The Myth of the Corporate Economy: Great Britain's Cotton Textile Industry, 1900-1913

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It is never difficult to defend an interest in the Lancashire cotton industry, for it has a unique place in the history of England's industrial revolution. Rostow gives it the ultimate accolade: "the original leading sector in the first take-off," and to Crafts and Harley, "the really big issue [in determining the rate of growth during the industrial revolution] is undoubtedly the weighting of cotton rather than the correct distribution of value added weights among the other sectors" [Rostow, 1990, p. 53; Crafts and Harley, 1992, p. 706]. Cotton overtook wool to become Britain's single most important source of income by 1810, and retained this position until the end of the nineteenth century. At its 1913 peak, the industry employed over half a million people and consumed over 2.1 billion pounds of raw cotton [Robson, 1957, pp. 331, 333; Deane and Cole, 1969, p. 163; Sandberg, 1981, p. 114; Mitchell and Deane, 1962, p. 186-8].

The industry's export performance was more remarkable still. It became the nation's biggest exporter during the Napoleonic Wars, a position it was to retain for 125 years; in 1830 it even exceeded all other exports combined [Deane and Cole, 1969, p. 31]. In 1880 over 80% of the world's cotton exports came from Britain, and mill owners boasted that they met the needs of the home market before breakfast and devoted the rest of the day to exports [Robson, 1957, p. 4; Aspin, 1981, p. 3]. At its peak in 1913, Britain exported over 7 billion yards of cloth, approximately equivalent to a shirt and pair of trousers for every man, woman, and child in the world [Sandberg, 1974, p. 4].

But 1918 saw the start of a decline that was to prove both long and unrelenting. By 1933 Japan had overtaken Britain to become the world's biggest exporter of cotton goods, although cotton was to remain Britain's biggest export until the outbreak of war [Aspin, 1981, p. 4]. In 1944 Keynes

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still saw cotton spearheading Britain's postwar export drive, asking "who will export cotton goods if Britain does not – Japan, America, who?" Even after the war government propaganda asserted that "Britain's bread hangs by Lancashire's thread" [Singleton, 1991, pp. 1, 37]. But it was not to be: despite general world-wide prosperity, output only twice reached its worst interwar level, and by 1959, within twenty years of cotton's being its largest export, Britain became a net importer of cotton cloth [Robson, 1957, p. 333; Singleton, 1991, p. 115]. Mills continued to close at the rate of almost one a week throughout the 1960s and 1970s, until the industry became little more than an increasingly distant memory [Aspin, 1981, p. 4]. The mills of Lancashire have indeed fallen silent.

British Entrepreneurial Failure and the Cotton Industry

The economic critique of Victorian Britain revolves around three themes: "that output grew too slowly because of sluggish demand, that too much was invested abroad because of imperfect capital markets, and that productivity stagnated because of inept entrepreneurship" [McCloskey, 1970, p. 446]. This paper concerns the third debate: did Britain suffer from an abnormally poor set of entrepreneurs?

British entrepreneurs stand accused of being poor salesmen, of neglecting science and research, and of favoring old staple industries over newer ones with brighter futures [Aldcroft, 1964]. But above all, it is argued that entrepreneurs after c. 1870 failed to adopt modern technology, preferring to remain with what they knew. Arnold Toynbee summed it up effectively: "if one were to single out the point in which Great Britain has been most at fault, one would put his finger on the conservatism of our captains of industry who have idolized the obsolescent techniques which have made the fortunes of their grandfathers" [quoted in Jewkes, 1951, p. 9]. The British manufacturer is said to have "basked in the complacent glory of economic hegemony" [Landes, 1969, p. 336].

Given the importance of the cotton industry to the British economy, and the scale of its decline, it is unsurprising that this thesis has been applied as vigorously to it as to any other. Before we go on to see how that criticism has been applied, we need to know just a little about the processes that make up a cotton industry. A glossary of textile terms is also given as an appendix. Cotton processing has two principal parts: spinning raw cotton into yarn, and then weaving the yarn into cloth. In this paper we confine ourselves to looking at cotton spinning. The case for technological conservatism in spinning is easily made. A newer form of spindle, the ring, was technically viable for coarse yarns – that is, counts of up to 40, by 1880, and by 1913 90% of spindles in the United States were rings rather than mules. In contrast under 25% of British spindles were rings [Lazonick, 1981, p. 90]. While the case is easily made, it is equally straightforward to assess. At least prior to the invention of the automatic loom, the quality of yarn produced by both machines was identical, so the question of technology is a readily quantifiable question of costs.

