Working Paper No. 66/01

Britannia Ruled the Waves

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October 2001

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Timothy Leunig[2]

Abstract

This paper uses new micro-level US data to re-examine productivity leadership in cotton spinning c. 1900. We find that output aggregation problems make the Census unreliable in this industry, and that Lancashire, not New England was the productivity leader for almost every type of yarn. This is true both for the operation of a given machinery type, and when comparing machinery typical in each country. Higher capital and labour productivity rates imply that Lancashire's combination of a more favourable climate, external economies of scale and more experienced workers dominated the advantages that New England firms derived from greater scale.

Keywords

COTTON ¦ ECONOMIES OF SCALE ¦ LANCASHIRE ¦ MULES ¦ NEW ENGLAND ¦ PRODUCTIVITY ¦ RINGS ¦ SPINNING

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[1] This paper is based on work in my doctoral dissertation. I thank my supervisor, James Foreman-Peck for his advice. An earlier version of this paper was given at the 1996 Cliometrics meeting. I would like to thank participants there, especially Steve Broadberry and Greg Clark. I thank the Royal Economic Society, Nuffield College Oxford, and Oxford University's Sir John Hicks Fund for financial support. All errors remain my own.

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I. Introduction

As befits the leading industry of its day, the Lancashire cotton industry has been studied extensively, both by contemporaries and by economic and social historians. The resulting literature is prodigious, with a recent select bibliography running to 3000 items (Wyke and Rudyard, 1997). All periods are well studied, with different questions dominant for economic and social historians of different periods. For those working on the period c. 1900, the key questions revolve around the causes and consequences of Lancashire's differences. Lancashire was the industry most attached to the spinning mule and the power loom, and least enthusiastic about the ring and automatic loom. It was the industry that grew by adding more and more firms, with little or no growth in firm size. And Lancashire remained vertically specialised almost beyond imagination. It is most often compared with its opposite number in New England, where firms were more likely to adopt the new (American-invented) technologies of the ring and automatic loom, to be large, and to be vertically integrated. Good summaries of the literature can be found in Marrison (1996), Mass and Lazonick (1990), and Rose (2000).

Much work has been done both to explain Lancashire's technological choices, and to document the possible advantages of moving over to a system more similar to that prevalent in New England. Yet despite this volume of work, there is little that looks explicitly at which country was the more effective at producing cotton goods. That is not to say that writers have been uninterested in productivity. There is a body of work that looks at *changes* in productivity over time in each country, and compares the rates of change in each, but there is little that compares the *level* of productivity in each country at any given point. This is surprising, since detailed and reliable productivity estimates can be used to assess more accurately the effects of a number of aspects of cotton spinning that differed in the two countries. It is, for example, frequently claimed, following Marshall (1919, 1920) that the Lancashire cotton industry benefited from external economies of scale (Farnie, 1979, p. 35). In addition, Lancashire workers, especially mule spinners, were renowned for

their high levels of skill and experience, which we would expect to lead to higher productivity (Copeland, 1912, pp. 72-3). In contrast, others have claimed that US firms gained from internal economies of scale, and from the co-ordinated introduction of newer generations of machinery in both spinning and weaving (Lazonick 1990 p. 154). Both the ring and the automatic mule offered considerably higher levels of capital productivity than the older technologies of mule and power loom. Further, capital and especially labour were scarce in the US, so, in line with the Rothbarth-Habbakkuk thesis, we would expect them to economise on those factors, at the expense of power and raw cotton, both of which were relatively cheap in the US (Young, 1902, pp. 12-13, Broadberry, 1997, pp. 77-80). This again points to high levels of labour productivity. We will use detailed estimates of productivity within the industry to assess the historical importance of these factors.

This paper begins by reviewing the limited literature on Anglo-American productivity in cotton spinning. We will argue that although Broadberry's work is clearly the best available, it is not, inherently, the best method available to assess productivity in this industry, and that the results are correspondingly hard to interpret. The paper will then go on to discuss the key issues in preparing reliable productivity estimates. In section IV we compile and compare a four sets of micro-level productivity estimates, covering Lancashire rings, Lancashire mules, New England rings and New England mules. The implications of these results are then drawn out in section V, while section VI concludes.

II. Literature

The most influential early work on productivity in the British and American cotton industries is that by G.T. Jones, in his book *Increasing Return.* He found 'that there was little, if any, net change in the efficiency of the British cotton … manufacturing industry during the period 1885-1910: whereas the real cost of manufacturing cotton in America in 1885 was 120 percent of the cost in 1910'. He then goes on to say that '*Ceteris paribus*, we

may conclude that America had a greater absolute advantage over England in the manufacture of … cotton textiles in 1910 than in 1885.' (Jones 1933, pp. 50-51)

