NBER WORKING PAPER SERIES

WAS THE TRANSITION FROM THE ARTISANAL SHOP TO THE NON-MECHANIZED FACTORY ASSOCIATED WITH GAINS IN EFFICIENCY?: EVIDENCE FROM THE U.S. MANUFACTURING CENSUSES OF 1820 AND 1850

Kenneth L. Sokoloff

Working Paper No. 1386

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
June 1984

The author gratefully acknowledges the comments and criticisms received on earlier versions of this paper from Jeremy Atack, Stanley Engerman, Robert Fogel, Claudia Goldin, Sanford Jacoby, Peter Lindert, Robert Margo, Larry Neal, Thomas Weiss, Finis Welch and two anonymous referees. He also wishes to thank Fred Bateman, Weiss, and Atack for providing him with a tape of their sample of manufacturing firms drawn from the schedules of the 1850 Census of Manufactures. Earlier versions of the paper were presented at the University of Illinois at Urbana-Champaign, U.C.L.A., the University of California at Davis, and the 1982 Cliometrics Conference. The research reported here is part of the NBER's research program in Development of the American Economy. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

NBER Working Paper #1386
June 1984

Was the Transition from the Artisanal Shop to the Non-mechanized Factory Associated with Gains in Efficiency?: Evidence from the U.S. Manufacturing Censuses of 1820 and 1850

ABSTRACT

There are few more dramatic episodes in economic history than the displacement of the artisanal shop by the factory during the early stages of the Industrial Revolution as the predominant form of manufacturing organization. Despite the attention this development has received, however, the issues of why and how it occurred remain in dispute. This paper employs recently-collected samples of data on northeastern firms from the 1820 and 1850 Federal Census of Manufactures to investigate this transition in the U.S. context. It argues that the evidence is consistent with the hypothesis that even the early non-mechanized factories enjoyed an efficiency advantage over the traditional artisanal shop organization. The growth of average firm size in nearly all manufacturing industries between 1820 and 1850 indicates a systematic movement toward the factory organizational form. Some shops did survive, but they accounted for only modest shares of industry value added and become increasingly concentrated in areas where the extent of the market was less likely to justify firm expansion. Moreover, the estimation of production functions suggests that the non-mechanized industries were generally characterized by scale economies up to a threshold size similar to that of a small factory.

Kenneth L. Sokoloff
Department of Economics
405 Hilgard Avenue
University of California
Los Angeles, CA 90024
(213) 825-4249

There are few more dramatic episodes in economic history than the displacement of the artisanal shop by the factory during the early stages of the Industrial Revolution as the predominant form of manufacturing organization. Despite the attention this development has received, however, the issues of why and how it occurred remain in dispute (Chandler, 1977; Dobb, 1963; Landes, 1969; Laurie and Schmitz, 1981; Mantoux, 1962; Smith, 1976). Perhaps the most prevalent view holds that the factory system enjoyed an advantage in technical efficiency over the traditional shop, and that increasingly important market forces selectively favored the former class of establishments in the competition for survival. A competing interpretation concedes that the introduction of sophisticated machinery and new power sources did render large plants more efficient in mechanized industries, but questions whether the factory system was technologically dominant in industries that were yet to be touched by such breakthroughs.

The position that the early non-mechanized factories provided a more efficient method of producing manufactured goods can be traced back at least as far as Adam Smith (1976). Although recognizing that the use of machinery was facilitated by the factory system, he argued that the extensive division of labor in such establishments was an important source of their efficiency advantage. Specialization by workers in narrowly defined tasks alone could significantly reduce the amounts of inputs required per unit of output. In recent years, this conventional formulation of why the early factories may have been technically superior to artisanal shops has come under challenge. Marglin (1974) and others have claimed that the critical feature of the factory system was the more intense labor elicited through the application of supervision and the interdependencies of job performance that accompanied separation of tasks.[1] Whereas they differ about the nature of the advance, Marglin and Smith agree in allowing early factories, both mechanized and non-mechanized, considerable potential for measured productivity growth.

Not all scholars accept this view that the non-mechanized factories represented a significant technical or organizational advance over the artisanal shop. Many doubt that the division of labor and other changes in the production process associated with the introduction of the factory system in non-mechanized industries were of sufficient importance to have accounted for more than minor increases in efficiency (Chandler, 1977; Laurie and Schmitz, 1981). They either question whether the factory system supplanted the traditionally-organized shops in industries that had not yet mechanized, or suggest that the emergence of the former as the dominant form of organization was largely due to factors other than productive advantage. What is at stake extends beyond the narrow question of whether one type of firm was more efficient than another. The controversy bears on the issues of whether substantial economic growth was realized by industrializing economies prior to the widespread utilization of machinery, and whether this initial phase of industrialization was powered by the increases in productivity, achieved through changes in the organization and composition of the manufacturing work force. It is also directly related to the fundamental question of whether major institutional change is the product of market forces or of some other set of phenomena.

Most studies of the emergence of early factories have focused on European countries. Recently-collected samples of data on northeastern firms from the 1820 and 1850 Federal Censuses of Manufactures encourage investigation of the development in the U.S. economy however.[2] During the first half of the nineteenth century, the Northeast led the other regions in experiencing a rapid expansion of the manufacturing sector, as well as a movement toward larger-scale production methods such as the factory system. This type of manufacturing firm organization spread well beyond machinery- and power-intensive textiles to gradually displace artisanal shops in industries as diverse as clocks, guns, hats, shoes, and umbrellas.

Although the new sources of evidence greatly enhance our ability to study the transition from artisanal shops to small factories, they do not contain all of the information we might seek for such a subtle project. Nevertheless, this paper argues that the evidence they do provide is quite consistent with the hypothesis that the early non-mechanized factories did enjoy an efficiency advantage over the traditional artisanal shop organization in most industries. Section II discusses how the growth of average firm size in nearly all manufacturing industries between 1820 and 1850 indicates a movement toward the factory organizational form. Some shops did survive, but they accounted for only modest shares of industry value added and seem to have become increasingly concentrated in rural areas where the extent of the market was less likely to justify firm expansion. In Sections III and IV, it is shown that the estimation of production functions also lends support to the view that the non- or less-mechanized industries[3] were generally characterized by scale economies up to a threshold size similar to that of a small factory.

II.

Perhaps the most basic requirement for demonstrating that the industrial expansion of the Northeast during the first half of the nineteenth century was accompanied by the displacement of traditional artisanal shops by more efficient factories is to document that manufacturing industries did indeed experience increases in firm size over the period. Evidence for such a general increase in the scale of manufacturing establishments, in the form of industry estimates of the average number of employees per northeastern firm in

1820 and 1850, is accordingly presented in Table 1.[4] The narrow range of manufactured goods produced in quantity in 1820 limits the number of industries that can be examined; but of the ten industries for which a sufficient number of observations is available, nine show a rise in the average number of workers employed, with the average industry registering growth in firm size of 66 percent over the thirty years. The data seem to strongly support the view that larger-scale manufacturing plants were superseding the shops over time, particularly since the firm size estimates for 1820 are likely to be biased upward because of the disproportionate underenumeration of small establishments in the census of that year.[5]

One might question the relevance of these estimates for work on the diffusion of the non-mechanized factory. Of the ten industries represented in Table 1, cotton and wool textiles were certainly mechanized, and several others could reasonably be judged as not having undergone the transition from shop to factory during the period under study. The qualitative results are not, however, sensitive to the inclusion of these industries. If the textile industries are omitted, the remaining eight average an increase in firm size of 43 percent between 1820 and 1850. If one further excludes the ambiguous flour milling, glass, and iron industries, the remaining five account for an average 66 percent rise. The two industries that relied most extensively on simple instruments, human power, and a factory-like work organization, hats and boots/shoes, experienced growth in firm size of 102 and 76 percent respectively.

Another way of investigating whether factories were supplanting artisanal shops is to compare at a point in time the average firm sizes, by industry, in the two regions to industrialize first, New England and the Middle Atlantic, to those in the rest of the country. This approach has the advantage of

TABLE 1

Number of Employees Per Northeastern Manufacturing Firm, 1820 and 1850

	1820	1850	Ratio of Firm Size in 1850 to that in 1820
Boots/Shoes[a]	19.1 (N=15)	33.6 (N=72)	1.76
Cotton Textiles	34.6 (92)	97.5 (856)	2.82
Flour and Grist Milling	2.4 (90)	1.8 (5128)	0.75
Glass	56.9 (8)	64.6 (76)	1.14
Hats and Caps	8.4 (32)	17.0 (812)	2.02
Iron and Iron Products	19.5 (73)	24.2 (1562)	1.24
Liquors	2.7 (165)	5.0 (633)	1.85
Paper[a]	14.3 (33)	22.4 (12)	1.57
Tanning	3.8 (126)	4.2 (3233)	1.11
Wool and Mixed Textiles	10.6 (107)	24.5 (1284)	2.31

[a]These industries were severely affected by the underenumeration of small firms in 1820. Hence, the average number of employees in firms of more than five workers are reported here for the two years. As such figures could not be computed from the state-level data from 1850, the estimates presented for that year were calculated from the information contained in the sample of manufacturing firm data drawn from the schedules of the 1850 Census of Manufactures.

