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NEW ANSWERS TO OLD QUESTIONS: TRANSPORT COSTS AND THE SLOW ADOPTION OF RING SPINNING IN LANCASHIRE

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Abstract

It has been argued that the additional cost of transporting ring yarn in the vertically and geographically specialised Lancashire cotton industry was sufficiently high to deter spinners from adopting rings. The absence of a transition to large scale vertically integrated plants is seen as a form of entrepreneurial failure. In this paper we use new evidence to show that the majority of yarn could have been woven within the district in which it was spun, and, further, that in such areas, the average distance between spinners and weavers was a matter of yards. Transport costs were no more important for these firms than for vertically integrated ones. This yields a testable hypothesis: vertically specialised firms located in these areas should have been as ready to adopt rings as were integrated firms. We test this proposition and find it to be correct: co-located independent, vertically specialised firms were as likely to adopt rings as were vertically integrated firms. As such the industry's failure to move to large scale vertically integrated production cannot be characterised as a form of entrepreneurial failure.

New Answers to Old Questions:
Transport Costs and the Slow Adoption of Ring Spinning in Lancashire

It is never difficult to defend an interest in the Lancashire cotton industry, for despite the fact that Britain grows no cotton, cotton has a unique place in the British economic history. To Rostow it represents: 'the original leading sector in the first take-off',[1] while 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.'[2] At the end of the eighteenth century cotton was the first industry to adopt the factory system,[3] by 1810 it had overtaken wool to become Britain's single most important source of industrial value-added,[4] a position it retained until the very end of the nineteenth century.[5] At its absolute peak in 1913, the industry directly employed over half a million people, who processed more than 2.1 billion pounds of raw cotton.[6] Cotton's export performance was more remarkable still: it became Britain's biggest export item in 1803, a position it was to retain for 135 years.[7] In 1830 it exceeded all other British exports combined,[8] and even as late as 1880 over 80% of the world's cotton exports came from Britain.[9] Mill owners boasted that they met the needs of the home market before breakfast and devoted the rest of the day to exports:[10] in 1913, Britain exported over 7 billion yards of cloth,[11] sufficient to make a shirt and pair of trousers for every person alive.

But 1918 saw the start of a decline that was to prove both long and unrelenting. In 1933 Japan, then a newly industrialising nation, overtook Britain to become the world's biggest exporter of cotton goods, even though cotton was to remain Britain's biggest export until the outbreak of war.[12] In 1944 Keynes still saw cotton spearheading Britain's post-war export drive, asking 'who will export cotton goods if Britain does not - Japan, America, who?',[13] and even after the war government propaganda asserted that 'Britain's bread hangs by Lancashire's thread'.[14] But it was not to be: despite general world-wide prosperity, output only twice reached its worst inter-war level,[15] and by 1958, within twenty years of cotton being Britain's largest export, Britain had become a net importer of cotton goods.[16] Mills continued to close at the rate of almost one a week throughout the 1960s and 1970s,[17] until the industry became little more than an increasingly distant memory. The mills of Lancashire have indeed fallen silent.

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[1] Rostow (1990), p. 53.
[2] Crafts and Harley (1992), p. 706.
[3] Singleton (1991), pp. 1-2.
[4] Deane and Cole (1969), p. 163.
[5] Sandberg (1981), p. 114.
[6] Mitchell and Deane (1962), pp. 186-8, Robson (1957), p. 333.
[7] Farnie (1979), p. 9.
[8] Deane and Cole (1969), p. 31. This year was not a fluke: cotton's share in exports *averaged* 45% in the 37 year period from 1814.
[9] Robson (1957), p. 4.
[10] Aspin (1981), p. 3.
[11] Sandberg (1974), p. 4.
[12] Aspin (1981), p. 4.
[13] Quoted in Singleton (1991), p. 37.
[14] Singleton (1991), p. 1.
[15] Robson (1957), p. 333.
[16] Farnie (1979), p. 9.
[17] Aspin (1981), p. 4.

1 The literature

The 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.'[18] This paper concerns the third debate: did Britain suffer from an abnormally poor set of entrepreneurs?