The first claim, that total factor productivity rose in Massachusetts but not in England, has been convincingly refuted by Sandberg (1974, pp. 101-2), who found that poor splicing of two Lancashire price series biased Jones' cost series upwards (see Marrison 1996 for a discussion). It is, however, Jones' second claim that is important here. He compared the *rates of change* in productivity in the Lancashire and Massachusetts cotton industries, but did not, at any point, compare the *levels* of productivity in the two industries. He was by no means alone in looking at changes rather than levels; indeed Sandberg (1974, pp. 93-119), generally hostile to Jones, corrects Jones' splicing but continues to use his erroneous methodology. Broadberry and Crafts (1990. Pp. 336-7) note that using rates of change for questions that require information on levels was standard practice until the 1970s. Jones claim that America's absolute advantage was larger in 1910 than 1885 is thus unwarranted. Massachusetts' higher rate of productivity is compatible with Jones' view. But it is also compatible with Lancashire having a persistent but declining absolute productivity lead, and with Lancashire leading in 1885 but being overtaken by 1910. In short, *changes* in productivity rates cannot tell us which country has the higher *level* of productivity. Indeed, the notion of economic catch-up, if applicable in this case, would suggest that a faster rate of growth indicates a lower level of attainment (Gerschenkron, 1962, Broadberry 1997, pp. 69-71). The faster rates of growth in Massachusetts – found by both Jones and Sandberg – would then imply that Lancashire, not Massachusetts, was the productivity leader.

Only two authors, Lazonick and Broadberry, have calculated the level of labour productivity in the British and American cotton industry in the pre-war period. Their aims and methodologies are profoundly different, but neither give satisfactory results.

As part of his work on comparative industrial relations systems, Lazonick (1981, 1990) looks at mule spinners producing count 32 yarn. He notes that British mill owners bought shorter staple raw cotton than their American counterparts. According to Lazonick, using inferior cotton reduced cotton costs, but lowered capital and labour productivity. After noting the difficulties in estimating comparative labour productivity, Lazonick (1981, p. 509-510) writes that ‘in the late 1890s output per “direct” worker-hour (that is, including auxiliary labor) in spinning no. 32s was at least 15-20 percent higher in Fall River than in Oldham.’ He also argues that if we correct for the higher proportion of skilled, experienced operatives in Lancashire, then ‘labor productivity in spinning 32s around the turn of the century was about 40 percent higher in Fall River than Oldham.’

Lazonick’s gives no details as to how he derives his estimates, and his evidence that Fall River’s spinners were more productive seems weak. He cites as sources Taggart and Cramer’s contemporary books on cotton mill management for Oldham and Fall River respectively, but neither source gives data on output per worker, or on capital labour ratios. Instead, they give data on output per spindle. In addition, Cramer (1904, pp. 152-157) writes explicitly that his book is ‘published for the Southern trade’ rather than for New England. Finally, Cramer’s figure for output per spindle is only 6 percent higher than Taggart’s for Lancashire (Cramer, 1904, p. 152-7, Taggart, 1923, p. 155). In short, it is hard to take as reliable Lazonick’s claim that Fall River mule spinners were either 15-20 percent or 40 percent more productive than their Lancashire rivals.

Broadberry’s motives for measuring productivity in cotton spinning are different. Whereas Lazonick was motivated by very specific questions about the industry, Broadberry is interested in the economy-wide productivity outcome of the interaction of a society’s willingness to accept product standardisation on the demand side with differing levels of skills on the supply side. These, via the two alternatives of mass production and flexible production, have implications for productivity in both the short and long run.

Rather than use micro-level data to compare spinning productivity at a particular count, therefore, he uses Production Censuses in the two countries to assess productivity in each cotton industry as a whole, sub-dividing the results into the spinning section and the weaving section (Broadberry 1994 p. 541). He also covers 28 other industries, (Broadberry, 1994). His methodology is straightforward. He takes data on the physical quantity of output and the number of workers directly from the Censuses for each country, and divides output by employment. For cotton, as for most other goods, output is measured by weight. Since heavier, coarse goods made up a higher proportion of US output, the use of weight as a measure favours the US. For this period Broadberry uses the 1907 British Census and the 1909 US Census, and finds that productivity in the spinning section was 20 percent higher in the US than in Britain (Broadberry, 1994, p. 541). He (1994, p. 523) notes that, overall, US productivity rose 3.3 percent between 1907 and 1909, which gives a best guess estimate of a 17 percent US productivity lead for cotton spinning in 1907.

There are two problems with this result. The first is that the level of aggregation makes it hard to interpret. It is compatible with at least three different stories. First, the US may have held the lead for the production of a given yarn using a given machine. In this case we would conclude that the internal economies of scale in US cotton firms were larger than the Marshallian external economies of scale available to the Lancashire cotton industry. This lead would then be compounded by America's greater use of generally more productive ring spinning, and re-compounded by the greater prevalence of coarse yarn in the US product mix. As an alternative, it may be that Lancashire's external economies of scale outweighed the internal economies available to US firms, but that the different mix of rings and mules in each country gave the US an overall lead in the production of any given yarn. Again, the different product mix would raise the US' overall lead. A third option would have Lancashire's external economies of scale dominating US internal economies of scale by a margin that was only overturned by both greater US ring use and a greater proportion of output made up of coarse yarn. The

aggregate nature of Broadberry's result does not allow us to say which of these three stories is correct, and it is for this reason that we argue that Broadberry's results are hard to interpret.