There are three principal cost differences that are important to a spinner installing new spindles. First, mule spindles require skilled labor, which is considerably more costly than the unskilled labor that a ring spinner can use. Second, the spinner of anything but the coarsest yarns is forced to purchase slightly better quality raw cotton in order to operate rings successfully. Finally, a ring spinner may face an additional transport cost premium. Unlike the mule spindle, which produces "cops," packages consisting entirely of yarn, the ring spindle spins onto a heavy wooden bobbin from which the yarn cannot be removed economically. The wooden bobbin has to be transported to the weaver with the yarn, and later returned to the spinner for re-use. As the bobbin weighed twice the yarn spun onto it, this implies a fivefold increase in transport costs. Lancashire's system of industrial organization, of individual firms either spinning or weaving, makes this a potentially important consideration, but it did not matter in the United States, where spinning and weaving were carried out by one firm on one site.

By reconstructing the factor costs faced by British and American spinners, Lars Sandberg argues that both behaved rationally in their choice of technologies [Sandberg, 1969, 1974]. The essence of his argument is simple: the skilled labor required for mule spinning was far more common in Lancashire than in the United States. As such, mule spinners were comparatively inexpensive to hire in Britain, and so British spinners continued to install mule spindles to a much greater extent.

Following several empirical corrections to Sandberg's work, Lazonick agrees that British managers were responding accurately to the costs that they faced [Lazonick, 1981]. But his empirical revisions raise the importance of the transport cost premium relative to that on labor costs, leading him to conclude that "[t]he primary constraint on the introduction of ring spinning in Lancashire was the cost of shipping ring yarn" [Lazonick, 1983, p. 205]. By developing integrated firms on the American model, the Lancashire industry could have avoided this constraint. By failing to do so, they proved themselves to be good managers but poor entrepreneurs.

Transport Costs

Lazonick's calculations, which conclude that the higher transport costs associated with using rings in a vertically specialized industry were the single most important cause of lower ring adoption in Lancashire, are based on a piece of contemporary industrial espionage which states that yarn traveled an average distance of 30 miles in order to be woven, at a cost of 15¢ per hundredweight [Whittam, 1907, p. 32]. This implies a transport cost premium of 0.5¢ per pound of yarn spun [Lazonick, 1981, p. 100]. This did not apply to warp yarn, which had to be rewound prior to weaving in any case. Ring spinners were able to rewind the warp yarn ready for weaving themselves, avoiding shipping their bobbins at all.

There are three objections to Lazonick's exercise, one factual, two methodological. First, his source, Whittam, overestimates the size of Lancashire. From the largest spinning town, Oldham, only one of the five Lancashire weaving towns, Preston, was over 30 miles away, the other four towns being considerably closer, with an average distance of 23 miles.

The methodological issues are more interesting. To show that transport costs are a constraint, we need to show not that spinners *chose* to transport their cotton considerable distances, but that they had *no choice but to do so.* Second, we are not interested in the distance that the *average* piece of yarn had to travel to be woven, but in the *proportion of spinners who had no choice but to transport their yarn more than some economically critical distance.* Even if yarn had to travel an average of 30 miles to be woven, the proportion of firms affected by transport costs could vary tremendously: if all firms had to move their yarn 30 miles all might have been constrained from adopting rings, but if half had to move their yarn 60 miles, and half had to move it only a few yards, only half would have been constrained in their choice of technology.

Clearly our knowledge of the different cost advantages of rings and mules is not precise enough for us to calculate the exact distance between spinner and weaver just sufficient to render rings uneconomic. But data from the *1906 Enquiry into the Earnings and Hours of Labour in the Textile Trades* allows us to calculate the proportion of yarn that could have been woven very close to the spinner – that is, the proportion for whom transport costs were unimportant.

