firms. By the 1820s, they had introduced their own new type of cotton mill: the Waltham-type. They integrated power spinning on throstles and powerlooms and a new form of organization of the workforce. According to Jeremy, these new mills succeeded in lowering the cost of production for the coarsest products.[638] However, until the American Civil War, both types of mills survived.[639] Rhode Island type mills and handweavers specialised in the segments of the market where fashion and flexibility were more important while the Waltham-type dominated the market for standardised products.[640]

In Spain, the first enterprises devoted to printing cotton cloth were established in Barcelona in the late 1720s.[641] These calicoes were sold in the protected markets of the

[635] Huberman (1996) and Clark (1994).

[636] On the early history of the U.S. cotton industry see, among others, Cohen (1990), David (1970), Harley (1992), Jeremy (1981), Nickless (1979), Temin (1988), and Zevin (1971).

[637] Zevin (1971) and Stettler (1977).

[638] Jeremy (1981).

[639] Cohen (1990).

[640] Harley (1992).

[641] On the history of the cotton industry in Catalonia before 1830 see Thomson (1992), Sánchez (1989)(1992) and Delgado (1995).

*Peninsula* and the Spanish colonies in America.[642] Because for most of the eighteenth century all cotton yarn was imported, as well a large part of the grey cloth consumed, cotton spinning and weaving were not important. It took about 60 years for Catalonia to develop cotton spinning. In 1802, the new spinning industry was heavily protected. The import of foreign yarn and cloth was forbidden. In the thirty years that followed the ban, domestic production and out-working were common practice in cotton spinning. Thus, cotton spinning tended to remain dispersed in the villages and small towns of the Pre-Pyrenees, where they could rely upon a good supply of cheap female and child labour, rather than becoming concentrated in the calico centre of Barcelona.[643] Initially, due to its unskilled workforce, Catalan spinning concentrated on the low grades of yarn (below 20 count). During the same period, handweavers proliferated in the major Catalan manufacturing towns.[644] Catalan cotton cloth was also coarse due to the ban on cotton yarn imports. Nevertheless, skilled handweavers produced a wide range of qualities by using other textile fibres such as wool, linen and silk.[645] This development of the domestic industry was accompanied by the scarce adoption of the steam engine and, in general, of any British machinery. However, in 1832, the Bonaplata mill introduced the new forms of organisation, the steam engine, and the most recent British machinery (e.g., the powerloom).[646] In a few years, the new machinery was universally employed in cotton spinning and dominated cotton weaving. The Catalan industry was characterised during this period by the rapid adoption of machinery innovations. For example, Catalan cotton mills made the transition from mule-jennies to self-actings in only a decade, such that by the 1850s more than 75 percent of spindles were moved by self-actors.[647] The diffusion of the new machinery paralleled the increase in the quality of local production since the average count increased to 30 count

[642] There is a large debate on the role played by the colonial and home markets in the development of Catalan cotton industry. On this aspect see the review of the literature in Delgado (1995).

[643] Gutiérrez (1834)(1837), Sánchez (1989) and Thomson (1992).

[644] Sánchez (1989).

[645] In chapter 6, there is a full discussion of the skills differences between handspinning and handweaving.

[646] Nadal (1974).

[647] Ronquillo (1851-1857) and Maluquer de Motes (1976).

from about 15 count.[648] Moreover, the vertically integrated cotton mills expanded rapidly and captured the market for medium-coarse cloth.[649] However, well before the 1860s, some horizontal spinning mills and domestic hand-weaving survived by producing for more fashion-oriented segments of the market.[650]

Labour management in the early factory period was similar in Catalonia, Lancashire and New England because all cotton factories combined two forms of factory management: sub-contracting and foremanship.[651] More specifically, workers in the preparatory section and spinners on throstles were supervised by foremen. Whereas spinners on mules were organised into autonomous, sub-contracted work teams. In particular, these spinners had functional autonomy because the craft-oriented machinery ran intermittently. Thus, they decided the pace of their work, organised their own work teams, had the authority to hire and fire assistants, and were paid by piece. However, by the 1850s, U.S. practice moved towards mass production with an unskilled workforce controlled by foremen.[652] The adoption of powerlooms and self-actings in the United States went hand in hand with the transition of sub-contracting to foremanship.[653] U.S. cotton mills substituted resource-using machinery, such as the throstle, for skilled labour, which was in short supply in the United States and other new settlement countries like Australia and Canada. In sharp contrast with the United States, the main consequence of diffusion of the self-acting in Catalonia and Britain was the reduction of the number of helpers but not the dislocation of craft control from the shop floor. Similarly, it seems that Catalan and Lancashire weavers managed to retain their autonomous position in production. Despite the fact that the introduction of the powerloom could have increased foremanship practices in some weaving factories.[654]

[648] Figuerola (1968), and Madoz (1846).

[649] See chapter 8.

[650] See chapter 8 and Comisión especial arancelaria (1867).

[651] Cohen (1990) in United States, Huberman (1996) and Clark (1994) in England, and Camps (1995) in Catalonia. See also chapter 6.

[652] Cohen (1990).

[653] Cohen (1990), especially chapter 6.

[654] Cohen (1990), pp. 73-74 gives inconclusive evidence on this aspect of the British cotton weaving industry. By contrast, Catalan sources such as Comisión especial arancelaria (1867) or

### 9.3 Technical Choice: Product Quality

Cotton cloth quality has always varied considerably from country to country. In particular, the disparities in product-mix of the U.S., Britain and Spain cotton industries were large. The next table contains data on this point:

**Table 9.2** Quality Distribution of Cloth Production:
Catalonia, New England and Britain, 1830-1860 (in average percent per year)

| **Catalonia** | **<20** | **20-40** | **40-60** | **60-80** | |
|---|---|---|---|---|---|
| 1830-40 | 68.37 | 31.44 | 0.10 | 0.09 | |
| 1840-50 | 25.94 | 71.89 | 1.83 | 0.35 | |
| 1850-60 | 18.06 | 76.43 | 4.04 | 1.47 | |
| 1830-60 | 25.93 | 70.31 | 2.77 | 0.99 | |
| **New England** | **<16** | **>18** | | | |
| 1830-40 | 75.99 | 24.01 | | | |
| 1840-50 | 73.44 | 26.56 | | | |
| 1850-60 | 76.12 | 23.88 | | | |
| 1830-60 | 75.27 | 24.73 | | | |
| **Britain** | **<20** | **20-40** | **40-60** | **60-80** | **>80** |
| 1830-40 | 17.12 | 45.24 | 24.16 | 8.03 | 5.44 |
| 1840-50 | 14.82 | 48.66 | 27.87 | 4.44 | 4.21 |
| 1850-60 | 8.10 | 48.79 | 34.29 | 4.60 | 4.22 |
| 1830-60 | 11.76 | 48.12 | 30.55 | 5.17 | 4.40 |

**Notes and sources:** Numbers subject to rounding errors. It should be noted that Spanish figures corresponded to Spanish counts and British and New England's to English counts. Therefore, since the Spanish counts were slightly finer than the corresponding English counts, Spanish figures understated the quality of the Spanish production. Figures are computed as arithmetic averages to avoid cyclical variation in quality due to changes in the prices of raw cotton and short-term market adjustments. New England data are drawn from Davis and Stettler (1966), table A.2. Note that the New England figures are based on a sample of firms but in the entire population. For the Catalonia and Britain data see table 9.2.

At first glance, this table suggests that New England produced heavier fabrics than Catalonia and Britain. For the period as a whole, the quality of the New England cloth did not change considerably because about 75 percent of production was constantly of the coarsest quality.[655] In a sharp contrast, Britain and Catalonia tended to concentrate their

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Cerdá (1968) clearly stated that weavers were paid by piece during this period.

[655] This result is similar to the evidence presented by Temin (1988) for the 1830s.

production in the medium range (counts from 20 to 60). By the 1850s more than three quarters of their production was in these counts thus abandoning the production of the coarsest qualities. In Catalonia the sharp decrease in the production of coarse cloth took place in the 1840s whereas in Britain in the 1850s. Finally, it should also be noted that British industry reduced the share of the finest qualities (over 60 count) although it was the country with the largest share of that type of cloth.[656] There are, of course, several possible explanations for the existence of these large differences in product quality. In the next paragraphs I speculate about several of them.

It is possible that quality-mix was a consequence of the life-cycle of the cotton industry; young cotton industries produce low quality goods because they did not require skilled or experienced labour and there was a large domestic market for them.[657] The history of the New England cotton industry gives little support to this argument because the industry matured but was still producing coarse goods.

It is often maintained that the characteristics and sizes of markets shaped the product choice of the cotton industry. For example, Sandberg has argued that only a worldwide exporter such as Great Britain was likely to have a large market for high-quality goods.[658] Therefore, according to this line of reasoning, all small countries should only develop the production of heavy cloth. The obvious counterexample is the small Swiss cotton industry that produced high-quality cotton goods and could successfully compete with Britain in some European markets for expensive cloth.[659] On the other hand, many authors have argued that the cotton mills in the U.S. were biased towards standard and cheap products because of the size and income of their home demand.[660] Following the same logic, one would expect Catalan cotton mills to produce cheap cotton goods since the Spanish home market for

[656] This sharp drop in the finest qualities can explain the drop in the quality index constructed by Sandberg (1968).

[657] Sandberg (1968), p. 15.

[658] Sandberg (1968), p. 15.

[659] Fisher (1991).

[660] See criticism on this argument in Temin (1988).

textiles was poorer and smaller than other European and American markets.[661] However, the Catalan cotton industry produced more medium-range than cheap goods. Therefore, it seems that the size of home market does not by itself furnish a convincing explanation for the quality-mix of the cotton industries. It would be more attuned, however, to relate the characteristics of the home production to the preferences of the home consumers. According to this line of reasoning, consumers in the U.S. were more prepared to buy standard products than European consumers. However, this argument cannot be verified quantitatively.