The second problem is that the Census does not provide accurate data on either yarn output or spinning section employment. For that reason, Broadberry's separation of the industry into spinning and weaving sections cannot be taken as reliable. We can see the problems by looking at the US data. The US Census does not provide data for total yarn output, only the amount of yarn produced by specialised spinning firms, excluding yarn produced by integrated firms. US specialised spinners accounted for less than one-quarter of yarn produced (1909 Census, pp. 51, 54), and further that yarn was atypically fine. The Census records that it was worth 23c per pound, higher than the average value of cloth produced in the industry as a whole (p. 50, cf pp. 50, 54). In fact, as the more detailed 1905 Census makes clear, yarn made by specialist yarn producers was primarily used for knit, not woven, goods (1905 pp. 48, 51). This sector is not, therefore, a reliable indicator of the output of the spinning sections in large integrated spinning-weaving firms. Second, the Census does not give employment data for the spinning and weaving sections. Broadberry allocates workers to the spinning and weaving sections in line with the value of output in each section, but this is essentially arbitrary. Indeed, given that the cost of raw cotton exceeds the total value-added in the industry (1909 Census, pp. 37, 48), value is a poor guide even to value-added, and is certainly not a reliable guide to employment.

III. Measuring labour productivity figures

Labour productivity is calculated by dividing production by employment. In the case of cotton spinning, however, we have to think carefully about whether weight or length is the better measure of output. Since one length of yarn can weigh 75 times as much as another, this question is important.

Spinning machines convert thin, lightly twisted pieces of cotton wool (roving) into yarn, by means of revolving spindles. Neglecting stoppages, the

output of the machine is determined by the speed at which the spindle turns. Every revolution of the spindle creates output equal to the circumference of the spindle, including any yarn that is already on it. Circumference is a unit of length, and in that sense spinning is fundamentally about producing lengths, not weights, of cotton. It is for this reason that the 1905 US Census argues that 'the efficiency of spindles is measured by the length rather than by the weight of their product.' (1905 Census, p. 53). Despite this, data considerations usually lead writers to use weight rather than length (Broadberry, 1994), with O'Brien (1995, p. 375) representing the exception rather than the rule.

It is straightforward to convert output in weight into output in length. Yarn is classified by 'count', which measures the yarn's fineness, meaning the width of the yarn, rather than whether the yarn is smooth or aesthetically pleasing. Count is a linear scale equal to the number of hanks (lengths of 840 yards) of yarn that weigh one pound, so that a pound of 32 count yarn contains twice the length of yarn of a pound of 16 count. Since spindles produce a certain length of yarn at any given speed, it will take, at first approximation, twice the time to produce a pound of 32 yarn as a pound of 16 yarn on any given machine.

The range of yarns produced was wide. Taggart (1923, pp. 157, 203) gives production data for Lancashire yarn from count 4 to count 300. At identical speeds, a machine would produce a greater weight of count 4 yarn in an hour than of count 300 in a week, even though the length per hour would be the same. Similarly, if one country specialised in count 4 yarn, and another in count 300 yarn, the former would be, ceteris paribus, 75 times as productive if we aggregated output by weight, but the two equally productive if we were to aggregate output by length.

Despite the 1905 Census correct preference for aggregation by length to weight, that aggregation still has limitations. First, at least for mules, spindle speed was not independent of count, with coarse mules running more than 50% faster than fine mules (Jewkes and Gray 1935, pp. 70, 209). As with weight, the same spindle will produce more coarse yarn than fine yarn, although the

ratio is only 1.5:1 when measured by length, rather than 75:1 when measured by weight. Nor can aggregation by either weight or length be supported by market prices – the price of yarn, whether per pound or per yard, varied with the count spun. The best way to assess productivity is not to aggregate output at all, but to produce productivity figures for different counts, viewing each count essentially as a separate product.

The issue here is not the industry's division into mass production and craft production sections. All cotton yarns, including count 300, are mass-produced. Fine yarns are not better yarns in a 'craft' sense than coarse yarns, they are simply thinner. Some consumers prefer coarse yarn to fine, even at the same price, because coarse yarns are better for some uses, such as sacking. To economists, different counts of yarn are examples of horizontal differentiation, that is, goods where consumers' choices depend on the use they wish to make of the product, rather than on their income. (Broadberry, 1997, pp. 24-5, Tirole, 1990, pp. 96-7, Hotelling, 1929).

Calculating labour productivity for each separate count of yarn also causes the aggregation problem to disappear: the weight of one length of any given count of yarn is constant. The absence of an equivalent to count for cloth makes it impossible to achieve an equivalent disaggregation for cloth. For that reason this paper restricts itself to spinning. As well as disaggregating yarn output to the level of individual counts, we will also construct separate productivity estimates for ring and mule spinners in each country. This is turn will allow us to separate out the three influences on productivity we identified earlier: the distinction between internal and external economies of scale, differing levels of ring and mule use, and differing ratios of coarse and fine yarns in the output mix.

IV. New estimates

We now construct four separate labour productivity series, for Lancashire rings, Lancashire mules, New England rings and New England mules. We choose to restrict our analysis to New England rather than to the US as a whole

because writers seeking to understand the cotton industry most often compare Lancashire with New England. In all cases our figures will apply to the period *c.* 1907, although inevitably there is some variation around that date. Each series will give productivity per week for a wide range of counts. We will then be able to separate out like-for-like productivity differences in the production of any given yarn from different machinery choices and different output mixes.