Notes and Sources:

The 1820 estimates of the average size of firms, by industry, were computed from the basic sample of manufacturing firms drawn from the 1820 Census of Manufactures. The basic sample from that year consists of the firms located in the forty randomly selected counties, and differs from the total sample in excluding firms from Philadelphia and Allegheny counties in Pennsylvania. See Sokoloff (1982) for more details on the sampling procedures. With the exceptions of the boots/shoes and paper industries, the 1850 estimates were calculated from the northeastern aggregate figures reported by the U.S. Census Office (1858). The number of firms on which the estimates are based appear in parentheses. The industries for which average firm size is reported was limited by the scarcity of observations and a desire to have them characterized by relatively homogeneous outputs.

allowing one to estimate the increase in firm size from cross-sectional information for a year when data are more plentiful. The logic underlying it is that the conditions that accounted for the traditional organization of the manufacturing firm, including extent of market, stock of knowledge, and others, will persist longer in those areas that lag with respect to industrial development. As long as the year of comparison is not too late, average firm sizes in these follower regions should yield reasonable estimates of the average pre-industrial firm sizes.

Such regional industry-specific estimates of the average number of employees per firm in 1850 are presented in Table 2. They also support the hypothesis that increases in the size of manufacturing establishments were realized in the Northeast during the early stages of industrialization. In nearly all industries, the average size of firms in either New England or the Middle Atlantic was larger than in the other regions of the country. This pattern holds over mechanized industries such as textiles, as well as non-mechanized ones like hats and boots/shoes, and is representative of the manufacturing sector in general. For the average of these sixteen industries, firms in New England employed three times as many workers as did those in regions outside the Northeast. The case for increases in firm size being associated with industrial development is further bolstered by examining the variation in firm size within the Northeast. As illustrated for the example of Massachusetts in Table 2, average firm size was largest in the areas where the extent of the market was greatest and industrialization had proceeded most rapidly.[6]

Although the finding that most manufacturing industries in the Northeast experienced an increase in the scale of establishments during the first half of the nineteenth century is well supported, this by itself does not imply

TABLE 2

Average Number of Employees Per Firm
Within Selected Industries, By Region: 1850

	New England	(Mass.)	Middle Atlantic	Other Regions	Ratio of New England to Other Regions
Agricultural Implements	8.8	(14.0)	5.1	4.7	1.9
Boots and Shoes	19.0	(37.0)	7.2	2.6	7.3
Cabinet Ware	6.9	(9.0)	5.6	4.3	1.6
Clothiers/Tailors	30.9	(43.0)	27.6	11.7	2.6
Coaches/Carriages	7.7	(6.8)	9.4	6.5	1.2
Cotton Textiles	112.3	(130.5)	69.3	66.6	1.7
Glass	109.5	(155.8)	57.8	42.2	2.6
Guns	22.9	(21.0)	5.4	2.4	9.5
Hats and Caps	18.1	(31.4)	16.5	5.8	3.1
Iron	16.6	(20.5)	23.7	25.6	0.6
Machinists/Millwrights	27.4	(32.0)	30.1	18.5	1.5
Nails	76.3	(73.6)	64.7	32.4	2.4
Paper	19.4	(22.0)	12.1	15.3	1.3
Saddles/Harnesses	7.3	(2.8)	3.4	3.1	2.4
Tanning	4.3	(6.1)	4.1	2.8	1.5
Wool Textiles	38.7	(79.7)	14.5	6.5	6.0
Average Over All Industries	13.9	(20.0)	7.8	5.1	3.0

Notes and Sources: These averages were computed from the industry data compiled from the 1850 Census of Manufactures and reported in the U.S. Census Office (1858). The figures presented refer to the number of employees, with males and females receiving equal weight, and the figures appearing in parentheses are the average firm sizes for Massachusetts industries. The particular industries appearing in the table were selected with two criteria in mind: the number of employees in the industry in the Northeast, and the degree of homogeneity of output of firms in the industry. The industry categoreis generally correspond to the definitions employed by the census. The iron industry is an exception. It is made up of five different categories reported in the census: forges, foundries, furnaces, miscellaneous iron manufactures, and iron rolling.

that changes in production methods were associated with the growth of firms. As noted above, some have argued that the production processes characteristic of non-mechanized factories were so similar to those of artisanal shops that no significant gains in productivity could have been realized by the transition from the latter form of organization to the former. Chandler (1977, pp. 53-54), for example, considers the larger establishments of the early nineteenth century, in industries other than textiles, as little more than expanded artisanal shops:

> After 1790, the artisans enjoyed growing local markets and had access to local supplies of yarn, leather, and wood and easily obtained cloth and metal from importers of British products. Although they became somewhat more specialized, they expanded their output to make their suits, dresses, hats, furniture, tableware, copper, brass, and pewterware by employing more apprentices and journeymen who continued to work in the traditional manner with traditional tools . . . The same could be said for the makers of sails, ropes, and glassware, and rum, whiskey, and beer. In all these trades new machinery was not extensively developed or used before the 1840s.

In his view, it was not until the widespread diffusion of sophisticated machinery and steam power during the 1840s that the manufacturing sector began to make substantial progress.

Other scholars concerned with the development of various industries that were late to mechanize their production processes have concluded that many had begun even earlier to make significant alterations in their methods of manufacture (Cole and Williamson, 1941; Davis, 1949; Deyrup, 1970; Gibb, 1943; Hazard, 1921). Their work has depicted the growth in the average size of firms as reflecting a gradual but systematic movement away from the traditional shops composed of a few highly skilled workers, and perhaps an apprentice, toward establishments resembling factories. These new types of firms were frequently marked by a minute division of labor that reduced the share of the work force with general skills, greater supervision and attention to maintaining an intense work regime, and a concern for standardization of product. One of the clearest statements of this transition in the organization of production appears in Hazard (1921, pp. 85-86):

> He [Gideon Howard, a manufacturer of shoes in South Randolph, Massachusetts] had a "gang" over in his twelve-footer who fitted, made and finished: one lasted, one pegged and tacked on soles, one made fore edges, one put on heels and "pared them up," and in case of handsewed shoes, two or three sewers were needed to keep the rest of the gang busy. . . These groups of men in a ten-footer gradually took on a character due to specialization demanded by the markets with higher standards and need of speed in output. Instead of all the men working there being regularly trained shoemakers, perhaps only one would be, and he was a boss contractor, who took out from a central shop so many cases to be done at a certain figure and data, and hired shoemakers who had "picked up" the knowledge of one process and set them to work under his supervision. One of the gang was a laster, another a pegger, one an edgemaker, one a polisher. Sometimes, as business grew, each of these operators would be duplicated. Such work did away with the old seven-year apprenticeship system.

In a recent article, Goldin and I found that in most manufacturing industries the proportion of the labor force composed of women and children increased with size of establishment (Goldin and Sokoloff, 1982). We argued that this variation in the composition of the work force was indicative of how the production methods differed with the scale at which firms operated. In our view, a sharply disproportionate number of women and children employed by medium (6-15 employees) and large (over 15 employees) establishments was due at least partially to the more extensive division of labor among workers utilized by such firms. Since workers in these medium- and large-sized factories were generally responsible for relatively narrowly defined or simple tasks, a greater share of them could be drawn from classes such as women and children, who were lacking in general skills. Attention to maintaining an intense work regime may have been another important feature of these firms, and could also contribute to their disproportionate number of female and child employees, since supervision and other measures aimed at maintaining discipline might be expected to have had a greater influence on their productivity than on that of adult males.[7]

Estimates of the proportion of the labor force composed of women and children in 1820 and 1850, by size category of firm, are presented in Table 3 for selected non-mechanized industries. One of the most striking features of this evidence is how firms in many of these industries do not appear to have grown far beyond the shop of fewer than five workers before allotting a greater share of positions to women and children. To take the example of establishments producing boots or shoes in 1850, women and children accounted for only 6.9 percent of the employees in small (1-5 workers) firms, while making up 23.2 and 39.9 percent of the labor force in medium (6-15 workers) and large (16 or more workers) firms respectively. Firms in such industries could evidently alter their factor proportions and production methods significantly without radically increasing their scale of operation. When judged relative to the mammoth industrial establishments of the late nineteenth century, the discrepancy between the average size of firms manufacturing boots/shoes in Massachusetts (37 employees) and in regions other than the Northeast (2.6 employees) perhaps seems inconsequential. However, the production processes utilized by firms of these sizes appear likely to have been substantially different, and the transition from one to the other may have been associated with significant gains in efficiency.

By documenting that there was a systematic tendency for firms to grow larger and that production processes varied with firm size, several conditions necessary for the existence of an efficiency differential between artisanal shops and small factories have been established. Before moving on to the estimation of production functions or indexes of total factor productivity, however, a problem common to such studies must be addressed. If the one form

TABLE 3

Composition of the Labor Force for Selected Non-Mechanized Industries by Size of Firm: 1820 and 1850

	Small Firms (1 to 5 Employees)	Medium Firms (6 to 15 Employees)	Large Firms (> 15 Employees)
	Percentage of Employees that were Women or Children		
1820			
Boots and Shoes	22.3%	32.9%	27.0%
Coaches/Harnesses	19.5	43.8	41.4
Furniture	11.0	43.6	--
Hats	18.8	35.8	--
Paper	--	55.1	60.3
Tanning	23.4	31.4	--
Total of All Industries	13.9	39.3	53.7
	Percentage of Employees that were Female		
1850			
Boots and Shoes	6.9	23.2	39.9
Clothing	33.9	41.3	57.1
Coaches/Harnesses	0.0	2.5	6.8
Furniture	0.0	0.0	4.5
Hats	--	69.8	65.2
Paper	7.0	18.6	60.4
Total of All Industries	3.7	10.1	28.1

Notes and Sources: See the note to Table 3 in Goldin and Sokoloff (1982). Estimates are reported for all cells which had more than two observations.

of organization is technically superior to the other, why are they observed to coexist?