It is sometimes argued that barriers to free trade modify the quality of the local production and foreign imports.[662] In most cases during the nineteenth century tariffs were in *ad valorem* terms. This kind of tariff has several relevant properties. First, duties were higher on cheap rather than expensive goods and, therefore, the level of protection was higher for the local production of heavy (low-quality) goods.[663] Second, it is perfectly clear that, *ceteris paribus*, countries with higher *ad valorem* duties would exclude from their home markets finer goods than countries with lower barriers. Third, increases in *ad valorem* duties augmented the range of protected goods towards fine (expensive) qualities. Finally, the quality range of foreign production excluded from the home market rests on the price of local production and the amount of the duty. For the same reason, when local costs fell and the duty actually remained constant, both the level of protection and the range of goods protected rose.

Several studies have discussed the influence of tariffs on the development of the cotton industry in the U.S..[664] Duties on cotton textiles imports were established in 1789 and changed no less than twenty times in the ante-bellum period. The first tariff on cotton goods was relatively lower (5 percent *ad valorem*) and comparable to other manufactured products tariffs. In the period from 1790 to 1811, the *ad valorem* duty grew in successive reforms up to 15 percent. The first great reform happened in 1812 when duties were practically doubled

[661] On the Spanish home market for textiles see Sánchez-Albornoz (1981) and Prados (1983).

[662] See, for example, Sandberg (1968) or Temin (1988).

[663] Sandberg (1968), p. 15.

[664] David (1970), Stettler (1977), Temin (1988), and Harley (1992).

(27.5 percent) to finance the war. Moreover, in 1816, a law was completed by Congress that established the minimum valuation for all pieces of cloth imported into the United States. Note that the system of minimum values reinforced the fact that duties rested more on coarse than fine cloth. In 1832 the system of minimum values was dropped and rates were generally lowered although the *ad valorem* rate was still higher (25 percent). From 1842 to 1846 there was another protective bubble and ad valorem rates were increased up to 30 percent. Finally in 1846 Congress lowered the tariff to 25 percent and eliminated the minimum valuation.[665] The U.S. tariff had disproportionate effects on the various cotton goods because it gave more protection to heavy rather than light cotton cloth. However, Harley has recently shown that the level of protection of the industry in the U.S., even after the reform of 1846, was enough to protect the production of coarse and medium-range cotton cloth.[666] Therefore, the level of protection, was so high that it probably had negligible effects on the New England's cotton mills choice between coarse and medium products.

The Spanish cotton industry was protected from 1802 by the ban on cotton yarn and cloth imports.[667] In theory, obviously, the level of protection in Spain was higher than in the United States. By the 1840s the scope of the ban was limited to yarn below 60 count and cloth produced with that type of yarn.[668] This modification of the structure of the tariff might not have directly affected Spanish production since the domestic industry produce very little yarn above the 60 count. Therefore, the level of protection was so high that it probably had negligible effects on the choice of the Spanish cotton mills between coarse and medium products. However, one must be aware that the ban on foreign imports was difficult to enforce during these years. As a consequence, smuggled British fabrics reached a large portion of the Spanish market.[669]

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[665] On tariff history in the cotton industry in the United States see Taussig (1931) and Stettler (1977), especially chapter 5.

[666] Harley (1992), table 2, p. 562.

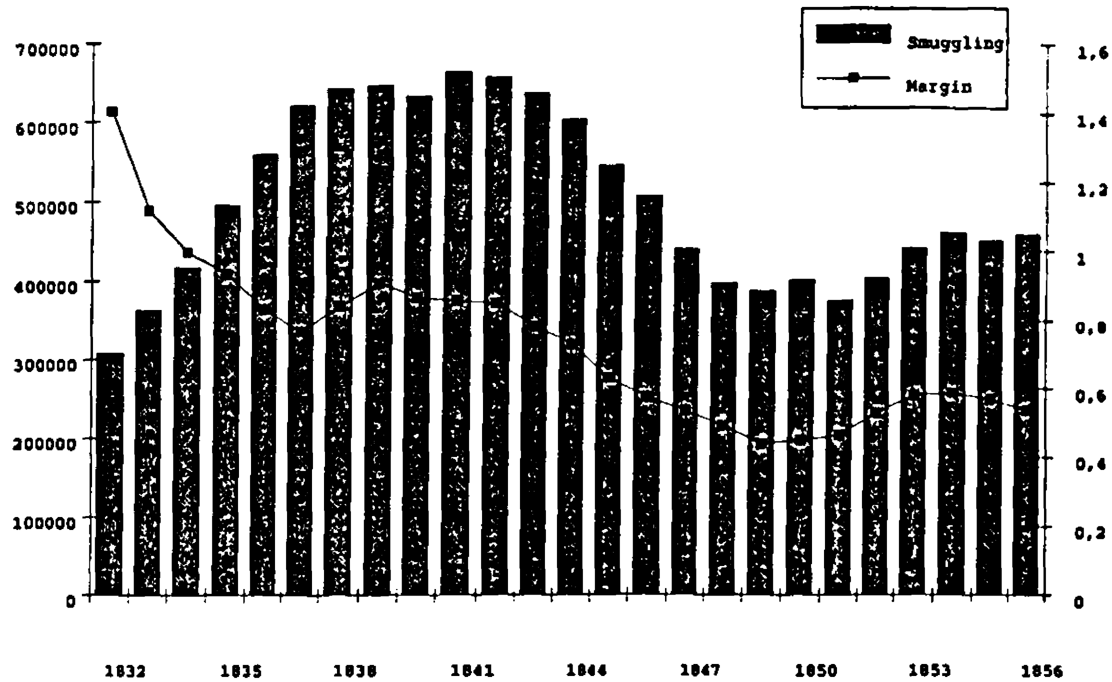
[667] Nadal (1974).

[668] Ronquillo (1851-1857) and Gimenez Guited (1862).

[669] Prados (1984).

The obvious question is whether changes in the enforcement of the ban can explain changes in the choice of quality of the Catalan mills. Specifically, if the movement towards the medium range fabrics in the 1840s was caused by an increase in the 'real' level of protection (i.e., in the risk of smuggling due to an increase in the repression of the illegal trade). Note that the amount of foreign goods illegally imported was a function of the margin received by smugglers, the premium risk obtained by consumers, and the risk involved in this illegal activity. For example, when the risk increases and the margin remains constant smuggling decreases (i.e., the 'real' level of protection and, therefore, the market for home industry increases). Moreover, if the risk of smuggling was little or unvaried over time, one could expect that, over the long-run, the amount of smuggled goods paralleled the margin received by smugglers and was independent of the risk incurred in illegal trade. Here, the hypothetical margin of smugglers is easy to compute since the premium risk received by consumers in Spain was negligible. The reason for this was that Spanish law punished only the smugglers and not the buyer, and the seizure of smuggled goods could only take place within the frontier zone. Thus, the margin of smugglers was equal to the domestic price of cotton goods minus transport costs and the foreign price of those goods. The next figure studies the relationship between the amount of smuggling and the margin of smugglers.

**Figure 9.1.** Smuggling of British Cotton Goods in Spain (in £) and Margin of Smugglers (five-year averages)




**Notes and sources:** The value of smuggling has been computed according to the formula proposed by Prados (1984). That is, British Smuggling of cotton goods in Spain = 0.2 * Exports to Portugal + 0.8 * Exports to Gibraltar. The data on the value of exports to Gibraltar and Portugal is furnished by Mann (1968), table 25. The margin of smugglers is defined as the difference between the Spanish and British prices of printing cloth minus transport costs divided by British prices. For Spanish and British prices see the further table 9.6.

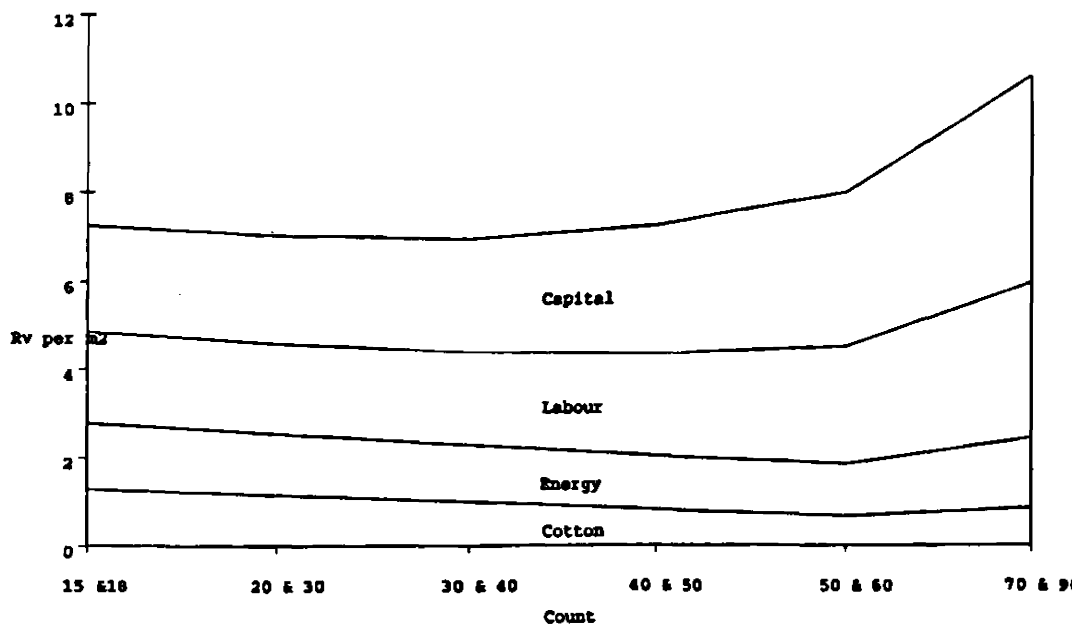
If the past figure shows the true trend in smuggling and smugglers' margin, one can reasonably infer that the amount of smuggled cotton goods relies on the changes in the price gap between home and foreign goods. That is, the ban worked like an *ad valorem* tariff fixed at a (high) constant rate. In particular, the rapid decrease in the early 1840s of the quantity smuggled was due to the decrease in the price gap (margin), not to an increase in the repression of the illegal commerce. However, figure 9.1 must be read and interpreted with caution since the data is highly imperfect. First, short-run variations cannot be captured by the formula that was used to compute the smuggling of British cotton goods because the formula was based in fixed coefficients. Second, the margin has been estimated as the difference between the prices of printer cloth in Spain and Britain. But it is possible that the difference between other types of Spanish and British cotton cloth did not evolve in unison with printer cloth. Third, the figure cannot explain why smuggling increased faster during the 1830s. In any case, it seems implausible to link the movement of the Catalan cotton industry towards medium range goods with a hypothetical increase in the repression of illegal trade. The level of protection grew due to the increase in the efficiency of the local production and, therefore, the local improvements were the main reason for the shift of production towards medium-range cotton fabrics.