Explicit data on labour productivity are not common. Instead, we use the identity that states that labour productivity is the product of capital productivity and the capital to labour ratio. Algebraically,

$$(Q/L) = (Q/K).(K/L)$$

where Q is the amount produced, L the amount of labour and K the amount of capital, in this case measured by the number of spindles. Data on both output per spindle and spindles per worker are readily available; we begin with the former before moving onto the latter.

There are two standard, well-known output per spindle series for Lancashire, contained in books on cotton spinning by Winterbottom (1907) and Taggart (1923). Taggart's series are more comprehensive, but Winterbottom's series have the advantage that they were produced in 1907. The observations in the two series are similar, with average divergences of fewer than four percentage points. Furthermore, the deviations at each count largely cancel each other out; overall the mule series differ by 0.1%, and the ring series by 1.3%. Winterbottom reprinted his series without change in the 1921 edition of his book, implying that output per spindle did not change between 1907 and the early 1920s. Since they are more comprehensive, and appear reliable for our period, we use Taggart's series. The 1912 US Tariff Board Report (p. 411) also has a series for British mule spinning productivity, which has average deviations averaging 1% from Taggart's figures. The 1912 Tariff Board series is, however, 7 percent lower at count 28, and 8 percent higher at count 70, implying that Taggart's figures are too high at low counts, and too low at

higher counts. Taggart's series also fits well with the small amount of information provided by the 1907 UK Census, which estimated average annual output per mule and ring spindle at 30 and 60 pounds respectively. According to Taggart's data, this would imply an average mule count in the mid-40s, and an average ring count in the low-30s. This is in line with Saxonhouse and Wright's study of machinery purchases (1984, p. 511), which show that, between 1878 and 1906, the most common counts for new mule and ring spindles was 41-60 and 31-40 respectively.

The closest that we have to an equivalent series for New England is Cramer's output series, used by Lazonick. But as noted Cramer wrote explicitly for the Southern trade, rather than for New England. Further, his figures are taken from the Whitin Machine Works catalogue rather than being actual production figures. The 1912 Tariff Board Report does not prove useful either – the output data also proves to be taken from the Whitin Machinery Works catalogue.

Instead of using these sources we use new archival evidence drawn from the surviving production records of three large New England firms: the Amoskeag, the Lyman and the Naumkeag. These records, kept in the Historical Collections section of Harvard Business School's Baker Library, give the actual output per spindle at a range of counts. We have 43 observations for mule spinning and 24 for ring spinning. We use regression analysis to estimate a single continuous series for New England mules and a corresponding series for New England rings. The procedure works well: both the data and the procedure are given in the appendix.

We need to be sure that these firms are representative of the New England industry as a whole. The 1909 Census gives sufficient evidence for us to show that this is so. The Census divides New England yarn output into three count categories, sub-20, 21-40 and supra-40 (p. 54). We divide these output data by our average output per spindle figures for each category to estimate of the number of spindles used. These estimates are compared to the total number of spindles, which is also recorded in the Census. The results are given in table

one, and suggest that these firms did closely mirror average productivity in the industry as a whole.

Our estimates are also in line with scattered observations from other sources. The 1912 Tariff Board Report notes that a new US mill would have output per ring per 56 hour week of 1.12 pounds of count 32 warp and 0.616 pounds of count 50 weft (pp. 800, 804). The regression gives figures of 1.07 and 0.55 pounds respectively. Since the Tariff Board figures are for a new mill in 1912, and the regression is designed to cover existing spindleage, an 8% margin in favour of the Tariff Board Report seems reasonable. Young records that a Lowell mill produces 1.35 pounds of count 28 warp per 58 hour week, our regression suggests 1.34 pounds for a week of that length (Young 1902, p. 28).

TABLE 1
Reconciling New England estimated capital productivity figures with aggregate spindle numbers and aggregate output

Counts	Annual output (thousand lbs)	Estimated spindles (thousands)
Sub 20	290,135	1,955
21-40	461,031	8,174
41+	114,721	5,428
Total	865,888	15,557
Actual spindles		15,384
Productivity underestimate		1.1%

Notes:
We assume that spindles are distributed uniformly within bands. We take sub-20 means 8-20. We take supra-40 to be 40-80.

Sources:
Output and actual spindleage, 1909 Census, pp. 54-55
Ring and mule output per 100 spindles per week, see text.
The Census does not record the number of days of operation of the average mill in 1909, so we assume that New England mills, like their British counterparts, worked a 49.9 week year, in line with the UK (1906 Enquiry p. xix). Layer records that the number of days worked by employees varied substantially from year to year, for that reason this result should be thought of as confirming the plausibility of our productivity results, rather than anything more precise.

We are now in a position to compare output per spindle in the two industries. It is worth noting that the original New England data is for a 58 hour

week (Layer, pp. 42, 43), whereas the British data are for a 55.5 hour week. For ease of comparison, the figures hereafter convert the New England data to a 55.5 hour week.

TABLE 2
Output per spindle
(pounds weight per 100 spindles per 55.5 hour week)

	Lancashire		New England	
Count	Mules	Rings	Mules	Rings
12		458	168	349
16	203	307	138	253
20	162	251	115	194
24	135	191	98	156
28	116	169	85	128
32	98	136	75	107
36	85	116	67	91
40	74	99	60	78
50	54	72	47	55
60	41	55	38	39
70	30	41	32	28
80	25	34	27	20
90	20	27	23	13
100	17	23	20	
110	15		18	
120	13		16	
130	11		14	
140	10		12	
150	9		11	
160	8		10	

Sources. See text

Table two shows that, when using a particular machine to spin a particular count, Lancashire generally had higher rates of capital productivity than did New England. This is true for rings at all counts, and for mules for all counts up to and including count 60. In contrast New England's supra-60 mules are found to be more productive than are those in Lancashire. That British rings were more productive that US ones is less controversial than it may at first sight appear; the same result was found by the 1912 Tariff Board Report, which looked at output in new mills (pp. 800, 811).