Those entrepreneurs stand accused of being poor salesmen, of neglecting science and research, and of favouring old staple industries over newer ones with brighter futures.[19] 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 up this approach effectively when he said in 1934 that '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'.[20] In short, the British manufacturer 'basked complacently in the sunset of economic hegemony.'[21]

Given its importance to the British economy, and the scale of its decline, it is unsurprising that this thesis has been applied as vigorously to the cotton industry as to any other. Before examining these criticisms it is important to understand the basic nature of the industry. 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 spinning. The case for technological conservatism in spinning is easily made. A newer form of spindle, the ring, was technically viable for coarse yarns by 1880,[22] and by 1913 90% of spindles in the United States were rings rather than mules.[23] In contrast under 25% of British spindles were rings.[24] This technological lag was to remain with the Lancashire industry until the end: in 1954 Britain, with fewer than 20% of the world's spindles, had over 80% of the world's remaining mule spindles.[25]

But if the case for technological conservatism 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 main cost differences that are important to a spinner deciding between rings and mules. First, mule spindles require skilled labour, which is considerably more costly than the unskilled labour 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 packages consisting entirely of yarn, the ring spindle spins its yarn onto a heavy wooden bobbin from which the yarn cannot be removed economically. The

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18 McCloskey, (1970), p. 446.
19 Aldcroft (1964).
20 Quoted in Jewkes (1951), p. 9.
21 Landes (1969), p. 336.
22 Coarse yarns are defined as those with a 'count' lower than 40. A yarn's count is literally a measure of its fineness: it equals the number of hanks (lengths of 840 yards) of yarn that weigh one pound. The usual British definitions were for coarse yarns to be counts up to 40, medium yarns those counts 40-80, while fine yarns were all counts finer than 80. Reflecting differences in output composition, the US defined coarse yarns as those of up to only 20, with medium consisting of counts 20-40 and fine all counts over 40. 1906 Enquiry, p. 26, US Census of Manufactures, 1905, p. 48.
23 Lazonick, (1981), p. 90.
24 Lazonick, (1981), p. 90.
25 Robson (1957), p. 355, corrected for mule equivalence.

wooden bobbin had 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.[26] Lancashire's industrial organisation system, consisting of individual firms each either spinning or weaving made 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.[27] By making the investment in large-scale production, U.S. firms were better placed to adopt new forms of high throughput technology, and, by implication, were in a better position to succeed commercially.[28]

By reconstructing the factor costs faced by British and American spinners, Lars Sandberg argued that both British and American spinners behaved rationally in their choice of technologies.[29] The essence of his argument is simple: the skilled labour 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 firms 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.[30] But his empirical revisions raise the importance of the transport cost premium relative to that on labour costs, leading him to conclude that 'The primary constraint on the introduction of ring spinning in Lancashire was the cost of shipping ring yarn'.[31] By developing integrated firms on the American model, the Lancashire industry could have avoided this constraint, and by failing to do so they prove themselves to be good managers, but poor entrepreneurs.

Lazonick's transport cost calculations are based on a piece of contemporary industrial espionage which states that yarn travelled an average distance of 30 miles in order to be woven. There are three objections to this exercise: one factual, two methodological. First, his source, Whittam, substantially overestimates the size of Lancashire. From the largest spinning town - Oldham - only one of the six Lancashire weaving towns - Preston - is over 30 miles away, the other five towns being considerably closer, with the average distance of 20.3 miles.[32] The methodological issues are more interesting. To show that transport costs were 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 yarn that had to travel more than the economically critical distance. Even were all yarn to have 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 then all might have been constrained from adopting rings, but if half had to move their yarn 60 miles, and half only had to move it a few yards, then only half would have been constrained in their choice of technology. In this paper we are able to estimate the proportion of coarse yarn output that could have been woven within - literally - yards of where it was spun, that is, we are able to

[26] On the way out, transport costs rise from 1 to 3, on the return leg from 0 to 2.
[27] The transport cost applies only to weft and not to warp yarn: warp yarn had to be rewound whatever the spinning method; ring spinners could rewind the yarn prior to shipping it to the weaver, saving the transport costs associated with moving ring bobbins.
[28] Chandler (1977), pp. 58, 68, 72, see also Chandler (1990), pp. 783, Lazonick (1983), pp. 197-8, 210.
[29] Sandberg (1969, 1974).
[30] Lazonick (1981).
[31] Lazonick (1983), p. 205.
[32] The six towns are Accrington, Bacup, Blackburn, Burnley, Preston and Rochdale. The distance to each from Oldham is taken from the Railway Clearing House Map of Lancashire, 1900, which gives the distance by rail to the nearest 0.01 mile. The average distance quoted includes the figure for Preston.

estimate the proportion of spinners who had no need to concern themselves with the transport costs potentially associated with ring spinning.