This dilemma is particularly troubling for the issue of the emergence of non-mechanized factories, because they were not substantially larger than the shops they displaced. If the artisanal shop persisted for only a brief period, one might claim that imperfections in capital markets, sunk human or physical capital, differences in entrepreneurial ability, and other such factors simply slowed the adjustment to the long-run equilibrium. Given that many firms in the industries at issue survived with fewer than six workers until 1850, a more careful evaluation is required.

Perhaps the most plausible theory of how shop-size establishments survived despite their relative inefficiency is that they were concentrated in rural areas where low population density and high transportation costs restricted the extent of the market. In order to test this hypothesis, estimates were computed from the 1850 sample, for urban and rural counties, of the distribution of industry value added across firm size categories (see Table 4). The analysis was conducted for two mechanized and six relatively non-mechanized industries. In all of those for which there were sufficient observations, the share of urban county value added produced by small shops was rather modest. Although they did not quite match the record of cotton textiles, where there were no shop-size firms, three of the non-mechanized industries (hats, paper, and tanning) had shop-size shares of less than 10 percent. Only in boots/shoes did shop-size firms achieve a share of more than 20 percent. Since that industry was characterized by extensive product differentiation, the high figure might simply reflect craftsmen who manufactured very specialized products and were not in direct competition with the larger factories.

TABLE 4

Distribution of Industry Value Added by Firm Size Classes:
With Northeastern Urban and Non-Urban Counties, 1850

	1-5 workers	6-15 workers	16 or more workers
Boots and Shoes			
Non-Urban	29.7%	18.3%	51.9%
Urban	22.9	13.2	63.9
Total	26.3	15.8	57.9
Coaches, Wagons, and Harnesses			
Non-Urban	22.0	11.4	66.6
Urban	15.7	60.7	23.5
Total	19.9	28.2	51.9
Furniture			
Non-Urban	74.3	9.1	16.6
Urban	11.0	7.5	81.6
Total	28.9	7.9	63.1
Hats			
Non-Urban	0.6	8.7	90.7
Urban	3.2	2.6	94.2
Total	2.4	4.3	93.2
Paper			
Non-Urban	8.3	22.6	69.1
Urban	3.1	32.0	65.0
Total	7.2	24.6	68.2
Tanning/Leather			
Non-Urban	67.1	32.9	0.0
Urban	8.6	70.2	21.1
Total	48.8	44.6	6.6
Cotton/Textiles			
Non-Urban	0.1	0.2	99.7
Urban	0.0	0.0	100.0
Total	0.1	0.1	99.8
Wool Textiles			
Non-Urban	6.4	19.9	73.7
Urban	--	--	--
Total	7.5	22.2	70.3

Notes and Sources: The percentages were computed from the northeastern firm data contained in the Bateman-Weiss sample of the 1850 Census of Manufactures. As that sample was designed to sample firms randomly within states, rather than across, state-specific weights were employed to construct the regional estimates presented here. Urban counties are counties that included a city with a population of twenty thousand and had at least forty percent of their population residing in "towns" with populations greater than twenty-five hundred. The dual criteria were utilized because the population figures for many counties in New York were decomposed only to the township level, leading many rural areas to appear highly urbanized if only the latter criterion is applied.

In general, the larger firms accounted for higher proportions of value added in urban counties than in rural ones. The contrast is especially marked for the furniture and tanning industries. Whereas the value-added shares for shop-size establishments were 74.3 and 67.1 percent respectively in rural counties, they were only 11.0 and 8.6 in the urban ones. The results for these two industries suggest how important the extent of markets and other factors that vary with locality were in determining the optimal size of firms at a given location.[8]

Finally, perhaps the most stringent test of whether the limited extent of market prevented firms from expanding to realize scale economies in production is to examine how frequently a firm that was smaller than the size at which scale economies were exhausted operated in close proximity to another establishment of the same industry. This would presumably have been a rare occurrence if factories were more efficient than shops, because the firm in question would have been driven to expand output or find itself out-competed. Although this analysis only strictly applies to firms producing homgeneous outputs and to the long run, the plausibility of there having been significant scale economies would be much reduced if it were common for establishments employing but a few workers to be located in the same neighborhood as other firms of the same industry. So comprehensive is the coverage of the firms in most of the Massachusetts counties by the McLane Report of 1832, that it can be employed to investigate how often artisanal shops were in such a position. With this in mind, the tanning and hat industries were selected as test cases, because they both had many small shops operating in Massachusetts as late as 1832 and were unambiguously non-mechanized (Sokoloff, 1984).

Enumerators counted 185 tanneries and 90 hat manufacturers in 135 and 43 Massachusetts cities respectively. A close examination of the geographic distributions of these firms, by size, suggests that the output of shops operating in proximity to other firms producing similar goods was not a quantitatively important phenomenon. Despite the very modest average size of the tanneries, 4.9 employees, only 12.8 percent of the industry's value-added was produced by shop-sized firms in cities where another tannery was located. The corresponding figure was even lower, 0.5 percent, for the hat industry. Another way of summarizing the bearing of these data on the issue of how or why the shops survived is to compute the proportion of their value-added that was accounted for by establishments that were sole producers of the particular commodities in the cities they were located in. This calculation reveals that such sole-producer firms produced 93.3 percent of the shop output of hats, and 60.7 percent of tanning-shop output.[9]

As city boundaries are only a crude proxy for the geographical extent of markets in 1832, reactions to these figures may vary. Nevertheless, given the virtual absence of hat shops competing directly with other manufacturers in the same city, most would probably agree that the geographical distribution of hat establishments lends strong support to the hypothesis that factories in this industry enjoyed an efficiency advantage over artisanal shops. The evidence on tanneries is less persuasive, but when one considers that the cross-section does not reflect a long-run equilibrium and that some tanning shops might have survived because of differentiated products, the data certainly do not sustain a rejection of the hypothesis.

III.

The estimation of production functions constitutes another method of investigating whether there were differences between the two types of firms in total factor productivity. If factories were indeed more efficient than artisanal shops, production functions should yield evidence of economies of scale. In addition, if there were, as one might expect, bounds on the extent to which scale economies could be achieved through separation of tasks and the intensification of labor, the estimated economies of scale in the less mechanized industries would be exhausted at some moderate level of output. The potential range of efficiency-enhancing measures was not so limited for highly mechanized industries, and their scale economies would presumably not be fully realized until some higher levels of output.

The firm data from the 1820 and 1850 censuses contain the basic information needed to estimate production functions. Both sources provide reports, at the establishment level, of the stock of capital utilized, the number of employees in different categories (i.e., male and female), the value of the raw materials consumed, and the value of output produced. Although the 1820 Census of Manufactures was marred by incomplete coverage of the existing firms, it has the virtue of having collected information on categories of inputs not covered in the 1850 census.

Enumerators for the 1820 census requested firms to report their number of employees in three categories: adult males, adult females, and children. They also surveyed proprietors on both the cost of the raw materials utilized and the amount of "contingent expenses" (i.e., the costs of insurance, fuel, repairs, and other miscellaneous items). As is typical of manufacturing (and agricultural) production data, the capital input is measured in terms of the value of the capital stock.[10] While some proprietors indicated in notes to their schedules that they were providing estimates of the present value of their capital stock, others chose to report the original cost. There also appears to have been no generally adhered-to rule for whether working capital was to be counted as a component of the capital stock.[11] Another attractive feature of the 1820 Census of Manufactures is that enumerators generally specified who owned each particular manufacturing firm, information that proved to be useful in constructing proxies for the entrepreneurial labor input.

The 1850 Census of Manufactures retrieved similar information from firms, but not in as much detail. Of particular concern is the practice of grouping all male employees together.[12] As the proportion of male employees that were boys rose with firm size, the failure to report boys separately leads to an overstatement of the labor input in large firms relative to small ones since, on average, boys had neither the physical strength nor the skills of adult males. A less significant defect is that the 1850 census did not gather estimates of the "contingent expenses" borne by firms. Finally, the 1850 sample does not contain information about the owners of the manufacturing establishments, making the task of imputing the entrepreneurial labor input especially formidable.