The three interpretations traditionally advanced in the literature have to be rejected. Neither the life-cycle of the industry, nor home market characteristics, nor barriers to free trade provide a sufficient explanation of the quality-mix of the three cotton industries summarised in table 9.2.

Anyone who attempts to analyse the choice among different cloth qualities is immediately confronted with the fact that the combination of inputs changes through the quality range. As mentioned above, a different combination of energy, raw cotton, labour, and human and physical capital was employed to produce each quality of cloth. Therefore, it should be relatively straightforward to relate product-mix with factor endowments.

Figure 9.2 and table 9.3 illustrate the costs of producing the different qualities of cotton cloth from the point of view of the Catalan manufacturers. The figure practically covers the entire universe of Catalan production of cotton cloth and can be considered representative of the state-of-the-art of the industry at the end of the 1850s. A major objection, however, might be raised against this cost figure. It is impossible to assess the importance of labourforce skills and machinery alternatives in the production of the different qualities. Since these two factories could produce the whole range of yarn and cloth.

**Figure 9.2.** Producing Costs of Cotton Cloth: Barcelona, 1860




**Notes and sources:** Count refers to the count of yarn used in produced the cloth. The source is Comisión especial arancelaria (1867). The figures are drawn from the answer of the España Industrial S.A.The cost of weaving in the quality 20&30 and 50&60 has been estimated. The cost of yarn in 15&18 counts is drawn from the answer of José Ferrer & Cía. This last figure has been modified to eliminate the transport costs of raw cotton and other materials from Barcelona to Vilanova, where this second firm was settled. Note that cotton comprises the wastage. Energy comprises not only coal for light and power but also other minor raw materials. Labour includes all labour cost even those outside the shop floor. Finally, capital costs comprise depreciation, profits and capital taxes.

The past figure shows that the production cost of cloth grew at different rates at each point; that is, the cost-quality relation was not a straight-line.[670] Interestingly, the increase in total costs is more important in the transition from the medium to finest qualities than in the transition from coarsest to medium qualities. For example, the cost of producing one m2 of coarse fabric (15 & 18 count) was about Rv 2.40. Whereas the cost of producing one m2 of medium range fabrics (30 & 40 count) was about Rv 2.56 (i.e., only about 6.6 percent more). More specifically, raw cotton costs per m2 decreased throughout the spectrum of coarse-medium qualities, in spite of the fact that wastage increases with count. In the fine

[670] This result invalidates the argument of Bils (1984) on the straight-line relation between costs and quality in cotton cloth.

qualities, particularly above 60 count, the raw cotton costs grew again due to the use of large staple and, therefore, expensive fibre. On the other hand, labour, capital and energy costs rose with count increases.

**Table 9.3** Share of Inputs in Total Costs of Cotton Cloth: Barcelona, 1860 (percent)

| | | Entrefinos | | Finos | Finos | Finos |
|---|---|---|---|---|---|---|
| | Gruesos | Medios | Entrefinos | Tupidos | Medios | Claros |
| **Yarn Count** | **15 &18** | **20 & 30** | **30 & 40** | **40 & 50** | **50 & 60** | **70 & 90** |
| Cotton | 53.41 | 47.00 | 38.51 | 27.70 | 18.98 | 18.31 |
| Energy | 8.94 | 10.10 | 11.76 | 13.77 | 15.21 | 15.58 |
| Labour | 24.39 | 27.84 | 31.26 | 37.37 | 42.92 | 42.16 |
| Capital | 13.25 | 15.06 | 18.47 | 21.16 | 22.90 | 23.95 |

**Notes and sources:** See the previous figure 9.2.

Table 9.3 displays the fact that the share of different inputs in total costs varied according to quality. Thus, the coarsest quality was the most raw-materials intensive and less labour-intensive, whereas the opposite holds for finest qualities. Note that the two factories in the sample could produce the whole range of goods given their stocks of human and physical capital.[671] For that reason, the ratios of capital to labour and energy to labour are rather constant. Although, they actually produced more medium quality than other types of cloth (e.g., the share of medium-quality cloth in the production of España Industrial S.A. was about 80 percent of the total). In other words, it seems that they were better prepared, given their stock of physical and human capital, to produce medium-range goods.

Figures for the whole Catalan cotton industry would probably diverge by some amount from the sample figures. Thus, firms specialised in the coarsest qualities used throstles instead of self-acting mules and, therefore, operated with relatively more capital and energy per worker than the sample firms. Conversely, cotton mills specialised in the finest qualities used mule-jennies instead of self-acting mules and employed less capital and energy

[671] They used steam-powered self-actings and powerlooms and organised their workforce into work-teams, as was typical in Catalan cotton firms.

per worker.[672] In a few words, the figures presented above presumably overstate the share of labour in the cost of coarse qualities whereas the contrary holds for finest qualities.

Manufacturers in Catalonia were constraint by the price they had to pay for raw cotton and for coal, which was primarily influenced by geological and geographical factors. The problem was alleviated by producing more fine cloth, which was less raw-materials intensive than coarse cloth. Thus, the efficient firm on the frontier of the local best-practice tried to produce cloth as fine as was possible with the level of efficiency of its workforce. The more skilled was their workforce, the finer was the production, and the high cost of raw materials was less important. In other words, cotton mills with unskilled labour specialised in products in which the skills inferiority of their workforce had relatively little impact on the final price (i.e., in coarse cloth). Whereas cotton mills with a skilled labourforce did exactly the opposite. The constraint on this movement towards fine cloth in Catalonia was the skill of the local labourforce because the finest qualities were generally beyond the abilities of the Catalan labourforce. However, it is not clear whether one should speak about the human capital constraint or the climatic constraint. The fact is that the thread breakages varied with the count level (high counts broke more often than coarse counts) and the dampness of the climate. Because Catalonia is less damp than Lancashire it is clear that thread tended to break more often in the former than the latter. For instance, during the summer, many spinning firms were at standstill in Catalonia due to the low levels of dampness.[673] In this segment of the market, the Spanish workforce could not compete with British production, even with the help of the high levels of protection. Thus, there is strong evidence that the efficiency of labour is important in determining the drift of best-practice technology in Catalonia.

Despite the fact that the data reported on the previous pages have their limitations, one can argue that they provide an explanation for the technical choice and quality-mix of the Catalan cotton firms and, by extension, of the British and U.S. cotton mills. On average, Catalan cotton mills produced cloth that was in the middle of the extreme choices; the

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[672] VonTunzelmann (1978), table 7.3, p. 185 demonstrates this for Lancashire. See also Gattrell (1977).

[673] See Farnie (1979) and the contemporary, Ferrer Vidal (1875).

unskilled and raw-materials intensive production of the coarse-cloth New England mills, and the skills-intensive and raw-materials saving choice of the fine-spinning Lancashire cotton mills. Therefore, one can argue that it is likely that Catalonia had a scarce supply of raw materials, but that her labour force was on average more skilled than the U.S. but less than in Britain.

The other components of the quality choice must, however, be allowed their due. Plant and equipment costs were higher in Spain and the U.S. compared to Britain. This by itself lowered their optimal quality because it raised their relative operating speeds. Labour costs were higher in the U.S. and lower in Spain. In isolation this would have had the effects actually observed, lower quality in the former than in the latter. These aspects along with the particular characteristics of the consumers' choices are not perfectly disentangled. However, the major question that remains is if this Catalan choice was competitive.

### 9.4. International Competitiveness: The Price of Outputs

International comparisons of the prices of cotton yarn are simple because cotton yarn was a relatively standard product. Cotton yarn was classified from coarsest to finest with successive numbers (counts). In the nineteenth century there were at least four different standards (English, French, Spanish and Belgian)[674] but the comparison of and conversion among them is easy. Moreover, for each count, there were two qualities of yarn, warp and weft. The next table compares the prices of 'Spanish 30 count weft' (second quality) and the corresponding British prices from 1830 to 1861.

[674] According to Jeremy (1971), cotton mills in the United States adopted the English standards in the 1820s-1830s. Asséo (1989) supplies the table used to convert the different standards but his numbers are not correct for Spanish count. The correct Spanish figures are available at Ferrer Vidal (1875) or Ronquillo (1851-1857).