It is worth investigating the accuracy of the *1906 Enquiry* before we begin. In 1906 the Board of Trade sent 2,329 detailed schedules to firms in the cotton industry, not including bleaching and finishing firms [*1906 Earnings and Hours Enquiry*, 1909, p. 241]. Of these, 967, or 41.5%, were returned, covering some 40.7% of all cotton operatives listed in the *1904 Factory and Workshop Returns* [*1906 Earnings and Hours Enquiry*, 1909, p. xiii]. The closeness of these two percentages suggests no sample bias toward either large or small firms. As virtually all the firms surveyed would have had either spinning or weaving departments, or both, our sample almost certainly includes data from all the 900 or so Lancashire firms who responded to the *Enquiry.*

Crucially for our purposes, we also know that the firms replying represent a geographically unbiased sample of the industry, suitable for district-based analysis. From Worrall's *Directory of Lancashire*, Farnie finds that the spinning district – comprising the Oldham, Bolton, Ashton, Leigh, Stockport, Manchester, and Rochdale districts in the *1906 Enquiry* – contained 82.8% of all spindles in 1896, with the weaving district – comprising the Accrington, Bacup, Blackburn, Burnley, and Preston districts in the *1906 Enquiry* – containing 66.4% of all looms [Farnie, 1979, p. 334]. On the basis of our results, given in Table 1, we repeat this calculation for 1906, and find that the spinning district was responsible for 79.9% of all yarn output (cf. 82.8%), with the weaving district containing 66.7% of all looms (cf. 66.4%). The closeness of our results with those of Farnie gives us considerable confidence in the reliability of our estimates. As the *Enquiry* itself notes, "the returns for each of the different industries included may be regarded as covering a sufficiently large proportion of the work people employed to yield sound statistical results" [*1906 Earnings and Hours Enquiry*, 1909, p. xiv].

The *1906 Enquiry* divided Lancashire into twelve named districts (and "other"), giving employment and wage information on each. That data is sufficiently detailed for us to be able to calculate both the amount of coarse yarn spun in each district and the local weaving capacity. Comparing the two figures allows us to see what proportion of coarse yarn could have been spun within any area. As we shall see, the districts were small enough that spinners whose yarn could have been woven within their district need not have concerned themselves with transport costs.

We have employment data on almost 10,000 mule spinners, almost 4,000 ring spinners, and over 70,000 weavers. The data on mule spinners is sub-divided according to whether they spun sub-40, 40-80, or counts of over 80. Of course, we are not interested in employment, but in yarn *output* and weaving *capacity* for each area. As we are interested in the *proportion* of yarn that could have been spun locally, we are not forced to convert to output in yards, but are able to use more tractable index numbers.

We begin with weaving. The employment data for weavers also gives the number of looms tended by each weaver. Multiplying the two figures together for each area gives the number of looms in that area – that is, its weaving capacity. We use this measure – one "loomsworth" of yarn – as our numeraire good, and adjust the spinning totals accordingly.

Converting employment figures into output figures for both mule and ring yarn is not as straightforward. The output of a mule depends on three factors: the number of spindles in each mule, the amount of yarn spun per cycle of the mule, and the time taken to complete one cycle. As there is no evidence that the number of spindles in a mule varied with the count spun, we follow the literature in assuming that all mules had an equal number of spindles [Sandberg, 1974, p. 29; Lazonick, 1981, p. 99]. The amount spun per cycle is equally simple to calculate: speed figures were always quoted for a standardized cycle. But mules spinning coarse counts operated at considerably higher speeds. These are given by Jewkes and Gray and allow us to construct our employment-output conversion factors for mule spinning [Jewkes and Gray, 1935, pp. 70, 209].

The conversion factor for ring spinning is calculated by adjusting the conversion factor for coarse mule spinning to reflect the facts that one ring produced 1.45 times as much yarn per hour as did one mule spindle, and that each ring spinner tended an average of just 638 spindles rather than the 2,064 tended by the typical mule team [Taggart, 1923, pp. 155, 203; Jewkes and Gray, 1935, pp. 126, 205; *1906 Earnings and Hours Enquiry*, 1909, p. 31]. Finally, we scale both employment-output conversion factors so that the total yarn output equals the total weaving capacity, taking into account that 13% of yarn was exported as yarn rather than being woven into cloth [Robson, 1957, p. 345]. It is worth noting that this whole process is highly robust: no reasonable set of conversion factors alters the final result by more than 1 percentage point. The results are given in Table 1.