Two types of production functions have been estimated over these bodies of data. In addition to the basic Cobb-Douglas form, the translog specification has also been extensively utilized. Although the translog functions seldom provided significantly (in a statistical sense) more explanatory power than the Cobb-Douglas, they will be discussed below because the translog form is more general and allows the estimate of the scale coefficient to vary over size of firm. The Cobb-Douglas was employed, and the results reported, in the form:

$$(1) \qquad V/L = A(K/L)^{\gamma}L^{s}$$

where V/L is the value added per equivalent worker, A is the intercept, K/L is capital per equivalent worker, and L is the measure of equivalent workers. This form can easily be derived from the more conventional formulation of the Cobb-Douglas production function:

$$(2) \qquad V = AK^{\gamma}L^{\beta}$$

and has the advantage that the coefficient on labor (s) yields a direct test of economies of scale since:

$$(3) \qquad s = (\gamma+\beta) - 1$$

A series of Cobb-Douglas production functions, estimated over firms from non-mechanized industries in the 1820 sample, are reported in Table 5.[13] Each of the first two regressions yields a statistically significant finding of economies of scale, with the scale coefficient ranging from 1.10 to 1.15. Additional variables are included in the latter two to investigate whether the apparent increase in productivity with size of firm was continuous and due to scale economies, discontinuous and associated with the use of the factory system, or some combination of the two possibilities. When the dummy for establishments with more than 5 employees, a proxy for factory size, was included in the third regression, it proved statistically insignificant, and only marginally raised the point estimate of the scale coefficient. The further inclusion of an interaction term between this dummy variable and the labor input (representing the degree of scale economies) also failed to significantly increase the explanatory power of the equation. This specification yielded an interesting pattern in the variation of productivity with establishment size however. The estimated coefficients in the fourth regression imply that scale economies were realized by non-mechanized firms up to a threshold size of more than 5 employees, but that firms of this larger size enjoyed a statistically significant, and substantial, step increase in productivity. Similar regressions were estimated with the dummy variable and the interaction term taking effect at a range of firm sizes between 6 and 15 employees. All of them yielded the result that establishments with more than 5 employees, large enough to potentially be classified as a non-mechanized

TABLE 5

Estimates of Cobb-Douglas Production Functions for Non-Mechanized Manufacturing in 1820

Dependent Variable: Log(Value Added/Labor Input)
Number of Firms = 534

	(1)	(2)	(3)	(4)
Intercept	3.224	3.309	3.308	3.181
	(27.15)	(19.14)	(19.08)	(17.62)
Log(Capital/Labor)	0.362	0.362	0.362	0.359
	(17.98)	(17.52)	(17.45)	(17.34)
Log(Labor)	0.154	0.097	0.100	0.236
	(4.93)	(2.67)	(1.95)	(3.10)
Log(% of the County Labor Force Employed In Agriculture)		-0.108	-0.108	-0.102
		(-4.05)	(-4.02)	(-3.81)
Dummy for New England		-0.046	-0.047	-0.063
		(-0.78)	(-0.78)	(-1.06)
Dummy for Factory Size (> 5 Employees)			-0.007	0.402
			(-0.08)	(2.11)
Interaction Between Factory Dummy and Log (Labor)				-0.240
				(-2.41)
Industry Dummies:				
Liquors		-0.042	-0.045	-0.038
		(-0.34)	(-0.35)	(-0.29)
Metal Products		-0.064	-0.066	-0.050
		(-0.42)	(-0.42)	(-0.32)
Milling		-0.051	-0.054	-0.048
		(-0.35)	(-0.36)	(-0.32)
Tanning		-0.287	-0.290	-0.290
		(-2.22)	(-2.16)	(-2.17)
Miscellaneous		0.033	0.035	0.031
		(0.27)	(0.25)	(0.25)
R^2	0.445	0.497	0.497	0.503

TABLE 5 (Continued)

Notes and Sources:

These regressions were estimated over the subset of the sample of manufacturing firms drawn from the 1820 Census of Manufactures that were in industries other than cotton textiles, wool textiles, or iron supplied the necessary information, and met the criteria imposed to exclude firms that were operating part-time. The intercept represents a paper mill located in the Middle Atlantic, and the average firm was located in a county where 57 percent of the labor force was primarily employed in the agricultural sector. An urbanization variable was not included in the specification, because the information needed to calculate urbanization rates was not available for several of the counties from which the sample was drawn. Value added was calculated as the value of output, minus the value of the raw materials consumed and the contingent expenses incurred. The capital input was set equal to what the firm reported in response to the question, "amount of capital invested." The measure of entrepreneurial labor employed was derived from the information on the ownership of each firm. If a firm listed one owner, the measure of entrepreneurial labor was set equal to one. If two owners were listed, two entrepreneurs were counted, and if three or more owners were listed, three entrepreneurs were counted. When a firm was reported as being owner by an individual (or individuals) and "company" (i.e., Jones and Company), the "Company" was disregarded. Thus, if the owners of a firm were Jones and Company, one entrepreneur would be imputed. When an establishment was incorporated or owned by a joint stock company, then it was assumed that a manager supervised the operation and was counted among the employees. In such cases, the ertrepreneurial labor input was set equal to zero. In the cases where firms did not report their owners, one entrepreneur

TABLE 5 (Continued)

was assumed. The labor input was defined as the number of entrepreneurs, plus the number of adult male employees reported, plus 0.4 times the total number of female and child employees enumerated. This weight for females and children was estimated from wage equations and is roughly equal to the ratio of the wage of adult females or boys to that of adult males during the early nineteenth century. The weight probably overstates the labor input of women and children in 1820, but the regressions were also estimated with weights of up to 0.6 without any change in the qualitative results. Several methods of detecting, and deleting from the sample, those firms that were operating part-time were tried. All yielded similar results. The regressions presented here were estimated over a subset of firms that had been derived by deleting approximately the lowest 18 percent of firms, with respect to total factor productivity, from the entire sample. Establishments that had explicitly indicated that they were part-time operations, as well as outliers constituting the top 1 percent, were also excluded.

factory, were more productive than smaller firms, but that the available scale economies were largely exhausted by this medium-size class of manufacturing enterprises.[14]

Other independent variables besides capital and labor were included in the reported regressions in order to control for a variety of factors that might be related to measured productivity, but as is clear from Table 5, the qualitative findings are not sensitive to them. The set of industry dummies, allowing for different intercepts, were intended to pick up industry-specific effects such as disparities in the quality of inputs (such as skilled vs. unskilled labor or young vs. older children) or fluctuations in the demand for particular commodities.[15] Similarly, the quality of inputs, the level of technology, the price levels of inputs and outputs, and the severity of cyclical disturbances might all have varied with industrial development across geographic areas, and these potential effects account for why the highly significant percentage-of-the labor-force-in-agriculture variable, as well as the New England dummy, were included in the specification. These factors should be controlled for in estimating whether economies of scale existed, regardless of whether they were related to variation in actual productivity, or to measurement problems.

Another method of testing the hypothesis that non-mechanized factories had significantly higher measured total factor productivity than artisanal shops is to estimate a regression over firms in non-mechanized industries with an index of total factor productivity as the dependent variable. The independent variables should include a dummy variable for establishments likely to be operating as factories and measures of other relevant firm characteristics. Such a regression is presented in Table 6, and it utilizes a threshold size, having more than 5 employees, as the proxy for factories. The highly significant coefficient on that dummy variable indicates that the total factor productivity of establishments with more than 5 employees was on average more than 20 percent higher than that of artisanal shops, after controlling for other factors. The qualitative result is sensitive to neither reasonable changes in the threshold size adopted to distinguish factories from artisanal shops, nor to plausible alterations in the output elasticities employed in constructing the index of total factor productivity.

The one feature of the analysis on which the finding that factories were more productive than artisanal shops does depend, however, is the inclusion of an imputed measure of entrepreneurial labor in the labor input. It is easy to understand why the results should be so sensitive to the treatment of this variable. The labor of the proprietor (or proprietors) accounts for a major share of the labor input in small manufacturing establishments, and an inappropriate decision to include (exclude) an imputed measure of it would bias estimates of the productivity of such firms downward (upward) relative to those of large firms where the fraction of the labor input provided by the proprietors is smaller. Fortunately, both intuition and empirical evidence provide a solid basis for imputing entrepreneurial labor and counting it in with the measure of the labor input. Entrepreneurs were not typically included in the enumeration of employees, but they seem to have been associated with higher levels of measured output.[16]

The evidence indicates that scale economies in non-mechanized manufacturing industries, were available only up to some threshold firm size. This would suggest that production functions should be estimated with a specification that allows the scale coefficient to vary over establishment size. The translog specification, which has been employed by other

TABLE 6

Regression with Index of Total Factor Productivity As Dependent Variable: Over Firms in Non-Mechanized Industries, 1820

	$R^2 = 0.141$	N = 534
	Coefficient	t-statistic
Intercept	44.398	6.27
Dummy for Factory Size (> 5 Employees)	9.284	2.77
Log (% of Labor Force Employed In Agriculture)	-7.128	-4.89
Dummy for New England	-2.319	-0.74
Industry Dummies:		
Liquors	1.967	0.27
Metal Products	3.095	0.36
Milling	2.280	0.28
Tanning	-9.646	-1.30
Miscellaneous	5.158	0.75

Notes and Sources:

The regression was estimated over firms in all but the textiles and iron industries. The index of total factor productivity (I) was calculated from the formulation

$$I = V/(K^{.30}L^{.70})$$

where γ and β were derived from a Cobb-Douglas production function estimated over manufacturing firms of all sizes. See the note to table 5 for the methods employed to impute the entrepreneurial labor input and to identify, and delete from the estimates, firms likely to have been operating only part-time. Indexes, with and without the entrepreneurial labor input imputed were also computed from the aggregate totals, within size categories and unweighted for industry mix. Normalizing the values of the estimates, such that they are equal to 100 for the artisanal shop class, yields the following results:

TABLE 6 (cont.)