The paper proceeds as follows. In section 2 we use the British government's official 1906 Enquiry into Hours and Earnings to calculate the location of spinning and weaving capacity within the twelve different districts of Lancashire. This allows us to test the extent to which yarn had to be moved from one part of Lancashire to another. We show that the majority of yarn could be woven within the district in which is was spun. We then go on to use an unpublished thesis on Blackburn to show that, within a cotton town, the distance between spinners and weavers was a matter of yards. Spinners situated in areas with sufficient weavers close by, which we term 'co-located', were no more constrained by transport costs than were integrated firms. In section 3 we show that the rates of ring adoption by co-located and integrated firms were similar.

2 The location of firms

In 1906 the Board of Trade sent out 2329 detailed earnings and hours schedules to firms in the cotton industry, of which 967, or 41.5%, were returned.[33] This is clearly a large sample, and was sufficient to form the basis of a 324 page statistical report. Two independent pieces of evidence lead us to believe that the 1906 Enquiry is a representative sample, both in terms of the size and geographical mix of firms responding. First, the 41.5% of firms that make up the 1906 Enquiry contain 40.7% of the workers recorded in the 1904 Factory and Workshop Returns.[34] This suggests that there is no large bias towards either large or small firms in the 1906 Enquiry. Second, the regional breakdown of the industry within Lancashire given in the 1906 Enquiry is compatible with that given by Worrall's annual directory. Using Worrall's Directory, Farnie shows that the spinning district contained 81.3% of all spindles,[35] while the weaving district contained 66.4% of all looms.[36] The equivalent figures from the 1906 Enquiry are 81.4% and 64.9% respectively.[37] This suggests that both the spinners and the weavers in the 1906 Enquiry represent a geographically balanced sample. Finally, the 1906 Enquiry itself notes that '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.'[38]

The 1906 Enquiry gives job specific employment data on 10,010 Lancashire mule spinners, 4,001 ring spinners, and 72,134 weavers.[39] In each case, the data is sub-divided according to the district in which the operative worked, with each of the twelve named districts consisting of a town and its hinterland.[40] Given that we can convert employment data

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[33] 1906 Enquiry, p. 241.
[34] 1906 Enquiry, p. xiii.
[35] The figure is for 1903. The spinning district comprises the Ashton, Bolton, Leigh, Manchester, Oldham, Rochdale and Stockport districts from the 1906 Enquiry. Williams and Farnie (1992), p. 46.
[36] The figure is for 1896; Farnie does not give figures for weaving after this date because Worrall's Directories became less reliable as time went on. The weaving district is made up of the 1906 Enquiry districts of Accrington, Bacup, Blackburn, Burnley and Preston. Farnie (1979), pp. 307, 334.
[37] From tables 2 & 3; the denominator excludes firms located in 'other'.
[38] 1906 Enquiry, p. xiv.
[39] These figures exclude piecers, 1906 Enquiry, pp. 29-31.
[40] In full, the twelve districts of Lancashire (some of which include small parts of the counties of Cheshire and Yorkshire) are Accrington (including Church and Oswaldtwistle), Ashton-under-Lyne (Droylsden, Dukinfield, Hurst, Mossley, Stalybridge), Bacup (Haslingden, Rawtenstall), Blackburn (Clitheroe, Darwen, Great Harwood, Mellor, Rishton, Whalley), Bolton (Farnworth, Kearsley, Little Hulton, Little Lever, Turton), Burnley (Barrowford, Blacko, Briercliffe, Brierfield, Clow Bridge, Colne, Dunnockshaw, Hapton, Higham,

into output data, and since we know that, for Lancashire as a whole, total spinning capacity must, by definition, be equal to the total weaving capacity,[41] the data in the 1906 Enquiry are sufficiently detailed for us to be able to calculate the amount of cotton that was spun and woven in each area. If we find that an area had insufficient looms to weave the yarn that had been spun locally, we know that at least some spinners in that area would have been forced to ship their yarn to another district for it to be woven into cloth: transport costs might then constrain their technological choice.

The data on weaving gives both the number of weavers in each of the 12 districts and the number of looms allocated to each worker. Multiplying the number of workers by the number of looms tended gives the total number of looms in that district, which may be thought of as that district's 'weaving capacity'. We shall use this unit - one 'looms-worth' of yarn as our numeraire good.