**Table 9.4** Prices of Yarn, Spanish 30 count: Britain and Spain (Cts. per Kg.)

| Year | British | Spanish | Year | British | Spanish |
|---|---|---|---|---|---|
| 1830 | 284.62 | 656.25 | 1845 | 205.11 | 406.25 |
| 1831 | 240.52 | 625.00 | 1846 | 246.79 | 375.00 |
| 1832 | 270.93 | 593.75 | 1847 | 190.63 | 343.75 |
| 1833 | 291.56 | 593.75 | 1848 | 181.40 | 329.38 |
| 1834 | 324.49 | 593.75 | 1849 | 183.08 | 312.50 |
| 1835 | 379.35 | 562.50 | 1850 | 245.18 | 375.00 |
| 1836 | 366.16 | 562.50 | 1851 | 213.90 | 375.00 |
| 1837 | 293.28 | 531.25 | 1852 | 214.63 | 343.75 |
| 1838 | 282.30 | 531.25 | 1853 | 211.40 | 329.38 |
| 1839 | 264.34 | 531.25 | 1854 | 192.72 | 375.00 |
| 1840 | 235.91 | 531.25 | 1855 | 196.84 | 343.75 |
| 1841 | 222.95 | 500.00 | 1856 | 222.91 | 343.75 |
| 1842 | 211.97 | 437.50 | 1857 | 233.63 | 343.75 |
| 1843 | 208.29 | 406.25 | 1858 | 256.62 | 343.75 |
| 1844 | 206.01 | 406.25 | 1859 | 264.52 | 343.75 |

**Notes and sources:** 1Pta. = 100 cts. British prices (counts 30 and 40) are an arithmetic average of the prices furnished by Mann (1968), The *Economist* (1845)(1850)(1855)(1860) and Huberman (1996). The conversion to the number Spanish 30 has been obtained according to the next formula: Price Spanish 30 = Price British 30 + 0.126 * (price British 40 - price British 30). The resulting prices have been converted to Pta with the variable exchange rate computed by Prados (1984). Spanish Prices are drawn from Diario de Barcelona (1866).

The table serves to illustrate, first, the large difference between the English and the Spanish price in this type of medium-quality yarn and, second, the decline of the price gap. Thus, in 1830 Spanish prices were 56 percent higher than the British prices. Whereas by the late 1850s the difference had been halved (the price difference was reduced to about 25 percent). It should be underlined that this reduction cannot be associated with the Spanish or British industry's cyclical experience, changes in exchange rates or the decrease of the price of raw materials in Spain. It is due to the continuous improvement of the productivity of the Catalan cotton mills.[675]

Cotton cloth is the least easy to compare because it was not a standard commodity. Prices of cotton cloth could vary with changes in yarn quality, widths, number of threads per inch, and finishing. The next table serves to illustrate the difficulties in comparing cloth prices:

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[675] See chapters 5 and 6.

**Table 9.5** Prices of Several Types of Grey Cloth: Britain and Spain, 1860 (in Pta.)

| | Density gr/m2 | Price Pta./kg | Price Pta./m2 |
|---|---|---|---|
| **British** | | | |
| 72 reed, Printer | 128 | 3.57 | 0.46 |
| 48 reed, Red End Long Cloth | 125 | 2.64 | 0.33 |
| 72 reed, Gold End Shirthings | 121 | 3.47 | 0.42 |
| 66 reed, Gold End Shirthings | 114 | 3.32 | 0.38 |
| 60 reed, Gold End Shirthings | 110 | 3.13 | 0.35 |
| 66 reed, Printer | 107 | 3.97 | 0.42 |
| **Spanish** | | | |
| 80 hilos, 5/4 2ª | 124 | 5.90 | 0.73 |
| 84 hilos, 5/4 A | 122 | 6.26 | 0.77 |
| 70 hilos, Entrefinos tupidos | 121 | 5.17 | 0.62 |
| 68 hilos, 5/4 3ª | 120 | 5.35 | 0.64 |
| 66 hilos, 7/8 1ª | 113 | 4.93 | 0.56 |
| 60 hilos. 7/8 2ª | 102 | 4.50 | 0.46 |

**Notes and sources:** The British prices are drawn from the *Economist* (1860) and correspond to January 1860 while the Spanish prices are drawn from Comisión especial arancelaria (1867). All Spanish prices are drawn from the answer of *José Ferrer and Cia.* except the price of *Entrefinos Tupidos* that is furnished by the answer of *España Industrial S.A.* Spanish grey cloths are chosen for their resemblance with the British products for which the *Economist* published prices. British prices are converted to Pta. with the exchange rate of Prados (1984). Numbers are subject to rounding errors.

It is difficult to find in the previous list two equal goods. Only, the "72 reed, Gold End Shirthings" and the '70 hilos, Entrefinos tupidos' were almost identical. The Catalan cloth was about one third more expensive than the British cloth. It is also possible to compare the price of the '66 reed, Printer' with a hypothetical Spanish cloth, which is an average of the two quotations of the '66 hilos, 7/8 1ª' and the '66 hilos, 7/8 2ª' (two very similar types of cloth). Here, the price of British cloth was 80 percent of the price of Spanish cloth. Note that these figures support the belief that Spanish finer cloth was relatively more expensive than British finer cloth.

**Table 9.6** Printer Grey Cloth Prices: Britain, United States and Spain, 1830-1860 (Cts. per m2)

| Year | British | Spanish | Year | British | US | Spanish |
|---|---|---|---|---|---|---|
| 1830 | 44.81 | 144.34 | 1846 | 33.73 | | 62.10 |
| 1831 | 51.36 | 121.66 | 1847 | 34.93 | 49.07 | 50.66 |
| 1832 | 49.52 | 121.66 | 1848 | 31.15 | 43.06 | 47.90 |
| 1833 | 51.36 | 121.66 | 1849 | 32.95 | 37.07 | 50.66 |
| 1834 | 53.98 | 112.97 | 1850 | 35.33 | 38.40 | 56.38 |
| 1835 | 58.43 | 104.70 | 1851 | 32.09 | 38.50 | 50.66 |
| 1836 | 57.38 | 101.74 | 1852 | 33.69 | 37.79 | 50.66 |
| 1837 | 44.81 | 96.01 | 1853 | 33.42 | 46.33 | 53.62 |
| 1838 | 48.48 | 90.29 | 1854 | 30.32 | 42.89 | 56.38 |
| 1839 | 49.79 | 87.75 | 1855 | 28.93 | 37.10 | 53.62 |
| 1840 | 41.93 | 90.29 | 1856 | 31.47 | 40.68 | 50.66 |
| 1841 | 41.93 | 88.38 | 1857 | 33.95 | 41.90 | 47.90 |
| 1842 | 34.85 | 67.61 | 1858 | 34.70 | 42.59 | 50.66 |
| 1843 | 35.90 | 65.07 | 1859 | 40.17 | 44.19 | 50.66 |
| 1844 | 35.90 | 62.10 | 1860 | 40.72 | | 46.42 |
| 1845 | 34.33 | 62.10 | | | | |

**Notes and sources:** British prices correspond to 66 reed printer until 1845 and are drawn from the *Economist* (1850)(1855)(1860). From 1830 to 1845 the price series of 72 reed printer, the only available, was spliced with the series of 66 reed using the relative weights of 1845. This series was drawn from Blaug (1961), p. 376. U.S. prices correspond to an average of the "28" 64*64 Metacomet" and "Print Cloth, 28" 7 yds." of the Aldrich Report. This series was drawn from Harley (1992), table 1, p. 562 (I transformed the series reported by Harley from yards to m2). Spanish prices correspond to an average of the prices of '66 hilos, 7/8 1" and '60 hilos, 7/8 2", as appeared in the Comisión Especial Arancelaria (1867). These prices correspond exactly with the maximum and minimum prices of the series of 'Tejido crudo para pintar', which was reported in the Diario de Barcelona (1867). Pta-Sterling exchange rates are drawn from Prados (1984) and the Dollar-Sterling exchange is $4.8 per £.

Table 9.6 displays the price difference among British, U.S. and Spanish printer cloth from 1830 to 1860. Two facts stand out. First, the difference between the Spanish and British prices was large, but the price gap reduced drastically from 1830 to 1861. For instance, in the 1830s Spanish prices habitually doubled British prices whereas at the end of the 1850s the price difference was about 25 percent. Second, the difference between Spanish and U.S. prices was about half the difference between Spanish and British prices.

From these results, one can conclude that the Spanish cotton industry could not survive without the help of tariffs. The figures for the duties that could have been imposed on British printer cloth to protect the Spanish industry are now calculated. Considering that the price of freight increased by a mere 10 percent the price of British cotton goods in Spain.[676] On average, the duty required on British printer fabrics to dissuade their export to Spain would be 100 percent *ad valorem* in the 1830s, 65 percent in the 1840s, and 43 percent in the 1850s. In sharp contrast, U.S. cotton mills would encounter many problems selling their cloth in Spain, even if they did not have to pay duties. The price of freight from New York to Barcelona, which was double the price from Liverpool to Barcelona, was enough to prevent U.S. cotton mills selling their products in Spain. Also, U.S. coarse cloth was not competitive in the Spanish market. In particular, including the price of freight, the final price of the U.S. domestic (heavy) cloth in Spain would be about 47 cts/m2 in 1860, more than the price of the relatively finer Spanish printer cloth (46 cts/m2).[677]

### 9.5. International Competitiveness: The Price of Raw Materials

The single most important raw material in the production of cotton cloth was raw cotton. From 1830 to 1860, the slave states of the South of the United States retained their position as the main world producers of this crop. Raw cotton was also cultivated in Egypt, Brazil, some Caribbean zones, and India. In spite of the clear dominance of the United States in the production of raw cotton, the major wholesale market in the world was in Liverpool. In this period 68 percent of the U.S. cotton industry was located in New England.[678] The factories in New England bought most of the raw cotton in the Port of New York, where it arrived from the Southern States. The raw cotton was cheaper in New York than in Liverpool, but recently Knick Harley showed that the price difference was less than contemporary commentators suggested.[679] In Spain, imports of raw cotton were centralised

[676] According to the Comisión especial arancelaria (1867), the price of freight from Liverpool to Barcelona was 37.25 cts. per kilo in the case of general merchandise. Taking into account that the insurance and bagging costs must be slightly higher in the case of cotton goods, one can assume that the cost of 10 m2, which weighed about 10 kg., must have been around 4-4.5 cts. per kilo. That is, ten percent of the British price of printer goods.

[677] The American price was drawn from Harley (1992), table 1, p. 562. Spanish prices correspond to the prices of "60 hilos, 7/8 2ª" in table 7.6. Exchange rates were computed as in table 7.6.

