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THE CHOICE OF TECNOLOGY IN THE MEDITERRANEAN BASIN: SOME EVIDENCE FROM THE SPANISH, ITALIAN, BRITISH AND US COTTON MILLS (1830-1860)

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Abstract

This paper is motivated by the attempt to understand the choice of technology in the cotton mills in the Mediterranean basin from 1830 to 1861. In the period before the 'cotton famine', alternative technological choices were relatively important. However, these technology alternatives cannot be interpreted without consideration heterogeneity of cotton cloth. In other words, to produce the different kinds of cotton cloth it was employed a particular amount of physical and human capital, labour, energy and raw cotton. Moreover, some types of machinery were more adept than others in the production of some kinds of cotton goods. Thus, this paper argues that the choice of product and machinery was intimately connected with the availability of skilled labour and relative factor prices in this early period of the factory-based cotton industry.

Keywords: Human capital; quality choice; factor endowments.

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1. Introduction

Studies on the cotton industry proliferate. Remarkably, the cotton industry has figured in recent debates over the amplitude and significance of the British Industrial Revolution, the loss of British competitive advantage, and the wealth and the poverty of nations in the nineteenth and the early twentieth centuries. As research moves forward, it seems obvious that the comparative history of European cotton industry in the period before the 'cotton famine' has been grossly neglected. There have been some splendid books and articles on some national cases but the comparative perspective has barely been touched. In particular, to date no study has systematically analyzed the cotton textile industry in the Mediterranean basin during the early industrialisation period. This chapter fills that gap by adopting a comparative perspective. More specifically, this chapter concentrates its energies on providing a careful analysis of the technological choices of four cotton industries: the two largest producers in the Mediterranean Basin and the two largest producers in the world, from 1830 to 1860.

Before the arrival of the 'cotton famine' in the 1860s, the most important settlements of the modern cotton industry in the Mediterranean basin were in Catalonia (Spain) and in the Crown of Piedmont-Sardinia.[1] Simultaneously, the world leadership in cotton textiles was in the hands of Lancashire (Britain), while New England (United States) occupied the second position. In these regions, the cotton industry represented the first large-scale application of modern technology and the factory system. However, these four cotton industries differed strongly. 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 technology 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.

Few economic historians believed in the absolute tyranny of fixed factor proportions

[1] Specifically, in the regions of Piedmont and Ligury.

and fixed attribute bundles; that is, in the argument that the choice of technology is technologically determined. Instead, the majority recognised that there exist a fairly wide range of alternative technology choices. However, economic historians vary in the reasons they stress. For Habakkuk (1962) the choice of different technologies reflects differences in factor endowments. In particular, he argued that land abundance and labour scarcity in United States led to high relative wages and the substitution of capital for labour. Instead, for North (1981) institutions to technological change had crucial importance since their historical development will decide the outcome of any economic activity in a community. Institutions should be seen in terms of cultural norms, written rules and unwritten codes of conduct that provide the framework within economic agents function. Finally, David (1985) posits more emphasis on the path-dependence of technological choices. Divergence on technological choices has occurred, in this view, but not simply because of differences in factor endowments or institutions. Rather, the argument is that it exists a dependence of successive developments on prior events. Consequently, it seems that by focusing explicitly on technological choice, one can open the door to a deeper understanding of how prior history, institutions and factor prices could affect technological innovation and long-run growth.

The recent literature on the history of cotton industry contains three broad perspectives as well. One maintains the unimportance of alternative technological choices in the cotton industry. In particular, Clark (1987) diminished the importance of alternative technology; thereby, he asserted that countries with different factor prices showed no evidence of any difference in cotton spinning techniques at the beginnings of the twentieth century. According to his view, the effort of workers was the major determinant of the performance of cotton industries. A second view stresses that patterns of adoption of technology are basically consistent with a rational response to prevailing factor costs. For Von Tunzelmann (1978) technological choices of British, Belgian, and American manufacturers were constrained in the first place by the price they had to pay for energy. For example, he pointed out that in the United States the abundance of (cheap) water power was the incentive offered to develop a new technology more power-intensive (the ring throstle). For Saxonhouse and Wright (1984), the choice of technology was driven by geographical factors and the capacity to innovate. In particular, they argued that the

diffusion of ring spinning was constrained by the availability of high-quality cotton and subsequently by ingenuity in devising alternatives like cotton mixing. Instead, Harley (1992) considered implicitly a more large set of factors in his comparison between British and American cotton industries in the mid-nineteenth century. Thus, he included the relative prices of raw cotton, energy, skills and labour as determinants of the technology. A third interpretation posits a more fundamental role in institutional factors. Lazonick (1990) claimed the importance of entrepreneurial failures for the choice of technology. In particular, he censured the British entrepreneurs for their alleged failure to choose the correct techniques in spinning and weaving during the late nineteenth and early twentieth centuries. According to his arguments, the fundamental error was retaining the horizontal specialization of the British industry into spinning and weaving factories. Similarly, Fisher (1991) emphasized the reluctance of Swiss textile entrepreneurs to adopt the new spinning machinery. He argued that these entrepreneurs 'were more risk avoiders than profit maximizers'.[2] Finally, for Otsuka, Ranis and Saxonhouse (1988) differential technological performance between Japanese and Indian cotton industry emanated from differences in market structure and government intervention. They pointed out that in Japan the relative absence of market intervention policies helped both to ensure an efficient choice of imported technology and to have it adapted in appropriate directions.