Table 1: Output of Sub-40 Yarn and Weaving Capacity in Lancashire, by District

District	2 Ring output	3 Sub-40 mule output	4 Total sub-40 output	5 Total yarn output	6 Weaving capacity	7 Local weaving potential	8 % of sub-40 "woven locally"
Oldham	7,317	51,670	58,987	86,048	3,960	3,960	7
Bolton	3,401	3,532	6,933	42,594	8,432	6,933	100
Ashton	2,662	19,935	22,597	33,404	12,003	12,003	53
Leigh	0	0	0	9,684	4,529	0	–
Stockport	4,643	10,910	15,553	20,478	10,266	10,266	66
Manchester	1,606	1,020	2,626	5,447	5,286	2,626	100
Rochdale	12,359	11,197	23,556	29,259	35,400	23,556	100
Accrington	0	733	733	6,182	11,136	733	100
Bacup	3,858	4,997	8,855	8,855	16,214	8,855	100
Preston	1,947	5,075	7,022	13,975	25,978	7,022	100
Blackburn	3,119	14,389	17,508	19,095	48,775	17,508	100
Burnley	1,689	0	1,689	3,344	58,209	1,689	100
other	3,647	1,334	4,981	5,487	6,763	(0)	(0)
Total	46,247	124,792	171,040	283,852	246,951	95,150	55.6
Excluding integrated plants			118,861	231,674	194,773	43,980	37.0

Source: *1906 Enquiry*

Note: All figures are in "loom equivalents"; figures may not sum due to rounding.

By comparing the amount of sub-40 yarn produced in a district with the weaving capacity in that district, we are able to judge the importance of transport costs as a constraint on the behavior of spinners in that area. Column seven gives the minimum of sub-40 yarn spun and weaving capacity, that is, the amount of sub-40 yarn that could have been woven locally; column eight expresses this as a percentage of the total sub-40 yarn spun in that area. It shows that the majority (56%) of sub-40 yarn, that is, a majority of yarn suited to ring spinning, could have been woven within the district in which it was spun.

While we know that these districts were not large, we would like to go further and state the number of weaving mills within a certain distance of each spinning mill. Although the *1906 Enquiry* does not allow us to do this, an extremely detailed case study of Blackburn does give this information.

In his unpublished 1970 thesis, J.R. Cotton provides detailed and systematic information on the changing structure of industry and employment in the County Borough of Blackburn [Cotton, 1970]. Using the records of the Blackburn and District Textile Manufacturers' Association, he is able to identify fully 132 mills in operation in Blackburn in 1919, and to state whether they were spinners, weavers, or integrated spinner-weavers at that date. Even more usefully for our purposes, he is able to exactly locate 118 of these mills: 8 spinners, 104 weavers, and 5 integrated firms, which he places on a large scale map, part of which is reproduced as an appendix. From this map we are able to calculate precisely the number of weaving firms close to each of the eight spinning firms. The results are given in Table 2.

Table 2: Geographical Proximity of Spinners and Weavers, Blackburn

	Number of weaving mills within 300 yards	Number of weaving mills within half a mile
Alston Mill Company	7	26
Brookhouse Spinning Co.	3	23
Daisyfield Ring Mill Co.	10	31
Hollin Bank Ring Mill Co.	8	34
J Hoyle & Sons	5	29
Imperial Ring Mill	5	21
Little Harwood Combing	10	31
Plant Mill Ring Spinning	11	31
Average	7.375	28.25

Source: Cotton (1970), Map 1.5.
Note: All distances are direct.

It is clear from this table that no Blackburn spinner would have had to concern himself with the costs of transporting yarn to a weaver. The average spinner had seven specialist weaving mills within 300 yards of his mill, and more than two dozen within half a mile.

This result is applicable more widely. Cotton demonstrates that the three principal determinants of mill location in Blackburn were proximity to canals, rivers, and "A" roads, among them explaining the location of at least three-quarters of all mills. Following the decline of water power, the two single most important factors determining location are good water supply and good drainage, factors that were important to all cotton mills, and always led to the clustering pattern seen in Blackburn.

We do not have evidence of the same caliber for other textile towns. Nevertheless, contemporary telephone directories allow us to locate a considerable number of cotton mills [National Telephone Company's *Directory*]. The firms listed in the telephone directory are unlikely to be an unbiased sample in terms of size: larger firms will be more likely to possess a telephone than smaller firms. This also implies an overweighting of spinners relative to weavers in our sample. But there is no reason to expect the firms listed to be a biased sample in terms of location. The 1907 telephone directory lists 63 cotton mills in Rochdale, of which 42 could be located. Of these 24, or 57%, were to be found in the very center of Rochdale, in an area of less than 2.5 square miles. In neighboring Heywood all 17 mills that could be located were clustered within one square mile. Clearly the pattern found for Blackburn holds more widely.