[678] DeBow (1970), table CXCVI, p. 180.

[679] Harley (1992), table 3.

in the Port of Barcelona because about 75 percent of the cotton industry (1861) was concentrated in Catalonia.[680] Catalan cotton mills bought their cotton in Liverpool, in New Orleans or, alternatively, from wholesalers in the Port of Barcelona.[681]

The next table shows the different costs of the same quality of U.S. raw cotton (US Middling) in the Ports of New York, Liverpool and Barcelona. All prices are final wholesale prices and include freight, cargo, duties, taxes and other minor costs.

**Table 9.7** Raw Cotton Prices: New York, Liverpool and Barcelona, 1830-1860 (Cts. per Kg.)

| Year | New York | Liverpool | Barcelona | Year | New York | Liverpool | Barcelona |
|---|---|---|---|---|---|---|---|
| 1830 | 122 | 157 | 188 | 1845 | 74 | 96 | 121 |
| 1831 | 119 | 128 | 192 | 1846 | 90 | 112 | 136 |
| 1832 | 121 | 158 | 182 | 1847 | 129 | 140 | 168 |
| 1833 | 149 | 196 | 199 | 1848 | 94 | 97 | 125 |
| 1834 | 154 | 198 | 239 | 1849 | 81 | 93 | 146 |
| 1835 | 211 | 226 | 273 | 1850 | 137 | 158 | 188 |
| 1836 | 202 | 214 | 257 | 1851 | 138 | 122 | 188 |
| 1837 | 145 | 141 | 227 | 1852 | 106 | 112 | 156 |
| 1838 | 110 | 150 | 184 | 1853 | 124 | 122 | 163 |
| 1839 | 154 | 175 | 212 | 1854 | 124 | 117 | 158 |
| 1840 | 94 | 128 | 175 | 1855 | 116 | 124 | 165 |
| 1841 | 108 | 138 | 155 | 1856 | 120 | 138 | 164 |
| 1842 | 87 | 116 | 134 | 1857 | 159 | 173 | 188 |
| 1843 | 75 | 105 | 133 | 1858 | 147 | 157 | 200 |
| 1844 | 94 | 113 | 166 | 1859 | 141 | 149 | 189 |

**Notes and sources:** Prices corresponded to US middling quality (and hence are adjusted for differences in grades see Harley (1992)). New York and Liverpool prices are drawn from Harley (1992) and converted to Pta. with the variable exchange rate computed by Prados (1984). Prices in Barcelona are drawn from Diario de Barcelona (1867).

It should be noted that market prices tend to fluctuate more severely in smaller than in larger markets due to the relative impact of each shipment. Therefore, there could be large

[680] Gimenez Guited (1862), p. 204.

[681] Spanish duties on raw cotton helped the direct import from producing sites with Spanish ships. The duty on raw cotton imports on Spanish ships from the producing sites was Rv. 7 per 100 kg. and the duty on deposit ports in non producer zones was Rv. 34.7 Rv per 100 kg. In foreign ships, the duty increased, respectively, up to Rv. 44 and Rv. 52 per 100 kg. Gimenez Guited (1862), p. 204.

differences between the Catalan and the other two markets in certain years. On average, the prices of raw cotton in Barcelona were 47 percent higher than in New York and 28 percent higher than in Liverpool. Moreover, the price differential with Liverpool did not decrease in the period while the difference with New York fell from an average of 47 percent in the 1830s to 35 percent in the 1850s.

Table 9.8 gives a detailed account of the import costs that affected the price of raw cotton in Barcelona. The data is based on a survey conducted by the government on a major Catalan cotton firm (España Industrial S.A.) that imported raw cotton from Liverpool. Therefore, this table must reflect the lowest import cost of raw cotton in Barcelona because this firm did not incur the costs generated by the wholesalers of the Port of Barcelona. Which could increase the prices by about 6-7 percent. Note that the two main headings are the freight from Liverpool to Barcelona and the Spanish duty on raw cotton imports. These expensive freights can be partly explained by the absence of return cargo from Barcelona to Liverpool.

**Table 9.8** Costs of Raw Cotton: Port of Barcelona, 1860 (in Rv.)

| | | |
|---|---|---|
| 1. Raw cotton (100 Kg.) | | 547.00 |
| 2. Commission for purchase (2%) | | 10.94 |
| 3. Brokerage (0.5%) | | 2.74 |
| 4. Insurance (1.125 %) | | 0.12 |
| 5. Bagging (1.5 %) | | 0.04 |
| 6. Freight | | 93.50 |
| 7. Duty | | 34.70 |
| 8. Tax on roads | | 2.78 |
| 9. Minor charges | | 4.20 |
| | Total | 696.02 |
| | Added cost | 149.02 |
| | Percent | 21.41 |

**Notes and sources:** 1 Pta. = 4 Rv. The data is drawn from Comisión especial arancelaria (1867).

The cost of coal was an important factor in the total expenses of Catalan cotton mills. In this period, cotton mills employed up to three different sources of motive power in their mills: horses, steam-engines and water-wheels. According to the contemporary sources, U.S. mills tended to use water.[682] Whereas British mills that were located in Lancashire, where water power was scarce and therefore expensive, tended to use steam engines.[683] An analysis of the comparative costs of different sources of energy in Britain and the United States found that U.S. power was nearly half as expensive as British power in the cotton industry in the 1830s.[684]

Catalonia did not enjoy coal deposits and her rivers were short and had irregular flow. Therefore, in comparative terms, energy costs were higher in Catalonia than in Britain or the United States.[685] Furthermore, the high cost of energy in Catalonia delayed the triumph of the steam engine over alternative motive powers. Sayró's report showed that in 1840 a small portion of all spinning machinery was turned by water or steam power and the overwhelming majority of all looms were still turned by hand.[686] This situation changed rapidly because, at the end of the 1850s, almost 75 percent of spindles and fifty percent of looms were turned by steam engines.[687] It is likely that the rapid triumph of steam power was due to the adoption of the new high pressure engines that saved coal. Consequently, they were more economically attractive for the Catalan cotton mills.[688]

In this period, most of the coal used by Catalan cotton mills was mainly imported in sail ships from Cardiff or Newcastle in Britain.[689] Large transport costs and tariffs, as shown in table 9.9, meant that the price of coal in the Port of Barcelona was about 76 percent higher than in Britain.

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[682] Montgomery (1840), Jeremy (1981) and Von Tunzelmann (1978).

[683] Von Tunzelmann (1978).

[684] Von Tunzelmann (1978), pp. 160-163, 266-278 and 282.

[685] Carreras (1983).

[686] Sayró (1842) and Madoz (1846).

[687] Comisión especial arancelaria (1867).

[688] Von Tunzelmann (1978), chapter 4.

[689] Nadal (1974).

**Table 9.9** Costs of Coal: Port of Barcelona, 1860 (in Rv.)

| | | |
|---|---|---|
| 1. Cardiff Coal (100 Kg.) | | 5.44 |
| 2. Freight | | 11.24 |
| 3. Dock and others | | 2.53 |
| 4. Duty | | 3.55 |
| | Total | 22.76 |
| | Added costs | 17.32 |
| | Percent | 76.10 |

**Notes and sources:** Comisión especial arancelaria (1867).

The figures on raw cotton and coal costs can help us approximate the sources of the absence of competitiveness in international markets of Catalan cotton cloth. In table 9.10 I present some estimates of the part of price gap between the Spanish and foreign printer cloth that was caused by the high cost of raw materials in Catalonia. For my economic analysis I assume that Catalan cotton mills did not change their production function even if the relative price of raw materials decreased. One could argue that this assumption can be highly misleading because the relatively high cost of raw materials meant that Spaniards economised more on raw materials when compared to British and U.S. producers. It is likely, however, that the differences in the price of raw materials influenced more the quality-mix than the quantity of raw materials employed in each quality. That is, each quality was produced with quasi-fixed proportions of raw materials.[690] For example, Spanish, U.S. and British cotton mills employed almost the same amount and quality of raw cotton to produce each single quality of cotton cloth.[691] However, it must be recognised that the large differences in the price of energy affected machinery speeds since U.S. cotton mills ran faster than both British and Catalan cotton mills.[692] On the other hand, Catalan mills copied the speeds of the similar British cotton mills.[693] Finally, it should be noted that the figures assume that British, Catalan and New England cotton mills were situated at the

[690] This holds after the Catalan cotton mills adopted steam power as the source of motive power.

[691] This question is easy to test by comparing the Spanish technical handbooks (e.g., Arau, (1855) and Calvet, 1857) with the British sources (e.g. Huberman (1996), Ure (1836)). Furthermore, Harley (1992) argues the same for the U.S. and British mills.

[692] See Montgomery (1840) and VonTunzelmann (1978), p. 202ff. on the different speeds of the U.S. and British cotton mills

[693] See Comisión especial arancelaria (1867).

import sites of raw materials, where the prices were the lowest. Since it is likely that in Catalonia and New England transport costs were higher than in Britain this presumption would reduce the price-gap. Consequently, it can be assumed that these figures represent the lower bound of the price-gap that can be explained by the higher cost of raw materials in Spain.