Weaving employment and capacity in Lancashire by district

District	number of operatives with				weaving
	2 looms	3 looms	4 looms	6 looms	capacity
Accrington	430	1452	1480	0	11136
Ashton	849	2575	645	0	12003
Bacup	654	1630	2264	160	16214
Blackburn	1591	3069	8984	75	48775
Bolton	1110	1212	644	0	8432
Burnley	1036	1429	10705	1505	58209
Leigh	461	337	649	0	4529
Manchester	618	690	495	0	5286
Oldham	250	628	394	0	3960
Preston	2114	2554	3522	0	25978
Rochdale	974	4394	4832	157	35400
Stockport	381	520	1986	0	10266
other	866	537	855	0	6763

Source: 1906 Enquiry table 1

Spinning employment data is given by type of machine (rings or mules), and for mules by the fineness of yarn spun (counts up to 40, 40-80, or over 80). For our purpose what is important is that counts of up to 40 could be readily spun on either mules or rings, whereas counts of over 40 could only be spun on mules. Effectively, the data tells us how much yarn was spun on rings (ring spun yarn), how much yarn could have been spun on rings but was not (sub-40 mule spun yarn), and how much yarn could not have been spun on rings (mule yarn over count 40).

The conversion from spinning employment to yarn output is not quite as straightforward as from weaving employment to weaving capacity. We need to take account of two factors. First, ring spinners tended fewer spindles than did mule spinners: 645 as

Nelson, Padiham, Trawden), Leigh (Atherton, Hindley, Tyldesley, Westhoughton), Manchester (Pendlebury, Salford, Swinton), Oldham (Chadderton, Crompton, Failsworth, Less, Middleton, Royton, Shaw, Springhead, Uppermill and neighbourhood), Preston (Adlington, Chorley and neighbourhood, Freckleton, Horwich, Longridge, Ribchester, Walton-le-dale), Rochdale (Bury, Heywood, Littleborough, Milnrow, Radcliffe, Ramsbottom, Tottington, Wardle, Whitefield, Whitworth, Todmorden and neighbourhood), and Stockport (Compstall, Denton, Hazel Grove, Hollingworth, Hyde, Marple, Stockport, Glossop), as well as 'other places in Lancashire and Cheshire' (Lancaster and neighbourhood, Wigan and neighbourhood, Worsley and Congleton).

[41] We take into account that, in 1907, 13% of yarn was exported prior to being woven, Robson (1957), p. 345.

opposed to 2064. Second, mule speeds varied inversely with the count of yarn being spun: the relative speeds of coarse, medium and fine mules are given by the ratio 100:81:63.[42] For rings, we follow the literature in assuming that each ring spindle produced as much as 1.45 (coarse) mule spindles.[43] Finally we ensure that the spinning output figures balance those for weaving capacity, taking into account that 13% of yarn was exported as yarn, rather than being woven into cloth.[44]

Spinning employment and output of yarn in Lancashire, by district

District	(sub-40) rings		sub-40 mules		40-80 mules		supra-80 mules		total
	empl.	output	empl.	output	empl.	output	empl.	output	output
Accrington	0	0	28	758	237	5180	0	0	5937
Ashton	227	2807	762	20615	352	7693	151	2589	33704
Bacup	329	4069	191	5167	0	0	0	0	9236
Blackburn	266	3290	550	14880	69	1508	0	0	19677
Bolton	290	3586	135	3652	1122	24522	549	9412	41174
Burnley	144	1781	0	0	72	1574	0	0	3354
Leigh	0	0	0	0	311	6797	141	2417	9215
Manchester	137	1694	39	1055	0	0	157	2692	5441
Oldham	624	7717	1975	53431	1130	24697	60	1029	86874
Preston	166	2053	194	5248	193	4218	140	2400	13920
Rochdale	1054	13034	428	11579	248	5420	0	0	30034
Stockport	396	4897	417	11281	172	3759	54	926	20864
other	311	3846	51	1380	22	481	0	0	5707
Total	3944	48774	4770	129047	3928	85851	1252	21465	285137

Source: 1906 Enquiry table 2
Notes: Output figures are in 'looms-worths'
Figures may not sum owing to rounding

We are now in a position to compare the amount of sub-40 yarn spun in any given district - whether by ring or mule - with the weaving capacity in that area.

42 From Jewkes and Gray (1935), see appendix.
43 This figure applies to counts 16-40, spun from American raw cotton. Taggart (1923), pp. 155, 203.
44 1907, Robson (1957), p. 345.