While I recognise the importance of institutional and cultural differentials across countries, my basic premise is that labourforce skills and factor endowments are of crucial significance to the choice of technology in cotton textiles. In the period before the 'cotton famine', alternative technological choices were relatively important. However, these technology alternatives cannot be interpreted without consideration heterogeneity of cotton cloth. In other words, to produce the different kinds of cotton cloth it was employed a particular amount of physical and human capital, labour, energy and raw cotton. Moreover, 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. In consequence, one can argue that the choice of product and machinery was intimately connected with the availability of skilled labour

[2] Fisher (1991), p. 151.

and relative factor prices in this early period of the factory-based cotton industry.

The remainder of this chapter is organised as follows. In the next section, the main characteristics (size, quality-mix and export performance) of these four cotton industries are discussed. Section 3 provide an analysis of technological developments in cotton textiles during the period. The following section discusses the process of diffusion of the cotton textiles' technology in Lancashire, New England, Catalonia and Lombardy. Section 5 develops a framework to understand how technological choices and quality-mix were interrelated and how quality choices were decided by factor endowments and workforce skills. Finally, the last section concludes and summarises.

2. Main characteristics: size, quality-mix and export performance

For the sake of comparison, it is useful to know how large the cotton industries of Catalonia, New England, Britain and Piedmont were. To answer this question, I rely on cloth produced 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.[3] For the reasons above, my choice was to compare cloth produced in square metres. Table 1 shows the results.

[3] See, for example, Blaug (1961), Huberman (1996) or Comisión especial arancelaria (1867).

Table 1. Production of Cotton Cloth: Catalonia, New England, Britain and Piedmont, 1830-1860 (In thousands of m2, average per year)

	Catalonia	New England	Britain	Piedmont
1830-40	21,291	229,440	680,614	9,690
1840-50	51,430	414,972	1,140,804	17,701
1850-60	109,132	612,815	1,852,892	34,165
1830-60	60,500	420,345	1,233,122	20,519

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 cloth 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. Piedmont's figures on raw cotton imports were drawn from Quazza (1961), p. 221. After deleting re-exports with coefficcients furnished by Castronovo (1965), pp. 282-283, these figures have been transformed into raw cotton consumption. Then, with quality figures of table 3 and Catalan weights, I convert raw cotton consumption into m2 of cotton.

This table immediately reveals that British cotton industry was gigantic when compared with its rivals. In particular, on average, it was about three times as large as the second largest cotton industry, the New England's. Moreover, in comparison with British's or New England's, both the Catalan and the Piedmont cotton industries were minuscule. Thus, by the 1850s, the British cotton industry was about seventeen times as large as the Catalan cotton industry and about fifty-four times as large as the Piedmont cotton industry. Finally, it should be noted that the cotton industry of New England did not progress like the cotton industry in Great Britain, Catalonia and Piedmont.

A common characteristic of these four regions was that they concentrated most of the cotton industry of their respective countries. By 1861, Catalonia produced about the 75 percent of Spanish cotton textiles.[4] However, some years before these indices of concentration were even higher when Catalonia enjoyed with the *de facto* monopoly of

[4] Gimenez Guited (1862) gives national figures on cotton industry production.

factory-based cotton industry in Spain. Thus, in the 1850s, new factory-based cotton industries emerged in the Province of Malaga (Andalusia) and the Basque Country.[5] Due to the political fragmentation and the presence of important trade barriers, Italian cotton industry was less concentrated than Spanish's. By the 1850s, Piedmont elaborated about 43 percent of Italian production but had gradually lost its share in Italian production with the emergence of the cotton industry in other regions.[6] Thus, other important settlements of cotton mills in Italy were in Lombardy, Ligury, Campania, Veneto and Tuscany.[7] In 1850, New England produced about 67 percent of U.S. cotton textiles.[8] It should be noted, however, that since the 1820s the development of the cotton industry in the Southern and the mid-Atlantic region had reduced the share of New England in U.S. figures.[9] In 1856, about 68 percent of British employment in cotton mills was in Lancashire. By sharp contrast with the other three regions, from 1822 to 1856, Lancashire increased its share in national output.[10]

It should be emphasized that the disparities in the quality of cloth among these countries were so notable as their differences in size. The next table shows some data on this point:

[5] Nadal (1974), pp. 218-225.

[6] Castronovo (1965), p. 284.

[7] A'Hearn (1998), p. 736ff.

[8] DeBow (1970), table CXCVI, p. 180.

[9] Harley (1992).

[10] For example, its share in employment in cotton textiles grew from about 55 percent to about 68 percent. Von Tunzelmann (1978), table 7.18, p. 239.

Table 2. Quality Distribution of Cloth Production:
Catalonia, Lombardy, 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	
Lombardy	**<20**	**20-40**	**40-60**	**60-80**	
1856	66.73	33.00	0.26	0.01	
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. Spanish figures corresponded to Spanish counts and British, Lombardy's 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. When it has been possible, 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. Lombardy's data are drawn from Zanelli (1967), table 42. For sources of the Catalonia and Britain data see the previous table 1.

At first glance, this table suggests that New England and Lombardy produced heavier fabrics than Catalonia and Britain.[11] 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.[12] Similarly, in Lombardy about two-thirds of the cotton cloth was of that quality. In a sharp contrast, Britain and Catalonia tended to concentrate their production in the medium range (counts from 20 to 60). By the 1850s more than three

[11] Unfortunately, quality data for the Piedmont is not already available though Lombardy's figures can be considered similar to those of Piedmont. Particularly, many literary testimonies tend to support the view that all Italian regions produced low-quality cotton goods. See, for example, references appeared at Zamagni (1993), pp. 89ff.