**Table 9.10** The Sources of the Spanish Price-gap in Printer cloth, 1845-1859

| | Final price difference | | Due to raw materials | | Percent explained | |
|---|---|---|---|---|---|---|
| | Britain | US | Britain | US | Britain | US |
| 1845 | 27.78 | | 8.47 | | 30.51 | |
| 1846 | 28.37 | | 8.36 | | 29.45 | |
| 1847 | 15.73 | 1.59 | 8.81 | 10.94 | 56.05 | 689.58 |
| 1848 | 16.75 | 4.84 | 8.77 | 9.93 | 52.38 | 205.16 |
| 1849 | 17.70 | 13.58 | 12.00 | 14.18 | 67.78 | 104.41 |
| 1850 | 21.05 | 17.98 | 9.00 | 12.52 | 42.76 | 69.62 |
| 1851 | 18.57 | 12.15 | 13.65 | 12.37 | 73.52 | 101.76 |
| 1852 | 16.97 | 12.86 | 10.82 | 12.39 | 63.77 | 96.30 |
| 1853 | 20.20 | 7.29 | 10.46 | 11.01 | 51.75 | 151.04 |
| 1854 | 26.06 | 13.49 | 10.44 | 10.30 | 40.08 | 76.37 |
| 1855 | 24.69 | 16.53 | 10.50 | 12.17 | 42.51 | 73.62 |
| 1856 | 19.18 | 9.97 | 8.50 | 11.59 | 44.32 | 116.20 |
| 1857 | 13.95 | 6.01 | 7.18 | 9.63 | 51.47 | 160.32 |
| 1858 | 15.95 | 8.07 | 10.75 | 12.76 | 67.39 | 158.23 |
| 1859 | 10.49 | 6.47 | 10.35 | 12.03 | 98.70 | 185.93 |

**Notes and sources:** The price differential has been computed with the data of the tables 9.6, 9.7 and 9.9. It has been assumed that American mills were water-powered. Furthermore, it has been included the Spanish industrial tax in the raw materials differential, because to my knowledge a similar tax did not exist in the other two countries. According to the data of the Comisión Especial Arancelaria (1867), the amount of coal employed in producing one m2 of printer cloth was 0.55 kg and the amount of raw cotton 0.126376 Kg. The industrial tax on this m2 amounted 2.8791 cts.

The results of this table are illuminating: on average, half of the price gap with Britain can be explained by the high costs of raw materials alone and, roughly speaking, the price-gap with the U.S. mills is explained by the high cost of raw materials in Spain. The table also confirms the rapid progression of the Catalan cotton mills in comparison with the British and U.S. cotton mills. In the next section, I test the robustness of these results by comparing the productivity of cotton factories in the three countries. Note that if the price gap was due to the technological superiority of British mills, and not to differences in minor costs,[694] the level of total factor productivity must be higher in Britain than in New England and Catalonia.

### 9.6. Productivity Comparisons

The literature on economic history emphasises that the productivity of labour and capital are not independent of their relative prices.[695] For example, Broadberry has recently argued that 'the origins of the gap [in labour productivity between the United States and Britain] lie in the abundance of land and resources in America compared with Europe' and adds that 'technology transfer from Britain to American [in the nineteenth century] required adaptation of local circumstances, economising on scarce skilled labour but utilising abundant resources'.[696] Similarly, development and growth theorists tend to emphasise that labour productivity differences among countries can be explained, at least partly, as a consequence of different levels of physical and human capital intensity.[697] In other words, countries well endowed with capital (advanced countries) had the highest labour productivity and the lowest capital productivity. Whereas the contrary holds for less developed countries. Therefore, it could be interesting to review the differences in the prices of capital and labour among New England, Catalonia and Britain before proceeding with the analysis of their productivity differentials.

Table 9.11 presents some information in the comparative costs of labour in the New England, Lancashire and Catalonia cotton industries. Admittedly, the data is highly imperfect because the figures are not adjusted for female and child employment. The table displays the well-known fact that the cost of labour was higher in the United States than in Britain

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[694] Harley (1992) suggested that British superiority was due to minor costs.

[695] Specifically, I define for this section productivity of labour as the result of dividing sectoral output by labour input and the productivity of capital as the result of dividing sectoral output by capital input.

[696] Broadberry (1997), p. 88-89. Obviously, this statements is based on the Habakkuk debate. See Habakkuk (1962) and, for example, James and Skinner (1985).

[697] See, for example, Barro and Sala-i-Martin (1994).

and Spain. Therefore, *ceteris paribus*, one can expect that in New England labour productivity was higher than in Lancashire and Catalonia.

**Table 9.11** Comparative Cost of Labour: New England, Lancashire and Catalonia, 1840 and 1860 (in Pta.)

| | N. England per day | Lancashire per day | Catalonia per day | N.England per hour | Lancashire per hour | Catalonia per hour |
|---|---|---|---|---|---|---|
| Spinning c.1840 | 2.88 | 2.27 | 1.21 | 0.23 | 0.23 | 0.10 |
| Spinning c.1860 | 3.06 | 2.50 | 2.21 | 0.28 | 0.25 | 0.19 |
| Weaving c.1840 | 2.80 | 2.06 | 1.87 | 0.23 | 0.21 | 0.16 |
| Weaving c.1860 | 3.13 | 2.37 | 2.60 | 0.28 | 0.24 | 0.23 |

**Sources and notes:** New England data are drawn from Layer (1955), table 6, p. 24 and table 14, p. 52; c. 1840 correspond to the period 1840-44 and c.1860 to the period 1855-1859. Lancashire data is drawn from Ellison (1968), p.66-67. Catalonia data for c.1840 is drawn from Madoz (1846) and comprised domestic industry, whereas data for 1860 is drawn from Comisión especial arancelaria (1867).

Table 9.12 furnishes a better comparison of the real costs of labour in Lancashire and Catalonia. Here the wages are presented on job basis. The differences in weekly wages are less than one would expect, on average about 15 percent. By contrast, once the wages are adjusted for the duration of the working week the differences practically double. If these wages represent the true marginal productivity of labour, one concludes that Lancashire workers were about thirty percent more efficient than Catalan workers.

**Table 9.12** Wages in Cotton Industry: Lancashire and Catalonia, c. 1860 (in Pta.)

| | | Lancashire | | Catalonia | | Lancashire/Catalonia | |
|---|---|---|---|---|---|---|---|
| | | Week | Hour | Week | Hour | Week | Hour |
| Preparation | Female | 38.4 | 0.64 | 34.30 | 0.50 | 1.12 | 1.29 |
| Spinners | Male | 100.8 | 1.68 | 84.00 | 1.22 | 1.20 | 1.38 |
| Assistants | Female | 48 | 0.80 | 42.00 | 0.61 | 1.14 | 1.31 |
| Card masters | Male | 134.4 | 2.24 | 120.00 | 1.74 | 1.12 | 1.29 |
| Spinning masters | Male | 124.8 | 2.08 | 120.00 | 1.74 | 1.04 | 1.20 |
| Weaving ancillary | Female | 45.6 | 0.76 | 36.00 | 0.52 | 1.27 | 1.46 |
| Weavers | Male-Female | 82.8 | 1.38 | 72.00 | 1.04 | 1.15 | 1.32 |

**Notes and sources:** The Lancashire data is drawn from Ellison (1968), p. 67 and the Catalonia data from Comisión especial arancelaria (1867). The working week was of 60 hours in Lancashire and 69 hours in Catalonia. British wages are converted to Pta. with the exchange rate of Prados (1984). Numbers are subject to rounding errors.

The price of machinery was also different in the three countries. Chadwick estimated that in 1860 the fixed capital in each new spindle in Britain was 24s and £24 in each powerloom. Assuming that each powerloom consumed the yarn of about 45 spindles, the cost of fixed capital per spindle (plus loom) in Britain was 34.6s.[698] In Spain, according to España Industrial's figures, the cost of fixed capital per spindle was Pta. 112.85 (95s).[699] McGouldrick shows that the standard cost of fixed capital per spindle (including buildings and the machinery of the weaving section) in the United States was $19.09 in 1860 (that is, about 79.54s).[700] However, this figure cannot be directly compared with the Spanish and British figures since it is based on water-power spindles whereas the other two are steam-power spindles. It is well known that the fixed capital costs of water-wheels were higher than the fixed capital costs of steam-engines. In particular, Temin's figures show that the fixed cost of water-wheels (including buildings) in the United States was 2.04 times the fixed cost of steam-power.[701] Since the cost of water-power installation was about 17.25 percent of all fixed capital costs in 1860,[702] U.S. cotton mills could reduce the total fixed

[698] Chadwick cited by Blaug (1961), p. 373.

[699] Comisión especial arancelaria (1867).

[700] McGouldrick (1968), table 46, p. 240.

[701] Temin (1966). Von Tunzelmann (1978), p. 162 argues that Temin's figures probably overstated the price difference between steam and water engines.

[702] McGouldrick (1968), table 46, p. 240-241.

capital by about 8.45 percent by using steam engines instead of water-wheels. In other words, the cost of one steam-power spindle in the United States (1856) was $19.09 (that is, about 72.8s).

It is likely that the relatively lower price of capital goods in Spain and the United States than in Great Britain was a consequence of the fact that practically all inventions in the cotton industry were made by British engineers. For instance, in this early period, the Catalan firms imported practically all spinning machinery and powerlooms from England or France (Alsace). Therefore, when one machine had to be repaired spares came from Britain, with high costs for the factories.[703] Finally, it should also be noted that in Spain and the United States duties had to be paid on imported machinery .[704]

In spite of the fact that the past figures are a very imperfect indicator, one would expect that, *ceteris paribus*, U.S. workers employed more machinery than British and Spanish workers. Similarly, one would also expect that labour productivity was higher in the United States than in the other two countries.

As mentioned above, the Törqvist indices of productivity developed in chapters 5 and 6 cannot be used serve for international comparisons of productivity because they measure absolute changes in total factor productivity. Therefore, to compare productivity levels among countries it is necessary to develop an alternative method. Basically, the objective is to construct a benchmark comparison of productivity levels using the same Translog production function.

Moving to output. The measure is based on the Translog approach to output measurement. First, the output in each country must be divided into homogeneous components.[705] Here, I decided to divide the production of cloth into five qualities according

[703] Ferrer Vidal (1875).

[704] Gimenez Guited (1862) and Taussig (1931).