Output of sub-40 yarn and weaving capacity in Lancashire, by district

1 District	2 total sub-40 output	3 weaving capacity	4 local weaving potential	5 % of sub-40 yarn that could be woven locally
Accrington	758	11136	758	100
Ashton	23422	12003	12003	51.25
Bacup	9236	16214	9236	100
Blackburn	18169	48775	18169	100
Bolton	7239	8432	7239	100
Burnley	1781	58209	1781	100
Leigh	0	4529	0	--
Manchester	2749	5286	2749	100
Oldham	61148	3960	3960	6.48
Preston	7301	25978	7301	100
Rochdale	24613	35400	24613	100
Stockport	16179	10266	10266	63.45
other	5226	6763	(0)	(0)
total	172595	240197	98075	56.82
excluding integrated plants	119820	187422	45300	37.81

Source: 1906 Enquiry — table 3

Notes: all figures are in 'looms-worths'
figures may not sum owing to rounding
totals exclude firms located in 'other'

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 behaviour of spinners in that area. Column 4 gives the minimum of the amount of sub-40 yarn spun and the weaving capacity, that is, the amount of coarse yarn that could have been woven locally. In column 5 this is expressed as a percentage of the area's total coarse yarn production. Overall the data show that a majority of yarn could have been woven within the district in which it was spun; indeed we find that in all but three districts, all of the coarse yarn could have been woven within the district in which it was spun.

This figure includes yarn spun and woven by integrated firms. As we are interested in the constraints on vertically specialised spinners, we need to remove integrated firms from the total. We know that such firms constituted 23.6% of the industry in 1907,[45] and that these firms were more likely to be found in the coarse counts section of the industry. To that end we assume that fully 80% of their output was coarse, rather than using the 60% figure for the industry as a whole. This implies that integrated firms in the twelve districts spun and wove 52,775 looms-worths of coarse yarn.[46] By excluding these firms we discover that 38% of coarse yarn spun by vertically specialised firms could have been woven within the district in which the spinner was located.

We can use an unpublished thesis by James Cotton on Blackburn to go further, and to assess the actual distance between spinners and weavers in an archetypal cotton town,

[45] Lazonick (1984), p. 394 corrected for mule equivalence using Sandberg (1969), p. 29.
[46] In addition, we estimate that integrated firms in 'other districts' spun and wove a further 1078 looms-worths of coarse yarn.

Blackburn.[47] Cotton's thesis covers the town of Blackburn itself, rather than the Blackburn district, as defined by the 1906 Enquiry.[48] He lists 132 mills in operation in Blackburn in 1919, stating whether they were vertically specialised spinners, weavers, or vertically integrated spinner-weavers at that date. Of these, he is able to exactly locate 118 of these mills: 8 spinners, 104 weavers and 6 integrated firms. He plots these on a large scale map (1:10,560), from which we are able to calculate precisely the number of weaving mills close to each of the eight spinning firms.

Geographical proximity of spinners and weavers: Blackburn

Spinning Mill	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	9	34
J Hoyle & Sons	5	29
Imperial Ring Mill	5	21
Little Harwood Combing	10	31
Plant Mill Ring Spinning	11	31
Average	7.5	28.25

Source: Cotton, (1970) Map 1.5. table 4
Note: All distances are direct

It is clear from this table that no Blackburn spinner would have had to be concerned with the cost of shipping yarn to the weavers. The average spinner had seven specialist weaving mills within 300 yards of his mill, while all of the spinning firms in Blackburn had more than twenty weaving sheds within half a mile. The closeness of spinners and weavers in Blackburn allows us to describe these mills as 'co-located', that is, located so close to each other that transport costs would have been no more important to these spinners than to integrated spinning-weaving firms.

This result is applicable more widely than just to Blackburn. Cotton demonstrates that the three principal determinants of mill location were proximity to canals, rivers and major roads, which between them explain the location of at least three-quarters of all mills.[49] Good water supply and good drainage facilities, the two single most important factors in determining location after the decline of water power, will apply to cotton mills in every town, and implies that all cotton firms, whether spinners, weavers or integrated firms, will display the same tight clustering pattern that is found in Blackburn.