[12] This result is similar to the evidence presented by Temin (1988) for the 1830s.

quarters of their production was in these counts thus abandoning the production of the heaviest qualities. In Catalonia the sharp decreases 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.[13]

Differences in export performance were also important. The weakness of the international position of Spanish, Italian and American cotton textiles during this early period should be emphasized. The export of cotton textiles from Spain or Italy was practically negligible and British exports were about thirty times as great as American exports, though Americans were the world's second-largest cotton textile producers.[14] On balance these three countries imported cotton textiles, mainly from Britain. By direct contrast, through the ante-bellum years, British exported about two-thirds of what they produce. Nevertheless, as Sandberg previously noted, from 1845 Great Britain has gradually lost its share of the world market, being replaced the new European and United States cotton industries.[15] The next table shows the evolution of cotton textiles exports from Britain towards these three countries and the Mediterranean basin.

Table 3. British Cotton Textile Exports, 1820-1858
(In thousands of £, average per year)

	World	Mediterranean Basin	United States	Spain	Italy
1820-29	16,948	3,544	1,825	808	1,422
1830-39	20,914	4,120	1,874	537	1,710
1840-49	24,361	5,207	1,359	584	1,537
1850-58	34,197	5,154	3,263	421	1,881

Notes and sources: Numbers subject to rounding errors. Figures are in Current values. The data are drawn from Mann (1968). Spanish figures include smuggling which has been computed according to the procedures described in notes to figure 1.

[13] This sharp drop in the finest qualities can explain the drop in the quality index constructed by Sandberg (1968).

[14] Harley (1992), pp. 576-579.

[15] Ellison (1968), pp.97ff.

Overall cotton exports of Britain grew faster than cotton exports to the United States, Italy and Spain. From 1820s to 1850s, total figures on British cotton exports more than doubled whereas exports to United States only increased about 78 percent, to Spain practically halved and to Italy grew by a mere 32 percent. It is also striking the Spanish and Italian experience when compared with the rest of the Mediterranean basin, where British exports experienced an abrupt increase. More specifically, in the early 1820s over the 80 percent of British cotton textiles exports to the Mediterranean basin were concentrated in the countries at the Iberian and the Italian peninsulas whereas by the end of 1850s only about the 50 percent.

Interestingly, Sandberg has proposed a quality-related explanation to the persistence of British exports in the countries with emerging cotton factory-based industries. According to him, Great Britain continued to export high-quality goods to the American and Western European markets while very cheap goods went to the rapidly expanding low-income markets.[16] Thus, the British cotton industry lost almost of all the markets for coarse and medium quality cloth in Europe. Note that the evidence presented in the past table 2 gives some support to Sandberg's arguments since American, Spanish and Italian cotton industries produced coarser quality than British's. The evident questions are why European producers and the United States specialized in relatively low-quality and not in high-quality cloth? and why these important differences in quality-mix among Catalonia, Lombardy and New England?

3. Technology in Cotton textiles

In this section I show that in the pre-cotton famine period several alternative technologies were available to entrepreneurs in cotton textiles.[17] Some technologies required more power than others, others were suitable for domestic production and others simply not, others relied in skilled workforce whereas others were suitable for unskilled labour. Equally important are the relation between machinery and the quality of goods because to make each

[16] Sandberg (1968).

[17] This section is based on Ellison (1968), Ure (1836) and Von Tunzelmann (1978).

quality only a narrow range of machinery could be used. Consequently, the range of 'appropriate' technological options were more limited than the large list of machines can suggest.

Both spinning and weaving machines of the mid-nineteenth century are improvements on pioneering machines that date from the Industrial Revolution. Power costs, and innovations in power sources, strategically affected these improvements.[18] However, the phases of development in fine and coarse spinning showed important differences, both in comparison with weaving and between themselves.

The mid-nineteenth century cotton spinning machinery is clearly recognizable descendant of the two spinning machines invented in the 1760s. The jenny was invented by James Hargreaves and the water frame was developed by Richard Arkwright. Hargreaves' jenny spun intermittently whereas Arkwright's water frame was based on continuous methods of spinning. While the jennies were made of wood and their small size made them appropriate for use in domestic units, the water frames were used in large factories. However, these two primitive spinning machines proved to be complementary rather than competitive because of their wider differences. The water frame was at least five times as productive as the jenny but could not produce fine counts; by that, it was used basically for the production of warps. On the other hand, yarn from jenny was most suitable for weft but this machine suffered a sharp decline in cost-efficiency when used for anything above quite coarse counts of yarn. In consequence, factory production of warp yarn in water frames also expanded cottage production of weft yarn in jennies.

In the following decades, new intermittent spinning machines meant the demise of Hargreaves' jenny but not the ruin of continuous methods, which could produce coarse yarn faster and cheaper than these new machines. Samuel Crompton invented the mule in 1779. This new spinning machine broke through the technical barrier to permit the economical spinning of fine yarns by machine methods. The first mules were made of wood and their small size made them suitable for use in domestic production. However, by 1790 new large

[18] Von Tunzelmann (1978), pp. 175-240.

mules were made of metal, powered by waterwheels and were being used in large factories, which were specialized in fine yarns.[19] By the 1830s, the mule was improved by Richard Roberts, who invented the self-acting mule. Until this new device appeared, a man's strength had been required for pushing the mule spindles back and forth on their carriage. When the self-actor removed this requirement, one spinner could now work up to 1200 spindles compared with about 300 on a traditional mule. Several constraints limited the universal use of self-acting mules: the self-acting mule required more power, more repairs, more technicians, and was less flexible (since had greater difficulty of changing quickly from one grade of yarn to another) than hand-mules. In effect, until the 1850s, the self-acting could only spin yarn below the count number 50. Extremely fine yarn was spun on the older hand-mules into the 1880s.