We now move on to assess the capital to labour ratio. This is very straightforward for New England, where the 1905 Census (p. 60) records that each ring spinner tended an average of 522 spindles, while each mule spinner

was responsible for 1124 spindles. Since each mule spinner had an assistant, the average number of spindles per mule operative was 562.[3]

These figures are much lower than those claimed by contemporaries. Copeland (1912, p. 298), for example, claimed that 'While American ring spinners are occasionally put in charge of as few as four hundred and fifty spindles, the average is from seven hundred and fifty to one thousand.' Young (1902, pp. 10, 44-45) gives estimates of 864-896 for rings, and 1564 per mule team. Uttley (1905, p. 13) noted that 'In the spinning-room I find the frames of such different lengths and the counts in such great variety that it is difficult to find a standard, but the average, I am told, is for a spinner to mind 6 sides amounting to 800 spindles.'

There can be no doubt that the Census is the most reliable source, and should be preferred to the estimates of Copeland, Young and Uttley. Archival evidence also supports the Census: Amoskeag ring spinners averaged 648 spindles, Tremont and Suffolk spinners 564 while Lyman spinners had 324, 352-998, 360-768 and 432-920 spindles each, according to the building they worked in. (Amoskeag: MHA, List of Machinery and Average Daily Earnings, p. 3. Tremont and Suffolk: HBL, Misc Papers, Census of Manufacturers, 1900, pp. 2, 5. Lyman: HBL, AB-1, MED-5). The average of these figures is 591 spindles, fairly close to the Census figure of 522, and much lower than the figures given by the contemporary writers. The records also support the Census estimate for mule spinning, with the Amoskeag mill having 965 spindles per mule team, the Tremont and Suffolk 962, and the Lyman between 590 and 2000, giving an overall average of 1074 per team, again reasonably close to the Census figure of 1124.

There seem to be two sources of bias in the figures provided by contemporaries. First, Uttley and Young visited New England to find lessons from which England could learn. Such a quest would make them more likely to choose mills known for good practice, rather than average or inefficient mills.

[3] For consistency we would prefer to use the 1909 Census, but this does not contain equivalent data.

Young (1902, pp. 34-35) certainly waxes lyrical about some of the places that he visited. In contrast to Manchester England, he claims that Manchester New Hampshire has ‘clear air, clear waters and sunny skies’, and compares the Amoskeag mill buildings to London’s Regent Street, before stating that they could ‘masquerade successfully as ancient colleges.’ A concentration on the most efficient mills would certainly yield biased impressions. The 1912 Tariff Board Report (pp. 416, 419) noted that US mills varied substantially in efficiency, and that they exhibited greater heterogeneity than British mills. This could explain why the best practice mills visited by Uttley and Young are so out of line with the averages recorded by the Census.

In addition British visitors to New England do not seem to use ‘average’ to imply the mean number of spindles for all spinners. Young (1902, pp. 10-12) explicitly stated that his figure of 896 is for ‘good spinners’, before noting that mill labour ‘is dear and bad’ and that ‘even a good mill in New England loses 5 per cent of its workpeople every week’. High labour turnover implies that many workers, even in good mills, were inexperienced, and may have been allocated substantially fewer spindles than their more experienced colleagues.

Since the UK Census does not give data on spindles per worker, we turn to Jewkes and Gray for evidence. For mule spinning Jewkes and Gray (1935, p. 205) give ten-yearly data on spindles per new mule in Oldham and Bolton. As we want data on spindles for existing machinery we need to know the average age of Lancashire’s mules. These machines lasted around fifty years (Sandberg, 1984, p. 388, Lazonick 1984, p. 394), and the industry grew 140 percent 1857-1907 (Robson, 1984, pp. 332-3), implying that the average mule in 1907 was installed *c.* 1886. In 1907 new mules in Oldham averaged 1044 spindles, while those in Bolton contained 986 spindles. Taking into account that Oldham’s contained more spindles than Bolton, this implies that the average mule operating in 1907 had 1032 spindles. A three-person mule team, responsible for a pair of mules, would have tended 2064 spindles between them, or 688 spindles per person.

The number of spindles tended by Lancashire ring spinners increased with the count spun. In order to ensure fairness in earnings, wages per spindle fell as the count rose. Dividing weekly earnings by the wage rate for different counts gives the number of spindles tended at each count (1906 Enquiry, p. 30, Jewkes and Gray, 1935, p. 121). Table three shows that Lancashire ring spinners had between 421 and 701 spindles each, depending on the count. Using the count distribution of rings given by Saxonhouse and Wright (1984, p. 511), we estimate that the average worker tended 645 spindles.[4] Overall, therefore, we find that both Lancashire mule and ring spinners had approximately 20 percent more spindles than their New England counterparts.