We have now established the two facts needed to evaluate the importance of transport costs for vertically specialised spinners. First, the 1906 Enquiry shows that there were sufficient weavers in all but three districts to allow spinners to have all of their coarse yarn woven locally. And second, detailed work on Blackburn shows that the distances between mills within a given locality were very small. Only in Oldham is it correct to think of all spinners - or even a majority of spinners - facing a transport premium if they chose to replace

[47] Cotton (1970).
[48] According to Worrall's Directory, 46% of firms in the 1906 Enquiry definition of Blackburn were in Blackburn itself. Of the remainder, over half were located in the small neighbouring town of Darwen. Worrall's Directory, 1902.
[49] Cotton (1970), chapter 1 (iii).

their mules with rings. For Lancashire as a whole 57% of coarse yarn could have been woven locally. As we noted above, the transport cost premium applies only to weft, and not to warp yarn. So all warp and 57% of coarse weft producers could have opted for rings without suffering additional transport costs, that is, transport costs were insignificant in 78% of cases.

This result is important for our understanding of the Lancashire cotton industry. Lazonick has claimed that transport costs were sufficient to deter the adoption of rings in Lancashire. This work has shown that whilst this view is correct for Oldham, Oldham is atypical and even unique. Transport costs were of no importance to spinners in most of the twelve districts of Lancashire. So whilst we might accept that the transport costs associated with rings did deter spinners in Oldham and, to a lesser extent, in Ashton and Stockport - all of which had peculiarly low rates of ring adoption, as table 2 shows - they could not have deterred spinners elsewhere. Vertically specialised and co-located spinners, that is, all spinners outside of Oldham, Ashton and Stockport, had as much reason to adopt rings as did vertically integrated spinning-weaving firms.

3 Technological choices of integrated and co-located firms

This paper argues that transport costs were no more important to co-located spinners than to vertically integrated spinner-weavers. This is a testable hypothesis: vertically specialised and co-located firms should prove to be as ready to adopt rings as integrated firms. Of course, we do not have precise information on either the technological choices of vertically specialised, co-located firms or on the technological choices of vertically-integrated firms producing sub-40 yarns. But we do have sufficient data for all coarse spinning firms in areas in which vertically specialised firms would have been co-located and, separately, for all integrated firms. So we are able to compare the choices of these two groups, and contrast their decisions with those made by firms spinning coarse yarns and located in areas with fewer weavers.

We know from table 2 that in those districts in which spinners and weavers were co-located, 29,507 looms-worths of coarse yarn were produced on ring spindles, while 42,339 looms-worths were produced on mules. In contrast, spinners in other districts spun only 15,421 looms-worths of coarse yarn on rings, with fully 85,328 looms-worths coming from mules. These raw figures suggest that there was a dramatic difference in the adoption of rings between firms in the two areas.

To compare technological choices we need to look not at gross machinery stocks in 1906, but at machinery installed after 1880, when the ring first became available.[50] Machinery installations may be divided into additional and replacement machines. We know that the spindleage in the eight co-located districts grew at 0.43% per year,[51] implying that 7,633 looms-worths of coarse yarn capacity was added between 1880 and 1906.[52] Given that the average mule lasted fifty years, [53] machinery installed between 1830 and 1856 would have needed replacing between 1880 and 1906. The massively successful self acting mule was conveniently invented in 1830, so it is safe to assume that all mules in place in 1856 were installed between 1830 and 1856.[54] No regionally disaggregated data exists for 1856, so we use data for the vertically specialised sector as a whole.[55] Farnie shows that 49.0% of the

[50] 1880 sees the first recorded British ring order, Saxonhouse and Wright (1984), p. 509.
[51] 1883-1903, which we assume also applies to 1880-1882 and 1904-1906. Williams and Farnie (1992), p. 46.
[52] (29,507 + 42,339) - (29,507 + 42,339)/(1.0043)^26.
[53] Sandberg (1984), p. 388 and Lazonick (1984), p. 394.
[54] Chapman (1987), p. 49.
[55] In any case, the move to a regionally specialised industry did not begin until the depression of 1877-9. Farnie (1979), p. 302.

spindles in place in vertically specialised mills in 1880 were installed prior to 1856, implying that 31,459 looms-worths of coarse yarn capacity would have needed replacing between 1880 and 1906.[56] In total, therefore, 39,091 looms-worths of coarse spinning capacity was installed in the eight co-located districts of Lancashire, made up of 29,507 rings and 9,584 mules. Co-located firms selected rings for 75% of new installations between 1880 and 1906.