We have now established the two facts necessary to evaluate the importance of transport costs on the slow rate of ring adoption in Lancashire. The *1906 Enquiry* shows that there were sufficient weavers in all but three of the districts for all spinners to have had all their sub-40 yarn woven locally. And detailed work on Blackburn, reinforced by data from contemporary telephone directories, shows that distances between mills within a locality were very small. Only in Oldham is it correct to think of all spinners facing a transport premium.

We have shown that 56% of coarse yarn could have been spun locally. As we noted above, the transport cost premium applies only to weft, and not to warp yarn. So all warp and 56% of coarse weft producers could have opted for rings without suffering additional transport costs; that is, transport costs were insignificant in 78% of the cases.

This result is important for our understanding of the Lancashire cotton industry. Lazonick alleges that transport costs were sufficient to deter the adoption of rings in Lancashire. This work has shown that, while this is correct for Oldham, Oldham is atypical and even unique. Transport costs were of no importance to spinners in eight of the twelve districts of Lancashire. While we might accept that the transport costs associated with rings did deter spinners in Oldham – which had a peculiarly low rate of ring adoption, as Table 1 shows – they could not have deterred spinners elsewhere. There is no sense, therefore, in which transport costs can be said to represent the "primary constraint on the introduction of ring spinning in Lancashire" [Lazonick, 1983, p. 205]. As such, there is no evidence that Lancashire's vertically specialized form of industrial structure slowed down its rate of technological change. Rather, through close proximity of spinners and weavers, Lancashire was able to combine the advantages of integration with those of competition.

A Model of Technological Choice

District-level data for Lancashire allows us to go further than simply assessing the validity of the transport cost argument: it allows a much more precise assessment of the rationality of Lancashire's cotton spinners than was previously possible. The usual method of assessing rationality is to calculate factor costs for the two machines, and then judge whether the observed investment behavior is broadly consistent with those costs. But as we have seen, different areas faced radically different transport costs. As such, industry-wide assessments of factor costs and ring adoption are unlikely to be an accurate test of rationality. Instead, we are able to test the rationality of Lancashire's cotton spinners by looking at whether the variations in factor costs at a district level explain the variations in the adoption of rings across Lancashire.

We noted earlier that there were three possible cost differentials that a spinner would have to consider when deciding on installing rings or mules. Of these, two – the labor cost differential, and the transport cost premium when applicable – might vary by district, but the third – the cost of longer staple cotton needed to use rings successfully – would be constant across Lancashire. We therefore disregard the additional cost of raw cotton as a variable determining the rate of ring adoption by district.

The model postulates that if Lancashire's cotton spinners were rational in their choice of technology, the proportion of rings in the machinery stock will be positively related to the labor cost saving available in that area and negatively related to any transport cost that would have had to have been paid. The direction of causality is clear. Individual firms were small; their choice of technology would not have affected wage rates. Similarly, while transport costs were endogenous in so far as firms could relocate, once location had been selected transport costs were exogenous.

The *1906 Enquiry* gives district-level data for the wages of 25,000 mule spinners and piecers [*1906 Earnings and Hours Enquiry*, 1909, p. 29]. By combining this with standard and reliable information on the number of spindles in new mules [Jewkes and Gray, 1935, p. 205] and on productivity per spindle [Taggart, 1923, p. 155] we construct mule spinning unit labor costs by district for an arbitrary but standard count of 32. We follow exactly the same procedure for ring spinning. *1906 Enquiry* data on almost 4,000 ring spinners [*1906 Earnings and Hours Enquiry*, 1909, p. 31] is combined with data on the number of spindles tended by those spinning count 32 yarn [Jewkes and Gray, 1935, p. 126; *1906 Earnings and Hours Enquiry*, 1909, p. 13], and on the productivity of rings at that count [Taggart, 1923, p. 203].

Unfortunately, Accrington has no ring spinners, Burnley no coarse mule spinners, and Leigh no coarse spun yarn at all, which prevents us from assessing the labor cost premium for these areas. We are therefore forced to drop these three districts from our analysis. The loss is not important: these three districts account for less than 2% of coarse yarn output.