[4] We have no evidence as to whether the number of ring spindles per operative varied with the count in New England as it did in Lancashire. If it did, then our series overstates New England labour productivity by 22 percent at count 12, and underestimates it by 12 percent for counts 43 and above. Even in that case, however, our series for New England are still correct on average.

TABLE 3
Ring spindles per operative, Lancashire

Count not less than	Weekly earnings (pence)	Weekly wages per 100 spindles (pence)	Spindles tended
8	182	43.243	421
10	182	39.783	457
12	182	37.188	489
14	182	33.729	540
17	182	31.134	585
22	182	29.405	619
29	182	28.107	648
37	182	26.811	679
43	182	25.945	701

Sources. Weekly earnings, *1906 Enquiry*, (p. 30); Weekly wages per 100 spindles tended, Jewkes and Gray (1935, p. 121).

Now that we have data on output per spindle and spindles per worker, it is a matter of simple arithmetic to calculate output per worker. Table four shows that Lancashire had considerably higher rates of labour productivity for all counts of mule spinning up to the mid-90s, and for all counts of ring spinning. Using all of the counts given in the table, Lancashire mule spinners were 30% more productive than those of New England, while Lancashire ring spinners were 70% more productive than their New England counterparts. When we restrict our attention to the historically more important sub-40 counts we find that Lancashire mule spinners lead by approximately two-thirds, while Lancashire ring spinners led by almost one-half.

TABLE 4
Output per operative
(pounds weight per 55.5 hour week)

	Lancashire		New England	
Count	Mules	Rings	Mules	Rings
12		2239	945	1824
16	1394	1658	774	1318
20	1115	1466	647	1015
24	929	1181	551	812
28	796	1047	478	668
32	675	881	421	559
36	582	751	374	475
40	507	674	336	408
50	372	503	265	286
60	281	383	216	205
70	208	287	180	147
80	169	242	153	104
90	139	186	131	70
100	115	158	114	
110	103		99	
120	90		87	
130	79		77	
140	70		68	
150	62		61	
160	54		54	

Notes and Sources. See text.

We can also analyse whether Lancashire retained its productivity lead when we compare the machinery typical in Lancashire with that typically used in New England. It is common to think of New England using rings and Lancashire mules, but this picture is too simplistic: the 1909 Census (p. 56) notes that 24 percent of New England's spindles were mules, while the 1907 Census records that 16 percent of Lancashire's spindles were rings. Furthermore, these rings were heavily concentrated in the low-count sector: Saxonhouse and Wright find that rings accounted for 45 percent of sub-30 spinning capacity installed between 1880-1906 (p. 511). Instead of comparing Lancashire mules with New England rings, therefore, we compare productivity in each place using the machinery mix that was typical in that country. For

Lancashire, we assume that spindles recorded by the UK Census are distributed in line with Saxonhouse and Wright's data (1984, p. 511). This implies that whilst 37% of sub-20 spindles were rings, 99.5% of supra-60 spindles were mules. In the absence of more specific data, we assume that the overall 76:24 ring:mule ratio given by the Census (1909, p. 56) holds for all counts in New England.

TABLE 5
Output per operative
(pounds weight per 55.5 hour week)

Count	Lancashire	New England
16	1492	1186
20	1246	926
24	1047	749
28	914	622
32	719	526
36	618	451
40	542	390
50	373	281
60	282	208
70	208	155
80	169	116
90	139	85
100	115	

Notes and Sources. See text.

Table five shows that when comparing the production of any given count, using the selection of machinery typical in each country, Lancashire was consistently ahead of New England. The lead was approaching 40% overall, and for counts of up to 40.

Until now we have been looking at the productivity of spinners themselves, rather than of all workers employed in the spinning section. It is of course possible that the productivity advantage of Lancashire spinners was gained only be employing more auxilliary labour.

There are two pieces of statistic evidence that suggest that the ratio of auxilliary to skilled labour was not materially different in the two countries. First, the US Censuses give the ratio of unskilled to skilled labour. The 1905 Census records that there were 1.04 other workers to every New England spinner and weaver, while the 1909 Census records that there were 1.5 such workers to every spinner and weaver in Massachusetts, New Hampshire and Rhode Island (1905 p. 40, 1909, p. 41). The British Census is not so detailed, but the 1906 Enquiry recorded 1.13 additional workers per spinner or weaver. Nothing here suggests that the ratio of assistants to spinners was radically different in the two countries. Lazonick, in fact, suggests that New England's ring spinners had more assistance than their Lancashire counterparts (Laz 1990 ch 4, esp p. 125)

Second, the 1912 Tariff Board Report recorded the labour cost of producing 12 counts of yarn in both countries. It gave 87 observations for US ring factories, and 79 observations for UK mule factories. The data show that the labour cost of converting yarn was 30.1% lower in England than in the US, and 36% lower if we exclude counts above 40 (pp. 417-420). This implies that Britain either had higher labour productivity, or lower wages, or both. Britain certainly had lower wages. The 1906 Enquiry records that the average wage in the UK cotton industry was $233 (p. xviii), whereas the 1905 Census records that US cotton workers received an average of $304 (pp. 39-40). This difference in wages is not, however, sufficient to explain the labour cost difference in the Tariff Board Report. Taken together, these two sets of figures imply that British mule spinners had a labour productivity lead of 9% over US ring spinners for all counts, and a lead of 16.6% for counts of 40 and below. When we take into account all labour used in spinning, it is again Britain, not the US, that is the productivity leader. Britain's lead is smaller here than in table five, but this does not imply that British spinners had more assistance. Rather it is an artefact of the data – the Tariff Board Report compared British mule spinners with US ring spinners, whereas table five covers a representative

selection of firms in each country. In addition, Tariff Board Report covered all of the United States, rather than just New England.