	Index With Entrepreneurial Labor Imputed	Index Without Entrepreneurial Labor Imputed
Firms with:		
1 to 5 Employees (N=396)	100	100
6 to 15 Employees (N=105)	130	107
More than 15 Employees (N=34)	135	103

investigators of nineteenth-century manufacturing (James, 1983), fails in our case to provide more explanatory power than the Cobb-Douglas form, but it has the definite advantage of yielding a point estimate of the firm size at which scale economies were exhausted. Translog production function estimates for both textile and non-textile firms are reported separately in Table 7 to illustrate the difference in available scale economies between mechanized and non-mechanized industries. Both regressions were estimated over those firms with more than 5 employees, so as to abstract as much as possible from the problem of how to deal with entrepreneurial labor and focus on establishments where that component of the labor input would be relatively minor. The scale coefficients for the two types of firms have been plotted in Figure 1, by level of value added, as an aid to the presentation of the results.[17]

As is clear from Figure 1, both textiles and the non-mechanized manufacturing industries exhibit economies of scale over some range of output. Not surprisingly, scale economies extend over much larger firm sizes in the highly mechanized textile industries than in the others. The scale coefficient equals 1.38 for textile firms, at the mean level of inputs, and does not fall to 1.0 (the point where scale economies have been exhausted) until approximately $54,000 in value added. This supports the conclusion, also sustained by the estimation of Cobb-Douglas production functions over the same set of firms, that statistically significant scale economies existed in the textile industries up to a rather substantial establishment size.[18] In contrast, the scale coefficient in other industries was 1.09 at the mean level of inputs, and was reduced to 1.0 at about $9,500 in value added. Consideration of this evidence must be tempered by the recognition that the translog specification does not provide significantly more explanatory power than the Cobb-Douglas.[19] Nevertheless, the evidence strengthens the case for non-

TABLE 7

Estimates of Translog Production Functions for Manufacturing In 1820: Over Firms with More than Five Employees

Dependent Variable: Log(Value Added)

	Cotton and Wool Textiles N = 92 (1)	Non-Mechanized Industries N = 138 (2)
Intercept	1.308	4.498
	(0.32)	(3.05)
Log(Capital)	0.686	0.113
	(0.70)	(0.35)
Log(Labor)	0.594	0.950
	(0.44)	(1.33)
$(\text{Log(Capital)})^2$	-0.048	0.006
	(-0.70)	(0.21)
$(\text{Log(Labor)})^2$	-0.189	-0.114
	(-0.75)	(-0.88)
Log(Capital)*Log(Labor)	0.164	0.042
	(0.70)	(0.35)
Log(% of the County Labor Force in Agriculture)	-0.418	-0.085
	(-1.91)	(-2.43)
Dummy for New England	0.176	-0.262
	(0.94)	(-2.70)
Industry Dummies:		
Cotton Textiles	0.086	
	(0.53)	
Liquors		-0.275
		(-1.23)
Metal Products		-0.048
		(-0.27)
Mills		-0.281
		(-0.99)
Tanneries		-0.197
		(-1.04)
Miscellaneous		-0.030
		(-0.22)
R^2	0.646	0.706

Notes and Sources: See note to Table 5. The intercept for the cotton and wool textile regression refers to a wool textile establishment in the Middle Atlantic.

FIGURE 1 (Continued)

Notes and Sources:

The scale coefficients for the two categories of firms were computed from the coefficients in the respective regressions in Table 8. They were calculated under the assumption that the same capital to labor ratio prevailing at the mean level of inputs was maintained at all firm sizes. Among the textile firms, the mean values of the inputs were 9.434 for the log of capital and 2.546 for the log of the labor input. Among the firms in the non-mechanized industries, the mean values were 8.907 for the log of capital and 2.425 for the log of the labor input. The average textile and non-mechanized firms were located in counties where 65 and 34 percent of the labor force respectively were primarily engaged in the agricultural sector. The scale coefficients mapped are the average of the ones computed for New England and the Middle Atlantic.

mechanized factories having been more productive than artisanal shops, because it demonstrates that scale economies are observed even when artisanal shops, whose proprietors account for a substantial share of their labor input, are excluded from the estimation. In addition, the implication that scale economies were much more limited in non-mechanized industries than in mechanized, fully exhausted at a firm size of about twenty adult-male equivalent workers, seems quite reasonable and consistent with the variation across industries in establishment size during the period.

Observing that scale economies were realized in non-mechanized industries up to only a modest threshold size should come as no surprise. One would expect that the scale economies attributable to the indivisibilities associated with utilizing certain types of machinery would be greater and require a larger establishment size than would the realization of economies stemming predominantly from the division of hand-performed tasks within a firm, and the indivisibilities associated with the use of simple tools, supervision, and a more disciplined work regime. There are limits to the extent to which tasks in a non-mechanized production process can be effectively sub-divided and the activity of workers can be regimented. Were the gains in productivity realized by introducing a more extensive division of labor and disciplined work regime, as well as other modest changes in production methods that did not require high-cost capital equipment, of a significant magnitude? The regression in Table 6 suggests that they were. In industries other than textiles and iron, establishments with more than five employees were on average over 20 percent more productive than the smaller firms. Both this estimate and the scale coefficients estimated by production functions imply that the transition from the artisanal shop (of, say, 4 workers) to the non-mechanized factory (of, say, 15 workers) was accompanied by a considerable advance in measured productivity.[20]

One might choose to dispute the claims that the production process in firms of fifteen employees was significantly different from that in firms of four or five employees, or that the larger establishment deserved being classified as a "factory." However, the evidence, presented in Table 3, that the composition of the workforce varied substantially between such firms, would seem to indicate variation in the production methods utilized. In particular, the higher proportion of women and children (and perhaps lesser-skilled employees in general) in the larger establishments is consistent with the view that the latter were characterized by more division of labor and supervision of workers. Moreover, differences between the production processes utilized by the two firms are suggested by the finding in Sokoloff (1984) that the fixed capital intensity of even non-mechanized manufacturing firms increased with establishment size over this range. As for the question of how one determines what size of firm constitutes a non-mechanized factory, it must be admitted that the selection of any such point is somewhat arbitrary. Nevertheless, firms in general do not appear to have grown far beyond five workers before taking on some of the characteristics typically associated with the early factories.

IV.

Production functions can also be estimated over the sample of firm data drawn from the 1850 Census of Manufactures. As mentioned above, however, the omission of certain variables from this body of evidence complicates the study of the extent of scale economies. Of particular concern is the failure to have boy employees enumerated separately from adult males. Since the proportion of male employees that were boys rose significantly with firm size, this feature of the data has the effect of biasing estimates of the scale coefficient downward. In addition, the lack of information on the identities of firm owners in the 1850 sample aggravates the problem of how to impute the entrepreneurial labor input.

A set of Cobb-Douglas production functions estimated over the firms from the 1850 sample in non-mechanized industries are presented in Table 8. All of the regressions indicate that factory-sized establishments had higher levels of productivity than did artisanal shops. The conventional production functions reflected in the first two equations find highly significant scale economies, with the scale coefficient varying slightly between 1.11 and 1.12, depending on whether one allows for different intercepts across industries.[21]

In the latter two equations, a dummy variable for the factory threshold size of more than 5 employees and an interaction term between that dummy and the labor input (which will pick up the change in the magnitude of scale economies above the threshold size) are added to the independent variables in the specification. When only the dummy variable is added in the third equation, the results suggests that both continuous scale economies and a step increase in productivity associated with firms larger than the threshold size led to a productivity advantage for factories. The fourth equation also finds tha non-mechanized factories were more productive or efficient than artisanal shops. But since the interaction term effectively cancels out the coefficient on the labor input for firms with more than 5 employees, the differential tends to be attributed, in an accounting sense, to a step increase in productivity that is on average enjoyed by all firms over the threshold size. What scale economies were available appear here to have been largely exhausted by factories of a rather modest size. The fourth equation does provide significantly more explanatory power, although marginally so, than does the

TABLE 8

Estimates of Cobb-Douglas Production Functions
For Non-Mechanized Manufacturing in 1850

Dependent Variable: Log(Value Added/Labor)
Number of Firms = 782

	(1)	(2)	(3)	(4)
Intercept	4.352	4.334	4.373	4.204
	(61.92)	(48.35)	(47.40)	(42.45)
Log (Capital/Labor)	0.240	0.256	0.255	0.249
	(19.79)	(17.38)	(17.36)	(17.09)
Log (Labor)	0.124	0.106	0.070	0.234
	(8.19)	(6.49)	(2.69)	(5.14)
Log (% of County		0.035	0.035	0.031
Population in Urban Area)		(3.47)	(3.47)	(3.10)
Dummy for New England		0.052	0.051	0.051
		(2.01)	(1.99)	(2.01)
Dummy for Factory			0.087	0.492
Size (> 5 Employees)			(1.75)	(4.69)
Interaction Between				-0.238
Factory Dummy and				(-4.37)
Log (Labor				
Industry Dummies:				
Coaches/Harnesses		-0.015	-0.021	-0.029
		(-0.26)	(-0.37)	(-0.51)
Clothes		-0.042	-0.058	-0.065
		(-0.63)	(-0.86)	(-0.97)
Mills		-0.092	-0.093	-0.043
		(-1.39)	(-1.40)	(-0.65)
Tanning		-0.092	-0.090	-0.097
		(-1.49)	(-1.44)	(-1.58)
Miscellaneous		-0.019	-0.020	-0.019
		(-0.42)	(-0.46)	(-0.43)
R^2	0.402	0.417	0.420	0.434

TABLE 8 (Continued)

Notes and Sources:

The regressions were estimated over firms from the 1850 sample that were of industries other than cotton textiles, wood textiles, iron, boots/shoes, construction, or consumer perishables, supplied the necessary information, and met the criterion imposed to exclude firms that were operating part-time. The intercept represents a midddle Atlantic establishment producing consumer household goods, and the average firm was located in a county where 33 percent of the population resided in urban areas. Value added was computed as the value of output minus the value of the raw materials consumed. The capital input was set equal to the reported investment in capital. The labor input was set equal to one plus the number of male employees reported, plus 0.5 times the number of females reported. The higher weight on female employees, relative to that employed with the 1820 firms, is adopted here because adult males and boys were enumerated together in the 1850 data, and because there was a higher female to male wage ration prevailing then. Weights of 0.4 or 0.6 yield the same qualitative results. Several methods of identifying, and deleting from the sample, those firms that were operating part-time were employed. All yielded similar results. The regressions presented here were estimated over a subset of firms that had been derived by deleting approximately the lowest 22 percent of firms, with respect to total factor productivity, from the entire sample. Outliers constituting the top 3 percent were also excluded.

second, but any choice between the alternative specifications would have to be offered tentatively. Nevertheless, what emerges as important is that a variety of specifications, including different threshold sizes for distinguishing factories from shops, yield basically the same implications. They are that the production technologies of non-mechanized industries were such that establishments with more than 5 or 6 employees were significantly more productive than those that were smaller. The sources of these scale economies, however, were so rapidly depleted, that there is no robust and statistically significant difference in productivity between non-mechanized establishments with more than 15 employees and those with 6 to 15.[22]

A regression with an index of total factor productivity as the dependent variable was estimated over the 1850 data, as one with a similar specification was over the 1820 sample. This equation is presented in Table 9, and it also supports the hypothesis that non-mechanized factories had higher measured total factor productivity than artisanal shops. The estimated coefficient on the dummy variable for establishments with more than 5 employees implies that even after adjusting for industry mix and location, the former class of firms was over twenty percent more productive than the latter.[23] When a dummy variable for establishments with more than 15 employees was added to the specification, it was positive but statistically insignificant, indicating that the further hypothesis that there was no difference in productivity between such firms and those with between 6 and 15 employees cannot be rejected. The result that factories were more productive than shops is not qualitatively sensitive to reasonable variation in the output elasticities utilized to compute the index. Moreover, it is especially impressive in that the failure to enumerate adult males separately from boys in the 1850 data tends to bias the measured productivity of larger establishments downward

TABLE 9

Regression with Index of Total Factor Productivity
As Dependent Variable: Over Firms in Non-Mechanized Industries, 1850

	R^2 = .092	N = 782
	Coefficient	t-statistic
Intercept	104.769	20.77
Dummy for Factory Size (> 5 Employees)	22.150	6.74
Log (% of County Population in Urban Area)	4.076	3.72
Dummy for New England	5.391	1.89
Industry Dummies:		
Coaches/Harness	-3.630	-0.57
Clothes	-11.095	-1.51
Mills	-6.563	-0.99
Tanning	-7.904	-1.18
Miscellaneous	-3.060	-0.62

Notes and Sources

The regression was estimated over firms in all but the textiles, iron, boots/shoes, consumer perishables, and construction industries. The boots/shoes industry was excluded because many of its establishments appear to have been putting-out enterprises. The index of total factor productivity (I) was calculated from the formulation

$$I = V/(K^{.234}\,L^{.766})$$

where γ and β were derived from a Cobb-Douglas production function estimated over manufacturing firms of all sizes. See the note to Table 8 for a description of the methods employed to impute the entrepreneurial labor input and to identify, and delete from the estimates, firms likely to have been operating only part-time. Indexes with and without the entrepreneurial labor input imputed were also computed from the aggregate totals, within size categories and unweighted for industry mix. Normalizing the values of the estimates, such that they are equal to 100 for the artisanal shop class, yields the following results:

TABLE 9 (cont.)

	Index with Entrepreneurial Labor Imputed	Index without Entrepreneurial Labor Imputed
Firms with:		
1 to 5 Employees (N = 594)	100	100
6 to 15 Employees (N = 105)	127	106
More than 15 Employees (N = 86)	129	101

relative to that of artisanal shops.

The correspondence between the production function analyses of the 1820 and 1850 samples of manufacturing firms in revealing the presence of scale economies up to a rather modest threshold establishment size lends further support to what was already a strong case for the finding. There seems to be a systematic pattern in the data of medium- and large-sized firms in non-mechanized industries having significantly higher measured total factor productivity than smaller enterprises, and it emerges despite a very conservative treatment of the part-time firm problem. The result is quite robust with respect to both specification and the subsets of the data over which the estimates are computed. It is somewhat sensitive to whether one includes a measure of entrepreneurial labor in the labor input, but the basis for this practice appears sound.

Given that the evidence for this systematic discrepancy in measured total factor productivity is substantial, a natural question is what to make of the finding. The most straightforward interpretation is that it reflects a difference between factories and artisanal shops in technical efficiency. Although some might doubt that production techniques and efficiency could have varied significantly over such a narrow range of establishment sizes, such skepticism would seem to be undercut by the observations that factor ratios did so. Moreover, if there was no appreciable difference in production methods, how does one account for the clear tendency over time for the larger firms to displace artisanal shops?

The competing view is that the apparent differential in efficiency is an artifact due to measurement problems. Probably the chief concern here is that labor has been implicitly measured with the assumption that employees worked the same number of hours per year in all of the firms over which the analysis was conducted. If there were a difference between factories and shops in the numbers of hours they operated on average per year, the relative productivity comparisons would be biased. However, the procedures adopted to identify part-time enterprises, and exclude them form the estimation, should have greatly reduced the significance of this factor. In addition, evidence from the 1832 McLane Report suggests that if there is any such bias, it might work against the relative productivity of factories since these establishments appear to have operated fewer hours per day than the smaller shops.[24] As for the possibility that the labor regime was more intense in factories, that workers expended more energy per unit of time, such a circumstance might well be considered an indicator of the greater efficiency of that form of organization.[25]

V.

While the result that scale economies were realized in non-mechanized industries over a rather limited range of establishment sizes might initially be surprising, it seems quite reasonable on reflection. In the context of a non-mechanized technology, one would expect there to be constraints on the degree to which stages in the production process could effectively be subdivided that would be binding at a relatively (relative to textile or other mechanized industries) small firm size. Similarly, gains that non-mechanized firms might realize from the intensification of labor, either by inducing workers to expend more energy or by eliciting more effective labor in reducing wasted motion, and whether achieved through greater supervision or another method of imposing a more disciplined work regime, would also be expected to be dissipated at a relatively modest plant size.[26]

Some might ask why firms did not grow to fully exhaust the potential scale economies. The answer appears to be that to a great extent, they had grown and were growing in regions where lower transportation costs and higher density of population produced markets of sufficient size to justify expansion.[27] As shown in Tables 1 and 2, average firm size increased in most northeastern manufacturing industries between 1820 and 1850. In the latter year, firms were larger in the Northeast than in the rest of the country, and were especially so in areas like the state of the Massachusetts or urban localities where industrial development had progressed most rapidly. The analysis of the production data has suggested that the scale economies in non-mechanized industries were virtually exhausted by establishments of medium size (6 to 15 employees). By 1850, few manufacturing industries in the Northeast had average firm sizes below this threshold class, and those artisanal shops that did survive were disproportionately located in outlying rural districts. Other conditions might also have affected or constrained decisions concerning the size at which a particular manufacturing firm would operate. Capital market imperfections and variation in the relative wages of different classes of labor, for example, could have contributed to the persistence of some artisanal shops. Moreover, the complete adjustments from shops to non-mechanized factories might be expected to have taken a generation, since skilled artisans who had made their investments in human capital prior to the expansion of the market or the availability of new technologies could have continued to operate as before but for lower returns.

Although the evidence presented here may provide substantial support for the hypothesis that non-mechanized factories were more efficient or productive than artisanal shops, it does not help to distinguish between the competing views as to what accounted for the differential. The higher measured total factor productivity of the larger establishments, the sharp contrast in labor force composition, the increase in capital intensity with firm size, the systematic displacement of shops by factories, and the early nineteenth century descriptions of how the organization of work differed between the two types of manufacturing enterprises are consistent with both theories of greater division of labor within the firm and of intensification of labor. More research, almost certainly at the industry level, is required before the relative importance of these and other factors in accounting for the productivity advantage of non-mechanized factories can be determined.

Despite the failure to resolve the issue of the source of the gain, the finding that non-mechanized factories were significantly more efficient than artisanal shops has substantial implications for the study of early industrialization in the U.S. Not only does it supply an explanation of the general increase in firm size during the early nineteenth century, but it also demonstrates that manufacturing industries did not have to be mechanized to experience significant productivity growth during the antebellum period. It also suggests another contributor, in addition to simply the shift of resources out of agriculture and into manufacturing, to the substantial improvement in the relative economic position of the Northeast with respect to the rest of the U.S. that took place between the Revolution and 1840 (Jones, 1980; Easterlin, 1971). More broadly still, it would seem to imply that future research on the issue of why the Northeast led in industrialization might profitably explore what conditions discouraged the expansion of the scale of production in manufacturing establishments outside that region.