Transport costs are very straightforward to assess. We have already discovered that Oldham did not have the weaving capacity to weave 93% of the yarn that it spun; similarly, Ashton could not weave 47% of its yarn, and Stockport 34% of its yarn. This yarn would have had to be "exported" to other districts to be woven. We know that Rochdale, Accrington, Bacup, Preston, Blackburn, and Burnley had more weaving than spinning capacity; they must have "imported" yarn from Oldham, Ashton, and Stockport. We assume that yarn was exported to each of the six weaving towns in accordance with their spare weaving capacity. Thanks to detailed government regulation of the industry we know both the exact distance, by rail, between any two places in Lancashire and the costs for any given journey – that is, we know the cost of shipping yarn from each spinning town [*Railway and Canal Traffic Acts*, 1888, 1892, 1894, 1913]. We multiply this by the proportion of yarn that had to be shipped – 93%, 47%, and 34% respectively – to give us the transport premium.

Finally, we use Table 1 to assess the proportion of coarse yarn that was spun on rings in each district. We use this as our dependent variable. Both dependent and independent variables are reproduced in Table 3.

Table 3: Factor Cost Differentials and the Choice of Technology, by District

District	Ring output / ring + mule output	Labor cost savings (¢/lb.)	Transport cost premium (¢/lb.)	Net factor cost advantage (¢/lb.)
Manchester	0.60	0.34	0	0.34
Rochdale	0.52	0.29	0	0.29
Bolton	0.48	0.33	0	0.33
Bacup	0.43	0.25	0	0.25
Stockport	0.29	0.26	0.15	0.12
Preston	0.27	0.09	0	0.09
Blackburn	0.17	0.05	0	0.05
Oldham	0.12	0.31	0.35	-0.04
Ashton	0.11	0.30	0.19	0.11

Sources: See text.
Notes: All figures apply to sub-40 yarn only.

There are several points that we should note concerning the data. First, the fact that mules account for at least 40% of output in all areas is an artifact of the data: it does not indicate that 40% of coarse spinners in all areas continued to select the mule in preference to the ring. Instead, it is caused by a combination of our data referring to *stocks* of machinery and the sheer longevity of British textile machinery: the mule lasted an average of some 50 years [Saxonhouse and Wright, 1984, p. 508; Lazonick, 1984, p. 394]. If, with the rest of the industry, the sub-40 spinning sector grew by one-third between 1880 and 1906, then around 40% of the spindles in place in 1906 were installed prior to 1880, that is, prior to the invention of the ring [Robson, 1957, pp. 332-3]. As a result, even were Lancashire spinners to have selected the ring without exception after 1880, only around 60% of the industry's output in 1906 would have been spun on rings: effectively our dependent variable has an upper bound of 0.60. This figure is, of course, an average for Lancashire as a whole: if one district was growing faster than the industry average, or had a higher than average number of spindles due for replacement after 1880, rings could form a higher proportion of total output than 60%.

In addition, we would expect some firms to install mules even in areas where those installing rings stood to benefit from a relatively large labor cost differential. These would be firms who exported their yarn to other countries – and who effectively faced a massive transport cost premium if they moved to rings. Although the vast majority of Lancashire's yarn was woven into cloth within the county, fully 13% was exported [Robson, 1957, p. 345]. Again, if we assume that the exporting sector grew at the same rate as the industry as a whole, our dependent variable for Lancashire as a whole would be bounded at 0.60 less 13%, or around 0.52.

Further, even in areas in which the *average* firm faced a substantial transport cost premium, not *every* firm would have had to pay such a cost were they to adopt rings. Even in Oldham 7% of spinners were able to have their yarn woven locally, and were therefore able to take advantage of the labor cost saving without paying the transport cost premium. Similarly in Ashton 53% and in Stockport 66% of spinners would have been able to disregard transport costs when making their technological choice decision. It is not correct to view all firms in one area as facing exactly the same conditions. One implication is that if spinners are rational we would expect a positive take-up of rings in any area in which the labor cost savings are positive, because all areas contained at least some firms for whom transport costs were not an issue. Equally we would expect the rate of adoption to be lower in areas where some firms face a transport cost premium than in areas where no firm faces such a cost premium on rings.