V. Discussion

We now know that, for just about any count, using any machine, Lancashire spinners had higher productivity than their New England counterparts. We can identify three reasons to explain Lancashire's lead. First, as Copeland noted, 'the climate of Lancashire is so even in temperature and so humid that it surpasses that of every other place in the world in its suitability for cotton manufacturing' (Copeland, 1912, p. 276). Consistent humid conditions make the cotton fibres more pliable, allowing machines to run at high speeds without causing breakages.

Second, firms in Lancashire gained from external economies of scale, whereby costs fall as the size of the industry increase. There are two aspects to external economies of scale that are worth noting. First, to quote Marshall's famous dictum (1920, p. 225), 'The mysteries of the trade become no mysteries; but are as it were in the air'. With better information, firms are able to approach the productivity frontier more easily. This implies that the productivity of Lancashire firms should exhibit less variation than those of New England. The 1912 Tariff Board Report provides evidence that this is so. It looked at the labour cost of spinning specific counts of yarn in the two countries, and found the standard deviation was 16 times higher in the US than in Britain, consistent with the notion that British firms were more able to learn from each other. Marshall also argued (1919, p. 601) that specialisation within the Lancashire cotton industry allowed business to specialise in producing a limited range of goods. Again, this is evidence that this was so. An American contemporary, Copeland, wrote that Lancashire's spinning mills 'are highly specialised, so that a labourer is often employed continuously on a single grade of work. In the United States the machinery is readjusted more frequently' (1912, p, 294). A management consultant, brought in to advise the Boott Mills in Lowell in 1902, was of the same opinion, arguing that Boott Mills had

‘attempted to make too great a variety of yarn and cloth.’ (UML FC Parker (1902), pp. 25-6. This, he argued, depressed productivity.

Thirdly, workers in Lancashire were, on average, considerably more experienced than those in New England. The Amoskeag Mill, New England’s largest, had labour turnover of 125% in 1912 (Nelson, 1995, p. 85), whereas Quarry Bank Mill, in Britain, had a labour turnover rate of just 27.5% (Rose 1977, p. 115). The role of experience and skill are obvious in mule spinning, but should not be discounted in other jobs. Hareven notes that ring spinning ‘requires some time to acquire the deftness necessary to piece ends quickly and properly’ (p. 398), while a now anonymous Boott Mill manager noted in 1859 that workers generally ‘will be worth more to us the last six months than they are the first twelve’ [quoted in Gross, 1993, p. 13].

Although we know that a remarkably suitable climate, external economies of scale and an experienced workforce aided Lancashire’s productivity performance, the literature contains no estimates of the sizes of these effects. Quantitative estimates of the productivity advantage that Lancashire gained from these three aspects would be a worthwhile addition to our understanding of the industry. In particular, this would help us to understand why Britain was able to maintain a productivity lead in cotton spinning at a time when the US had superseded Britain in a large range of other industries.

Finally, it is worth noting that although textile mills were the first big firms in the United States, Alfred Chandler (1977, p. 68) did not see them as the first modern enterprise. Rather, he noted that textile mills ‘embodied, it must be stressed, an integration, not a subdivision of work’. Similarly he argued (1977, p. 337) that mergers were rare, and even more rarely successful in this industry, as it was an example of an industry ‘where the concentration of production did not significantly reduce costs and where distribution did not involve high-volume flows or did not require special services.’ If the industry had few scale economies, it should perhaps not surprise us that the American

model, of large-scale factories, should not automatically lead to higher capital-labour ratios and higher labour productivity.

VI. Conclusion

This paper finds that Britain, not New England, had higher rates of productivity in cotton spinning prior to the First World War. This is true on both a 'like for like' basis, using the same type of machinery, and when comparing productivity on the machines that were typically used in each. Although this result appears to contradict the results that Broadberry derived using the Census, the two can be reconciled. These results, unlike Broadberry's take into account the differences in the production mix – the ratio of fine to coarse yarn – produced in each country. In particular, the Census unit of output – aggregate weight – is biased towards a country producing coarse goods, in this case the United States. At a disaggregated level, we find that, for almost all types of yarn, both capital and labour productivity were higher in Lancashire. We attribute this result to a combination of climate, external economies of scale and greater experience on the part of the workers.

APPENDIX: CALCULATING CAPITAL PRODUCTIVITY RATES FOR NEW ENGLAND

Data on output per spindle per week are taken from production records for the Amoskeag, Naumkeag and Lyman mills, kept in the Historical section of Harvard Business School's Baker Library. We have 43 observations for mule spinning, and 24 observations for ring spinning. The mule data cover counts 12 to 160, while the ring data cover counts 13 to 90. All data are for a 58 hour week.