Spindleage in Oldham, Ashton and Stockport, the three areas with insufficient weavers, grew at 0.79% per year,[57] implying that 18,583 looms-worths were added between 1880-1906.[58] Again using industry-wide figures for spindleage in vertically specialised firms in 1856 implies that 40,254 looms-worths of capacity would have needed replacing between 1880 and 1906. In total, then, we estimate that 58,837 looms-worths of new coarse spinning capacity were installed in Oldham, Ashton and Stockport between 1880 and 1906, of which 15,421 were rings and 43,416 were mules. Spinners in these areas chose rings in just 26% of cases.

We can repeat the exercise for integrated firms. We know that, at the end of 1906, integrated firms contained 7.6 million mules and 5.54 million mule-equivalent rings.[59] Again, we are interested in spindles installed between 1880 and 1906, rather than in place in 1906. Rather than expanding, the integrated sector contracted between 1880 and 1906, so there were no additional spindles. The integrated sector did not exist prior to the 1830s, so all the 10.6 million spindles in place in 1856 must have been installed between 1830 and 1856.[60] Of these 10.6 million spindles due for replacement between 1880 and 1906, 3.6 million were not replaced as part of the sector's decline.[61] We therefore know that between 1880 and 1906 the integrated sector installed 7 million spindles, of which 5.54 million were rings: rings were chosen by integrated firms in 79% of cases.

The rates of ring adoption by co-located firms and vertically integrated firms - 75% and 79% - are clearly very close.[62] Neither are at all similar to the 26% ring adoption rate of firms in Oldham, Ashton and Stockport.[63] Because transport considerations did not affect the costs of adopting rings for a vertically specialised spinner in a co-located district, the choices made by such firms were similar to those made by integrated firms. In contrast, transport costs were a consideration for vertically specialised firms in the Oldham, Ashton and Stockport districts, and hence rates of ring adoption were substantially lower in those districts.

4 Conclusion

[56] Farnie, (1979), p. 317, from the Returns of the Factory Inspectors. The 1880 figure is based on a linear interpolation of figures for 1878 and 1885.

[57] 1883-1903, which we assume also applies to 1880-1882 and 1904-1906. Williams and Farnie (1992), p. 46

[58] (15,421 + 85,328) - (15,421 + 85,328)/(1.079)^26.

[59] i.e. taking account that 1 ring produces as much as 1.45 mules. Sandberg (1969), p. 29, Lazonick (1984), p. 394.

[60] Farnie (1979), pp. 313, 317.

[61] Farnie (1979), p. 317, Sandberg (1969), p. 29, Lazonick (1984), p. 394.

[62] Of course, vertically integrated firms located in co-located districts are included in both calculations, adding a converging bias to the result. The size of this effect is slight: using the weights in table 3 for the relative size of the integrated and specialised sectors in coarse yarn output (31%, 69% respectively) implies that the overall rate of 75% ring adoption in co-located areas consists of integrated firms selecting rings 79% of the time, and specialised firms selecting rings 74% of the time. Once more, 74% and 79% are clearly very similar.

[63] Just as the inclusion of integrated firms in the regional calculations overstates the closeness of choices between co-located and integrated firms, so it also understates the difference in choices between vertically specialised firms in the co-located and non-co-located regions of Lancashire: again, using the industry wide ratio of integrated to vertically specialised firms implies that the overall 26% ring adoption rate in Oldham-Ashton-Stockport was made up of integrated firms selecting rings 79% of the time and specialised firms choosing rings in just 10% of cases.

This paper tests Lazonick's claim that the additional cost of transporting ring yarn in the vertically and geographically specialised Lancashire cotton industry was an important factor slowing the adoption of ring spinning in the late nineteenth and early twentieth centuries. We have used new evidence, covering 86,145 operatives, to show that spinning and weaving were not as geographically separated as has previously been thought. Every coarse spinner in 8 of the 12 districts of Lancashire had a sufficient number of weavers close by to allow them to have all of their yarn woven into cloth locally. We describe such spinners and weavers as being 'co-located'. Detailed work on Blackburn shows that co-located spinning firms had literally dozens of weavers within, say, half a mile, demonstrating that transport costs would be trivial for such firms. We show that, in terms of readiness to adopt ring spindles, there is no difference between the behaviour of co-located and integrated firms.[64] Only in the Oldham district did a majority of coarse spinners face a transport cost premium were they to have installed ring spindles: the rate of ring adoption in Oldham was correspondingly low. More generally, when we consider the potential role of transport costs we should not think of the industry as divided between vertically integrated and vertically specialised firms; instead, we should divide it into those firms who were co-located or vertically integrated, that is, firms who had access to local weaving capacity, and those firms who were neither co-located nor vertically-integrated, and thus had no access to local weaving capacity.