[705] The sources are enumerated in the notes to table 7.1.

to Huberman's definitions.[706] Then, output is converted to m2 equivalents of coarsest cloth using relative unit values. Since relative unit values are different in the three countries, the relative unit values employed are an average of the weights of the three countries. With this method I get a measure of output that considers quality and the differences between the relative prices.[707]

The comparison of the total amount of production is also hampered by the fact that the British, the Spanish and the U.S. spinning industries exported part of their yarn production. British factories exported yarn to their domestic industry and other countries. Catalan factories exported yarn to the domestic and to the mixed-fabrics industry. In Britain, the total amount 'exported' represents about 32 percent of yarn output. More formidable problems arise again with the Catalan industry. The fact is that most of the cloth production was in the hands of the domestic industry in 1850. Consequently, a large part of the yarn output was exported. I assume that output from self-acting mules and throstles was used for the powerweaving whereas the production in mule-jennies was exported. This assumption is corroborated by the original census because vertically integrated firms employed usually throstles and powerlooms but not mule-jennies.[708] For Britain, I assume that the highest quality yarn was exported to handweaving[709] and international exports were proportionally distributed among the different qualities. In Catalonia, it was assumed that the production of the powerlooms was 80 percent G2 quality and 20 percent GF quality. It should be noted that these two assumptions are biased against Catalonia and Britain since a less restrictive assumption (exports are distributed regularly along the spectrum of qualities) would have increased their output figures. The following table presents the results of these calculations:

[706] Huberman (1996).

[707] Relative values are obtained from Harley (1992), *The Economist* (1845)(1850)(1855)(1860) and Comisión especial arancelaria (1867). It is impossible to obtain U.S. prices for the finest qualities and decided to use only Spanish and British unit values.

[708] Junta de fábricas (1850).

[709] According to VonTunzelmann (1978), pp. 195ff. powerlooms were not economically profitable for the production of the finest cloth.

**Table 9.13** Output in Cotton Factory System: New England, Catalonia and Britain, 1850

| **Output** | G1 | G2 | GF | F1 | Equivalent G1 |
|---|---|---|---|---|---|
| New England | 355,692 | 133,164 | | | 514,823 |
| Catalonia | | 21,929 | 5,482 | | 38,199 |
| Britain | 173,536 | 619,398 | 376,820 | 96,072 | 2,071,790 |
| **Price** | 1.000 | 1.195 | 1.8054 | 4.973 | |

**Notes and sources:** output figures in thousand of m2. The quality G1 corresponds to the coarsest quality. For a very detailed description of the qualities see section 2.2 in chapter 2.

Moving to labour input. The British figures are drawn from Blaug (1961) and Von Tunzelmann (1978). The New England figures are from DeBow (1970) and the Catalonia figures are from Junta de Fabricas (1850). With all workers in self-actings, throstles and powerlooms. Relative wages are not available for children in Britain and New England since figures are only available on a male/female basis (in both countries, female wages were about 60 percent of male wages). Catalan figures are also adjusted for children, and sources show that adult female wages were about 50 percent of adult male wages. This ratio was adopted elsewhere.[710] The labour input figures are presented in the table 9.14:

**Table 9.14** Labour in Cotton Factory System: New England, Catalonia and Britain, 1850

| **Labour** | Males | Females | Children | Equivalent Males | Equivalent Hours |
|---|---|---|---|---|---|
| New England | 15,974 | 41,148 | 6,846 | 38,534 | 140,956,185 |
| Catalonia | 3,350 | 3,282 | 1,883 | 5,457 | 17,382,987 |
| Britain | 106,368 | 147,956 | 12,263 | 184,646 | 553,939,293 |

**Notes and sources:** see text.

The direct computation of the amount of capital would be highly misleading because of the differences between the prices of machinery among the three countries (see above). Therefore, the choice was for a quantity measure of capital (steam-power spindles equivalent), which comprises spindles plus horsepower and powerlooms. The U.S. figures were obtained from Stettler (1977), but the water-power spindles (75 percent) were

[710] Thus, the weights are females = 0.51 males and children = 0.23 males. Working hours from Layer (1955), Ellison (1968) and Cerdá (1968).

converted to steam-power spindles with the equivalence estimated above (1 water-power spindle = 1.0925 steam-power spindles). The Spanish figures were obtained directly from the Junta de fábricas (1850) census, and correspond to all self-actings and throstles (the assumption is that mule-jennies produced for the export sector). British data is obtained from Blaug (1961) the 20 percent of doubling spindles and the percentage of spindles that worked for the export sector were eliminated (see above). The next table shows the data on capital input:

**Table 9.15** Capital in Cotton Factory System: New England, Catalonia and Britain, 1850

| Capital | Equivalent Spindles | Hours | Value Fixed | Value Inventories |
|---|---|---|---|---|
| New England | 2,748,503 | 10,054 | 56,775,550 | 38,464,555 |
| Catalonia | 147,368 | 469 | 20,117,206 | 13,567,736 |
| Britain | 10,852,929 | 32,559 | 18,775,568 | 8,782,120 |

**Notes and sources:** Capital hours are million of equivalent steam-power spindles hours. Fixed capital, inventories, rental rates are in local currencies. See text for sources.

The last step in computing Translog indices of total factor productivity levels consists of estimating the relative shares of capital and labour. The shares are an unweighted average of the shares of capital and labour in the three countries. With this method I get a measure of total factor productivity that considers the differences between the relative endowments among countries.

The wages for Britain were obtained from Wood.[711] The New England wages were computed from DeBow (1970). Catalan wages were a weighted average of the figures for 1840 and 1860, from Madoz (1846) and Comisión especial arancelaria (1867). Capital share was computed with the rental price of capital. Therefore, perfect competition was assumed and that the same depreciation rates were used in the three countries. That is $Ri = Pi(t)*r + Pi(t)*\xi$ or the rental rate of i is equal to the price times the rate of return plus the price times the depreciation rate. The fixed capital values are obtained by multiplying the number of spindles

[711] Cited by Blaug (1961)

by their value (see text). I also computed inventories by means of the figures of Blaug (1961), McGouldrick (1966) and Ronquillo (1851-57). The depreciation rates are 7.5 percent in machinery, 2.5 percent in buildings, and zero for inventories. It was assumed that the rate of return (interest rate plus 1 percent) was 5 percent in Britain, 6 percent in New England, and 7 percent in Catalonia.

**Table 9.16** Factor Shares in Cotton Factory System: New England, Catalonia and Britain, 1850

| | rental rate | wages | share capital | share labour |
|---|---|---|---|---|
| New England | 8,979,000 | 11,715,143 | 0.43 | 0.57 |
| Catalonia | 3,514,685 | 4,103,504 | 0.46 | 0.54 |
| Britain | 2,457,480 | 7,990,424 | 0.24 | 0.76 |
| **Average** | | | 0.38 | 0.62 |

**Notes and sources:** Rental rates and wages are in local currencies. See text for sources.

The results of all these calculations are presented in the table 9.17.

**Table 9.17** Comparative Levels of Productivity in Cotton Factory System: New England, Catalonia and Britain, 1850 (New England=100)

| | **Labour Productivity** | **Capital Productivity** | **TFP** |
|---|---|---|---|
| **a) per employee basis** | | | |
| New England | 100.00 | 100.00 | 100.00 |
| Catalonia | 52.39 | 138.38 | 55.32 |
| Britain | 83.98 | 101.91 | 90.92 |
| **b) per hour basis** | | | |
| New England | 100.00 | 100.00 | 100.00 |
| Catalonia | 60.17 | 158.91 | 97.37 |
| Britain | 102.40 | 124.27 | 110.64 |

**Notes and sources:** see text.

Let me first discuss the productivity figures on a per employee basis. New England superiority in TFP is based on its higher labour productivity since its capital productivity is the lowest. This highest labour productivity is due to the high capital-labour ratio, and also the longest working hours. In 1850, the British work-day was limited to 10-hours whereas in the U.S. industry the work-day was 11.8 hours.[712] It should be appreciated that the number of working hours during the year in Catalonia was less than in New England and Great Britain. The work-day was slightly shorter in Catalonia than in the United States, (11.5 hours per day) but Catalan mills were at a standstill for longer periods than their competitors (in Catalonia the yearly days of work were 277 while in New England 310). According to contemporaries, these prolonged standstills of the Catalan cotton mills were a consequence of a sharp crisis and fluctuations in the home market, delays in the reception of spares for machinery, and the longer and drier summers.[713] Note that this characteristic of the Catalan cotton mills also affected the productivity of capital goods and, obviously, the level of inventories.

Moving to the per hour results, where capital and labour are adjusted for working hours. The first point to note is that the British cotton industry was the leader in TFP and labour productivity. In other words, by 1850 British cotton mills were the most efficient. This result completely explains why the British could sell their products in all kinds of markets. Second, the TFP gap between the Catalan and New England cotton industries practically disappeared. In broad terms, this result is coincident with the evidence presented in table 7.10: New England superiority over Catalonia can be explained by the lower price of raw materials in New England. This latter result also gives some support for the argument that the lack of competitiveness of the Catalan cotton firms in international markets was partly explained by the climatic conditions of Catalonia.

Readers familiar with the literature comparing productivity and factor proportions in Europe and U.S. could find this result somewhat unexpected.[714] Most economic historians in their productivity comparisons have been unable to explain why British cotton mills dominated the world markets for cotton cloth during the whole nineteenth century. When their productivity record was apparently inferior to that of U.S. producers. Nevertheless, they have paid little attention to the influence of quality-mix on productivity. Most traditional

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[712] For New England data see Layer (1955) and for British data see Ellison (1968).

[713] See Cerdá (1968) and Ferrer Vidal (1875).