Output per spindle: (a) mule spinning

Count	Output	Count	Output	Count	Output
12	176	39	64.5	80	29.5
17	136	40	60	80	27.5
20	121.9	40	68	85	28.5
23	111	40	65.8	85	26.5
23	99.9	45	51.9	87	26
25	98.9	45	55	90	27.3
25	105.2	48	45	90	25
28	84.3	50	50	100	23.3
30	79	55	57	100	20
31	80	55	45.5	110	15
33	80	60	40.6	125	10
34	75	65	36.3	130	15.7
35	69.1	70	33	160	10
38	55	75	30.7		
38	70.4	75	27		

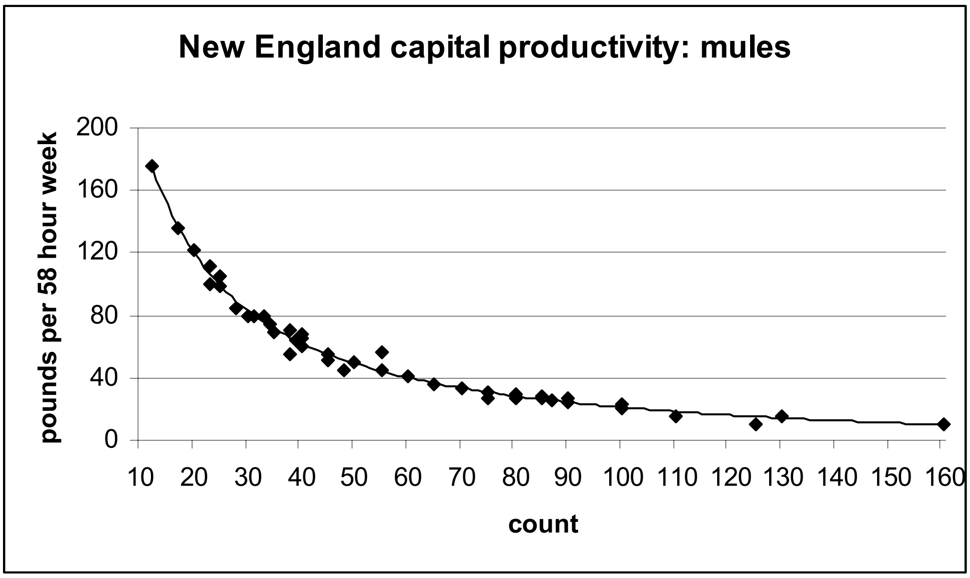
Output per spindle: (b) ring spinning

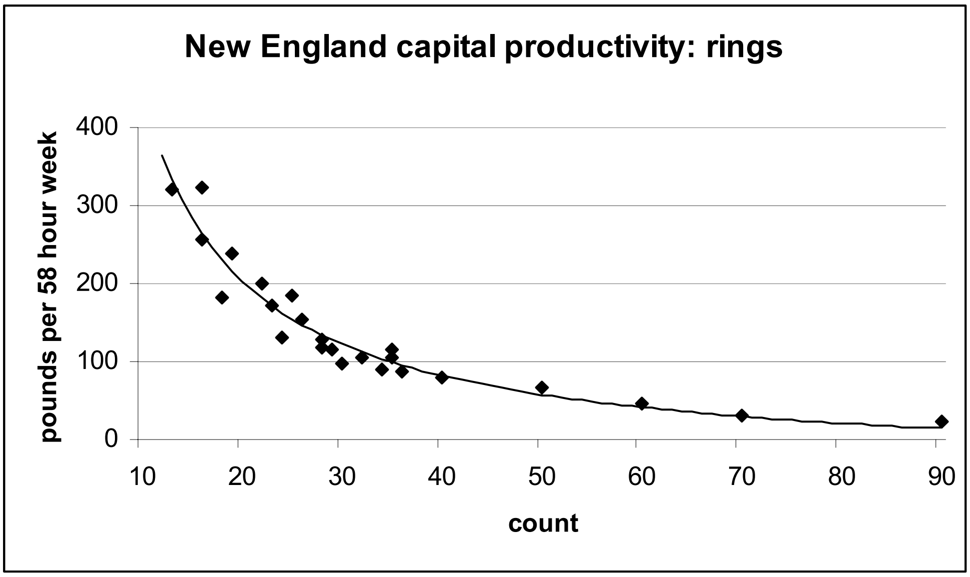
Count	Output	Count	Output	Count	Output
13	320.4	25	185.2	35	104.4
16	257	26	153.6	35	116.2
16	323.8	28	116.7	36	86.7
18	181.7	28	127.2	40	79.9
19	238	29	116.6	50	67
22	200.9	30	98.2	60	45
23	171.7	32	105.9	70	32
24	130.3	34	90.5	90	24

We regress output on count to generate capital productivity series for mules and for rings that are both smooth and complete. Graphs of the actual and estimates lines are given below.

	Mule spindles	Ring spindles
Intercept	-9.2	-39.9
	(4.9)	
1/count	3141	4861
	(25.6)	(16.9)
$1/count^2$	-11079	
	(7.0)	
Adj R^2	0.99	0.93
SE	4.0	22.3
F	1704	286

OLS regression performed using Stata; t-statistics in parentheses. The $1/count^2$ term was not significant in the ring spindle regression and has been omitted.




New England capital productivity: rings
pounds per 58 hour week
400
300
200
100
0
10
20
30
40
50
60
70
80
90
count

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