Footnotes

[1]In Marglin's view, the appearance of greater technical efficiency is a result of the mismeasurement of the labor input, that is, by hours of work. He argues that a proper gauge of the labor input would measure the amount of work provided, or the energy utilized, by the individual worker.

[2]The 1820 and 1850 samples were drawn by Sokoloff and by Bateman and Weiss respectively. This paper will also make some use of a sample assembled by Sokoloff from the 1832 Treasury Department survey of manufactures, commonly known as the McLane Report. See Sokoloff (1982) and Bateman and Weiss (1981) for descriptions of these bodies of evidence.

[3]These categories of industries will henceforth be lumped together and referred to as "non-mechanized." In this paper, they consist of all manufacturing industries other than textiles and iron. This system of classification is based on the widely-recognized contrast between the textile industries and the rest of the manufacturing sector, in terms of the extent to which the production process was based on the employment of sophisticated machinery, as well as on information contained in the McLane Report. An analysis of these data for eight of the leading manufacturing industries indicates that cotton and wool textiles had by far the highest investments in tools and machinery per unit of labor employment. See Sokoloff (1984).

[4]Further evidence that average firm size in the Northeast increased during the period appears in Sokoloff (1982, Ch. 2).

[5]In some counties, particularly those that were densely populated, census enumerators appear to have surveyed only the larger manufacturing establishments, regardless of industry. The rationale for this practice is unclear. See Sokoloff (1982) for further details.

[6]Regressions with size of firm (measured in a variety of ways) as the dependent variable, and industry dummies, extent of urbanization in county, proportion of county labor force in agriculture, etc. as independent variables, have been estimated for both 1820 and 1850. The coefficients are always positive on the urbanization variable, negative on the proportion of the labor force in agriculture variable, and highly significant.

[7]The piece rate system of compensation may have also served as a method of maintaining work intensity among women and children. For further discussion of these issues, see Goldin and Sokoloff (1982).

[8]Chi-square tests where conducted to determine whether one could reject the hypothesis that the distribution of firms across size classes was the same in urban counties as in rural ones. Utilizing the 1820 sample, one could reject the hypothesis at the 5 percent level for all of the industries appearing in Table 4 except cotton textiles and paper. By 1850 hats and wool textiles had joined the latter two industries in having similar distributions of firms across size classes in rural and urban counties. These results are consistent with the view that transportation costs were sometimes able to protect firms organized as shops in non-mechanized industries from establishments organized as factories. These shops may have been able to survive in rural areas because their factory competitors only enjoyed modest efficiency advantages. In cotton textiles, wool textiles (eventually), and a few other industries, the scale economies were evidently so substantial that transportation costs could offer no effective shield for shops.

[9]A small proportion of enumerators reported the aggregate totals, such as the number of employees, for all of the tanneries or hat manufacturers in a particular city, rather than list each establishment in that location separately. In carrying out the analysis, it was assumed that in such cases

all of the respective firms were identical and of the average size.

[10]Economists would typically prefer to have information on the rental value of the capital, or an indication of the amount of capital actually being utilized, to information on the value of the capital stock. Either of these types of information would lead to an improved measure of the capital input. Production functions estimated with the value of capital stock have, however, performed quite well in practice. See the discussion of this point in Griliches and Ringstad (1973).

[11]Both of these errors and irregularities in the measurement of the capital input will tend to bias estimates of the capital coefficient toward zero.

[12]Examination of the information on wage rates provided by firms indicates that boys must have been included among male workers, rather than reported separately as child employees. The average male wage rate is much lower in industries known to have employed many boys, such as cotton textiles, than in other industries. Furthermore, the cotton textile male wage indicated by the 1850 returns, when compared to the adult male wage estimated from the 1832 McLane Report, would seem to suggest that adult males in that industry suffered an enormous decline in their real wages between the two years, while males in agriculture, and in manufacturing industries that employed few boys, reaped large gains. See Goldin and Sokoloff (1982, fn. 28) for further details.

[13]It would be preferable to estimate production functions separately for each industry classification. However, the number of firms in the 1820 and 1850 samples of manufacturing firms is inadequate for this procedure. Manufacturing-wide production functions have frequently been estimated, and the approach utilized here, of allowing the intercept to vary across

industries, resembles that employed by Griliches and Ringstad (1973). Regressions that allowed the scale coefficient to vary across industries were also estimated, but no statistically significant differences were observed. The production function estimates presented in this paper constrain the capital coefficient to be the same in all industries. Relaxation of this assumption does not alter the qualitative results. The form of Cobb-Douglas production function estimated here yields lower R^2 than the coventional form does.

[14]In general, the regressions implied that scale economies were realized only up to the threshold size specified by the dummy variable and the interaction term in the particular equation. The coefficients on the dummy variables were typically positive, large, and highly significant, indicating a step increase in productivity for all establishments above the threshold size. When the regressions were also estimated with a dummy variable and an interaction term for firms with more than 15 employees, the two additional independent variables proved statistically insignificant. It should be noted that if artisanal shops operating in outlying areas enjoyed local monopolies and were able to set output prices above competitive levels, then estimates of the degree of scale economies or of the productivity differential between shops and factories would be biased downward.

[15]The introduction of industry dummies amounts to requiring that the effects of the rest of the variables have to be estimated from the variation around the industry means. Since much of the systematic variation in variables, such as the capital-labor ratio, is between industries, the use of industry dummies reduces the systematic variation in the variable, relative to the noise, from which the coefficient is to be estimated. This leads to a biasing downward of some coefficients and a general decline in the precision

(and statistical significance) of the estimated coefficients. This factor is one reason for not allowing the capital coefficient to vary between industries. For more discussion of this point, see Griliches and Ringstad (1973).

[16]If it was inappropriate to add a measure of entrepreneurial labor to the labor input of the reported employees, then its inclusion would bias estimates of the total factor productivity of small firms downward relative to that of larger ones. The evidence, however, seems to indicate that an entrepreneurial labor component should be included in the computation of a total labor input. First, it is clear that the owners of firms were not counted among the employees. For example, nearly 7 percent of the firms reporting only one employee were owned by two individuals. Of greater significance are the indications that at least among small firms, entrepreneurs were associated with additional output by establishments. Below, for example, are listed the average outputs for firms with a given number of employees and one owner versus those with two owners. Given that the second owner would be less likely to contribute to output than the first owner, if it can be shown that the second owner does, it seems reasonable to infer that the first owner did.

Average Value Added Per Firm

Number of Employees In Firm	One Owner	Two Owners
1	572.2 (N=85)	591.8 (N=6)
2	821.3 (N=109)	1095.7 (N=6)
3	1269.4 (N=59)	1633.6 (N=7)
4	1796.9 (N=39)	2055.2 (N=9)
5	2115.0 (N=23)	2400.0 (N=3)
6	2299.6 (N=16)	2403.3 (N=6)

Although the number of observations in many of the individual cells is small, the consistent finding that firms with two owners had higher value added than those with one seems to suggest that the marginal entrepreneurs increased output. Although the difference is small between the two classes with one employee, the discrepancy may be narrow because the firms with one owner had an average capital stock that was more than 50 percent greater than that of firms with two owners. Notice also that if one did not count entrepreneurs at all, firms with one worker would have the highest value added per worker.

[17]The translog production function has the following form:

(1) $$V = \gamma + \alpha_L L + \alpha_K K + \alpha_{LL} L^2 + \alpha_{KK} K^2 + \alpha_{LK} LK$$

where all of the variables are logged. The scale coefficient (S) for any specified levels of inputs can then be solved for:

(2) $$s = \alpha_L + \alpha_K + 2\alpha_{LL} L + 2\alpha_{KK} K + \alpha_{LK}(L+K)$$

Hence, the estimate of the scale coefficient varies with the size of firm. An alternative production function with a variable scale coefficient is utilized by Atack (1977) and Atack (1983).

[18]The estimates imply that scale economies in textiles were exhausted at approximately one hundred and fifty workers. One of the peculiar features about the production function estimates, however, is that they suggest that total factor productivity in textiles was significantly lower than in the non-textile industries. As the magnitude of the discrepancy is quite large and implausible, the author suspects that it is attributable to the unusually severe effect of the economic contraction on the textile industry (forcing firms to operate well below capacity), the generous exclusion of low productivity (likely part-time operators) non-mechanized firms from the regression, and possibly a widespread reporting of the original cost of capital rather than the market value of the capital stock.

[19]When a Cobb-Douglas production function was estimated over this sample of non-mechanized firms, those with more than 5 employees, the scale economies were not statistically significant.

[20]The fourth equation in Table 5 implies that the total factor productivity of an establishment with 15 equivalent workers would have been approximately 7 percent higher than another with 4 equivalent workers. This estimate is for two firms in the same industry, and based on the assumptions that they have identical capital to labor ratios and are located in counties with the same proportion of the labor force in agriculture. It should be recognized that the point estimates of the productivity differential between non-mechanized factories and shops are sensative to how conservative one is in dealing with the part-time operations problem. Those presented here were computed from the subset of establishments left after the bottom 18 percent of firms, with respect to total factor production, were excluded fromt the analysis (in addition to those that explictly indicated on the census schedule that they were operating only part-time). The smaller the number of firms dropped from the analysis, the larger the estimate of the total factor productivity differential between factories and shops.