[714] See a review of the literature in the recent contribution of Broadberry (1997).

indicators of output in the cotton industry such as the amount of cloth produced or the weight of raw cotton consumed are very imperfect measures of output in this industry.[715] All these measures implicitly assume that all countries produce the same kind of cloth; in other words, there is only one quality of output. Evidently this assumption can lead to unexpected results. For example, one country that produces low quality cloth has, *ceteris paribus*, higher productivity than another country that produces high quality cloth. Because the latter needs, on average, more inputs (labour and capital) to produce each m2, or kg, of cloth. It was argued above that the production of the finest requires efficient labourforce. In other words, countries with higher productivity, *ceteris paribus*, tend to specialise in the finest qualities. A straightforward solution to the problem of different quality-mixes is derived from the Translog approach to comparative output measurement. Which is the standard method for the international comparisons of industry productivity.[716] Obviously, when this method was adopted in my calculation of output, the picture changed substantially. The British superiority in international markets can be explained by its high productivity.

### 7.7. Conclusions

This chapter has raised several issues. First, it showed that the choice of technology and the quality-mix of the cotton industries were strongly related. Low quality production was a consequence of cheap raw materials and the inferiority of the labour force. Whereas the contrary holds for the finest qualities. Furthermore, other factors traditionally highlighted in the literature, such as the characteristics and size of the home demand, appear to be less important in determining the quality-mix and the drift towards best practices.

So far, this chapter has established the sources of the lack of competitiveness of the Catalan cotton industry in international markets throughout the whole period in spite of its rapid productivity progress. The Catalan cotton industry was not competitive with the British industry because of the higher cost of raw materials in Catalonia and Catalan production was

[715] Note that all PPP measures that assume that unit values can be computed directly (see, for example, Broadberry (1997)) in both countries are strongly biased against high-quality producers.

[716] See Dean *et al.* (1996).

less efficient. However, the New England cotton industry was not more advanced than the Catalan industry. U.S. production was less expensive than Catalan production because the U.S. cotton mills had access to the cheapest sources of raw materials and energy.

Third, the size of the Catalan cotton textile production in a counterfactual world without the Spanish tariffs cannot, of course, be estimated. However, it is likely that without tariffs nearly all the Catalan cotton factories would have succumbed to British competition. For instance, the price difference between Catalan and British cloth was larger than the total cost of labour in Catalonia. So, even reducing wages Catalan firms would have been unable to match British prices. A less ambitious Catalan cotton industry, with only a few competitive firms, some skilled handweavers and calico printing firms creating quality-differentiated products, and employing foreign (British) yarn, might have had lower costs.[717] Without the tariffs the industry might have been more adapted to Catalan and Spanish circumstances. Employing a larger and more skilled labourforce and supplying a larger share of the home and foreign markets. However, there is no doubt that Spanish consumers would have benefited from the elimination of the ban on foreign imports of yarn and cloth.

Finally, this chapter could serve to introduce several new questions into the debate over the sources of the backwardness of the Mediterranean countries. It is important to emphasise that the Mediterranean manufacturing system was closer to the British, and by extension to the European model, than to the U.S. model. In other words, Catalan factories employed skilled workforce and flexible methods of production. Note that the U.S. model, which was based on the use of an unskilled labourforce and the very intensive use of raw materials, was not suitable for the Mediterranean circumstances. Since raw materials, which were mainly imported, were relatively expensive.[718] However, the adoption of a British-type cotton industry was not a viable option for Catalonia. Given the higher cost of raw materials in Catalonia than in Britain and the unquestionable superiority of the British mills.

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[717] The examples are Switzerland and Germany in this early period. Both countries maintained a local cotton industry which employed British yarn. Note that with this method they were able to maintain their local markets, and in the case of Switzerland, to gain some foreign markets.

[718] See, on the high cost of raw materials in Italy, Bardini (1997).

# Chapter 10

# Conclusion

The decision to state my interpretation and to show its main points at the end of the study means that, at this point, I have arrived at the end of the story. However, it is easy for the author to suppose that their presentation is as clear to others as it is to himself. The deviation of the discourse towards different problems and questions may sometimes have suggested different directions from those I intended, and the argument may not always have been as visible as I would have wished, especially since it has been spread over many methodological discussions. Consequently these conclusions will try to set out the main claims in a way to try to remove any residual uncertainties and be explicit some of the wider implications of the argument.

The objective of this dissertation has been to analyses the main supply-forces behind the early industrialisation in Catalonia. I have addressed this task by computing the contribution of the different components of the neo-classical production function to modern industries' growth. It is perhaps worth repeating at this point that my concern has been to establish the relative importance of each input in order to discriminate which was the main element for growth, but I never assumed or defended that any input was unnecessary for growth or that inputs act independently one from other. In any case, the use of the neoclassical growth equation (i.e., the Solovian model) is a convenient means to instil some coherence into the large body of evidence concerning the different inputs for growth. However, such as many readers probably know, the neo-classical growth equation lets an important part of the rate of growth unexplained. Therefore, it would be convenient to complement that analysis with a more profound discussion based on the analysis of the 'residual' (i.e., the part of the output growth which cannot be explained by the accumulation of inputs). For that reason, in a second part of this study, I analysed the forces shaping the 'residual' by means of four case-studies.

In a nutshell, the computation of the neo-classical growth equation suggest that there is a discontinuity in industry growth rates as an outcome of the increase in total factor productivity in a span of years. Neither capital accumulation, nor the transference of labour within manufacturing appears to be so important as productivity growth. Note that the increase in productivity growth rates was accompanied by a relevant increase in the quality of the industrial production. However, as shown in chapter 2, the large output growth rates of the modern sectors, which were mainly a result of these productivity shift, produced wide effects on the Catalan economy but narrower effects on the whole Spain. In other words, the increase of the efficiency level in the modern industries was not translated into a process of 'take-off' at national level. Consequently, during this early period, industrialisation remained as a regional phenomena, which did not ensure a shift at national level towards sustained growth rates.

In the second part of the dissertation, I offered evidence that this increase in efficiency was the consequence of the development of new business institutions. Therefore, the transition from the decentralised forms of production (the artisanal shops and the putting-out system) to the centralised forms of production (the non-mechanised and mechanised factories) was a major ingredient in Catalan early industrialisation. The presence of these large establishments explains the higher productivity of Catalonia, when compared to other Spanish regions. Furthermore, the evidence presented above supports the hypothesis that factor endowments associated with scale economies explains the presence of these large establishments in Catalonia. The localization patterns of large industries are positively correlated with the density of population, which was probably the result of some precocious agricultural transformation. Obviously, this result is more consistent with the standard neo-classical Heckser-Ohlin model than other historical explanations based on entrepreneurial failure or institutional constraints to growth.

The Catalan economy was also characterised by the fast adoption of foreign technologies. The presence of a large human capital stock, which was mainly the result of the children's informal education which took place in the workplace rather than in the schoolroom, allowed Catalan industrial firms to adopt and modify new technologies. Moreover, the high levels of protection of certain industries, more prominently the cotton industry, made possible the adoption of technologies that were not at first sight especially adequate to the Catalan factor endowments. For instance, the climatic conditions, the higher cost of coal and raw cotton in Catalonia made impossible for Catalan cotton industry to become competitive in foreign markets.

Scholars who regard industrialisation as synonym of the adoption of British machinery can argue, then, that protection was at the roots of the early Catalan industrialisation. Viewed from this angle, the misallocation of resources which was triggered by tariff policy is less significative than the dynamic gains which were obtained with the development of a mechanised cotton industry. However, as I noted in chapter 9, the development of the cotton industry damaged other industries, such as mixed fabrics textiles, which were more adapted to Catalan factor endowments. It is also doubtful that the dynamic effects of the protection of cotton industry were larger than those which would have been derived from the development of other industries. At the beginning, these industries were apparently less sophisticated than the cotton industry but in many ways they were more appropriate to the Catalan and Spanish conditions. Moreover, it should be considered that scale economies not only available in mechanised industries but also in the nonmechanised ones since centralised plants began to displace decentralised units-of-production even before the widespread diffusion of the water and steam-driven machinery.

This explanation of the process of early industrialisation in Catalonia is based on a reappraisal of the role of local and disembodied innovation (i.e., the innovation which is not embodied in the design of new machinery) in the process of industry growth. Other sources for growth, like the accumulation of capital and labour or the transference of foreign technology in the form of machinery, have their place in the story, but only within the context of impulses emanating from the local transformations. Explanations which assign a leading role to the transference of British technology to the Continent do, of course, exist already; but as I will suggest, the most influential of these are seriously weakened by the excessive emphasis placed on the influence of the British model in the development of the followers. Moreover this perspective fails to incorporate much of the recent research on British and European economic history, and tends to assume rather to establish connections between the export of British machinery and the local processes of development. In this case, as it is frequent in the historiography on the European industrialisation, the literature has been shaped by assumptions about the role of capital in economic growth.

The interpretation of the new evidence suggest that conventional approaches to early industrialisation in the regions of Europe need to be reconsidered. In particular, it is necessary to recognise the fact that economic growth was not simply the consequence of the accumulation of capital, trade barriers to British competition or the imitation of the British model. Factor endowments and market forces, specially those connected with the development of new business institutions and new products and processes, were far more important and independent than standard texts of economic history have tended to allow. Identifying the changes in business institutions produced by the market forces establishes, in principle, the crucial connection between the local conditions and factor endowments and industrialisation, and hence offers a way of overcoming one of the difficulties faced by the traditional interpretations of the processes of industrialisation. By restating the main themes of the early industrialisation in Europe and more particularly Spain, in these terms, it becomes possible to offer an alternative explanation of the fact that early industrialisation was not a wide-ranging process.

I believe that the case study I have presented has sufficient coherence and enough evidence to merit serious consideration, and I hope that it will carry forward the study of the subject in a constructive manner. Simultaneously, I am quite aware that the new evidence opens lines of research rather than closes them: the relationship between the demography and the scale economies of the industry, the consequences of the reduction of the transport cost in industry efficiency, the relation between industry and agriculture, the long-term effects of the barriers to free competition all of these are large topics that invite further study. Whatever judgement is made of this particular interpretation, however, I hope that I have succeeded for integrating the analysis of Catalan industrialisation in the new debates on European economic history. Anyhow, evidence of intention is no indication of the result of an enterprise, which must properly left to the judgement of others.

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