This article shows that 78% of Lancashire's yarn could have been produced on rings without incurring anything except trivial additional transport costs. 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'.[65] As such, there is no evidence that Lancashire's vertically specialised 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.

Appendix: spinning employment - output conversions

Converting spinning employment data into data for output requires information on capital-labour ratios, that is, the number of spindles tended by each worker, and on capital-output ratios, that is the speeds at which those machines ran.

Capital-labour ratios for mule spinners come from Jewkes and Gray, who give data on the number of spindles in newly installed mule spindles in Oldham and Bolton every ten years.[66] Of course, not every spindle in place in 1906 was newly installed, so we use the figures for new mules in 1886-7, effectively assuming that the average mule was twenty years old. Given that we know that mules lasted some 50 years,[67] and that the industry was growing this seems a reasonable proxy. The growth in mule length was slow and reasonably constant over time: Oldham mules grew by 11 spindles per year in the decade to 1886, and by 9 spindles per year in the following two decades.[68] We weight the figures for Oldham and

[64] Of course, there were differences between them in other senses, most obviously the co-located sector of the industry was growing, whereas the integrated sector was in decline, Marrison (1996), p. 240.
[65] Lazonick (1983), p. 205.
[66] The data for Oldham is the more reliable. Jewkes and Gray (1935), p. 205.
[67] Sandberg (1984), p. 388, Lazonick (1984), p. 394.
[68] Figures for Oldham, Jewkes and Gray (1935), p. 205.

Bolton by the ratio of mule spinners in those towns,[69] to give an average capital labour ratio of 2046 spindles per operative.

For ring spinning we find the capital-labour ratio by dividing average earnings by the wage rate paid per 100 spindles. Wages rates per 100 spindles varied with the count spun, so we weight the corresponding number of spindles tended by the total spindleage at that count. We find that the average ring spinner tended 645 spindles.

Ring wage rates and capital-labour ratios

Count	weekly wages, pence	wages per 100 spindles, pence	number of spindles tended	spindles installed 1880-1906
8-9	186.57	43.243	431	109,307
10-11	186.57	39.783	469	109,307
12-13	186.57	37.188	502	109,307
14-16	186.57	33.729	553	163,960
17-21	186.57	31.134	599	359,840
22-28	186.57	29.405	634	988,582
29-36	186.57	28.107	664	1,247,275
37-42	186.57	26.811	696	699,307
43 and over	186.57	25.945	719	536,316
average			645	

Sources: col 2, 1906 Enquiry, p. 30 table 5
col 3, Jewkes and Gray, p. 121
col 5, Saxonhouse and Wright, p. 511, sub-divided pro-rata where necessary.
Notes: col 4 = col 2/col 3; average spindles tended represents the average of col 4 weighted by col 5

Jewkes and Gray also give detailed information on mule speeds, according to the count spun. For sub-40 counts, we weight the different speeds by the ratio of installed machinery. In the absence of detailed information we use linear weights for counts above 40.

Mule speeds

count	time taken,	weighting	speed ratios

[69] 3165 and 1806 respectively, 1906 Enquiry, pp. 33, 35.

	seconds		
sub 20	38.81	0.13	
21-30	39.54	0.21	
31-40	40.42	0.66	
sub 40			1
41-50	43.73	0.25	
51-70	49.56	0.5	
71-80	55.30	0.25	
40-80			0.81
81-90	59.30	0.5	
91-100	67.00	0.5	
supra 80			0.63

Sources: col 2, Jewkes and Gray (1935), pp. 70, 205, 209. table 6
col 3, sub-40 counts, Saxonhouse and Wright (1984), p. 511, 1878-1906, other counts have linear weights.

Note: time taken gives the number of seconds to complete 3 cycles of the mule, i.e. a larger number indicates a slower machine.

For ring speeds we use the standard assumption that the output of one ring spindle was equal to that of 1.45 coarse mule spindles.[70]

We therefore multiply mule employment figures first by 2046 and then by the relevant speed ratio given in table 6, and ring employment figures by 645 and then by 1.45. Finally, we convert all spinning output figures into looms-worths by multiplying by a constant so that spinning output equals weaving capacity, taking into account that 13% of yarn was exported.[71]

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[70] This figure applies to counts 16-40, spun from American raw cotton. Taggart (1923), pp. 155, 203.

[71] 1907, Robson (1957), p. 345.

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