[21]The qualitative result of significant scale economies is sensitive to the imputation of an entrepreneurial labor input. Since the 1850 sample does not contain information on the owners or proprietors of establishments, it was assumed that each firm had an entrepreneurial labor input of one adult male. Regressions of the number of owners on the number of employees, estimated over both the 1820 sample and the <u>McLane Report</u> sample, indicate that the number of entrepreneuers increased only slightly as the number of employees did. Assuming one entrepreneur per firm thus appears to be a reasonable approximation, and probably introduces only a very small upward bias in the

scale coefficient. Again as with the 1820 sample, the magnitude of the estimated scale economies is quite sensitive to how many firms are excluded to deal with the part-time oeprations problem. THe truncation point employed here, leading to the exclusion of the least productive 22 percent, is a conservative one. A less stringent standard would yield an estimate of even more extensive scale economies.

[22]When a dummy variable and an interaction term for establishments with more than 15 employees were added to the specification utilized in the fourth regression, they failed to significantly increase the explanatory power of the equation. When Cobb-Douglas and translog production functions were estimated over all establishments with more than 5 employees, they yielded results similar to those found with the 1820 sample. In particular, the translog specification suggested tha scale economies were present and exhausted by roughly $9,000 of value added, while the Cobb-Douglas found no significant scale economies over this range of establishment sizes. When the Cobb-Douglas production function is estimated over firms with between 5 and 24 employees, however, the scale economies observed are statistically significant. This discrepancy in qualitative results may be due to the failure of the 1850 census to separately enumerate adult males and boys, and the consequent overstatement of the labor input in larger firms relative to that in smaller ones.

[23]The qualitative result is not sensitive to reasonable alternative difintions of the threshold size tht distinguishes factories from shops. As discussed above, the point estimate of the productivity differential decreases as the number of establishments excluded form the analysis by the adjustment made for part-time firms increases. It is also negatively related to the threshold size utilized in the specification.

[24] Several hundred of the firms appearing in the McLane Report sample reported the average number of hours per day that they operated. Regression analysis suggests that after controlling for industry, hours of operation were negatively related to firm size. This finding is of only marginal statistical significance however.

[25] Whether a form of organization that increases measured total factor productivity by raising the intensity of work could be technically more efficient than the alternative form of organization is a complex issue. The extensive treatment that the question deserves cannot be provided here however. Instead the simple logic of the market-forces argument in favor of the proposition in this case is presented briefly, although some might claim that it lacks historical relevance. If the organizational form with the more intense labor regime (i.e., the factory) progressively displaced the other (i.e., artisanal shop), this would suggest that the value of the marginal gain in productivity was more than enough to compensate workers for their greater exertions. If one assumes that the labor intensity supply schedule of the individual worker is everywhere upward sloping, and the value of marginal product schedule downward sloping, then the transition from the artisanal shop equilibrium (with respect to wage rate and labor intensity) to the non-mechanized factory equilibrium (with a higher wage and greater labor intensity) would seem to have been associated with a shifting out of the marginal product schedule. Since proprietors of manufacturing firms, as well as workers, were increasingly attracted toward the factory, then the shift in the marginal product schedule was presumably the result of a disproportionate increase in output with respect to inputs (including work intensity). Otherwise, the proprietors would opt for the more traditional form of organization. This interpretation receives support from the wage regression

estimates obtained from the various samples of manufacturing firm data that wage rates increased with establishment size.

[26]In both the _McLane Report_ and the 1850 Census of Manufactures, there were many shoe establishments with small amounts of capital reported, and yet many employees. These firms were also marked by substantially lower rates of compensation for their workers (especially women). As many putting-out shoe establishments did operate in eastern Massachusetts during this period, the author suspects that many of the firms in the sample with very low labor productivity were putting-out enterprises. Why these workers were so much less productive remains a puzzle, but it may stem from their working fewer hours, without supervision, or in a less-disciplined environment.

[27]Lindstrom's (1978) findings that intra-regional trade and specialization in manufactured products increased dramatically in the Northeast during the first half of the nineteenth century are also consistent with the view that the extent of the market facing individual firms or localities was growing. See Taylor (1951) for further discussion of these developments.

References

Atack, J. (1977), "Returns to Scale in Antebellum United States Manufacturing." Explorations in Economic History 14, 337-359.

_______ (1983), "Optimal Plant Size and Industrial Structure Before the Modern Industrial Corporation." Unpublished manuscript, University of Illinois.

Bateman, F. and Weiss, T. (1981), A Deplorable Scarcity: The Failure of Industrialization in the Slave Economy. Chapel Hill: University of North Carolina Press.

Chandler, A.D. (1977), The Visible Hand: The Managerial Revolution in American Business. Cambridge, Massachusetts: Harvard University Press.

Cochran, T.C. (1981), Frontiers of Change: Early Industrialism in America. New York: Oxford University Press.

Cole, A.H. (1926), The American Wool Manufacture. 2 vols. Cambridge, Massachusetts: Harvard University Press.

_______ and Smith, W.B. (1935), Fluctuations in American Business, 1790-1860. Cambridge, Massachusetts: Harvard University Press.

Cole, A.H. and Williamson, H.F. (1941), The American Carpet Manufacture. Cambridge, Massachusetts: Harvard University Press.

Davis, L.E. (1957), "Sources of Industrial Finance: The American Textile Industry, A Case Study." Explorations in Entrepreneurial History 9, 189-203.

Davis, P. (1949), The Development of the American Glass Industry. Cambridge, Massachusetts: Harvard University Press.

Deyrup, F.J. (1970), Arms Making in the Connecticut Valley: A Regional Study of the Economic Development of the Small Arms Industry 1798-1870. York, Pennsylvania: George Shumway.

Dobb, M. (1963), Studies in the Development of Capitalism. New York: International. Originally published in 1947.

Easterlin, R.A. (1971), "Regional Income Trends, 1840-1950." In R.W. Fogel and S.L. Engerman (Ed.), The Reinterpretation of American Economic History. New York: Harper and Row.

Field, A.J. (1980), "Skill Intensity in Early Industrialization: The Case of Massachusetts." Journal of Human Resources 15, 149-175.

Gibb, G.S. (1943), The Whitesmiths of Taunton. Cambridge, Massachusetts: Harvard University Press.

Goldin, C. and Sokoloff, K. (1982), "Women, Children and Industrialization in the Early Republic: Evidence from the Manufacturing Censuses." Journal of Economic History 42, 741-774.

__________ (1984), "The Relative Productivity Hypothesis of Industrialization: The American Case, 1820-1850." Quarterly Journal of Economics 99, forthcoming.

Griliches, Z. and Ringstad, V. (1973), Economies of Scale and the Form of the Production Function. Amsterdam: North Holland.

Habakkuk, H.J. (1962), American and British Technology in the Nineteenth Century: The Search for Labour-Saving Inventions. Cambridge, England: At the University Press.

Hazard, B.E. (1921), The Organization of the Boot and Shoe Industry in Massachusetts Before 1875. Cambridge, Massachusetts: Harvard University Press.

James, J.A. (1983), "Structural Change in American Manufacturing, 1850-1890." Journal of Economic History 43, 433-460.

Jones, A.H. (1980), Wealth of a Nation To Be. New York: Columbia University Press.

Landes, D.S. (1969), The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present. Cambridge, England: At the University Press.

Laurie, B. and Schmitz, M. (1981), "Manufacture and Productivity: The Making of an Industrial Base, Philadelphia 1850-1880." In T. Hershberg (Ed.), Philadelphia: Work Space, Family and Group Experience in the Nineteenth Century. New York: Oxford University Press.

Lebergott, S. (1964), Manpower in Economic Growth: The American Record Since 1800. New York: McGraw-Hill.

Lindstrom, D. (1978), Economic Development in the Philadelphia Region, 1810-1850. New York: Columbia University Press.

Mantoux, P. (1962), The Industrial Revolution in the Eighteenth Century. New York: Harper and Row. First English edition published in 1928.

Marglin, S.A. (1974), "What Do Bosses Do? The Origins and Functions of Hierarchy in Capitalist Production." The Review of Radical Political Economics 6, 33-60.

Nardinelli, C. (1980), "Child Labor and the Factory Acts." Journal of Economic History 40, 739-755.

Report of the Committee on the Machinery of the United States of America (1969). In N. Rosenberg (Ed.), The American System of Manufactures. Edinburgh: Edinburgh University Press. Originally published in 1855.

Smith, A. (1976), An Inquiry into the Nature and Causes of the Wealth of Nations. Chicago: University of Chicago Press. Originally published in 1776.

Smith, D.C. (1971). History of Papermaking in the United States (1691-1969). New York: Lockwood.

Sokoloff, K.L. (1982). "Industrialization and the Growth of the Manufacturing Sector in the Northeast, 1820-1850." Unpublished Ph.D. dissertation, Harvard University.

____________. (1984). "Investment in Fixed and Working Capital During Early Industrialization: Evidence from U.S. Manufacturing Firms." Journal of Economic History 44, forthcoming.

Taylor, G.R. (1951). The Transportation Revolution, 1815-1860. New York: Holt, Rinehart, and Winston.

U.S. Census Office (1858). Abstract of Manufactures, According to the Returns of the Seventh Census. Washington, D.C.: 1858.

U.S. House of Representatives (1833). Documents Relative to the Statistics of Manufactures in the U.S. 2 vols. Washington, D.C.: Duff Green.

Ware, C. (1966). The Early New England Cotton Manufacture: A Study in Industrial Beginnings. New York: Russell and Russell. Originally published in 1931.