Finally, we need to be realistic as to how much of the variation in the machinery stock in 1906 can be explained by factor costs in one year alone: factor costs would have varied slightly over the years between 1880 and 1905. But with labor costs determined by wage lists, and railway charges ossified by government regulation, these are not large concerns. Naturally, we would also prefer to have more than 9 observations, but the individual returns for the *1906 Enquiry* – covering over 900 firms – were destroyed to preserve confidentiality. Despite these reservations it is clear that the model performs well.

$$\ln\left(\frac{proprings}{1 - proprings}\right) = \underset{(0.4703)}{-1.7} + \underset{(1.9832)}{5.36labsav} - \underset{(1.0953)}{5.80transprem}$$

Standard errors are given in parentheses, adjusted $R^2 = 0.76548$, $F = 14.05631$

There are three conclusions that we can draw from this model. First, the standard errors are all low, telling us that spinners definitely responded to the factor costs that they faced. Second, the co-efficients on the labor saving and the transport premium variables are very close, implying not just that spinners were responding to factor costs but that they were responding closely and accurately. A 1% fall in transport costs would have led to the same increase in ring take-up as a 1% rise in the labor cost advantage. Finally, our high R^2 shows that factor costs were indeed the primary determinant of technological choice, accounting for over three-quarters of the variation in the dependent variable.

The data assembled and the model derived from it show that even tiny variations in factor costs across the different districts – equivalent to just 2% of the final selling price of yarn – could cause the rate of ring adoption to vary from 11% to 60%. Such a determination to respond to even the smallest cost advantage suggests that the Lancashire cotton spinner, far from being irrational in his choice of technology, was an economic optimizer of textbook quality. In one sense this ought not surprise us, for the Lancashire cotton spinning industry was as close to a textbook definition of perfect competition as any manufacturing industry has ever been: 900 or so firms located in close physical proximity, with free entry and exit into the industry and low sunk costs, producing a homogenous good and supplying the majority of cotton goods sold in the world's non-tariff protected markets, and fully open to competition from imports in the home market. In such a market there is no room for sentimentality or technological conservatism.

Conclusions

This paper yields two main conclusions. First, and contrary to the institutional critique, it seems clear that the extreme levels of vertical specialization in Lancashire did the industry no harm. Factor cost advantages, not transport cost constraints, led Lancashire's spinners to select the mule so much more often than their competitors. And second, the intense degree of horizontal competition forced spinners to select the machinery most suited to their situation with an impressive degree of precision. We should see this period not as Lancashire in decline, but as Lancashire at its zenith.

Glossary

Bobbins are cylindrical barrels of wood placed over ring spindles. Yarn is attached to the bobbin. When spinning is complete, the yarn and bobbin are removed as one, and cannot be separated without rewinding the yarn.

Cops are small packages of yarn. When mule yarn is spun it forms a cop on the spindle: that is, the yarn can be lifted from the spindle as a package made up entirely of yarn. It is light and easy to transport: "a mule cop is like a good soldier always ready to go anywhere" [Whittam, 1907, p. 32].