The continuous method of spinning was also improved in the first half of the nineteenth century. In 1828, John Thorp and Charles Danforh developed independently the throstle, a variant of water frame, in the United States.[20] This spinning machine automatically and continuously performed the drawing, twisting, and winding of yarn. The only intervention in the spinning process required from workers in throstles was to piece up yarns when they broke and to replace bobbins. It should be noted that these tasks could be easily learned in few days of training. In a sharp contrast, the self-acting required continuous attention from operatives and specific skills.[21] By the 1850s, Americans made other important improvements in continuous spinning. For example, the development of cap spinning and ring spinning allowed continuous spinning to achieve higher speeds than before. These primitive ring throstles required very great motive power and were not possible to spin yarn of fine grades on it in sufficient quality. Because of these disabilities, self-acting mule was not eclipsed by early rings. For example, in the 1860s, only the American industry had almost as many ring as mule spindles.[22]

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[19] Von Tunzelmann (1978), p. 224.

[20] The classical account of the American inventions in throstle and ring technology is Copeland (1912). See, also, Jeremy (1981).

[21] See, for example, Cohen (1990) and Huberman (1996).

[22] Saxonhouse and Wright (1984), p. 274.

At the beginnings, the diffusion of the new machinery in cotton spinning, which cheapened the price of yarns, expanded handloom weaving. The first serious efforts to mechanize the operation of the handloom date back to the attempts of Edmund Cartwright in 1787. In 1803, Horrocks patented the first truly workable powerloom. But it was not until after 1815 that power-driven machinery (i.e., powerlooms) began to interpret more than an insignificant role in cotton weaving. As with the mule, the primitive powerloom technology was modified over many years, and it was not until the 1850s that weaving by machine triumphed over traditional handloom weaving in England. It took considerably longer in other countries and textile industries.[23]

4. Technological choices

During the first half of the nineteenth century technological leadership remained in the hands of the British cotton industry. As showed above, a great part of the progress in cotton technology during the period was due to British engineers.[24] Though some European regions and after New England made many technological advances, Lancashire supplied all or most of the textile machinery to most manufactures in all Europe. The first European cotton mills were completely British in design and equipment. Many British skilled workers, including women, performed important technical functions in the new factories. For example, they provided technical advice and guidance, supervision, management and trained local workers in the new technology. According to Bruland (1989), British machinery

[23] The extended co-existence between powerloom and handloom has led to an intense debate. For Von Tunzelmann (1978), some improvements in the application of power to cotton textiles production, particularly the adoption of high-pressure steam engines, reduced power costs substantially, by that significantly enhancing the profitability of power weaving. Moreover, the diffusion of the powerloom was partially interconnected with that of self-acting since this spinning machine produce regular yarn such as was required by primitive powerlooms. Instead, for Lyons (1987)(1989) the delay in the triumph of mechanized weaving have a different explanation since powerlooms were more profitable than handlooms from about 1820. According to his view, handloom weavers adapted to the misfortunes of technological displacement because they moved to areas of rising economic opportunity, had their children earn higher incomes, and maintained family cohesion. In other words, to compete with more efficient powerlooms, handloom weavers squeezed their wages. Therefore, it seems that the triumph of powerlooms depended on the relative costs of energy and labour.

[24] On the British advances during the period see, for example, Chapman (1987), VonTunzelmann (1978), Ellison (1968), and Mann (1968).

suppliers provided to foreign textile firms a complete array of information, equipment, and labour. In other words, they provided the 'technological capability' to new cotton factories. However, once got this 'technological capability' non-British factories ran by themselves.

In Britain, 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 particular, British cotton firms produced more cheaply than did in India.[25] By the 1830s, however, technological leadership in cotton spinning moved to the production of coarse yarn.[26] Robert's self-acting mule along with cheaper steam power and refinements in powerlooms in the following decade, greatly reduced prices of ordinary cloth. Therefore, by the mid-nineteenth century, British cotton industry remained organized in two different branches: fine and coarse-spinning mills.[27] Also, many coarse mills integrated vertically powerloom weaving.[28]

The first modern spinning machinery (i.e., Arkwrights' water frames) appeared in the United States during the last years of the eighteenth century.[29] 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.[30] In this early period, American cotton-textile mills, which were known as the Rhode Island type, were comparable to British coarse spinning firms.

In few years, American practices diverged from British's. American cotton mills

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[25] Von Tunzelmann (1978), p. 224.

[26] Von Tunzelmann (1978), pp. 184ff.

[27] Gatrell (1977).

[28] Gatrell (1977) and Lyons (1985).

[29] 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).

[30] Zevin (1971) and Stettler (1977).

preferred water instead of power-driven machinery and worked their machines more quickly than the British.[31] As noted above, American engineers not only run the same British machinery at faster speeds but also improved continuous methods of spinning, which required more installed power. Perhaps, more interestingly, by the 1820s Americans 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.[32] However, until the American Civil War, both types of mills survived.[33] 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.[34]

Catalan cotton industry was older than New England's. The first enterprises devoted to printing cotton cloth were established in Barcelona in the late 1720s.[35] These calicoes were sold in the protected markets of the *Peninsula* and the Spanish colonies in America.[36] Because for most of the eighteenth century all cotton yarn was imported (mainly from Malta), 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 since the import of foreign yarn and cloth was forbidden. Through 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.[37] Initially, due to its unskilled workforce and the use of jennies

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[31] Montgomery (1840) and Von Tunzelmann (1978), pp. 266ff.

[32] Jeremy (1981).

[33] Cohen (1990).

[34] Harley (1992).

[35] On the history of the cotton industry in Catalonia before 1830 see Thomson (1992), and Sánchez (1989).

[36] There is a large debate on the role played by the colonial and home markets in the development of Catalan cotton industry. See the review of the literature in Delgado (1995).

[37] Gutiérrez (1834)(1837), Sánchez (1989) and Thomson (1992).

and water frames, Catalan spinning concentrated on the low grades of yarn (below 20 count). During the same period, handweavers proliferated in the major Catalan manufacturing towns.[38] 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.[39] This development of the domestic industry was accompanied by the scarce adoption of the steam engine.

In 1832, the Bonaplata mill introduced the new forms of organisation, the steam engine, and the most recent British machinery (e.g., the powerloom).[40] 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.[41] The diffusion of the new machinery paralleled the increase in the quality of local production since the average count increased to 30 count from about 15 count.[42] Moreover, the vertically integrated cotton mills expanded rapidly and captured the market for coarse-medium cloth. However, well before the 1860s, some horizontal spinning mills and domestic hand-weaving survived by producing for more fashion-oriented segments of the market.[43]

In the first phases of the adoption of the new machinery, during the 1830s and the early 1840s, British and French technicians and workers played a leading role but, by the 1840s, the foreign workers had been completely substituted in their tasks by local technicians. Therefore, after the initial period, Catalans developed the capacity to maintain their own machinery, adopted the new technologies and, obviously, ran them without any

[38] Sánchez (1989).

[39] In Rosés (1998a), there is a full discussion of the skills differences between handspinning and handweaving.

[40] Nadal (1974), p. 198.

[41] Ronquillo (1851-1857) and Maluquer de Motes (1976).

[42] Figuerola (1968), and Madoz (1846).

[43] Rosés (1998b), chapter 8.

foreign help. Through the post-adoption phase, Catalan firms incorporated a stream of incremental developments and modifications to improve and adapt foreign technology to local requirements.[44] For instance, similarly to Americans', they developed their own type of centralized, vertically integrated, water-driven cotton spinning and weaving factory: the *colonia*.[45]

The cotton industry in the Piedmont was less developed than in the other three regions that are considered in this study.[46] During the eighteenth century, several regulations and laws protecting wool and silk industries prevented the expansion of cotton textiles. Up to the second decade of the nineteenth century, cotton textile firms did not adopted some modern spinning machinery (i.e., mule-jennies). In this early period, cotton industry was predominantly domestic and rural, employing unskilled workforce. Moreover, capital for this early development came from foreign entrepreneurs, mainly Swiss and French. These foreign entrepreneurs also introduced technology and production methods of their countries of origin. Therefore, most of the Piedmont cotton mills bought almost all their machinery to Alsatian and Swiss engineering firms. It should be noted, however, that machines did not differ from original British designs.[47] By the 1830s, economic policy increasingly benefited cotton textiles since the government established high tariffs on cotton imports. As happened in Catalonia before 1832, these protective measures increased the production but failed to stimulate the adoption of power-driven machinery.[48]

Certainly, the turning point in the history of the Piedmont cotton industry was in 1842. The government of Piedmont reduced drastically tariffs on cotton goods. Contrary to the most pessimistic observations, these free-trade measures did not ruin the industry but contributed to its modernization since it eased the substitution of factories for small units-of-

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[44] Rosés (1998a).

[45] Carreras (1983) and Nadal (1991)..

[46] This account of Piedmont cotton industry is based on Quazza (1961) and Castronovo (1965).

[47] See Fisher (1991), pp. 145ff.

[48] Castronovo (1965) argued that, during this early period, coal costs made uninteresting the adoption of steam power in cotton textiles.

production.[49] In addition, by the same year, modern waterwheels and throstles were introduced in Piedmont. Only few years later, by the 1850s, several spinning factories adopted some self-acting mules. In a sharp contrast, cotton weaving did not show signals of modernization. This branch of cotton textiles did not experience any kind of mechanical breakout up to the 1870s, when the first powerlooms were used by the new vertically integrated cotton spinning and weaving factories. Therefore, up to the 1870s, cotton spinning took place in factories whereas domestic system and putting-out predominated in cotton weaving.[50]

Labour management in the very early factory period was similar in Catalonia, Piedmont, Lancashire and New England because all cotton factories combined two forms of factory management: sub-contracting and foremanship.[51] 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. practices moved towards a new system of production with a workforce mainly formed by females and children controlled by foremen.[52] The adoption of powerlooms and self-actings in the United States went hand in hand with the transition of sub-contracting to foremanship.[53] In Piedmont, where the division-of-labour had been less important,[54] the adoption of throstles and self-actings signified the elimination of piece-rate payments among spinners. According to Castronovo, operatives in the Lombardy's cotton factories were subject of rigid norms and only foreign technicians and foremen had

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[49] Castronovo (1965), p. 24-25.

[50] Castronovo (1965), p. 164.