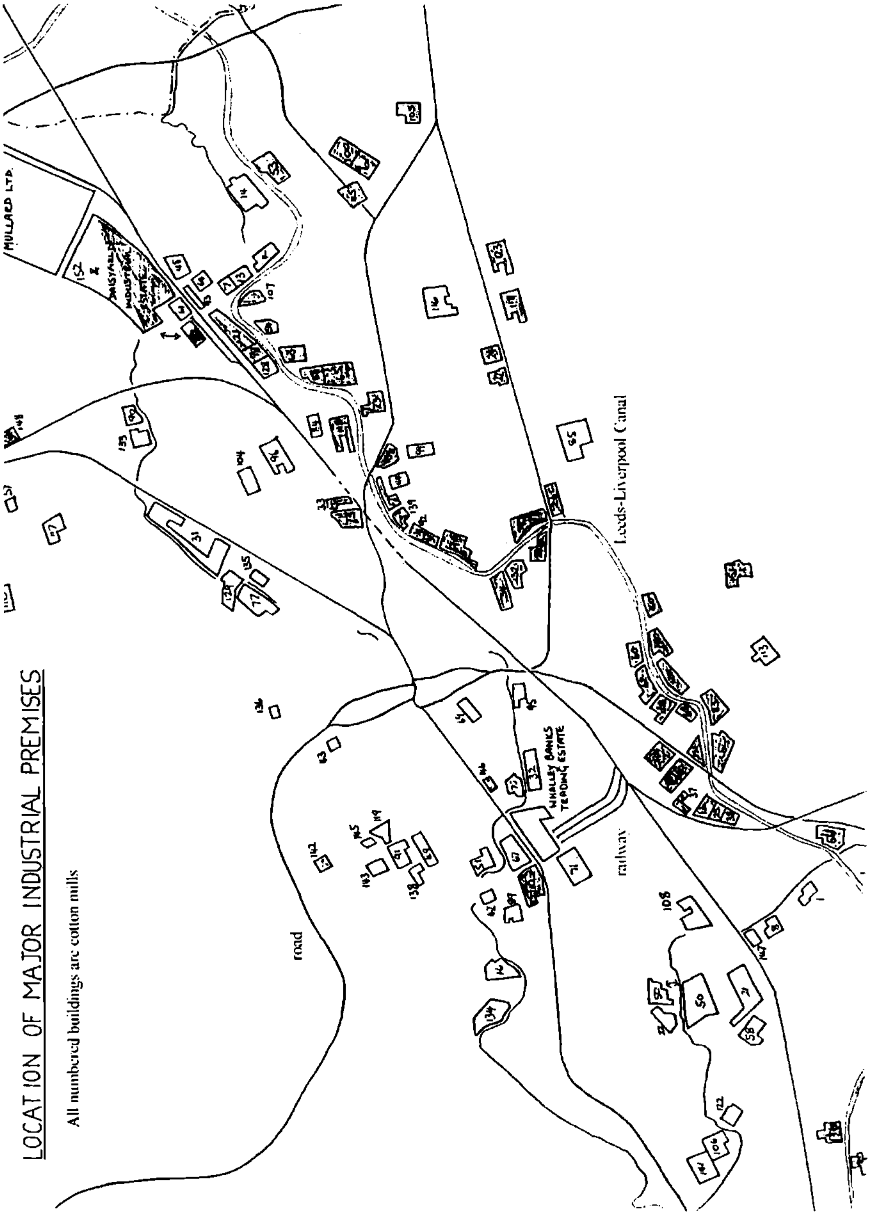
Count describes the fineness of the yarn. One pound of count 40 yarn would contain 40 hanks of yarn. A high count indicates a fine yarn.

Mule spinning was invented by Samuel Crompton in 1779, and combined the advantages of Arkwright's water frame with those of Hargreaves' spinning jenny. The "self-acting" mule was designed by Richard Roberts in the mid-1830s, and was improved until at least the 1880s. It is an intermittent spinner, i.e. it imparts twist to the yarn and winds it as two separate actions. This makes it gentler on the raw cotton allowing the spinner to economize on raw cotton, but it did demand skilled labor. It was the most common form of spindle in Britain even in the 1950s.

Piecers were assistants to mule spinners. In Lancashire each mule spinner had an adult big piecer and a more junior little piecer; in New England each mule spinner had just a big piecer.

Raw cotton arrived as bales of tangled fibres, whose quality and value was measured in a number of ways, most important of which is the length of fibre, or staple. It is also called cotton wool.

Ring spinning was developed from the throstle, a compact version of Arkwright's water frame, and perfected in the United States by 1880. It was a continuous spinner, spinning and winding yarn onto a wooden bobbin simultaneously. Its adoption in the United States was rapid, all but replacing the mule by 1913, but was much slower in establishing itself in Britain.



Cotton's Map of Blackburn

Roving consists of raw cotton just prior to spinning. It is a long loose sliver of cotton wool, lightly twisted.

Spinning is the process by which thin strands of elongated roving are twisted to make yarn. Spinning is made up of two actions: imparting twist to the roving to make it into yarn, and winding the newly spun yarn into a convenient package, either onto a spindle as a cop, or onto a bobbin. There are two principal types of spinning: mule spinning and ring spinning. Earlier methods, such as the spinning jenny and the throstle had been superseded by this period; the current method, open end spinning, was not introduced until the 1960s, although the basic principle by which it works was known in the early nineteenth century.

Staple length describes the length of each of the fibers of raw cotton, prior to spinning. It is the most important factor determining the value of the raw cotton.

Warp yarn is the yarn that is held in position during weaving. It has to be slightly stronger than weft. It is sometimes called twist yarn.

Weaving describes the process by which yarn is made into cloth on a loom.

Weft yarn is the yarn that is placed in a shuttle and shot back and forth between the warp in order to make cloth. It is sometimes called woof yarn or filling.

Yarn describes the cotton after it has been spun. The fineness of yarn is measured in counts. Yarn is sometimes called thread.

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