[51] Cohen (1990) on United States, Huberman (1996) and Clark (1994) on England, and Camps (1995) and Rosés (1998a) on Catalonia.

[52] Cohen (1990).

[53] Cohen (1990), especially chapter 6.

[54] Castronovo (1965), pp. 222ff.

some autonomy.[55] By sharp contrast with the United States and Piedmont, 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 even if the introduction of the powerloom could have increased foremanship practices in some weaving factories.[56]

The difference in the technological development of the four cotton industries is indeed quite starling. We have seen that there are marked differences in the adoption of the factory system, labour management, the new machinery, and even in the type of machinery preferred. At first glance, American, Spanish and Italian cotton industries employed during several decades inferior machinery and techniques than British's. However, by the 1850s, this technology gap with Britain had been practically cut by these followers. Then, the typical American, Spanish, or Italian cotton mill possessed the same machinery as the most modern British cotton mill. Energy costs were partly responsible for this delay in the adoption of new machinery, which was more power-intensive. Thus the invention of the high-pressure steam engine, which decreased coal costs, might ease the adoption of self-actings and powerlooms in Spain.[57] However, at this point, many readers can agree that it seems difficult to explain the choice of technology only in terms of technological gaps and energy costs.

5. Explaining technological choices

The discussion thus far suggests that the choices of technology and quality were closely connected in cotton textiles before the 'cotton famine'. For instance, American producers preferred throstles instead of hand-mules because they produced coarse fabrics. Meanwhile, fine spinning mills in Britain never employed throstles and preferred hand-

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[55] Castronovo (1965), pp. 224-226.

[56] 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 Cerdá (1968) clearly stated that weavers were paid by piece during this period.

[57] Von Tunzelmann (1978) relates the adoption of self-actings and powerlooms in England to the invention of high-pressure steam engines.

mules. Therefore, it can be argued that one can interpret technological choices by explaining the final determinants of quality-mix. It should be noted that several alternative explanations for quality choices had been advanced in the literature on cotton textiles.

Sandberg pointed out that 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.[58] Instead, mature cotton industries were able to specialize in high quality cloth as a consequence of their skilled labour. However, the same 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.[59] 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.[60] 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.[61] Following the same logic, one would expect Catalan cotton mills to produce cheap cotton goods since the Spanish home market for textiles was poorer and smaller than other European and American markets.[62] 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

[58] Sandberg (1968), p. 15.

[59] Sandberg (1968), p. 15.

[60] Dudzik (1987).

[61] See criticism on this argument in Temin (1988).

[62] On the Spanish home market for textiles see Sánchez-Albornoz (1981) and Prados (1983).

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.[63] During the nineteenth century, two types of tariffs were employed: *ad valorem* and fixed duties. The *ad valorem* duties have several relevant properties. First, *ad valorem* 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.[64] 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. In fixed duties, instead, when local costs decreased and the duty was not modified, the level of protection grows but not necessarily the range of goods protected by the tariff.

Several studies have discussed the influence of tariffs on the development of the cotton industry in the U.S.[65] Through the ante-bellum period, the U.S. tariffs were in *ad valorem* terms. Duties on cotton textiles imports were established in 1789 and changed no less than twenty times up to Civil War. 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 (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

[63] See, for example, Sandberg (1968) or Temin (1988).

[64] Sandberg (1968), p. 15.

[65] David (1970), Stettler (1977), Temin (1988), and Harley (1992).

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.[66] 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.[67] 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.[68] 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.[69] 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.[70]

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

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[66] On tariff history in the cotton industry in the United States see Taussig (1931) and Stettler (1977), especially chapter 5.

[67] Harley (1992), table 2, p. 562.

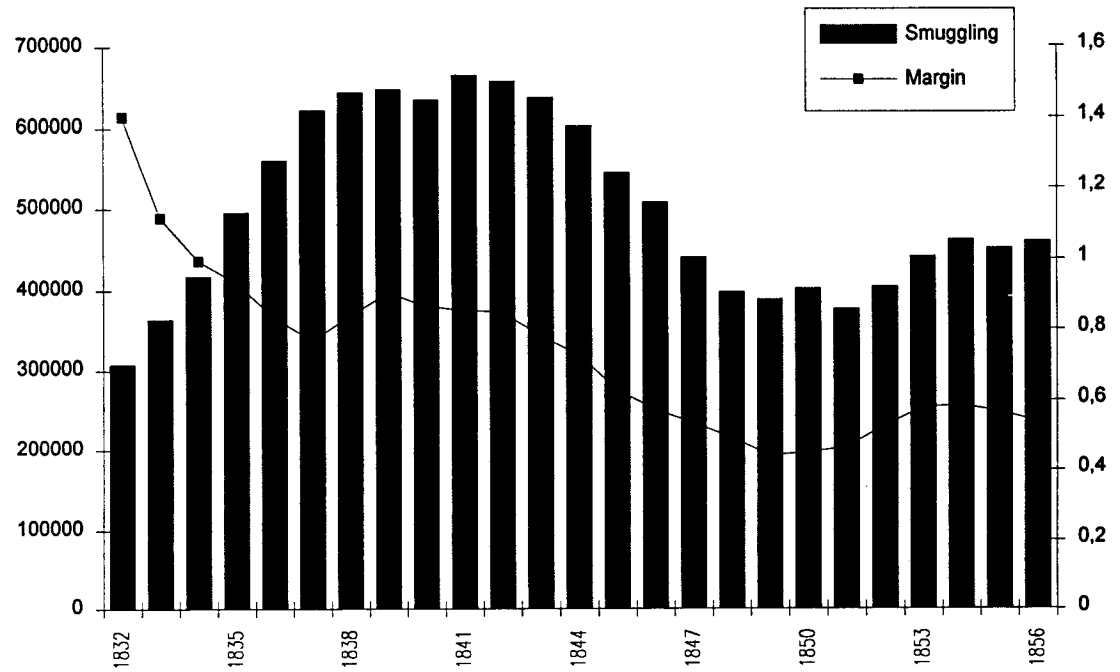
[68] Nadal (1974).

[69] Ronquillo (1851-1857) and Gimenez Guited (1862).

[70] Prados (1984).

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 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 Rosés (1998b), chapter 9.

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) 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 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.

In Piedmont, duties on cotton textile imports were first established in 1815 and were reformed several times up to 1860.[71] These tariffs were based on fixed duties for each kind of yarn or cloth. Up to 1851, Piedmont tariff policy gave more protection to coarse rather than finer cotton goods and to weaving than spinning. The first duties were established in 1815 and reformed several times in the next years. An important reform happened in 1830 when duties increased in coarse yarns (below 26 count) to 2 Lire/Kg, in medium yarns (from 26 to 49 count) to 1.50 Lire/Kg, and in fine yarns (up to 50 count) 1 Lire/Kg Similarly, duties on cotton cloth also grew and were fixed from a minimum of about 4 Lire/Kg in grey cloth to a maximum of 5-5.5 Lire/Kg in printed cloth. In 1842 the system of fixed duties was dropped and rates were generally lowered although the effective protection was still higher.[72] For instance, the common price of local yarns of the 8 count was about 2.5 Lire/Kg whereas the price of the imported British yarn, incluiding duties, arrived to about 2.8 Lire/Kg (that is; 1.94 Lire plus 0.9 Lire of duty).[73] Finally in 1851 Cavour lowered the tariffs and signed a free-trade agreement with Belgium, a major producer of cotton textiles. Moreover, the structure of duties was modified imposing the higher duties on the fine qualities. After these reforms, duties on yarn were fixed from a minimum of 0.2 Lire/Kg in coarse yarn to a maximum of 0.6 Lire/Kg in fine yarn while duties on cloth were fixed from a minimum of 0.75 Lire/Kg in grey cloth to a maximum of 1.5 Lire/Kg in printed cloth. In spite of these reforms, the level of protection of the industry in Piedmont was enough to

[71] On Piedmont's duties see Castronovo (1965), pp. 305-312.

[72] New duties were 0.9 Lire/Kg in coarse yarn, 2 Lire/Kg in grey cloth, 0.75 Lire/Kg in fine yarn, and 2.5-4 Lire/Kg in printed cloth.

[73] These prices are drawn from Castronovo (1965), pp. 249-250. British prices were prices at the Port of Genoa; thereby they comprised transport and insurance costs.

preserve the home production of coarse and medium-range cotton yarn.[74] Likewise, duties on cloth were so high that foreign cloth encountered many problems in Piedmont markets.[75] Consequently, the level of protection was so intense that it presumably had insignificant effects on the Piedmont's cotton firms option between coarse and medium products.

It should be also considered that tariffs were endogenously, not exogenously, determined. In other words, the government did not establish duties independently from the pressures of local groups. Spain and Italy furnished many examples of duties influenced by local industrialists. In Spain, when the ban on foreign cotton imports was reformed in the 1840s, the employers' organization (the Junta de Fabricas de Cataluña) showed little opposition to reduce the ban to yarn up 60 count. The reason was that local spinners produced little yarn above 60 count and mixed-fabrics weavers needed this type of yarn.[76] Similarly, in Piedmont, Ligury weavers, specialized in fine cloth, promoted lower tariffs on fine yarn because the scarce local production of that good.[77] Moreover, protection on cloth was higher than on yarn because the numerous handweavers could exert strong pressure on successive governments.[78] To sum up, one can argue that some cotton goods received more protection than others simply because they were produced by the local industry. In consequence, duties were not established to modify the quality of home production.

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 2.

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[74] After 1852, the price of Piedmont yarn of 8 count was about 2 Lire/kg whereas the price of the same British yarn, incluiding duties, in Genoa was about 2.2 Lire/Kg. Similarly, the price of local yarn of 30 count was about 2.8 Lire/Kg while the price of the same British yarn, incluiding duties, in Genoa was about 2.9 Lire/Kg All prices are drawn from Castronovo (1965), pp. 249-250, except of the price of the British yarn of 30 count which has been extrapolated from the data on Milan of Zanelli (1967), table 15, p. 94.

[75] For example, the duty represented about 30-40 percent of the home price of grey cloth. The prices and duties are drawn from Castronovo (1965), pp. 295-296 and 310.

[76] Comisión especial arancelaria (1867).

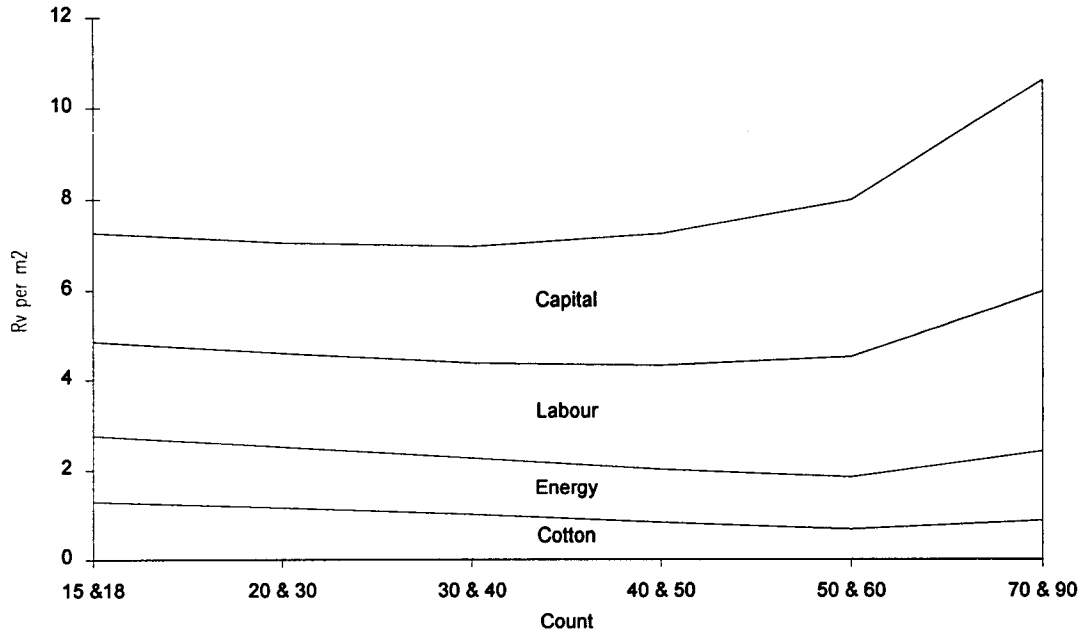
[77] Castronovo (1965), p. 302.

[78] Castronovo (1965), pp. 305ff.

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 2 and table 4 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 the two factories considered could produce the whole range of yarn and cloth.

Figure 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.[79] 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, although wastage increases with count. In the fine qualities, particularly above 60 count, the raw cotton costs grew again due to the use of large staple

[79] This result invalidates the argument of Bils (1984) on the straight-line relation between costs and quality in cotton cloth.

and, therefore, expensive fibre. On the other hand, labour, capital and energy costs rose with count increases.

Table 4. Share of Inputs in Total Costs of Cotton Cloth: Barcelona, 1860 (percent)

Yarn Count	Gruesos 15 &18	Entrefinos Medios 20 & 30	Entrefinos 30 & 40	Finos Tupidos 40 & 50	Finos Medios 50 & 60	Finos Claros 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 2.

Table 4 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.[80] 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 per worker.[81] 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.

[80] They used steam-powered self-actings and powerlooms and organised their workforce into work-teams, as was typical in Catalan cotton firms.

[81] VonTunzelmann (1978), table 7.3, p. 185 demonstrates this for Lancashire. See also Gattrell (1977).

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.[82] 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 skills 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 less skilled labour specialised in products in which the inferiority of their workforce had relatively little impact on the final price (i.e., in coarse cloth) whereas cotton mills with a highly skilled labourforce did exactly the opposite. The constraint on this movement towards fine cloth in Catalonia was the efficiency of the local labourforce because the finest qualities were generally beyond the abilities of the Catalan labourforce.[83] 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.[84] In this segment of the market, the Spanish workforce could not compete with British products.

Differences in the workforce skills facing the four countries at the time Give strong support to the arguments advanced in the previous paragraph. During the first half of the nineteenth century, in Britain and Catalonia workers were employed in different positions according to their skills. In hand and self-acting mules workers were skilled whereas in

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[82] In Rosés (1998b) costs differentials among Catalan, British and U.S. cotton mills are fully discussed. On average, raw cotton prices in Barcelona were 47 percent higher than in New York and 28 percent higher than in Liverpool. Similarly, the price of coal in the Port of Barcelona was about 76 percent higher than in Britain.

[83] Contemporary and recent studies stressed the importance of human capital formation in determining the level of workers efficiency in early cotton industry. See, for example, Boot (1995) and Rosés (1998a).

[84] See Farnie (1979) and the contemporary, Ferrer Vidal (1875).

throstles and preparatory machines workers were unskilled. Thus, in the production of coarse yarn workers were unskilled whereas the contrary holds for the finest qualities. Instead, the U.S. and Piedmont mills used self-acting mules and throstles, and unskilled labourforce to produce coarse cotton cloth. In particular, a contemporary described the situation of the cotton factories in Italy with the following words: 'when a factory is unable to specialize in its working, then fewer, low-quality goods are produced, since it is forced to use what could be called *generic* machinery... and has *generic* workers as well'.[85]

6. Conclusions

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 Piedmont, British and U.S. cotton mills. On average, Catalan cotton mills produced cloth that was in the middle of the extreme choices; the 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. Piedmont cotton mills, with similar raw-materials restrictions than Catalan's, produced slightly finer cloth than U.S. cotton mills. However, these cotton mills could not produce so fine as Catalan or British cotton mills due to their unskilled workforce. Thus, there is strong evidence that the efficiency of labour, which is mainly result of prior human capital accumulation, is important in determining the drift of best-practice technology in cotton textiles.

The other components of the quality choice must, however, be allowed their due. Plant and equipment costs were higher in Spain, Italy 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 and Italy. In isolation this would have had the effects actually observed, lower quality in the former than in the latter. These

[85] Ellena cited by Zamagni (1993), p 89.

aspects along with the particular characteristics of the consumers' choices are not perfectly disentangled.

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